NVEnergy

May 10, 2021

Nevada Division of Environmental Protection
NDEP - Bureau of Corrective Actions
901 S Stewart St
Carson City, NV 89701
Attn: Alison Oakley

Subject: NV Energy Reid Gardner Station
Administrative Order on Consent (AOC)
Quality Assurance Project Plan (QAPP) – April 2021 Final

Ms. Oakley:

Based on your concurrence letter dated April 1, 2021, revised cover sheets and spine labels dated April 2021 reflecting that the QAPP is considered final are enclosed.

If you have any questions, please feel free to contact me directly at 702-402-5477.

Respectfully,

Mathew Johns
Director, Environmental Remediation and Resource Development
NV Energy

CC: Cliff Banuelos, NDEP (electronic copy via FilesAnywhere)
John Kivett, ARCADIS, US

P.O. BOX 98910, LAS VEGAS, NEVADA 89151-0001 6226 WEST SAHARA AVENUE, LAS VEGAS, NEVADA 89146
P.O. BOX 10100, RENO, NEVADA 89520-0024 6100 NEIL ROAD, RENO, NEVADA 89511 nvenergy.com

NEVADA DIVISION OF
ENVIRONMENTAL
PROTECTION

STATE OF NEVADA
Department of Conservation & Natural Resources
Steve Sisolak, Governor
Bradley Crowell, Director
Greg Lovato, Administrator

April 1, 2021

Mathew Johns
Director - Env Remediation and Resource Development
NV Energy
6226 W. Sahara Ave. MS #25
Las Vegas, NV 89146

Re: **NV Energy Reid Gardner Station**
NDEP Facility ID #H-000530
Nevada Division of Environmental Protection Review of:
Draft Quality Assurance Project Plan, Version 2.5 and Responses to Comments

Dear Mr. Johns:

The Nevada Division of Environmental Protection (NDEP) has received and reviewed NV Energy's *Draft Quality Assurance Project Plan, Version 2.5* and RTCs (QAPP v2.5 and RTCs). The QAPP v2.5 and RTCs are dated March 12, 2021 and respond to NDEP comments dated November 23, 2020. The QAPP v2.5 proposes data quality objectives and field, administrative, and analytical procedures designed to meet these objectives.

NDEP **concurs** with NV Energy's QAPP v2.5 and RTCs.

Please contact me with any questions about the comments at (775) 687-9396 or aoakley@ndep.nv.gov

Sincerely,

Alison Oakley, CEM
Environmental Scientist III
Bureau of Corrective Actions
NDEP-Carson City Office

ec Andrea Issod, Sierra Club, andrea.issod@sierraclub.org
Andy Chaney, Environmental Health Supervisor, Environmental Compliance Section, Southern Nevada Health District, 280 S. Decatur Blvd., Las Vegas, NV 89107, chaney@snhd.org
Benjamin Moan, Remediation & LUST Supervisor, Las Vegas Office, bmoan@ndep.nv.gov
Bill Carrig, Stanley Consultants, Inc., CarrigBill@stanleygroup.com
Cliff Banuelos, Tribal Liaison, NDEP, cbanuelos@ndep.nv.gov
Dante Merriweather, Environmental Compliance Section, Southern Nevada Health District, 280 S. Decatur Blvd., Las Vegas, NV 89107 , merriweather@snhd.org
Darren Daboda, Moapa Tribal Administrator, admin.mbop@moapabandofpaiutes.org
Don Hopper, NV Energy, DHopper@nvenergy.com
Donna Houston, Sr. Environmental Health Specialist, Environmental Compliance Section, Southern Nevada Health District, 280 S. Decatur Blvd., Las Vegas, NV 89107, houston@snhd.org
Ginger Somerville, Arcadis, Ginger.Somerville@arcadis.com
Herb Sequera, Interim Director Of Environmental Health, Southern Nevada Health District, 280 S. Decatur Blvd., Las Vegas, NV 89107, sequera@snhd.org
Jason Reed, NV Energy, Jason.Reed@nvenergy.com
Jeff Collins, NDEP, Bureau Of Corrective Actions Chief, jrcollins@ndep.nv.gov
John Kivett, Arcadis, John.Kivett@arcadis.com
John Solvie, Planning Manager, Water Quality, Clark County Water Quality Reclamation District, 5857 E. Flamingo Road, Las Vegas, NV 89122, jsolvie@cleanwaterteam.com
Joseph R. Leedy, Principal Planner, Water Quality, Clark County Water Quality Reclamation District, 5857 E. Flamingo Road, Las Vegas, NV 89122, jleedy@cleanwaterteam.com
Kevan Samsam, CA Department Of Water Resources, kevan.samsam@water.ca.gov
Matt Johns, NV Energy, Mathew.Johns@nvenergy.com
Mike Leigh, NDEP Bureau Of Sustainable Materials Management, mleigh@ndep.nv.gov
Nikita Lingenfelter, NDEP, Bureau Of Water Pollution Control, nlingenfelter@ndep.nv.gov
Paul Eckert, NDEP Bureau Of Sustainable Materials Management, peckert@ndep.nv.gov
Rebecca Svatos, Stanley Consultants, 2658 Crosspark Rd Suite: 100, Coralville, IA 52241, svatosbecky@stanleygroup.com
Robert Wiygul, Counsel Sierra Club And Moapa Band Of Paiutes, Robert@waltzerlaw.com
Scott Dethloff, NV Energy, Scott.Dethloff@nvenergy.com
Scott Smale, DoD And Remediation Branch Supervisor, ssmale@ndep.nv.gov
Starla Lacy, NV Energy, Starla.Lacy@nvenergy.com
Todd Tietjen, Regional Water Quality Program Manager, Southern Nevada Water Authority, PO Box 99954, Las Vegas, NV, 89193-9954 , todd.tietjen@snwa.com
Tony Garcia, NV Energy, tony.garcia@nvenergy.com
Vickie Simmons, Moapa Band Of Paiutes Chairperson, chair.mbop@moapabandofpaiutes.org

cc Clark County Emergency Management, 500 S. Grand Central Parkway - 6th Floor, P.O. Box 551713, Las Vegas, NV 89155-1713

NVEnergy

March 11, 2021

Nevada Division of Environmental Protection
NDEP - Bureau of Corrective Actions
901 S Stewart St
Carson City, NV 89701
Attn: Alison Oakley

Subject: NV Energy Reid Gardner Station
Administrative Order on Consent (AOC)
Draft Generic Quality Assurance Project Plan (QAPP) Version 2.5 – March 2021

Ms. Oakley:

Enclosed please find the Draft QAPP Version 2.5 dated March 2021 for your review. This was revised based on your comments dated February 17, 2021. A Document and Response to Comments Tracking Form is also enclosed.

If you have any questions, please feel free to contact me directly at 702-402-5477.

Respectfully,

Mathew Johns

Mathew Johns
Director, Environmental Remediation and Resource Development
NV Energy

CC: Cliff Banuelos, NDEP (electronic copy via FilesAnywhere)
John Kivett, ARCADIS, US

Document and Response to Comments Tracking Form
NV Energy – Reid Gardner Station
Administrative Order on Consent Implementation

Document Title Draft Quality Assurance Project Plan, Version 2.5 (QAPP v2.5)

Preparer Stanley Consultants, Inc.

Draft #1

To	NDEP	From	NV Energy
Submittal Date	11/23/2020	Comment Date	2/17/2021
Response Date	3/12/2021		
Commenter	Alison Oakley	Responder	Mathew Johns

Comment #1

Section B2.5, Sampling Equipment, Preservation, and Holding Times, Table 5, Groundwater Sampling – Parameters, Methods, Containers, Holding Times, and Reporting Limits Summary, page 62: The target reporting limit of 0.01 mg/L for thallium is greater than the maximum contaminant level of 0.002 mg/L

Comment #1 Response

NV Energy updated the target reporting limit of thallium to 0.000121 mg/L, which is the laboratory method detection limit (MDL).

Comment #2

Section B.3.2.2, Field Parameters, page 70, second paragraph, first sentence: Groundwater samples collected for field screening activities should be tested as soon as practicable after collection and should not be placed on ice or otherwise preserved prior to field testing

Comment #2 Response

NV Energy added a sentence to Section B.3.2.2 stating that groundwater samples should be analyzed for field parameters as soon as possible and will not be preserved prior to analysis of field parameters.

Additional Revision

NV Energy added a strikethrough to the soil matrices for 2-chloroethyl vinyl ether on page 91 of the Pace Analytical Quality Manual in Appendix C and added a note mentioning that after consultation with the lab, Pace does not have the capabilities to analyze for 2-chloroethyl vinyl ether in soil matrices.

Additional Revision

NV Energy added SVOCs to Tables 4 and 5 of the QAPP and updated the tables with minor formatting changes.

AOC IMPLEMENTATION ACTIVITIES
NV ENERGY
REID GARDNER STATION
MOAPA, NEVADA

Data Quality Objectives and Generic Quality Assurance Project Plan
NV Energy Reid Gardner Station
Version 2.5
Final
April 2021

PREPARED BY:

STANLEY CONSULTANTS, INC.
2658 Crosspark Road - Suite 100
Coralville, IA 52241
(319) 259-6658 Fax: (319) 259-6659

A1.0 APPROVING OFFICIALS

NV ENERGY:

March 11, 2021

(Signature) Mathew Johns (Date)
Director, Environmental Remediation and Resource Development

STANLEY CONSULTANTS, INC.:

March 11, 2021

(Signature) Rebecca Svatos, CEM, PE (Date)
Project Manager

March 11, 2021

(Signature) Todd Knause (Date)
Quality Assurance Officer

NEVADA DIVISION OF ENVIRONMENTAL PROTECTION:

4/13/21

(Signature) Alison Oakley, CEM (Date)
Bureau of Corrective Actions, Environmental Scientist III

4/13/21

(Signature) Scott Smale (Date)
DoD Programs Branch Remediation Supervisor

A1.1 NV Energy Certification

I certify that this document and all attachments submitted to the Division were prepared under the direction or supervision of NV Energy in accordance with a system designed to gather and evaluate the information by appropriately qualified personnel. Based on my inquiry of the person or persons who manage the system(s) or those directly responsible for gathering the information, or the immediate supervisor of such person(s), the information submitted and provided by NV Energy is, to the best of my knowledge and belief, true, accurate, and complete in all material respects. I am aware there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Signature: Mathew Johns
Name: Mathew Johns
Title: Director, Environmental Remediation and Resource Development
Company: NV Energy
Date: March 11, 2021

A1.2 Certified Environmental Manager Certification

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and to the best of my knowledge comply with all federal, state and local statutes, regulations and ordinances.

Services Provided: Preparation of Quality Assurance Project Plan for investigation activities at the Reid Gardner Station near Moapa, NV.

Signature:
Name: Rebecca L. Svatos
Title: Project Manager
Company: Stanley Consultants, Inc.
Date: March 11, 2021
EM Certificate Number: 1931
EM Expiration Date: September 30, 2021

A1.3 Acronyms and Abbreviations

AOC	Administrative Order on Consent
ASTM	American Society for Testing and Materials
BCA	Bureau of Corrective Actions
bgs	below ground surface
BLM	Bureau of Land Management
CEM	Certified Environmental Manager
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Chain of Custody
CRP	Community Relations Plan
CSM	Conceptual Site Model
°C	Degrees Celsius
DO	Dissolved Oxygen
DQI	Data Quality Indicator
DQO	Data Quality Objective
DTW	Depth to Water
EDD	Electronic Data Deliverable
EPA	Environmental Protection Agency
FTP	file transfer protocol
GW	Groundwater
HASP	Health and Safety Plan
HAZWOPER	Hazardous Waste Operations and Emergency Response
HDPE	High-density polyethylene
ICOCs	Indicator Constituents of Concern
ID	Identifier
LCD	Laboratory Control Duplicate
LCS	Laboratory Control Sample
MDL	Method Detection Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
NAC	Nevada Administrative Code
NDEP	Nevada Division of Environmental Protection
NELAC	National Environmental Laboratory Accreditation Conference
NFA	No Further Action
NOAA	National Oceanic and Atmospheric Administration
NRS	Nevada Revised Statutes
O&M	Operations and Maintenance
OSHA	Occupational Safety and Health Administration
PARCC	Precision, Accuracy, Representativeness, Comparability, and Completeness
PE	Professional Engineer
PMP	Project Management Professional
QA	Quality Assurance
QAM	Quality Assurance Manual
QAD	Quality Assurance Division

QAO	Quality Assurance Office or Officer
QAP	Quality Assurance Plan
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QC	Quality Control
RBCA	Risk Based Corrective Action
%R	Percent Recovery
RL	Reporting Limit
RPD	Relative Percent Difference
RQL	Reported Quantitation Limit
RGS	Reid Gardner Station
SDG	Sample Delivery Group
SNWA	Southern Nevada Water Authority
SOP	Standard Operating Procedure
SOW	Scope of Work
TIC	Tentatively Identified Compound
TOC	Top of Casing
USGS	United States Geological Survey
VOC	Volatile Organic Compounds

A2.0 TABLE OF CONTENTS

TABLES

APPENDICES

A:	Project Location Maps
B:	Compendium of Field Standard Operating Procedures
C:	Laboratory Quality Assurance Manuals
D:	Example Field Checklist and Summary Forms
E:	Data Validation Standard Operating Procedures
F:	Ordway and Associates Data Validation Memorandum of Understanding

A3.0 DISTRIBUTION LIST

Copies of this QAPP will be distributed as follows:

Nevada Division of Environmental Protection
Bureau of Corrective Actions
DoD and Remediation Projects
901 South Stewart Street
Suite 4001
Carson City, NV 89701
Alison Oakley, Project Coordinator (1 copy)

Nevada Division of Environmental Protection - **Intertribal Environmental Liaison**
cbanuelos@ndep.nv.gov (1 electronic copy only)

Arcadis
1140 North Town Center Drive, Suite 320
Las Vegas, NV 89114
John Kivett, Project Manager (1 electronic copy only)

NV Energy
NV Energy
6226 West Sahara Avenue
Las Vegas, NV 89146
Matt Johns, Director, Environmental Remediation (1 electronic copy only)

California Department of Water Resources
P.O. Box 942836
Sacramento, CA 94236
Kevan Samsam

Moapa Band of Paiute Indians
Moapa Band of Paiutes
1 Lincoln Street
P.O. Box 340
Moapa, NV 89025
Tribal Chair (1 electronic copy only)

Sierra Club Environmental Law Program 2101 Webster Street
Suite 1300
Oakland, CA 94612
Attn: Coordinating Attorney, Gloria D. Smith, Andrea Issod (1 electronic copy only)

Moapa Town Library
1340 Highway 168
P.O. Box 250
Moapa, NV 89025
Attn: Jan (1 copy)

Stanley Consultants
Stanley Consultants, Inc.
2658 Crosspark Road – Suite 100
Coralville, IA 52241
Becky Svatos, Project Manager (1 copy)

Pace Analytical
6000 South Eastern Avenue
Las Vegas, NV, 81119
Jared Starkley, Project Manager (1 electronic copy only)

Isotech Laboratories, Inc.
1308 Parkland Court
Champaign, IL 61821

Ordway and Associates
1710 Wilmor Drive
Jefferson City, MO 65101
Fred Ordway, Data Validation Lead (1 electronic copy only)

OGI Environmental, LLC
8820 West Russell Road, Suite 140
Las Vegas, NV 89148
Rob Thompson, Project Manager (1 electronic copy only)

A4.0 PROJECT ORGANIZATION

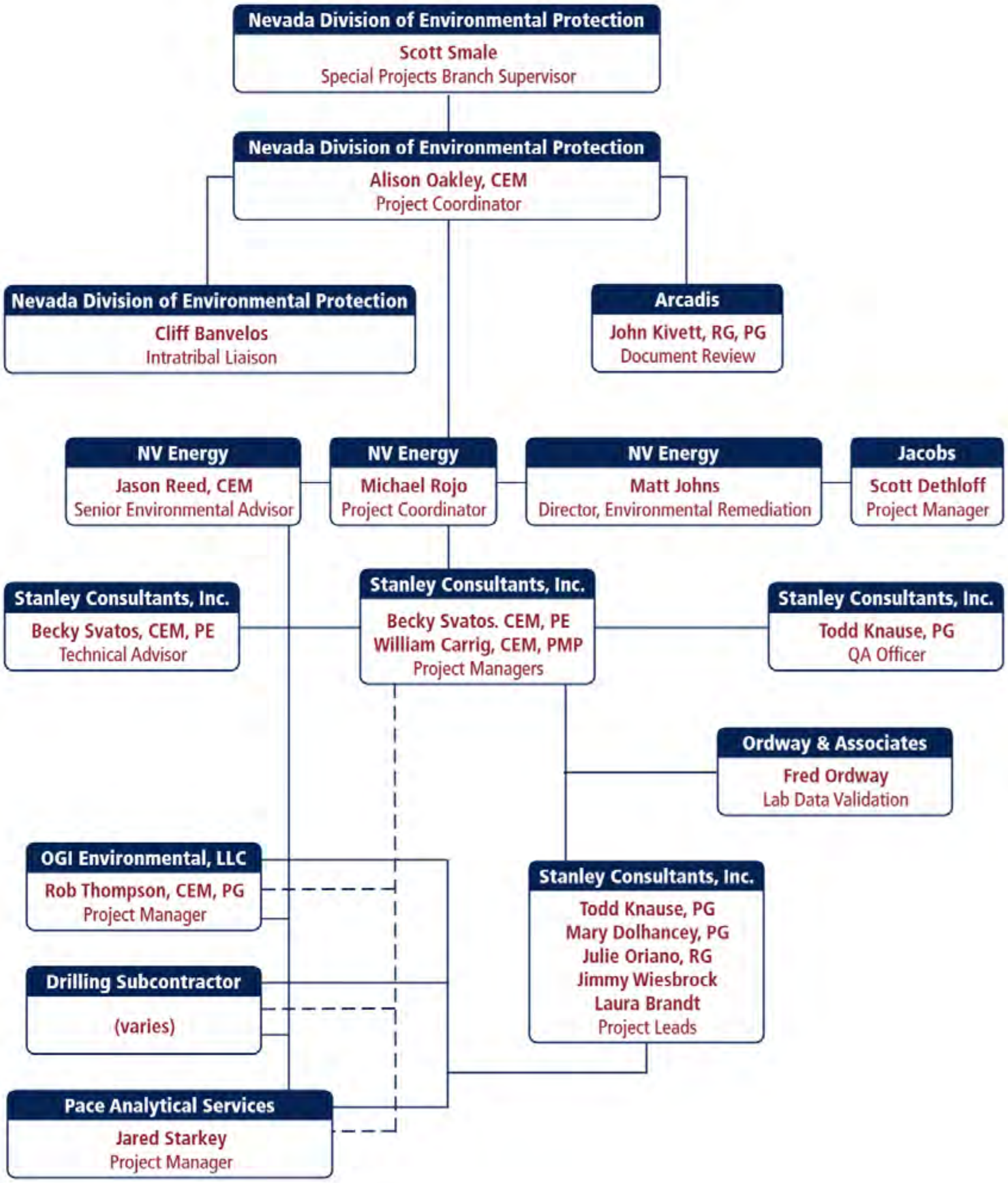
Mr. Scott Smale is the NDEP Department of Defense and Remediation Projects Branch Supervisor. The NDEP Project Coordinator, Ms. Alison Oakley, is responsible for reviewing and approving the QAPP and the Standard Operating Procedures (SOPs), for providing direction regarding the AOC implementation process, and for review and approval of all project submittals. Ms. Oakley reports to Mr. Smale, who assists Ms. Oakley with the review and approval, and provides guidance on the AOC implementation process. Mr. Cliff Banuelos serves as the NDEP Intertribal Environmental Liaison. The NDEP has contracted document review services to Arcadis. Mr. John Kivett, RG, PG serves as the lead for Arcadis and reports to the NDEP Project Coordinator, Ms. Oakley.

Representing NV Energy is Mr. Mathew “Matt” Johns, Director, Environmental Remediation. The NV Energy Environmental Services Supervisor for the Reid Gardner Station (RGS) and this Administrative Order on Consent (AOC) project (Project) is Mr. Michael Rojo. Mr. Rojo serves as the NV Energy Project Coordinator and coordinates efforts between the consultants, and state and federal agencies. In addition, Mr. Jason Reed, Senior Environmental Advisor for NV Energy and Certified Environmental Manager (CEM), also coordinates Project efforts between consultants and government agencies. Mr. Scott Dethloff, Project Manager with Jacobs Engineering Group (Jacobs) also provided project guidance and deliverable review.

Ms. Becky Svatos, CEM and Professional Engineer (PE), and Mr. William Carrig, CEM and Project Management Professional (PMP) are Project Managers for Stanley Consultants, Inc (Stanley Consultants), and oversee consultant activities on the Project. Ms. Svatos reports to the NV Energy Project Coordinator. All daily project activities including implementation of the Work Plans will be managed by Stanley Consultants’ Project Leads, Ms. Laura Brandt, Ms. Julie Oriano, Ms. Mary Dolhancey, and Mr. Jimmy Wiesbrock. The Project Leads coordinate field sampling activities with OGI Environmental (OGI) and the drilling subcontractors; laboratory analytical services with Pace Analytical Services (Pace Analytical and Isotech Laboratories. The laboratories used are subject to change based on their capabilities, performance, certifications, etc. In addition, there may be a need to select a laboratory based on a specialized analysis. Data validation services are provided by Ordway and Associates. Mr. Todd Knause of Stanley Consultants is the Quality Assurance (QA) Officer and reviewer of the Data Quality Objectives (DQO) and Generic Quality Assurance Project Plan (QAPP), site-specific Work Plans, and the Health and Safety Plan (HASP). The Stanley Consultants’ Project Manager (or designee), as well as NV Energy’s Project Coordinator (or designee), will also review and approve the Work Plans and HASP prior to submittal to the Nevada Division of Environmental Protection (NDEP).

The project organization flow chart is provided below on the next page.

PROJECT ORGANIZATION FLOW CHART



A5.0 PROBLEM DEFINITION/BACKGROUND

NV Energy must determine to what extent current and past site activities have impacted the RGS and offsite properties; and what corrective actions are necessary to eliminate potential impacts to sensitive receptors, and risks to human health or welfare and the environment.

A5.1 Introduction and Background

The RGS was a coal-fired electric power generation facility that produced approximately 600 megawatts of power from four generating units. The RGS is located approximately 45 miles northeast of Las Vegas, within the Moapa Valley (Figure 1 in Appendix A). The RGS was developed in 1964 and became commercially operational in 1965. Units 1, 2, and 3 were permanently shut down at the end of 2014 and Unit 4 was shut down in early 2017. Demolition and decommissioning of the former power generation facilities are scheduled to be completed in 2020.

NV Energy and the NDEP entered into an AOC for the RGS on February 22, 2008 (NDEP, 2008). The AOC calls for NV Energy to continue with environmental contaminant characterization activities and for the identification of corrective actions and/or clean-up measures for the soil, surface water and groundwater at the RGS. Additionally, the AOC calls for the implementation and long-term operation and maintenance (O&M) of these NDEP-approved corrective actions. This QAPP is prepared for NDEP review and approval under the 0AOC.

This update to the November 2011 approved QAPP (Stanley Consultants, 2011) is prepared for NDEP review and approval under the AOC process. The purpose of this QAPP update is to address changes in personnel, laboratories, and contractors involved in the implementation of the AOC activities as well as to update some procedures.

This QAPP governs the environmental contaminant characterization, screening and selection of corrective action, and implementation and long-term O&M of NDEP-approved corrective actions concerning pollution conditions at the RGS. These corrective actions and O&M procedures will continue until the corrective action standards are achieved in accordance with the AOC. Analytical data collected as part of the implementation of this AOC will comply with DQOs established by the United States (U.S.) Environmental Protection Agency (EPA), as indicated in this QAPP. Additionally, where appropriate, analytical data will be validated by a third party, Ordway and Associates.

The State of Nevada, through the Nevada Administrative Code (NAC) and Nevada Revised Statues (NRS), has programs for evaluation of environmental impacts. The State legislature has empowered the NDEP to administer and enforce Nevada's environmental laws, including but not limited to air pollution control, hazardous waste disposal, and water pollution control. The appropriate programs may overlap in some instances regarding regulations governing environmental impairment and releases to soil, groundwater and air. Voluntary and non-voluntary risk-based cleanup programs are administered by the state's Bureau of Corrective Actions (BCA).

A5.1.1 Current and Historical Ponds

In May 1997, the NDEP issued an Administrative Order requiring NV Energy to submit a site-wide plan and schedule to eliminate the migration of contaminants into the groundwater. In compliance with the order, NV Energy submitted a plan and a schedule committing to either line all evaporation and ash settling ponds with double-synthetic liner systems or remove the ponds from service. Between 2001 and 2008, Ponds 4B1, 4B2, 4B3, 4C1, 4C2, E1, E2, and F were taken out-of-service, solids removed, lined and put back into service. Ponds 4A1 and G were removed from service and Pond D was converted into a stormwater retention pond following solids removal and lining. Beginning in 2014, all evaporation and settling ponds located adjacent to the Muddy River began the process of being permanently closed.

As of September 2018, NV Energy has permanently closed 11 ponds (Ponds 4A, 4B1, 4B2, 4B3, D, E1, E2, F, G, 4C1, 4C2). Closure of the ponds involved removal of structures, solids and visually impacted soils above the groundwater beneath the ponds. As a result of this work, NV Energy completed the requirements of the 1997 Administrative Order. Since closing existing ponds, NV Energy has constructed two new high-density polyethylene (HDPE) double-lined evaporation ponds on the mesa (M-5 and M-7) to receive plant wastewater (Appendix A, Figure 2).

A5.1.2 Areas of Investigation

The NDEP-approved Preliminary Source Area Identification and Characterization Report (PSAICR) dated July 2013 (Stanley Consultants, 2013), identified 35 potential source areas at the RGS that will be further characterized to determine applicable corrective action. These potential source areas and their associated characterization status and corrective action status as of April 2020 are listed in Table 1. The locations of the potential source areas are shown on Figure 2 in Appendix A:

Table 1 - Potential Source Areas and Current Status

	Source	**Description**	**Characterization Status**	**Corrective Action Status**
Potential Pond Source Areas	PA-1	Hogan Wash	Field investigations conducted 2017-2018 Draft report to NDEP 7-31-19	Currently under evaluation
	PA-2	Former Ponds 4B and 4C	Field investigations conducted in 2015, 2017 and 2018 Report preparation in progress	Pond solids removal complete - 867,000 cubic yards (cy) Pond 4C-1 Solids Removal Completion Report approved by NDEP 7-24-17 Pond 4C-2 Solids Removal Completion Report approved by NDEP 7-24-17 Revised Ponds 4B-1, 4B-2, and 4B-3 Solids Removal Completion Report to NDEP 6-20-19 Need for groundwater corrective action being evaluated
	PA-3	Former Pond 4A	Field investigations conducted 2015-2018 Report preparation in progress	Pond solids removal complete – 501,000 cy Pond Solids Removal Completion Report approved by NDEP 4-5-17 Need for groundwater corrective action being evaluated
	PA-4	Closed Fly Ash Fill Area Under Landfill Haul Road	Future characterization	Future evaluation
	PA-5	Former Pond D	Characterization in progress since 2015 Report preparation in progress	Pond solids removal complete – 290,000 cy Pond Solids Removal Completion Report approved by NDEP 10-11-11 Need for groundwater corrective action being evaluated
	PA-6	Former Ponds E-1 and E-2	Characterization in progress since 2015 Report preparation in progress	Pond solids removal complete - 317,900 cy Pond E-1 Solids Removal Completion Report approved by NDEP 11-21-18 Pond E-2 Solids Removal Completion Report approved by NDEP 7-24-17 Need for groundwater corrective action being evaluated
	PA-7	Former Ponds F and G	Characterization in progress since 2015 Report preparation in progress	Pond solids removal complete - 136,800 cy Pond F Solids Removal Completion Report approved by NDEP 11-8-13 Pond G Solids Removal Completion Report approved by NDEP 10-11-11 Need for groundwater corrective action being evaluated
	PA-8	Hydrogen Peroxide Tank Release	No Further Action determination by NDEP 9/24/18	Peroxide tanks removed; release was abated
Potential Station Source Areas	SA-1	Unit 4 Treated Water Pond	Investigation Closed determination by NDEP 5/3/19	Pond removed in 2017; no impacts identified
	SA-2	Unit 4 Cooling Tower	Characterization complete - Draft report to NDEP 11-15-18	Cooling tower demolished in 2017; no impacts identified (assumed)
	SA-3	Unit 4 Cooling Tower Catch Basin	Future characterization	Future evaluation
	SA-4	Coal Piles and Fly Ash Under Unit 4 Coal Pile	Characterization complete - Revised Unit 4 report to NDEP 9-6-19 Units 1-3 report approved by NDEP 3-21-18	Underlying ash fill to be removed Corrective action design in progress Need for groundwater corrective action being evaluated
	SA-5 & SA-6	Area of Previous Fly Ash Fill	Future characterization	Future evaluation
	SA-7	Unit 4 Settling Pond (Foster Wheeler Pond)	Work planning in progress	Future evaluation
	SA-8	Units 1, 2, 3 Catch Basin	Investigation Closed determination by NDEP 10-19-16	Basin demolished in 2015; no impacts identified
	SA-17	Reported Previous Waste Disposal Area	Investigation Closed determination by NDEP 11-8-16	No buried waste or impacted soil found
	SA-19	Units 1, 2, 3 Scrubbers and Unit 4 Absorber	Work planning in progress	Future evaluation
Potential North Station Source Area	SA-18	ASP-1, ASP-2, ASP-3, Former Clear Wells, Former Fly Ash Disposal Area	Work planning in progress	Future evaluation
Potential Petroleum Source Areas	SA-9	Units 1 and 2 Emergency Diesel Generator	Work planning in progress	Future evaluation
	SA-10	Former Units 1,2,3 Lube Oil Rack	No Further Action determination by NDEP 9-20-16	414 cubic yards petroleum-impacted soil removed and disposed offsite in 2016
	SA-11	Former Gasoline UST (1000-gallon) and Warehouse 1	No Further Action determination by NDEP 1-17-17	665 cubic yards petroleum-impacted soil removed and disposed offsite in 2016
	SA-12	Former Diesel AST (850,000- gallon)	No Further Action determination by NDEP 11-17-17	Diesel AST demolished in 2009, no release from tank
	SA-13	Former Diesel Fuel Unloading Area	Characterization complete	Initial soil removal in 2015 Remaining soil removal deferred until after demolition
	SA-14	Former Underground Product Piping, Petroleum Tanks	Characterization complete Draft LNAPL CSM to NDEP 1-2-19	LNAPL recovery system operated from 1986 to 2015 Need for additional corrective action under evaluation
	SA-15	Free Product Recovery System	No Further Action determination by NDEP 5-5-17	2,672 cubic yards petroleum-impacted soil removed and disposed offsite in 2016
	SA-16	Vehicle Maintenance Area	No Further Action determination by NDEP 5-5-17	6,364 cubic yards petroleum-impacted soil removed and disposed offsite in 2015 and 2016
Potential Mesa Source Areas	MA-1	Closed Sanitary Landfill	Evaluation of Mesa Area groundwater in progress (MA-1 to MA-9 less MA-7)	Future evaluation
	MA-2	Special Asbestos Waste Cell (Active Permit)		
	MA-3	Disposal Area for Construction and Demolition Debris		
	MA-4	Class III Industrial Waste Landfill (Active Permit)		
	MA-5	Closed Ash Disposal Site		
	MA-6	Evaporation Ponds P1 - P5	Evaluation of Mesa Area groundwater in progress (MA-1 to MA-9 less MA-7)	Future evaluation
	MA-7	Landfill Used for Industrial and Non-Industrial Waste	Characterization complete - Report approved by NDEP 9-1-11	Purchasing BLM land - Area of buried debris to be capped
	MA-8	Disposal Area for Water Treatment Waste	Evaluation of Mesa Area groundwater in progress (MA-1 to MA-9 less MA-7)	Future evaluation
	MA-9	Former Mesa Dredge Pond		

A5.2 Problem Statement and QAPP Objectives

This QAPP was developed by NV Energy to ensure that data collected and procedures implemented during the site characterization activities can be used to confirm that the corrective remedies meet the performance criteria and goals for the RGS and surrounding area, ensures compliance with applicable environmental laws, and addresses current and future risk to human health, welfare, and the environment. The Project involves evaluating impacts to soil, groundwater and surface water from various sources including evaporation and settling ponds, landfills, fuel use and storage, and other potential source areas listed in Table 1.

Previous soil and groundwater investigations and regular monitoring events have detected environmental contaminants at the RGS and surrounding properties. These contaminants are potentially associated with the operation of the coal-fired electrical power generation facility and may threaten human health or welfare and the environment at or near the RGS. Environmental investigations to date have not defined and characterized the extent of soil and groundwater contamination and ascertained whether or to what extent contamination has potentially migrated off-site and impacted sensitive environmental receptors such as the adjacent Muddy River and water supply wells.

The QAPP is the critical planning document for the environmental data collection process as it details how quality assurance (QA) and quality control (QC) activities will be implemented during the duration of the site characterization and monitoring activities. In order to collect defensible and replicable environmental data for decision making purposes, the investigations should be conducted in three phases: planning, implementation, and assessment. During the Planning Phase, DQOs are developed that define the expectations and requirements of the decision maker (i.e., data users). In the Implementation Phase, the specifications or standard operating procedures (SOP) for the data collection activities are established to meet the DQO of the data users. During the Assessment Phase, the data is evaluated to determine whether the DQO have been satisfied. Statistical tools are used to determine whether the error in the data is small enough to meet the DQO of the decision makers.

This QAPP is comprised of four elements which are as follows:

- Section A – Project Management
- Section B – Measurements and Data Acquisition
- Section C – Assessment and Oversight
- Section D – Data Validation and Usability

The major objective of the QAPP is to provide a framework for the completion of the monitoring and characterization activities for the groundwater and surface water and soil sampling and analyses within and around the RGS and for the identification and implementation of the corrective actions applicable to each media as necessary to ensure compliance with applicable environmental laws. The common objective of all parties is to seek permanent remedies for all affected media that address current and future risks to human health or welfare and the environment.

The goal of the field investigations is to collect environmental monitoring and measurement data using approved methodologies and procedures that are representative of site conditions and can be replicated, validated and verified. The data and information gathered are subject to specific quality assurance and quality control (QA/QC) requirements to ensure that the accuracy, comparability, completeness, precision, and representativeness of the data are known and documented.

This QAPP must be comprehensive and generic enough to potentially consider all possible sampling scenarios within the AOC implementation. Yet, it must be specific enough to produce accurate, meaningful and useful information that will satisfy DQOs. This document takes the approach of a generic QAPP that applies to all AOC implementation activities and provides for the use of Work Plans and Addendums for specific field data collection activities.

It is the purpose of the QAPP to provide a program of decision making and assessment that provides data quantity and quality that is sufficient to identify areas requiring corrective action, evaluate corrective action alternatives, and implement the selected corrective actions.

A5.2.1 Program Considerations

The NDEP BCA oversees the investigation and cleanup of releases of regulated substances using a multi-media (air, water, soil, and ecological resources) approach. The Bureau also administers the environmental response program, superfund and brownfields programs, a reimbursement fund for eligible petroleum claims, and a certification program for environmental consultants. The certification program (i.e., Certified Environmental Manager) is designed to ensure that competent individuals are providing services and information to the businesses and citizens of the State for environmental investigations and cleanups. The NDEP BCA Remediation Program oversees cleanup activities and determines remedial requirements for contaminated sites throughout the State. The Remediation Branch personnel work with responsible parties and contractors to implement corrective actions in a timely and effective manner and has enforcement authority to implement its programs.

This QAPP has been prepared to address the QA/QC requirements associated with the collection of environmental data for the characterization of the RGS. All sampling activities will be approved by and conducted under the oversight of the NDEP or their representative per the AOC. The QAPP has been designed to support the data collection activities associated with various sampling and analysis tasks. The QAPP is a general guidance document for implementing QA/QC procedures for all sampling and analysis activities associated with the AOC implementation at the RGS. The NDEP has mandated through the AOC that the QAPP meet the U.S. EPA policies and guidance. All sample collection and analyses shall be per approved methods and procedures with the analytical laboratory being certified under applicable Nevada Law. This QAPP is based on several EPA guidance documents including the following references: *Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4*, February 2006 (USEPA, 2006)*. EPA Region 9 Guidance for Quality Assurance Program Plans, R9QA/03.2* (USEPA, 2012), *EPA Requirements for Quality Assurance Project Plans - EPA QA/R-5,* (USEPA, 2001), *Guidance for Quality Assurance Project Plans - EPA QA/G-5,* (USEPA, 2002), and *Uniform Federal Policy for Quality Assurance Project Plans: Evaluating, Assessing, and Documenting Environmental, Data Collection and Use Programs, Part 1: UFP-QAPP Manual (*IDQTF, 2005*).*

This generic site wide QAPP addresses all affected areas defined by previous assessment activities at the RGS. A site-specific Work Plan will be prepared and submitted to the NDEP for review and approval, for each investigation. An Addendum to the Work Plan may be used for subsequent investigations at the same source area. These documents will reference this QAPP and its requirements.

Phased decision logic was used to produce a hybrid design to meet the needs of NV Energy within the strictures of data quality needs of the Quality Assurance Division (QAD) of the EPA and the NDEP. This provides for the most direct application of the data produced to address the closure of individual source areas as they meet the established action levels and conditions for terminating remediation activities as outlined in NAC 445A - Title 40: Public Health and Safety, *Chapter 445A: Water Controls*, Nevada Revised Statues (NRS), Nevada Legislator, 2007 (NAC, 2007a), NAC 459 - Title 40: Public Health and Safety, *Chapter 459: Hazardous Materials*, Nevada Revised Statues (NRS), Nevada Legislator, 2007 (NAC, 2007b), NAC 534 – Title 40: Public Health and Safety, *Chapter 534: Underground Water and Wells*, Nevada Legislator, 2002 (NAC, 2002), and NAC 590 – Title 40: Public Health and Safety, Chapter 590: *Motor Vehicle Fuel, Petroleum Products and Antifreeze* (NAC, 2000).

Several different screening (ex., EPA RSLs) and action levels (ex., EPA MCLs) are considered when evaluating ICOC concentrations in groundwater, soil or surface water. These are summarized in Tables 2 and 3.

Table 2 - Soil ICOCs
QAPP
NV Energy – Reid Gardner Station

Parameter Name	BTV > 20 Feet[1]	BTV 0-20 Feet[2]	BTV All Classifications[3]	BTV Clay[4]	BTV Non-Clay[5]	EPA MCL-based soil leaching to GW SSL[6]	EPA Radionuclide Adult SSL[7]	EPA Risk-based soil leaching to GW SSL[8]	EPA RSL Industrial Soil[9]	NDEP BCL Indoor Worker w/o Dermal[10]	NDEP BCL Outdoor Worker[11]	NDEP LBCL (DAF 1)[12]	NDEP LBCL (DAF 20)[13]	TCLP Regulatory Level[14]
General Chemistry (mg/kg)														
Chloride	180	6,200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fluoride	NA	NA	NA	NA	NA	NA	NA	120	47,000	93,300	51,900	NA	NA	NA
Phosphate as P	NA	NA	0.99	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	6,000	30,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Metals (mg/kg)														
Antimony	NA	NA	0.8	NA	NA	0.27	NA	0.35	470	934	519	0.3	6	NA
Arsenic	NA	NA	90	NA	NA	0.29	NA	0.0015	3	4.35	2.15	1	20	NA
Boron	NA	NA	NA	39	18	NA	NA	13	230,000	100,000	100,000	21.4	427	NA
Cadmium	NA	NA	NA	0.8	0.25	0.38	NA	0.69	980	1140	642	0.4	8	NA
Chromium (total)	NA	NA	NA	49	23	180,000	NA	NA	NA	NA	NA	NA	NA	NA
Chromium (hexavalent)	NA	NA	1.9	NA	NA	NA	NA	0.00067	6.3	12.2	7.01	2	40	NA
Molybdenum	NA	NA	6.3	NA	NA	NA	NA	2	5,800	11,700	6,490	3.37	67.4	NA
Selenium	NA	NA	NA	5.6	NA	0.26	NA	0.52	5,800	11,700	6490	0.3	6	NA
Sodium	770	17,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thallium	NA	NA	NA	NA	NA	0.14	NA	0.014	12	23.4	13	0.4	8	NA

Notes:

mg/kg - milligrams per kilogram

[1] Recommended background threshold values approved by the NDEP for sampling locations located more than 20 feet below ground surface (bgs), as determined by NVE Background Report, December 2014 (Stanley Consultants, 2014b)

[2] Recommended background threshold values approved by the NDEP for sampling locations located 0-20 feet below ground surface (bgs), as determined by NVE Background Report, December 2014 (Stanley Consultants, 2014b)

[3] Recommended background threshold values approved by the NDEP for sampling locations located at all depths and for all soil classifications (i.e. clay, silt, sand, gravel), as determined by NVE Background Report, December 2014 (Stanley Consultants, 2014b)

[4] Recommended background threshold values approved by the NDEP for sampling locations located in clay soils, as determined by NVE Background Report, December 2014 (Stanley Consultants, 2014b)

[5] Recommended background threshold values approved by the NDEP for sampling locations located in non-clay soils, as determined by NVE Background Report, December 2014 (Stanley Consultants, 2014b)

[6] Protection of Groundwater Soil Maximum Contaminant Level (MCL)-based SSL per RSLs from EPA Regional Screening Levels Master Table

[7] Radionuclide activity was compared to the Adult Soil Screening Levels (SSLs) for Ingestion of Soil found in the EPA's Soil Screening Guidance for Radionuclides using default equation values for Ingestion of Soil; February 17, 2010

[8] Protection of Groundwater Soil Risk-based SSL per RSLs from EPA Regional Screening Levels Master Table

[9] Industrial Soil screening levels from EPA Regional Screening Levels Master Table

[10] Basic Comparison Levels for Industrial/Commercial Worker without Dermal as published in the Updated User's Guide and Tables, issued for the BMI Plant Sites and Common Areas Projects

[11] Basic Comparison Levels for Outdoor Industrial/Commercial Worker as published in the Updated User's Guide and Tables, issued for the BMI Plant Sites and Common Areas Projects

[12] Leaching Basic Comparison Levels (DAF1) as published in the Updated User's Guide and Tables, issued for the BMI Plant Sites and Common Areas Projects

[13] Leaching Basic Comparison Levels (DAF20) as published in the Updated User's Guide and Tables, issued for the BMI Plant Sites and Common Areas Projects

[14] Toxicity Characteristic Leaching Procedure limits from Code of Federal Regulations, Title 40 - Protection of Environment; tests leaching concentration, if over limit, then soils are hazardous; applies to all parameters analyzed as TCLP; added July 2013

Parameters with no BTVs either did not have a BTV established in the Background Conditions Report or the BTV was below a relevant screening level and the screening level would be used for remediation decision-making

Table 3 - Groundwater ICOCs
QAPP
NV Energy - Reid Gardner Station

Parameter Name		BTV Muddy Creek Mesa[1]	BTV Muddy Creek North[2]	EPA Secondary MCL[3]	EPA Tap Water[4]	NDEP 2002 Background Level[5]	NDEP BCL - Residential Water[6]	Nevada Primary MCL[7]	Nevada Secondary MCL[8]	Nevada WQS Ammonia[9]	Nevada WQS Aquatic Life 1-Hour[10]	Nevada WQS Aquatic Life 96-Hour[11]	Nevada WQS Beneficial Uses[12]	Nevada WQS Irrigation[13]	Nevada WQS Municipal or Domestic Supply[14]	Nevada WQS Salinity[15]	Nevada WQS Watering of Livestock[16]
General Chemistry (mg/L)																	
Chloride		510	370	250	NA	520	NA	NA	400	NA	NA	NA	NA	NA	NA	NA	NA
Phosphorus, Dissolved (as P)		2.1	0.21	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.1	NA	NA	NA	NA
Sulfate		2,800	1,200	250	NA	1,070	NA	NA	500	NA	NA	NA	NA	NA	NA	NA	NA
Total Dissolved Solids (residue, filterable)		4,700	2,500	500	NA	2,570	NA	NA	1,000	NA	NA	NA	NA	NA	NA	723	NA
Metals (mg/L)																	
Antimony, Dissolved		0.06	0.038	NA	0.0078	NA	0.006	0.006	NA	NA	NA	NA	NA	NA	0.146	NA	NA
Arsenic, Dissolved		0.12	0.11	NA	0.000052	0.16	0.01	0.01	NA	NA	0.34	0.15	NA	0.1	0.05	NA	0.2
Boron, Dissolved		8.9	0.99	NA	4	1.4	6.67	NA	NA	NA	NA	NA	NA	0.75	NA	NA	5
Cadmium, Dissolved		NA	NA	NA	0.0092	NA	0.005	0.005	NA	NA	0.006	0.0005	NA	0.01	0.005	NA	0.05
Chromium, Dissolved		0.1	NA	NA	NA	1	NA	0.1	NA	NA	NA	NA	NA	0.1	0.1	NA	1
Fluoride, Dissolved		4.1	3.5	NA	0.8	NA	1.3	4	2	NA	NA	NA	2.6	1	NA	NA	2
Molybdenum, Dissolved		0.39	0.068	NA	0.1	0.03	0.167	NA	NA	NA	6.16	1.65	NA	NA	NA	NA	NA
Selenium, Dissolved		0.19	0.15	NA	0.1	50	0.167	0.05	NA	NA	0.02	0.005	NA	0.02	0.05	NA	0.05
Sodium, Dissolved		790	450	NA	NA	520	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thallium, Dissolved		0.11	0.07	NA	0.0002	NA	0.000334	0.002	NA	NA	NA	NA	NA	NA	0.013	NA	NA

Notes:

[1] Recommended background threshold values approved by the NDEP for sampling locations located in the Muddy Creek Mesa zone, as determined by Background Report, December 2014 (Stanley Consultants, 2014b)

[2] Recommended background threshold values approved by the NDEP for sampling locations located in the Muddy Creek North zone, as determined by Background Report, December 2014 (Stanley Consultants, 2014b)

[3] Secondary MCLs. These are not site specific and unit of measure consistent with units of the parameter listed in the table.

[4] Federal Tapwater screening level as defined by US EPA Regional Screening Level (RSL) Summary Table

[5] Site specific background level for a particular pollutant (see document RGS_AOC_DP21_NDEP_Fact_Sheet.pdf)

[6] Basic Comparison Levels for Residential Water as published in the Updated User's Guide and Tables, issued for the BMI Plant Sites and Common Areas Projects (November 2009)

[7] Primary MCL groundwater screening levels from EPA Regional Screening Levels Master Table

[8] Radionuclides water quality standards as established by regulation 40 CFR 141.25 and 141.66

[9] Secondary MCL as established by NAC 445.A.455 promulgated by NDEP

[10] Range of values from NAC445A.118 Table 2 (Chronic Water Quality Criteria for Total Ammonia for Waters Where Freshwater Fish in Early Life Stages May be Present) based on pH = 7-9 and temperature=14-26 degrees C; 30-day average standard. The limit for "Nitrogen, Ammonia (as N)" is not included because it is dependent on changing values; see NRS 44A.425, 445.520.

[11] Nevada Water Quality Standard Aquatic Life 1-hour average; from NAC445A.1236 (Standards for toxic materials applicable to designated waters); hardness = 300 mg/L in formulas.

[12] Nevada Water Quality Standard Aquatic Life 96-hour average; from NAC445A.1236 (Standards for toxic materials applicable to designated waters); hardness = 300 mg/L in formulas.

[13] Nevada Water Quality Standard Beneficial Uses; from NAC445A.2168 (Muddy River at the Glendale Bridge) TN and TP annual average standards.

[14] Nevada Water Quality Standard Irrigation; from NAC445A.1236 (Standards for toxic materials applicable to designated waters); hardness = 300 mg/L in formulas.

[15] Nevada Water Quality Standard Municipal or Domestic Supply; from NAC445A.1236 (Standards for toxic materials applicable to designated waters); hardness = 300 mg/L in formulas.

[16] Nevada Water Quality Standard for Salinity; from NAC445A.1233 "Below Hoover Dam"; flow-weighted annual average standard.

[17] Nevada Water Quality Standard Watering of Livestock; from NAC445A.1236 (Standards for toxic materials applicable to designated waters); hardness = 300 mg/L in formulas.

A6.0 PROJECT/TASK DESCRIPTION AND SCHEDULE

This QAPP addresses sampling and analytical activities relative to the AOC implementation at the RGS. The RGS was divided into the potential source areas described in Section A5.1.3 and shown on Figure 2 in Appendix A.

A6.1 Work to be Performed

The Scope of Work (SOW) to be completed under this QAPP is per the NDEP-approved final version of the AOC signed on February 22, 2008 (NDEP, 2008). The SOW provides for the continuation of the environmental contaminant characterization activities, allows for the identification and/or screening of corrective actions, and allows for the implementation and long-term O&M of the NDEP-approved corrective actions at or associated with the RGS.

The overall objective of the SOW is to provide a framework for the completion of the characterization activities for water and soil within and around the RGS and for the identification and implementation of the corrective actions applicable to each media, as necessary. The common objective of all parties is to seek permanent remedies for all media that address current and future risks to human health and the environment.

Detailed Work Plans, or an Addendum if a previously approved Work Plan requires modification, are required for submittal to NDEP for review and approval prior to the start of any field activities.

A6.2 Schedule for AOC Scope Implementation and Deliverables

An overall schedule for AOC implementation activities was submitted to NDEP on December 20, 2019. Updates are provided to the NDEP in monthly AOC reports. During field activities, schedule updates are provided to NDEP in work plans and monthly status reports.

A7.0 QUALITY OBJECTIVES AND CRITERIA FOR MEASUREMENT DATA

The QAPP sets forth generic objectives to address the AOC implementation needs. The specific sampling design strategy for the potential source areas listed in Table 1 will be set forth in separate Work Plans approved by NDEP. A Compendium of field SOPs and guidelines for commonly used investigation activities is provided in Appendix B.

A7.1 Purpose/Background

The major objective of the QAPP is to provide a framework for the completion of the monitoring and characterization activities for the groundwater and surface water and soil sampling and analyses within and around the RGS and for the identification and implementation of the corrective actions applicable to each media as necessary to ensure compliance with applicable environmental laws. The common objective of all parties is to seek permanent remedies for all affected media that address current and future risks to human health or welfare and the environment.

The purpose of this element is to document the DQOs of the Project and to establish performance criteria for implementing the requirements of the AOC. This element sets pre-defined objectives and decisions to clarify objectives for the AOC implementation. The objectives of the parties entering into the AOC are to protect human health and welfare, and the environment, at and near the RGS by the design and implementation of appropriate response actions by NV Energy, to establish a process for NV Energy to reimburse the Division's oversight costs, to resolve the potential claims of the State against NV Energy, and to ensure compliance with applicable environmental laws. The AOC governs the performance and/or completion of environmental characterization, the screening and selection of corrective actions and other response actions, and the implementation and long-term O&M of the NDEP-approved corrective actions concerning pollution conditions.

A7.2 The Data Quality Objective (DQO) Process

The DQO process is used to establish the performance or acceptance criteria, which serves as the basis for designing a plan for collecting data of sufficient quality to support the goals of the Project. The DQO process consists of seven interactive that allows for more than one of these steps to be revisited as more data is collected. Each step in the DQO process includes the following:

Step 1: State the Problem
Step 2: Identify the Goal of the Study
Step 3: Identify Informational Inputs
Step 4: Define the Boundaries of the Study
Step 5: Develop the Analytic Approach
Step 6: Specify Performance or Acceptance Criteria
Step 7: Develop the Plan for Obtaining Data

Specific information associated with each step are described later in this section. The first five of these steps focus on identifying qualitative criteria. The sixth step establishes acceptable quantitative criteria on the quality and quantity of the data to be collected, relative the end use of the data. The seventh step a data collection design is developed that will meet the qualitative and quantitative criteria established at the end of the sixth step.

The seven-step DQO process will be used to evaluate the quality and usefulness of the existing data to develop an overall approach to characterize the RGS and the potential source areas, evaluate and implement corrective actions to protect human health and the environment, and to ultimately obtain closure of the RGS. Site-specific Work Plans will be developed to characterize the potential source areas illustrated on Figure 2 in Appendix A and previously described in Section A5.1.3. A Conceptual Site Model (CSM) is being developed based on the characterization of potential source areas identified at the RGS. Development of the CSM is critical to understanding the impacts of the potential source areas on the entire RGS and off-site properties.

A7.2.1 Step 1: State the Problem

NV Energy must determine to what extent current and past site activities have impacted the RGS and offsite properties. Previous investigations and quarterly monitoring activities have not determined the extent of soil and groundwater contamination, potential impacts to sensitive receptors, and risks to human health or welfare and the environment. Additional characterization is required to define the limits of contamination, evaluate remedies for the environmental impacts, and to achieve site closure. The measurement and method of the determination must comply with the AOC, NAC 445A (NAC, 2007a), and NDEP BCA requirements. The method must produce defensible data. The determination must be relevant to issues of achieving site closure.

Unlike a property with a single land use, the RGS has had multiple uses that potentially have impacted the environment. The QAPP must, to a degree, predict and anticipate what might be needed within the Project area to address current and historical land use activities, in support of NV Energy’s decisions.

Key elements to be considered are:

- The site characterization data will be evaluated as part of a study to enable informed decisions on corrective remedies to achieve closure and no further action (NFA) required determinations by NDEP.
- An NFA determination does not mean contamination does not exist.
- The approved remedy may be a risk-based corrective action adequate to mitigate hazards to public health and the environment on current and future land uses.
- The approved remedy may include engineering and/or institutional controls to obtain closure and issuance of an NFA determination.
- Background levels will need to be established for use in the decision-making process.

A7.2.2 Step 2: Identify the Goal of the Study

The decision is to determine whether the RGS, or a potential source area, is or is not impacted at levels requiring corrective action. Based on the outcome of the data collection activities, there are two actions.

- The RGS or potential source area is "clean" with respect to hazardous substance and/or petroleum product releases and, based on measured conditions relative to the environmental impairment criteria outlined in NAC 445A (NAC, 2007a), poses no reasonable risk to public health and the environment and no further action is required.
- The RGS or potential source area is impacted from hazardous substance and/or petroleum product releases, based on measured conditions of environmental impairment outlined in NAC 445A (NAC, 2007a), and poses reasonable risk to public health and/or the environment. Additional evaluation is necessary in determining an appropriate corrective remedy to obtain closure.

This QAPP does not attempt to derive the site-specific process of each potential source area that resulted in the environmental impact, nor does it attempt to develop a CSM. Instead, it provides a detailed decision framework applicable to any potential source area within the Project area to produce useful and reliable data for the purpose of making informed decisions. The QAPP supports detailed site-specific Work Plans to implement characterization, risk assessment, feasibility and treatability studies, remedial design, compliance monitoring, and closure activities.

A7.2.3 Step 3: Identify Informational Inputs

The decision for closure of a potential source area and the RGS per the NDEP-approved Closure Plan will be in general accordance with *Standard Guide for Risk-Based Corrective Action Applied to Petroleum Release Sites*, Designation E 1739-95 (Reapproved 2015), ASTM International, West Conshohocken, PA, (ASTM, 2015a).

The concept of risk-based corrective action, (RBCA) standardized by the ASTM in *Standard Guide for Risk-Based Corrective Action*, American Society of Testing and Materials (ASTM), Designation E 2081-00 (Reapproved 2015), ASTM, West Conshohocken, PA, (ASTM, 2015b), provides the basis for Nevada's RBCA program. The formulation of the ASTM standard was a joint effort between federal, state, local and industry officials. The ASTM E 1739-95 (Reapproved 2015) standard can be applied to non-petroleum releases as well.

Action levels are defined by NAC 445A.22605 as "…*the level of concentration of a hazardous substance, hazardous waste or a regulated substance in soil, groundwater and surface water that is established pursuant to NAC 445A.2272, 445A.22735, and 445A.2275 and for which corrective action may be required by the Director*."

A7.2.4 Step 4: Define the Boundaries of the Study

The decision must be bound spatially and temporally to be effective. The scales of the physical area and timeframe must be appropriate to the limits of the Project and the nature of site characterization to complete the studies to evaluate appropriate corrective remedies.

A7.2.4.1 Spatial Boundaries

The Project and context of the study including potential sourced identified and summarized in Table 1 is bound by three primary horizontal spatial boundaries and one vertical boundary:

- Horizontal
  - Regional
  - Adjacent impacted properties within the Project area
  - Location-specific
- Vertical
  - Depth of contamination.

Study Area-Regional Boundaries

The RGS consists of an estimated 650 acres located approximately three miles southwest of the Town of Moapa in Clark County, Nevada. Moapa, a town with an approximate population of 1,025 (US Census, 2012), is located approximately 52 miles northeast of Las Vegas, Nevada. The RGS is bound by the abutting properties which are as follows (Clark County, 2018):

North: USA Bureau of Land Management (BLM), Moapa 80 LLC, F C Real Estate 3 LLC, Rajarataka LLC, Union Pacific Railroad

East: Hidden Valley Ranch, BLM

South: BLM

West: BLM, John A Hendrick Living Trust

All properties in the Project study area are located in Township 15 South, Range 66 East, Sections 4, 5, 6, 7, 8 and 9 of the Moapa Valley including potential sourced identified and summarized in Table 1.

Property-Specific Boundaries

This QAPP considers the RGS including potential sourced identified and summarized in Table 1 and adjacent properties to constitute the physical Project area boundaries. AOC implementation activities will consider both the horizontal and vertical spatial effects of ICOCs. The decision process integrates risk and exposure practices with site assessment activities and the selected remedy to ensure the protection of human health and the environment.

A7.2.4.2 Temporal Boundaries

Completion of additional site characterization studies to collect data in support of decision-making will be conducted over the life of the QAPP. Individual potential source area investigations will be conducted under site-specific Work Plans approved by NDEP. The schedule of AOC implementation activities is subject to change.

A7.2.5 Step 5: Develop the Analytic Approach

The purpose of developing the decision rule for the Project is to assemble the DQOs into a clear statement that the Project will use to determine the feasibility of closure for a specific potential source area and the RGS Project area. The statement must estimate parameters of usefulness, a scale for application, specific action levels, and describe the logical basis for choosing among alternative options. The decision rule is a series of logical tests expressed as "if…then" statements. The rule defines the process that NV Energy will use in determining if the RGS or a potential source area is considered environmentally impaired relative to meeting the requirements for closure.

A decision rule is usually a comparison of a parameter of interest to a specific quantitative action level. By comparing concentrations of ICOCs to specific action levels, NV Energy can decide if a potential source area is feasible for closure with no further action necessary or if an alternative course of action is warranted. These actions may include additional characterization, monitoring, corrective action, or modification of the selected remedy.

The primary action limit for the Project will allow a decision to be made by comparing concentrations of ICOCs in groundwater, soil and/or surface water to existing federal or state action levels.

The secondary action limit for the Project will allow a decision to be made by comparing concentrations of ICOCs in groundwater, soil and/or surface water to site-specific action levels established by determining the human health risks posed by the chemicals under NAC 445A (NAC, 2007a) or to site-specific background levels.

The following will be decided for potential source areas and the RGS after having undergone assessment and characterization studies. The elements of the decision rule are as follows:

- If the maximum concentrations of ICOCs in groundwater, soil, or surface water associated with the potential source area or study area do not exceed any of the Project action (ex., MCLs) or screening (ex., RSLs) levels, then NV Energy will consider the potential source area or study area not to be impacted and it is feasible for it to be closed without regard to land use or having to consider remedy of environmental impairment. Several different action and screening levels are considered when evaluating ICOC concentrations in groundwater, soil or surface water. These are summarized in Tables 2 and 3.
- If the concentrations of ICOCs in groundwater, soil, or surface water associated with the potential source area or study area exceed any of the Project action or screening levels,

then NV Energy will consider the potential source area or study area impacted and it is not feasible for it to be closed without further investigation and/or corrective action.

The QAPP does not attempt to derive the site-specific process of each potential source area or study area that might exist within the RGS. Instead, it provides a detailed decision framework applicable to any potential source area or study area within the RGS to produce useful data of a quality that supports the decision that must be made. This QAPP supports a detailed Work Plan to implement additional characterization, monitoring, or closure sampling activities at potential source areas and study areas within the RGS Project area.

A7.2.5.1 Limits to the Decision

The measuring of ICOCs and other parameters to levels of parts-per-billion (ppb) and parts-per trillion (ppt) can lead the public to a misconception that analytical methods are exact measurements of site conditions. Although very controlled, environmental sampling and laboratory analysis are not perfect. Both are performed by SOPs within the acceptable ranges of performance to estimate, as best the method can, the amount of ICOC present. The Project team must develop means to limit or control the cumulative negative impact of performance within these ranges and where they might overlap. The cumulative effect is known as the total Project "error." The following can potentially contribute to the total Project "error."

- Variability of contaminant conditions between sampling points measured within the Project area. NV Energy cannot physically or financially sample everything, everywhere.
- Variations in the measurements made during sampling, handling, and analysis of samples if SOPs are not strictly followed.
- Rounding or adding values during report preparation or variation in methods available for data evaluation.

It is not financially or physically feasible within the AOC SOW to produce an evaluation that is one hundred percent (100%) free of decision error. The setting of limits for data collection and analysis is a practical acknowledgement that few things or methods are truly perfect and that performance within predetermined and accepted limits makes the decisions on data reasonable.

A7.2.6 Step 6: Specify Performance or Acceptance Criteria

A7.2.6.1 Project-Specific Hypothesis

As part of the site closure process, NV Energy needs to determine if the project decision hypothesis is true. For the NV Energy Project, the hypothesis is:

> *"The RGS is not impacted (environmentally impaired) and NV Energy can consider it feasible for closure without considering remedy of groundwater, soil or surface water."*

A7.2.6.2 Project-Specific Null Hypothesis

Using the EPA data quality process for data collection, NV Energy will address the issues of the margin of Project error through a process called “testing the null hypothesis”. This is the design of the sampling and analysis program to prove the contrary or "opposite" hypothesis. This is the hypothesis upon which the total Project "error" has the least negative effect after the decision is made, thereby reciprocally providing the most positive effect resulting from the decision. For this Project the null hypothesis is:

> *"The RGS is impacted (environmentally impaired) and NV Energy cannot consider it feasible for closure without considering remedy of groundwater, soil, and/or surface water."*

In developing the assessment data collection program, to limit cumulative Project errors so that they do not become significant to the quality of the decisions, NV Energy considered the types of errors significant to the Project. The NV Energy team set acceptable limits within which the errors are considered to have the least effect on the quality of the decision.

In the case of this Project, erroneously accepting that the null hypothesis is true (false acceptance decision error) could result in NV Energy identifying a potential source area or the RGS as being impacted and not feasible for closure when it is actually not impaired.

Conversely, erroneously accepting that the null hypothesis is false (false rejection decision error) could result in NV Energy identifying a potential source area or the RGS as not being impacted and considering it feasible for closure without remedy, when it is actually impaired and requires remedy.

A7.2.6.3 Project Specific Factors

The sampling and analysis approach must set limits appropriate to a Project. In setting these limits, the definitive use of the results must be considered. In establishing limits, the issues set forth as inputs to the decision are again re-visited. Relative to the RGS, the following are significant limits of this Project:

- A decision to accept a potential source area(s) as feasible for closure without the need for a remedy does not mean the area has not been impacted by land use activities or that the area will no longer be utilized.
- A decision to consider a potential source area(s) not feasible for closure has two elements: rejection based on generic State standards or based on site-specific limits.

- Under NAC 445A (NAC, 2007a), site-specific engineering and/or institutional controls are acceptable remedies that do not require physical cleanup. However, an NFA determination would be based on the condition of these controls and may potentially limit the use of the property.

Other issues considered significant and specific to setting limits on this Project include:

- Potential point source distributions of contaminants identified during previous investigations in groundwater, soil or surface water will require judgmental sampling within limited areas or "hot spots" to identify a reasonable probability of identification.
- "Hot spots" in soil are directly related to the physical dimensions of the operation or historical activity that are limited by the RGS property boundary, unless otherwise noted.
- ICOCs will be considered in those groups identified under NAC 445A (NAC, 2007a) and the AOC.
- Measured values for "hot spot" ICOCs may be moderately variable due to random distribution within the soil media. Previous sampling and analysis data may not be available or may be suspect due to sampling or analytical methods.

A7.2.6.4 General Project-Specific Limits on Decision Error

The primary comparison to determine "impacted" or "not impacted" will be made relative to the potential sources identified and summarized in Table 1 standards for groundwater, soil, and surface water described in the NDEP-approved Closure Plan.

Cumulative Project error could allow NV Energy to erroneously consider a potential source area or the entire RGS as being "not impacted" and would position the RGS for a no further action" (NFA) required determination. No further investigation of environmental impacts would be conducted other than what might be performed by future owners, operators, or developers as part of their acquisition due diligence. Although this future assessment has a high probability of occurrence due to current industry practice and RGS is currently being decommissioned, there is no guarantee the property will be further evaluated. This Project has been designed to minimize decision error by incorporating field and laboratory QC procedures.

The erroneous inclusion of a potential source area or the entire RGS as being "impacted" and the resultant negative effect of considering the area or site not feasible for closure without corrective action, is mitigated by the use of a secondary decision process to consider background or site-specific standards. Decision of a potential source area or the entire RGS as being feasible for closure but requiring further consideration of corrective action as part of that closure, does not remove that location from potential reuse. It does force further consideration of potential environmental impacts that may influence continued use. For this process of closure feasibility, a lesser emphasis can be placed on the effect of false acceptance decision error since it does not completely remove the Station from final consideration of closure and/or reuse.

Simply stated:

- *If the decision is that the RGS or potential source area is impacted and it is not, then time and money has been expended on unnecessary corrective action, but human health and the environment have been protected;* or
- *If the decision is that the RGS or potential source area is not impacted and it is, then human health and/or the environment has not been protected.*

A7.2.6.5 Point Source Project-Specific Limits

Potential source areas may have point sources of contamination identified as a result of previous investigations. Ultimately, NV Energy will make a decision whether any sampling will be conducted on a target location after conferring with the NDEP. The ability to accurately locate the contaminant source(s), the nature and extent of the release(s), and the direction of groundwater flow will determine the number and type of samples to be conducted.

The Project considered the potential for contaminant point source conditions on decision error for data collection and evaluation within the Project area. A point-source condition will be measured using judgmental sampling. This requires the following:

- Point source judgmental sampling and analysis will attempt to prove the null hypothesis that a potential source area or the RGS is contaminated and cannot be consider feasible for closure.
- The limits for laboratory measurements will be within those limits of precision, accuracy, and repeatability as set forth in the published regulatory method specific to the analysis and as controlled by the laboratory in procedures set forth in Appendix C.
- Point-source judgmental sampling and analysis for groundwater, soil, and surface water will design the strategy to identify the number of samples and locations.
- No less than one (1) soil sampling location will be used for soil point source identification, with one (1) at the estimated center of the potential source.
- No less than one (1) groundwater sampling location will be used for groundwater point source identification, with one (1) at the estimated center of the potential source.
- Judgmental sampling will require ninety percent (90%) completeness of groundwater, soil, and surface water sample locations.

A7.2.6.6 Non-Point Source Project-Specific Limits

Target locations for this Project are unlikely to have non-point sources of contamination. Therefore, non-point sources will not be addressed in this generic DQO/QAPP. If need be, it can be added to the site-specific Work Plan(s).

A7.2.6.7 Project Action Limits

The action limits for the Project will be:

- A location is not impacted and feasible for NV Energy to consider for closure, without remedy, if judgmental samples of groundwater, soil, or surface water do not exceed the State standards set forth in the NDEP-approved Closure Plan.
- A location is impacted, but feasible for closure with special consideration of a remedy of environmental impairment or restricted land use, if concentrations of target analytes in groundwater, soils, or surface water do not exceed any of the site-specific standards, or the NDEP grants an exemption.

A7.2.7 Step 7: Develop the Plan for Obtaining Data

A7.2.7.1 Optimizing the Design

Unlike traditional environmental investigations, which often have a single property with a single point source and an end-use in mind, this Project is a study of multiple potential source areas within the RGS. As a result, the QAPP cannot optimize the sample design relative to data quality. This will be achieved in the site-specific Work Plans.

A7.2.7.2 Adjustments to Generic Designs

This Project sets the following revised site-specific limits on decision error and factors to optimize the generic sampling and designs to be used by the Work Plans as follows:

- The Project will design sampling and analysis to prove the null hypothesis that the potential source areas of the RGS are contaminated and cannot be considered feasible for closure without considering corrective action.
- Point source judgmental sampling and analysis cannot set statistical limits on the sampling design strategy and will rely on the control of laboratory data quality and margins built into the NAC thresholds to support the decision.
- Impacts to groundwater will be assessed for preliminary screening characterization using judgmental sampling methods. This is appropriate for the NV Energy decision as a preliminary characterization to NAC 445A (NAC, 2007a) standards. Previous assessments indicate potential groundwater and surface

water impacts have the highest likelihood to result from leaching of impacted soils. Groundwater for point source evaluation will use judgmental sampling to bias the measurements to areas of existing soil data points.

A7.3 The Data Quality Indicator (DQI)

The site-specific DQOs specify the data type, quality, quantity, and uses needed to make decisions, and are the basis for designing data collection activities. Decisions will be made based on data obtained from sampling and analysis programs. The quality of the laboratory data will be assessed through the evaluation of the data quality indicators (DQIs) which are the basis for assessing the precision, accuracy, representativeness, comparability, completeness, and sensitivity of the data, and is described in detail in A7.3, below. The DQIs are both qualitative and quantitative and their utility is determined through the data review, verification and validation process.

Performance criteria will be based on laboratory results for the target compounds (i.e., ICOCs) for each respective matrix tested; other parameters such as geologic logs, groundwater and surface water elevations, etc.; and visual observations such as staining and odors, as appropriate. Other observations, such as statistical analyses, will be used in conjunction with analytical results to establish whether a sufficient number of samples at appropriate locations has been collected.

This element of the QAPP discusses the desired DQO of the project results to ensure that the goals, as defined in the AOC, are met. The project DQOs developed specifically for meeting the requirements of the AOC have been determined based on EPA's seven-step DQO process. The DQOs have been developed to align data collection with project objectives. The objectives are a blend of qualitative and quantitative statements that:

- Clarify the intended use of the data relative to meeting the requirements of the AOC.
- Define the type of data which may be required to support the primary decision on whether corrective action is required.
- Identify conditions under which specific types of data should be collected relative to the goals of the AOC.
- Specify tolerable limits appropriate for the use of data for the project, which address the probability and effect of making a decision error due to uncertainty in the data.

Field sampling programs are designed to provide the type and quantity of data needed to satisfy each of the aforementioned objectives. Separate Work Plans and addendums specify the data collection activities including the number of samples, respective locations, and sampling techniques. Data collected through implementation of the AOC may be used to characterize the nature and extent of affected soil, surface water, and groundwater to support the evaluation of corrective/remedial action, and/or to assist in determining the need for additional actions. The implementation of the AOC SOW will be conducted and documented so that the data collected are of sufficient quality and quantity for their intended use of obtaining site closure and satisfy federal, state, and local data quality guidelines.

The quality of the data will be assessed through the procedures further described in this QAPP. The analytical testing results will be subjected to data validation, as appropriate. Data are considered valid if the specified limits on PARCC are achieved. The results of detected target constituents will be considered in evaluating the need for additional sampling of soil, groundwater, and surface water.

A7.3.1 Precision

Precision is a measure of mutual agreement between two or more individual measurements of the same property, obtained under similar conditions. Examination of precision is a means to evaluate the reproducibility of measurements under a similar set of conditions and is expressed in terms of relative percent difference (RPD). Laboratory duplicates include matrix spike duplicates (MSDs) and laboratory control sample duplicates (LCSDs). Analytical results from LCSDs, and MSDs provide information on laboratory precision.

Field duplicates (i.e. split) provide a measure of the total analytical method bias (field and laboratory variance) including bias resulting from the heterogeneity of the duplicate sample set itself. Field duplicate samples may be collected if there is sufficient mass available and necessary to meet the DQOs. In instances where there may not be enough mass to collect a field duplicate, a field replicate or co-located sample may be collected

The precision of duplicates or replicates is assessed by calculating the RPD between the duplicated or replicated results. The laboratory RPDs are presented in Tables 4, 5, and 6 of Section B2.5. In general, if the laboratory or field duplicate RPD exceeds 30 percent (30%) for organics and 20 percent (20%) for inorganics, the data are qualified as described in the applicable validation procedure *National Functional Guidelines for Organic Superfund Methods Data Review* EPA-540-R-2017-002, January 2017 (USEPA, 2017a) and *National Functional Guidelines for Inorganic Superfund Methods Data Review* EPA-540-R-2017-001, January 2017 (USEPA, 2017b). The RPD between duplicate or replicate sample results is calculated by the following equation:

$$RPD\,(\%) = \left[\frac{S - D}{\left(\frac{S + D}{2} \right)} \right] \times 100$$

Where S is the concentration of the original sample and D is the concentration of the duplicate sample.

A7.3.2 Accuracy

Accuracy is a measure of closeness or agreement of the observed value or test response to the true or acceptable reference value or the test response from a reference method. It is influenced by both random error (precision) and systematic error (bias).

The term “bias” is the constant or systematic distortion of a measurement process which differs from random error that manifests itself as a persistent positive or negative deviation from the known or true value. This can result from improper data collection, poorly calibrated analytical or sampling equipment, or limitations or errors in analytical methods and techniques.

Accuracy is expressed as the percent recovery (%R) of a spiked sample. In the laboratory, a sample is spiked with a known concentration of a chemical from a list of analytes detectable by the method being evaluated. Accuracy of laboratory analyses will be assessed by laboratory control samples (LCSs), matrix spikes (MSs), surrogate standards, and/or standard reference material. All of which use high purity chemical compounds of known concentrations to calibrate instruments and confirm the accuracy of the method. All potentially significant sources of error have been evaluated explicitly for the application of the method and the matrix under investigation. The details of testing methodologies are well documented and published in technical journals.

The results provide information on matrix interference and method performance. The %R is calculated as follows:

$$\%R = 100 \times \frac{X_s - X}{T}$$

Where X_s is the measured value of the spiked sample, X is the measured value of the unspiked sample, and T is the true value of the spike solution added.

A7.3.3 Representativeness

Representativeness is a qualitative measure of the degree to which data accurately and precisely characterize a population, parameter variations at a sampling point, a process condition, or a condition; the correspondence between the analytical result and the actual quality or condition experienced by a contaminant receptor. The design of each sampling program, as detailed in the site-specific Work Plan, is developed to collect data that are representative of site conditions.

Many factors can influence how representative the analytical results are for an area sampled. These factors include the selection of appropriate analytical procedures, the sampling plan, matrix heterogeneity and the procedures and protocols used to collect, preserve, and transport samples. Field duplicate or field replicate collection, as defined under precision, is also used to assess representativeness. If the RPD between the two samples exceeds 50 percent (50%) for organics or inorganics, the laboratory will be contacted to evaluate the discrepancy.

A7.3.4 Completeness

Completeness is the measure of the amount of valid data obtained from a measurement system as compared to the planned amount, usually expressed as a percentage; also, a measure of the degree to which the sampling scheme represents the available range in something, regardless of what was planned.

A completeness value less than 90 percent (90%) indicates that corrective action is necessary to limit the number of unacceptable results and to avoid similar results in future sampling events. Completeness is calculated using the following equation:

$$\%Completeness = 100 \times \frac{Number\ of\ Valid\ Results}{Number\ of\ Expected\ Results}$$

A7.3.5 Comparability

Comparability is the qualitative measure of the confidence with which one data set, element, or method can be considered as similar to another; e.g., taken from the same location, taken in a similar manner, etc. It is dependent on consistency of sampling conditions, procedures, preservation and analytical methods.

A7.3.6 Sensitivity

Sensitivity is the ability of a method or instrument to detect target compounds at the concentrations of interest. Detection and quantification limits vary with the specific instruments used and analytical methods applied. Specific laboratory methods have been selected based on method detection capabilities and laboratory-specific detection capabilities such that laboratory reporting limits are less than applicable regulatory standards i.e., action levels) and/or screening levels. Targeted method detection limits (MDLs) and reporting limits (RLs) are provided to the laboratory prior to submitting samples for analyses. Samples with high contaminant concentrations, such that dilutions are performed to avoid damaging laboratory instruments, are a leading cause of RLs exceeding applicable criteria. When RLs exceed regulatory standards and the ICOC is reported as non-detect, the laboratory may be asked to reanalyze the sample for the specific ICOC.

A8.0 SPECIAL TRAINING REQUIREMENTS AND CERTIFICATIONS

The Project must consider special training requirements necessary to the requirements of the AOC, NACs, and NRS. This QAPP has considered these needs.

A8.1 Purpose and Background

The purpose of this element is to provide the specialized training necessary to complete the Project. The training skills must be verified, documented and updated as necessary to assure the competency of all the personnel performing Project-related activities. Training and certification records will be maintained and contain enough detail to verify the suitability and relevance of the certification and training.

A8.2 Training

The Project has identified special needs as part of the DQO process. In addition, the Project considered the following necessary to have a quality completion of the Project:

A8.2.1 Certified Environmental Manager (CEM)

The NAC 459 (NAC, 2007b) and the AOC requires the Project Manager be a CEM and certify all deliverables.

A8.2.2 Registered PE

Issues relative to site remedies and corrective action plans could involve the need for professional judgment or resolution under NRS 625.005 through 625.0590, inclusive.

A8.2.3 Nevada Registered Well Driller

Nevada has a program of registration for companies who drill soil borings, water supply wells and monitoring wells into groundwater of the State of Nevada. The company and staff must demonstrate proficiency and experience in the drilling, sampling, installation and abandonment of wells and the methods necessary under NAC and NRS 534 (NAC, 2002). This project requires drilling and sampling of groundwater through monitoring wells.

A8.2.4 Nevada Certified Laboratory

Nevada has a program of certification of laboratories that perform analysis of environmental samples in the State of Nevada. The laboratories certified under Nevada Law must use approved procedures and the latest EPA (SW-846) methods as presented in *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods; Third Edition; and subsequent* *updates; Final Update III-A EPA SW-846*, March 1999 (USEPA, 1999b), or other methods deemed satisfactory by the NDEP in obtaining the highest quality data. Pace Analytical Services will serve as the lead or primary testing facility and their Quality Assurance Manual (QAM) in Appendix C. Stable isotope analyses may be conducted on some samples and will be provided by Isotech Laboratories. Their Quality Assurance Plan (QAP) is also located in Appendix C of this QAPP. Periodically, other specialty analyses may be required which will be contracted through the primary laboratory. Specialty analyses may not be certified under the Nevada Certified Laboratory Program.

A8.2.5 Health and Safety

All field staff involved in sampling and analysis activities will have been trained in Occupational Safety and Health Administration (OSHA) Title 29, Code of Federal Regulations (CFR) Part 1910.120 (29 CFR 1910.120). requirements for hazardous waste site workers, including use of respirators. This will include a minimum of 40-hours of base Hazardous Waste Operations and Emergency Response (HAZWOPER) training and appropriate 8-Hour annual refresher training. Personnel will be enrolled in an annual medical monitoring program, as appropriate.

A property-specific HASP will be prepared and kept at the RGS. All site workers are required to review the HASP prior to initiation of field activities. In addition, a location- specific HASP will be prepared for site-specific Work Plans. All HASPs will be generated and supervised through a professional trained and experienced in the field of health and safety.

A8.2.6 Data Quality Process

The EPA regions periodically conduct training sessions on DQOs, validation, and QA procedures. The objective of the training is to enhance project planning and DQO/QAPP development. The interactive workshop for "*Systematic Planning Process and Quality Assurance Project Plans*", was attended by the Quality Assurance Officer (QAO) or designee.

A8.3 Certification

The QAO (or designee) will verify and document that specialized training certification is up to date. The Project Manager or Project Lead supervising field activities will verify that subcontractor personnel have the necessary training documentation prior to implementation of the field activities. If the specialized training expires while conducting the field activities, the individual will have 72 hours to submit documentation to the QAO or Project Lead of enrollment in a recertification course within the next 30 days. If recertification cannot be obtained within 30 days of expiration, the individual may no longer participate in conducting the field activities. Copies of the recertification documents will be forwarded to the QAO upon receipt. Failure to do so will prohibit this individual from resuming field activities at the RGS.

Documentation and certification as to the requisite skills and training necessary in A8.2 will be required as follows: Copies of certificates for project documentation will be kept in the project files of record at Stanley Consultants' offices. Pace Analytical Services, OGI, others collecting data at the RGS, and drilling contractors will retain copies of corporate and personnel certificates at their respective offices.

Below is a listing of specialized training received by the Project Team members:

- Nevada Certified Environmental Manager (CEM)
    - NV Energy Senior Environmental Advisor
    - Stanley Consultants Project Manager
    - Stanley Consultants Technical Advisor
    - Stanley Consultants Field Team Leader

- Nevada Registered Professional Engineer
    - Stanley Consultants Project Manager

- Nevada Registered Water Well Driller
    - Drilling Contractor (varies)

- Nevada Certified Laboratory
    - Pace Analytical Services
    - IsoTech Laboratories, Inc.

- OSHA Hazardous Waste Operations and Emergency Response (HAZWOPER) Training
    - Drilling Field Staff
    - OGI Environmental Field Staff
    - NV Energy Senior Environmental Advisor
    - Stanley Consultants Project Manager
    - Stanley Consultants QAO
    - Stanley Consultants Project Leads
    - Stanley Consultants Field Team Leader
    - Stanley Consultants Field Staff

- Data Quality Process
    - Ordway and Associates Lead
    - Stanley Consultants QAO

A9.0 DOCUMENTATION AND RECORDS

This element sets forth the types of data that will be retained in project files and the proper retention and disposition of project documents. Stanley Consultants' Project Manager, in coordination with the QAO, will be responsible for ensuring the most current approved version of the QAPP is available for use by OGI, Stanley Consultants, and other sampling team personnel.

A9.1 Critical Documentation

The following documentation must be maintained to track and control the quality of Project work. The documents will be essential in recording deviations and in evaluating compliance with this QAPP. The documents are shown hereafter with the assigned responsibility.

A9.1.1 Electronic Status Reports

The Project Manager or Project Leads will deliver, by e-mail, electronic status reports to members of the team. The project summaries will be delivered on a monthly basis, depending on the status of overall Project activity. During periods of field activities, the electronic status reports will be prepared and distributed on a daily and/or weekly basis. Copies of the status reports will be filed with Project documents at Stanley Consultants' office locations. Status reports will show the date and distribution list.

A9.1.2 Daily Field Reports

During field activities, the Project Lead, or designee, will compile a daily report, various activity summary sheets and forms found in Appendix D, as well as records supplied by OGI, drillers, drilling subcontractors, and others collecting data at the RGS as applicable to the field activities. These will be forwarded to the Project Manager, or designee, on a weekly schedule. Generic field forms are provided in Appendix D. Forms used in the field may vary depending on recording media used (i.e., paper or electronic).

Stanley Consultants' Project Lead, or designee, will oversee and/or coordinate all AOC implementation field activities conducted by OGI and others collecting data at the RGS.

A9.1.3 Field Logbook

During field activities, the Field Team Leader, or designee, will compile and complete a daily logbook. The Project Lead, or designee, will maintain the logbook, in addition to filling out various field activity summary forms. Copies of the field logbook and summary sheets will be delivered to the Project Manager, or designee, on a weekly schedule. Between field activities, the Project Lead will maintain the logbook at the central files in Stanley Consultants' offices. The Field Logbook or File Folder will contain at least the following information:

- Approved copy of Work Plan;
- Site sketch or map with location of each sample point and any relevant photographs;
- Current copy of access agreement negotiated with the property owner (if applicable);
- Current copy of public utility clearance for property with location sketch (if applicable);
- Full descriptions of any deviation from the SOPs, the Work Plan or the QAPP;
- Description of daily field sampling conditions and physical parameters as appropriate to the methods and the media involved;
- Daily calibration records of any field instruments appropriate to the methods and media involved; and
- Field Logbook if utilizing a Field File Folder.

A9.1.4 Custody Records

The Project Lead, or designee, will maintain copies of completed chain-of-custody (COC) records and field sampling summary forms provided in Appendix D and supplied by OGI, Stanley Consultants and others collecting data at the RGS. Generic Field Forms are provided in Appendix D as examples. Actual forms used in the field may vary depending of recording media (i.e., paper or electronic). The Field Team Leader will deliver COC copies to the Project Lead, Project Manager or designee on a daily basis. After field activities, COCs will be maintained with the Field Logbook or in the central files at Stanley Consultants' offices.

The QA designee of the analytical laboratory will maintain the original COCs with sample data and annotate with laboratory custody information. A copy of the original COCs with a record of laboratory custody will be provided to the Project Manager, or designee, with the written laboratory reports.

A9.1.5 Laboratory Deliverables

The QA designee of the analytical laboratory, shown in Section A4, will maintain the narrative descriptions and explanations for deliverables. These will be maintained consistent with the requirements of record retention found in EPA QA guidance documents listed in the References following Section D4 of this QAPP. These will contain, but shall not be limited to, the details of record-keeping that are found in Appendix C: Pace Analytical Services, *Quality Assurance Manual, December 2, 2018, Revision No. 6.1.* Pace Analytical Services , Isotech and other specialty laboratories will deliver Level II or Level IV data packages, depending on Project requirements. Level IV data packages will contain the following:

- Client name and address, project name and number;
- Sample date, sample receipt and analysis date, sample identification name or number, sample matrix;

- Analytical methods and RL, analytical results and units, data qualifier code and description, analysts' and QA/QC reviewer's name;
- COC and cooler receipt form;
- Case narrative referencing or discussing analytical procedures and any difficulties that were encountered and deviation from SOPs and the QAPP;
- Corrective action report, if necessary;
- QA/QC reports with recoveries and limits for MSs, MSDs, surrogate spikes, internal standards, LCSs, method blanks, and laboratory duplicate samples;
- Instrument calibration curves, standards, performance checks, sequence logs, continuing calibration and tuning checks;
- Sample and standards preparation logs;
- Bench reports;
- Raw analytical data.

The Level II analytical reports will contain the following information:

- Client name and address, project name and number;
- Sample date, sample receipt and analysis date, sample identification name or number, sample matrix;
- Analytical methods and RL, analytical results and units, data qualifier code and description, analysts' and QA/QC reviewer's name;
- COC and cooler receipt form;
- Case narrative referencing or discussing analytical procedures and any difficulties that were encountered and deviation from SOPs and the QAPP;
- Corrective action report, if necessary;
- QA/QC reports with recoveries and limits for MSs, MSDs, surrogate spikes, internal standards, LCSs, method blanks, and laboratory duplicate samples.

Analytical records will be maintained by Pace Analytical Services for a period of five years. Samples will be retained by Pace Analytical Services for 30 days following issuance of laboratory reports. After 30 days, Pace Analytical Services will dispose of samples in accordance with applicable regulations, unless requested to hold the samples until validation is complete. Isotech and other specialty laboratories will be required to maintain analytical records consistent with the primary laboratory.

A9.2 Data Reporting Package Format and Control

Laboratory data will be delivered in electronic format to the QAO, or designee. The QAO, or designee, will be responsible for reviewing the data for completeness and transmission errors prior to distributing the data package to Ordway and Associates for data evaluation and to the project files. Electronic Data Deliverables (EDDs) will be transferred via email from Pace Analytical Services Quality Officer to the Stanley Consultants QAO in an Excel® spreadsheet format developed by NV Energy. Data fields will include the following:

- Sample identifier (ID),
- Date,
- Method,
- RL,
- MDL,
- Analytical Compound,
- Results,
- Unit, and
- Qualifier.

The QAO, or designee, will store the data in the project folders on Stanley Consultants' servers until the data validation has been completed. At which time, the Project Manager, or designee, will distribute the EDD via Files Anywhere, the Project's file transfer protocol (FTP) site. The laboratory data will be copied into a master spreadsheet of analytical data for the Project in an Excel® format and integrated into an Access® database maintained by Stanley Consultants. Within each spreadsheet will be the following data fields:

- Location,
- Date,
- TOC Elev. (i.e. Top Of Casing Elevation),
- DTW (i.e. Depth To Water),
- GW Elev. (i.e. Ground Water Elevation), and
- Analytical Compounds.

Field documents will be recorded on standard paper formats of Stanley Consultants' using pre-printed forms, bound logbooks, and in indelible pen (examples are provided in Appendix D). Line-through corrections with initials and date will be made in lieu of erasures. The Field Team Leader will retain all project documents within their physical control at the end of any Project field day. During pre-, interim, or post-field periods, the Field Team Leader will see that copies of the Project field documents are delivered to the Project Manager, or designee, and retained in Project files.

Electronic filing of data transferred to electronic platforms will be stored on the Stanley Consultants' network, resident at the server with nightly backup by separate means. The electronic file protocol for the Project will be per Stanley Consultants' Corporate Manuals for documentation and record-keeping, mirroring with electronic folders the hard file names and identifiers. Electronic platforms and formats for the project will consist of the following standards or equivalent updates:

- Word Processing - Microsoft® Word 2016
- Spreadsheets - Microsoft® Excel 2016
- Database - Microsoft® Access 2016
- Schedule - Microsoft® Project 2016
- Drafting - AUTOCAD® 2016 and ArcGIS® 10.2.2
- Archiving - Adobe Acrobat® XI Pro

Public outreach and delivery of the project findings are a critical element of the Project's success. NV Energy will maintain the Project deliverable data and status reports as described in the AOC and has developed a Community Relations Plan (CRP) to aid in this process. Electronic copies of final deliverables, including laboratory results, are provided to NDEP for posting on the NDEP website for the Project.

A9.3 Document Retention and Retrieval

The Project Manager will be responsible for supervising the administrative support personnel in maintaining the Project files for the duration of the project. The Project files will be kept in Stanley Consultants' offices while the Project remains active. Upon completion of the Project, Stanley Consultants will archive the Project files at a secure storage facility for a period of 5 years after the completion of the Project. After 5 years, the disposition of the Project files will be determined by NV Energy.

Document distribution will be as indicated for the QAPP in Section A.3, with the exception of Pace Analytical Services and OGI. It will be the responsibility of the Project Manager to assure that the most current version of the QAPP is available for distribution. Document retention will be as follows:

- Final reports as hardcopy files at NV Energy offices by the Project Coordinator or successor for a minimum of 5 years.
- "FILE" copies of final reports will be maintained at Stanley Consultants' offices for a minimum of 5 years. After a period of two years from Project completion, documents will be transferred to inactive status and archived.
- Electronic copies of report text, drawings, and spreadsheets will be maintained electronically for a period of at least one year from the final reporting and close of Project prior to transfer to electronic files for a minimum of an additional 5 years of storage.

Retrieval of hard copy records by authorized parties can be accomplished from NV Energy files through the NV Energy Project Coordinator.

Retrieval of hard copy records by authorized parties can be accomplished from Stanley Consultants' Project Manager.

Laboratory reporting requirements and data retention will be in accordance with Appendix C and applicable EPA analytical methods shown in Tables 2,3 and 4.

SECTION B - DATA GENERATION AND ACQUISITION

B1.0 SAMPLING PROCESS DESIGN

This element of the QAPP describes the technical and practical implementation of the sampling design developed and discussed in Section A7 through the DQO process for this Project. Because this document is a generic QAPP, specifics on sampling location, depth, media, procedures, etc. will be included in subsequent site-specific Work Plans that may follow SOPs and guidelines for commonly used investigation activities provided in Appendix B and will specify which SOPs will be used during the implementation of the AOC field activities.

B1.1 Purpose and Background

The Project requires judgmental designs for the selection of sampling locations to address contaminant locations. The generic design of the QAPP must be flexible and adaptable to explore conditions of environmental impact that have yet to be defined and/or fully characterized. The generic design must produce quality, defensible data sufficient to meet a balance of needs for decision-making and the strictures of NDEP and EPA programs.

B1.2 Scheduled Project Activities

The dynamic nature of a generic QAPP, which is designed for the study of RGS cleanup and closure feasibility, does not allow for specifying specific dates of completion. A tentative schedule for AOC implementation activities has been approved by the NDEP. This schedule will be revised throughout the duration of the Project.

B1.3 Rationale for the Generic Designs

The development and discussion of DQOs in Section A7 identified the need for two types of assessment/characterization to make primary and secondary decisions to determine groundwater, soil, and/or surface water impacts. From the DQO development in Section A7, the following hold true:

- The primary decision relative to impacts in groundwater, soil, and/or surface water will relate to NAC 445A (NAC, 2007a) State standards. The secondary decision for groundwater, soil, and/or surface water impacts will relate to NAC 445A (NAC, 2007a) site-specific RBCA standards.
- The Project area has point source potential release types.
- Optimization of the design in Section A7 produced a judgmental approach to sampling and analysis of groundwater and surface water for making direct comparison modified by fixed association with soil sampling locations.

- The Project will design sampling and analysis to prove the null hypothesis that the potential source area of the RGS is contaminated and cannot be considered feasible for closure without considering corrective action.
- Point source judgmental sampling and analysis cannot set statistical limits on the sampling design strategy and will rely on the control of laboratory data quality and margins built into the NAC thresholds to support the decision.
- Impacts to groundwater will be assessed for preliminary screening characterization using judgmental sampling methods. This is appropriate for NV Energy decisions as a preliminary characterization to meet NAC 445A (NAC, 2007a) standards. Previous assessments indicate potential groundwater and surface water impacts have the highest likelihood to result from leaching impacts from soils. Groundwater for point source evaluation will use judgmental sampling to bias the measurements to areas of existing soil data points.

B1.4 Assumptions of the Generic Designs

Without having completed the site characterization studies of all the potential source areas, few specific assumptions can be made herein. However, a number of baseline common assumptions were considered in the DQO process and are set forth here in summary:

- The media of soil will not likely be affected by local changes in weather or seasons but may be impacted by groundwater elevation fluctuations.
- Heterogeneity of soil materials is anticipated, both natural and manmade, and is considered to have no significant effect on the limits of the decision.
- The media of groundwater may be influenced by vertical elevation, but these are not expected to significantly affect chemical changes.
- The deep Muddy Creek Formation and shallower alluvium aquifers may act somewhat independently of each other. Groundwater in each respective aquifer may flow horizontally in somewhat different directions. Confining pressures may create an upward (vertical) flow component in some areas potentially inhibiting vertical contaminant migration.
- The media of surface water may be influenced by changes in the weather or seasons, but these are not expected to significantly affect contaminant changes.

At this time, no contingency plan to account for unknown conditions and exceptions can be formulated. If such conditions are identified as part of developing a Work Plan, the Project Manager, or designee, will write a site-specific procedure for attachment to the Work Plan.

B1.5 Generic Procedures for Locating and Selecting Samples

The most appropriate plan for selecting samples for any particular location and potential condition of environmental impairment considers the following under this Project:

- The exploration is a single phase with the probability of existing sampling and analysis data utilized in the decision-making process.
- The method of selection must be consistent between all study areas of concern.
- Physical structures may obstruct access for a specific sampling design approach.
- Optimization and ongoing prioritization of study areas and potential source areas of concern may have to occur as site characterization data becomes available.

The number and specific sampling locations will be determined on the basis of the QAPP, prior to the field mobilization, as part of the Work Plan development. The Work Plan will be based on the results of the earlier studies and will have a site map showing sampling locations.

B1.5.1 Lateral (Surface) Sample Locations

Sample locations and frequency must be determined in a consistent manner for continuity between study areas and potential source areas within the Project area to provide a meaningful consideration of feasibility for closure by NV Energy.

B1.5.1.1 Point Source Conditions-Soil

The previous investigations indicate the size of a potential point source release will vary depending on the physical size and duration of the operations which generated the source of impairment (e.g., drums, tanks, ponds, landfill, or other potential sources). The size of the operational area bears directly on the likelihood of biasing the sampling to obtain a maximum-to-standard comparison. Two assumptions are made in the generic judgmental design based on industry observation:

1. The probability of encountering a reasonable estimate of the maximum concentration is immediately at the center of the point source and decreases with distance from the center.
2. The probability of encountering a reasonable estimate of the maximum concentration is near the surface (not the immediate surface due to biological and ultraviolet ionization effects within the top few inches of soil) beneath the point source and decreases with depth (unless subsurface point source).

Some offsets may not be identified until field mobilization. Offsets from the approved locations in the Work Plan may be made by the Field Team Leader, or designee, with justification and documentation in the Field Logbook and Daily Field and Electronic Status Reports.

B1.5.2 Vertical (Subsurface) Sample Locations

The intended use of NAC 445A (NAC, 2007a) exposure pathways for evaluating human health risks as part of the decision process exerts a direct bias on the location of samples in the Project area.

B1.5.2.1 Soil

NAC 445A (NAC, 2007a) site-specific standards for soils consider all relevant exposure pathways in evaluating potential public exposures to ICOCs. In calculating site-specific standards, ASTM 1739-95 (*Standard Guide for Risk-Based Corrective Action Applied to Petroleum Release Sites*, Designation E 1739-95 (Reapproved 2015), ASTM International, West Conshohocken, PA, 2015) (ASTM, 2015), differentiates between a surface zone of less than two (2) feet and a second soil zone of exposure to soils below two (2) feet of the surface. These zones will determine primary sample intervals, modified within the second zone by adaptive field screening methods described later.

Point source soil sampling will be positioned to accumulate data for the secondary decision, a comparison to NAC 445A (NAC, 2007a) site-specific standards. The Work Plan will identify the anticipated depth of contamination based on land use, nature of release, and previous investigation results, if any. Depth and location of either judgmental or statistically located samples will be as follows:

- A Range 1 sample collected from surface to a depth less than two (2) feet at any soil sampling location, excluding any part of the sample identified as pavement or granular crushed rock or gravel surfaces.
- A Range 2 sample collected at greater than two feet in depth at any soil sampling location if historical data indicates a probability of fills placed in excess of two feet in depth, the location has existing structures, or subsurface source. The structure contingency addresses possible foundation backfills using on-site materials. The specific sampling interval will be selected on the basis of non-critical field measurements and/or observations. If field measurements or observations do not indicate biased selection of a sample interval for laboratory testing, the sample will be obtained from a depth just above the capillary fringe of the shallow groundwater aquifer. Depth to the shallow groundwater aquifer varies across the RGS from less than five (5) feet below ground surface (bgs) adjacent to the Muddy River to greater than 150 feet bgs at the Mesa.

B1.5.2.2 Groundwater

Groundwater will be sampled from existing and future proposed monitoring wells. The shallow well screens will intersect the groundwater surface as estimated at the time of drilling. Deeper wells will be screened in saturated zones of higher transmissivity that may act as preferential pathways for contaminant migration. In addition, discrete grab samples may be collected using direct push (DP) technologies in highly transmissive zones that are potentially impacted based on field screening measurements.

B1.5.2.3 Surface Water

Surface water will be sampled from existing and future proposed locations including, but not limited to, the Muddy River, ponds, springs, and irrigation diversion ditches.

B1.5.3 Groundwater Sample Locations

Groundwater sampling for ICOCs at all study areas and potential source areas will be conducted using a judgmental design consistent with the optimization discussions of Section A7. In summary:

- The groundwater condition is considered in association with the contaminant as it relates to a point source in soils.
- The number of monitoring wells will be distributed using systematic random distribution within the study area or potential source area of concern taking into consideration the existing monitoring wells. The locations will be shown on a figure attached to the Work Plan.

B1.6 Critical and Non-Critical Measurements

The Project will make use of two types of measurement; critical and non-critical. The non-critical measurements will consist of two subtypes: qualitative and quantitative. Chemical and physical measurements will be made as shown in the Tables 2, 3 and 4.

B1.7 Validation of Non-Standard Methods

The project may make use of non-standard laboratory test methods requiring validation.

B2.0 SAMPLING METHODS

This element of the QAPP sets forth the procedures for collecting samples and identifies the approved sampling methods. It includes protocols for sample collection, handling, documentation, transport, testing, and disposition within the Project area. These protocols were developed based on accepted SOPs in addition to guidance documents. These methods are discussed in the SOPs and guidelines for commonly used investigation activities provided in Appendix B and will be followed by team members.

B2.1 Purpose

The QAPP for this Project intends to set forth, in generic terms, the methods and procedures for sampling based on current and historical land uses or areas and potential source areas of concern identified in the previous investigations. Potential source areas based on previous investigations are presented in Figure 2 in Appendix A. Study areas and potential source areas may be added or eliminated from the Project based on future sampling data.

A Work Plan will be developed for each study area or potential source area. Each Work Plan will be completed pursuant to this QAPP and will be submitted to the NV Energy Project Coordinator for distribution, review, and approval by the NDEP. Implementation of the Work Plan efforts will require NV Energy to address the decisions discussed in Section A7.

B2.2 Sample Collection, Preparation and Decontamination

All sample containers, preserved and unpreserved, will be prepared and provided by the analytical laboratory. The following common elements are identified as generic issues to maintain and direct the quality of samples collected for the Project.

B2.2.1 Appropriate Sampling Methods

The end use of data within NAC 445A (NAC, 2007a) requires the use of traditional sampling methods to acquire representative samples of materials. Methods proposed for general use and selected for Work Plans will be equivalent to or exceed ASTM, EPA, or the industry standard of professional care currently in practice.

The field sampling team will make use of the SOPs and guidelines for commonly used investigation activities provided in Appendix B, as appropriate, for collecting data. The appropriate SOPs will be referenced in Work Plans for field activities.

B2.2.1.1 Soil Sampling Methods

Sampling within the Project area considered the following in selection of generic QAPP methods. Development of site-specific Work Plans will make use of previous investigation data and the findings of the initial studies to refine specific methods to site conditions:

- Both cohesive and granular soils are likely to be present.
- Fill may contain debris such as; asphalt, brick, concrete, metal, and wood, which inhibits direct push technology.
- Saturated and unsaturated soils will be present.
- Methods should be consistent with the NDEP BCA program for use under NAC 445A (NAC, 2007a).
- The NAC 445A (NAC, 2007a) site-specific standards determination dictates a discrete sampling approach.

SOPs and guidelines for commonly used investigation activities provided in Appendix B may be used in collecting samples. Specific protocols for implementation will be identified in the specific source area Work Plans. Field sample handling, preservation, and transport will be as specified in the specific source area Work Plans, and Appendix B of this QAPP.

Laboratory handling, preservation and storage will be as stated in Appendix C, *Pace Analytical Services Quality Assurance Manual, February 25, 2020, Revision No. 3,* and *Isotech's Quality Assurance Plan, March 22, 2012.*

B2.2.1.2 Groundwater Sampling Methods

Sampling within the Project area generally considered the following in selecting QAPP methods that generally follow the SOPs and guidelines for commonly used investigation activities provided in Appendix B. Development of the Work Plans will make use of previous investigation data and the findings of the initial studies to refine specific methods to site conditions:

- Site closure feasibility determination requires assessing the quality of the first encountered groundwater aquifer.
- The first groundwater will be accessible within a range of 5 feet to 150 feet bgs.
- Site characterization will investigate whether the deeper groundwater aquifers are isolated from the shallow aquifer by clay and/or silt.
- Soil competence will require maintaining borehole integrity though use of casing or hollow stem augers to access groundwater.
- NAC 445A (NAC, 2007a) requires the installation of monitoring wells in accordance with NAC 534 (NAC, 2000) for the collection of groundwater samples. Collecting groundwater samples from within the augers or open boreholes is inappropriate and would only be used for screening level data.

SOPs and guidelines for commonly used investigation activities provided in Appendix B may be used for collecting groundwater samples and referenced in the subsequent Work

Plans. The Work Plans will identify specific protocols for implementation. field sample handling, preservation, and transport will be as specified in the SOPs and guidelines for commonly used investigation activities provided in Appendix B and the specific source area Work Plans.

B2.2.1.3 Surface Water Sampling Methods

Sampling within the project area generally consider the following in selecting generic QAPP methods; development of the Work Plans may make use of previous investigation data and the findings of initial studies to refine specific methods to site conditions:

- Site closure feasibility determination requires assessing the surface water quality within the Project area.
- Surface water bodies within the Project area include: Muddy River, irrigation diversion ditches, ponds, and springs.

Surface water samples may be collected per SOPs and guidelines for commonly used investigation activities provided in Appendix B. Field sample handling, preservation, and transport will be as specified in SOPs and guidelines for commonly used investigation activities provided in Appendix B and the specific source area Work Plans.

B2.2.2 Base Requirement of Methods

Essential to the quality of the samples in the Project is the use of proven field methods and procedures. Sampling and testing methods and procedures will be per SOPs in Appendix B that meet the criteria of the AOC and NAC 445A (NAC, 2007a) for end use.

Analytical procedures have defaulted to the limits of standard methods prescribed as adequate to the preliminary characterization for feasibility in this Project. All laboratory analytical methods and procedures are approved by ASTM, EPA, NDEP, or other regulatory agency.

B2.2.3 Cleaning and Decontamination

SOPs and guidelines for commonly used investigation activities provided in Appendix B will be used for cleaning and decontamination. If necessary, alternative procedures will be specified in the Work Plan.

The analytical cleaning and decontamination limits provided by the laboratory procedures and standard methods are prescribed in Pace Analytical QAM and Isotech Laboratories' QAP in Appendix C and applicable EPA analytical methods shown in Tables 2, 3 and 4.

B2.3 Adequacy of Support Facilities

Pace Analytical Services has a current Nevada analytical certification and will provide sample containers and chemical preservatives. They will coordinate with sub-contracted laboratories (i.e., specialty labs) to provide the required containers and preservatives.

B2.4 System Failure Response and Correction Action Process

In general, the Project Manager, or designee, is responsible for the quality of field data and exercises final corrective action responsibility in producing resolution and determinations of data suitability regarding failures. NV Energy requires a feasibility-level decision. A minimal or individual failure of any one sample is not critical to the quality of the process, as long as the overall system and approach are maintained to remain suitable.

B2.4.1 Field Sampling Failures

The QAO, or designee, is responsible for auditing and controlling the overall quality and implementation of field sampling procedures to produce acceptable data. Failures identified in the field will be documented in the field logbook. During field audits by the QAO, or designee, failures noted and corrective actions implemented will be documented in the field logbook and/or checklists in Appendix D. Example Field Forms are provided in Appendix D. Forms used in the field may vary depending on the recording media (i.e., paper or electronic).

The Project Manager, or designee, is responsible for similar management control while at the RGS. The Project Manager, or designee, will make similar use of the previously referenced forms. The Project Manager will be notified of all corrective actions recommended or implemented by the QAO.

The Work Plan will state the precise sampling strategy. With the unknown nature of RGS potential source areas, in addition to the variability of soils and terrain within the Project area, it is likely that field adjustments may be required to sampling designs. Stanley Consultants has anticipated some preliminary default corrective action responses to maintain the quality of the field data collection program. Default corrective action responses do not need to be approved by the Project Manager or QAO but must be logged in the field logbook or annotated on data forms to clearly reflect the change. The following are default responses:

- Offsets up to 15 feet from the approved sampling locations in the Work Plan may be made by the Field Team Leader.
- A sample location may be offset to the first safe location, irrespective of distance, if the requirement is driven by a formerly unidentified safety issue (i.e., illegal utility hookup identified by property owner after mobilization).
- Soil sampling protocols may be adjusted to accommodate localized changes in soil/fill lithology to best promote sample recovery and characterization.

- A soil sample with a measured recovery of seventy percent (70%) of the design interval will be considered adequate for representation of the interval, providing adequate volume for the analytical method is procured and preserved.
- Well screen lengths and elevations may be field adjusted from the design to accommodate a localized interception of the well screen by apparent groundwater at approximately the middle of the screen.
- In the event of a post-field sample failure (e.g., express carrier loses or damages a sample in shipment, laboratory breaks or compromises a sample), the NV Energy Project Coordinator, or designee, can immediately schedule a re-sampling activity if the measurements are identified as critical, there is sufficient budget remaining, and the Stanley Consultants' Project Manager is notified immediately in writing with an appended budget, if deemed necessary.

B2.4.2 Laboratory System Failures

Laboratory failures will be dealt with using the procedures in the QAM in Appendix C.

B2.5 Sampling Equipment, Preservation, and Holding Times

The design for field sampling has been made with a bias to single-use, disposable equipment and material whenever possible. Where disposable equipment is not practical, cleaning (decontamination) procedures will be per SOPs and guidelines for commonly used investigation activities provided in Appendix B.

Laboratory prevention and monitoring to provide against sample interference by cross- or extraneous contamination will be addressed within the criteria of the standard methods and as set forth in procedures in the QAM and QAP in Appendix C and applicable EPA analytical methods shown in Tables 4, 5 and 6.

Proper sample size, preservation, and control are essential and will be per EPA-approved analytical methods and SOPs. The applicable SOPs for sampling will be referenced in the Work Plans for specific field activities. Laboratory controls will be within the criteria of the standard methods and as set forth in the procedures in Appendix C. Example laboratory analytical methods are summarized in the SOPs and guidelines for commonly used investigation activities provided in Appendix B. Tables 4, 5 and 6 below provide example analytical methods, preservation, sampling containers, hold times and target reporting limits for soil, groundwater and surface water, respectively. The source-specific Work Plans will have an updated version of this table reviewed and approved by the NDEP prior to field activities.

Table 4 Soil Sampling and Analyses Requirements

Parameter	Maximum Holding Time	Cool to 6°C?	Preservation	Sampling Container Volume	Container Material	Analytical Method	Target Reporting Limit mg/kg[1]	MS/MSD Limits (%REC)	LCS/LCSD Limits (%REC)	RPD Limits (%)
METALS (SC) - DRY WEIGHT										
Antimony	6 months		None	4 oz	Glass	EPA 200.7, 200.8, 6010 and 6020	0.2	75-125%	80-120%	<20%
Arsenic	6 months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	0.5 (MDL = 0.01)	75-125%	80-120%	<20%
Barium	6 months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	0.5	75-125%	80-120%	<20%
Boron	6 months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	10	75-125%	80-120%	<20%
Cadmium	6 months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	0.1 (MDL = 0.04)	75-125%	80-120%	<20%
Calcium	6 months		None	4 oz.	Glass	EPA200.7, 200.8, 6010 and 6020	10	75-125%	80-120%	<20%
Chromium	6 months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	0.25	75-125%	80-120%	<20%
Copper	6 months		None	4oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	1.0	75-125%	80-120%	<20%
Iron	6 months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	10	75-125%	80-120%	<20%
Lead	6 months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	1.0	75-125%	80-120%	<20%
Magnesium	6 Months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	25	75-125%	80-120%	<20%
Manganese	6 Months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	2.0	70-130%	85-115%	<20%
Mercury	28 Days		None	4 oz.	Glass	EPA 245.1, 245.2, 245.5, 3112, 7470, 7471	0.1 (MDL)			
Molybdenum	6 Months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	1.0	75-125%	80-120%	<20%
Selenium	6 Months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	0.2	70-130%	85-115%	<20%

Parameter	Maximum Holding Time	Cool to 6°C?	Preservation	Sampling Container Volume	Container Material	Analytical Method	Target Reporting Limit mg/kg[1]	MS/MSD Limits (%REC)	LCS/LCSD Limits (%REC)	RPD Limits (%)
Sodium	6 Months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	20	70-130%	85-115%	<20%
Thallium	6 Months		None	4 oz.	Glass	EPA 200.7, 200.8, 6010 and 6020	0.1	70-130%	85-115%	<20%
GENERAL CHEMISTRY (SC) -DRY WEIGHT										
Alkalinity	14 Days	✓	None	4 oz	Glass	EPA 310, and 2320	10	80-120%	90-110%	<20%
Ammonia	28 Days	✓	None	4 oz	Glass	SM4500-NH3 C/D	5.0	90-110%	80-120%	<10%
Chloride	28 Days	✓	None	4 oz.	Glass	EPA 300.0 and 9056A	10	80-120%	90-110%	<20%
Fluoride	28 Days	✓	None	4 oz.	Glass	EPA 300.0 and 9056A	10	80-120%	90-110%	<20%
Nitrate as N	48 hours	✓	None	4 oz.	Glass	EPA 300, 352, 353, 4110, 4500, 9056, and 9200	1.0	80-120%	90-110%	<20%
Nitrite as N	48 hours	✓	None	4 oz.	Glass	EPA 300, 352, 353, 4110, 4500, 9056, and 9200	1.0	80-120%	90-110%	<20%
Nitrogen, Total Kjedahl	7 days	✓	None	4 oz.	Glass	EPA 351.2	30	90-110%	75-121%	<20%
pH	ASAP	✓	None	4 oz.	Glass	EPA 1312 and 9045	0.10 units	-	99-101	<1 (LCS) NA (MS)
Phosphorus (total)	28 Days	✓	None	4 oz.	Glass	EPA 365.3 and 4500	1.0	90-110%	82-117%	<20%
Sulfate	28 Days	✓	None	4 oz.	Glass	EPA 300.0, 375.4, 4110, 9038, and 9056	50	80-120%	90-110%	<20%
Sulfide	28 Days	✓	None	4 oz	Glass	EPA 376.1, 376.2, 4500, 9034, and 9030	5.0	80-120%	85-115%	<20%
Sulfite	ASAP	✓	None	4 oz.	Glass	EPA 377,1, and 4500	20	85-115%	85-115%	<20%

Parameter	Maximum Holding Time	Cool to 6°C?	Preservation	Sampling Container Volume	Container Material	Analytical Method	Target Reporting Limit mg/kg[1]	MS/MSD Limits (%REC)	LCS/LCSD Limits (%REC)	RPD Limits (%)
TOC	28 Days	✓	None	4 oz.	Glass	EPA 5310 and 9060	100	80-120	85-115	<20
VOLATILE ORGANIC COMPOUNDS (VOCs)										
VOCs	14 Days	✓	None	1 Me-OH vial, 1- 2oz jar	Glass	EPA 8260	Varies	Varies	Varies	Varies
SEMI-VOLATILE ORGANIC COMPOUNDS (SVOCs)										
SVOCs	14 Days	✓	None	4 oz.	Glass	EPA 8270	Varies	Varies	Varies	Varies
POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)										
PAHs – Standard List	14 Days/40 Days	✓	None	4 oz.	Glass	EPA 8270-SIM	Varies	Varies	Varies	Varies
TOTAL PETROLEUM HYDROCARBONS (TPH)										
GRO (C6-C12)	14 days	✓	None	4 oz.	Glass	8015B	0.25	10-151%	72-127%	<28% (MS), <20% LCS
DRO (C13-C28) + ORO (C29-C40)	14 days	✓	None	4 oz.	Glass	8015B	0.25	50-150%	50-150%	<20%
SPECIATION (SG) - DRY WEIGHT										
Speciation: Arsenic (III, V)	6 Months		None	4 oz.	Undisturbed tube	1632 and HPLC-ICP-MS	[2]	-	-	-
Speciation: Selenium (IV, VI)	6 months		NS	4 oz.	Undisturbed tube	BR-0061-HPLC and IC-IICP-CRC-MS	[2]	-	-	-
Iron (II)	6 Months		None	4 oz.	Undisturbed tube	ICP-MS	[2]	-	-	-
Iron (III)	6 Months		None	4 oz.	Undisturbed tube	ICP-MS	[2]	-	-	-
Chromium (VI)	30 days (Extraction) 7 days (Analysis)		None	4 oz.	Undisturbed tube	ICP-MS	[2]	85-115%	80-120%	<20%
SOIL PHYSICAL (SP)										

Atterberg Limits	None		None	Plastic bag		ASTM D4318	None	-	-	-
Bulk Density	None		None	Plastic bag		ASTM D7263 and D5057	None	-	-	-
Parameter	**Maximum Holding Time**	**Cool to 6°C?**	**Preservation**	**Sampling Container Volume**	**Container Material**	**Analytical Method**	**Target Reporting Limit mg/kg[1]**	**MS/MSD Limits (%REC)**	**LCS/LCSD Limits (%REC)**	**RPD Limits (%)**
Grain Size	None		None	Plastic bag		ASTM D422/D6913	None	-	-	-
Percent Moisture	None		None	8 oz. Jar or Plastic bag		TBD	None	-	-	-
Falling Head Permeability	None/		None		Undisturbed tube #3	ASTM D5084 and D2434	None	-	-	-
SEQUENTIAL BATCH LEACHING TEST (SBLT)										
Arsenic	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Antimony	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Boron	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Cadmium	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Chloride	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Chromium	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Chromium (VI)	24 hours	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Fluoride	28 days	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Molybdenum	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
pH	ASAP	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-

Phosphorus	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Parameter	**Maximum Holding Time**	**Cool to 6°C?**	**Preservation**	**Sampling Container Volume**	**Container Material**	**Analytical Method**	**Target Reporting Limit mg/kg[1]**	**MS/MSD Limits (%REC)**	**LCS/LCSD Limits (%REC)**	**RPD Limits (%)**
Selenium	28 days	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Sodium	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Sulfate	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
TDS	6 Months	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
Thallium	28 days	✓	Cool, 4°C	8 oz.	Glass	200.8, 300.0, 1312, and 7199		-	-	-
GEOCHEMICAL (SG)										
Minerology – X-Ray Diffraction	NA		None	4 oz.	Glass	X-Ray Diffraction (XRD)		-	-	-
Minerology – X-Ray Fluorescence	NA		None	4 oz.	Glass	X-Ray Fluorescence (XRF)		-	-	-
Loss on Ignition	NA		None	4 oz.	Glass	(LOI) ASTM D7348		-	-	-
Sequential Extraction Analysis	NA		None	4 oz.	Glass			-	-	-
Batch Adsorption Potential	NA		None	4 oz.	Glass	6010 and 6020	Varies	-	-	-
CSIA, δ^{34}S-sulfate	4 Weeks After Extraction	✓	None	4 oz	Jar	CRDS and EA-IRMS		-	-	-
CSIA, δ^{18}O-sulfate	4 Weeks After Extraction	✓	None	4 oz	Jar	Barium Sulfate Precipitation. CRDS and EA-IRMS		-	-	-

1 – Laboratory MDL's are expected to be frequently updated by the lab

NA – Not Available

NS – Not specified

Table 5 Groundwater Sampling - Parameters, Methods, Containers, Holding Times, and Reporting Limits Summary

Parameters	Max Holding Time	Analytical Method	Preservation	Sampling Container	Sampling Container Material	Target MRL (mg/L)	MS/MSD Limits (%REC)	LCS/LCSD Limits (% REC)	RPD Limits (%)
FIELD PARAMETERS									
pH	ASAP	EPA 150.1, 4500, 9040, and 9045	NA	100 mL field container	NA	NA	-	-	-
Specific Conductance	ASAP	EPA 120.1, 2510, 9050	NA	100 mL field container	NA	NA	-	-	-
Temperature	ASAP	SM 2550 B	NA	100 mL field container	NA	NA	-	-	-
Turbidity	ASAP	EPA 180.1	NA	NA	NA	NA	-	-	-
Dissolved Oxygen (DO)	ASAP	SM 5210 B	NA	NA	NA	NA	-	-	-
Oxidation Reduction Potential (ORP)	ASAP	APHA SM 2580	NA	NA	NA	NA	-	-	-
Fe (II)-Dissolved	ASAP	HACH Method 8146	NA	NA	NA	NA	-	-	-
Manganese-Dissolved	ASAP	HACH Method 8034	NA	NA	NA	NA	-	-	-
LABORATORY ANALYSES – GENERAL CHEMISTRY									
Alkalinity (bicarbonate)	14 Days	EPA 310 and 2320	≤6°C	500 mL	Plastic	1.0	80-120%	90-110%	<20%
Alkalinity (carbonate)	14 Days	EPA 310 and 2320	≤6°C	500 mL	Plastic	1.0	80-120%	90-110%	<20%

Parameters	Max Holding Time	Analytical Method	Preservation	Sampling Container	Sampling Container Material	Target MRL (mg/L)	MS/MSD Limits (%REC)	LCS/LCSD Limits (% REC)	RPD Limits (%)
Alkalinity (total)	14 Days	EPA 319 and 2320	≤6°C	500 mL	Plastic	10	80-120%	90-110%	<20%
Ammonia (Nitrogen, Ammonia (as N))	28 Days	EPA 350 and SM4500-NH3C/D	≤6°C	250 ml	Plastic	0.2	80-120%	80-120%	<20%
Dissolved Organic Carbon (DOC)	28 Days	EPA 415.1, 415.2, 5310, and 9060	≤6°C	3-40 mL vials	Amber glass	5.0	80-120%	85%-115%	<20%
Chloride	28 Days	EPA 300.0 and 9056	≤6°C	500 mL	Plastic	1.0	80-120%	90-110%	<20%
Fluoride	28 Days	EPA 300.0 and 9056	≤6°C	500 mL	Plastic	0.5	80-120%	90-110%	<20%
Nitrate (as N)	48 Hours	EPA 300, 353, 354, 4110, 4500, 9056, and 9200	≤6°C	500 mL	Plastic	0.1	80-120%	90-110% %	<20%
Nitrite	48 Hours	EPA 300, 353, 354, 4110, 4500, 9056, and 9200	≤6°C	250 mL	Plastic	0.1	80-120%	90-110%	<20%
Specific Conductance	28 Days	EPA 120.1, 2510, 9050	≤6°C	250 mL	Plastic	2.0	85-115%	85-115%	<20%
Phosphorus, Dissolved	28 Days	EPA 365.2	≤6°C	250 mL	Plastic	0.1	80-120%	82-117%	<20%
Sulfate	28 Days	EPA 300.0, 375.4, 4110, 9038, and 9056 A	≤6°C	500 mL	Plastic	2.0	80-120%	90-110%	<20%
Sulfide	7 Days	376.1, 376.2, 4500, and 9030	Zinc Acetate and NaOH to pH >9, ≤6°C	500 mL	Plastic	0.6	80-120 %	85-115	<10%
Sulfite	ASAP	EPA 377.1 andSM-4500	≤6°C	500 mL	Plastic	2.0	80-120%	85-115 (Total) 90-110% (Dissolved)	<10%
TDS	7 Days	SM-2540C	≤6°C	500 mL	Plastic	10	-	77.4-122.6%	<10%
Total Kjeldahl Nitrogen (TKN)	7 Days	EPA 351.2, 351.3, 351.4, and 4500	≤6°C	250 mL	Plastic	0.5	75.2-121%%	90-110%	<20%
LABORATORY ANALYSES – METALS									

Parameters	Max Holding Time	Analytical Method	Preservation	Sampling Container	Sampling Container Material	Target MRL (mg/L)	MS/MSD Limits (%REC)	LCS/LCSD Limits (% REC)	RPD Limits (%)
Aluminum, Dissolved	6 Months	EPA200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.2	75-125%	80-120%	<20%
Antimony, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.002	75-125%	80-120%	<20%
Arsenic, Dissolved	6 Months	EPA 200.7, 200.8. 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.00047(MDL)	75-125%	80-120%	<20%
Barium, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020 B	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.005	75-125%	80-120%	<20%
Boron, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	$HNO_3$to pH <2, ≤6°C	500 mL	Plastic	0.75	75-125%	80-120%	<20%
Cadmium, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020B	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.0005	75-125%	80-120%	<20%
Calcium, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH<2, ≤6°C	500 mL	Plastic	1.0	75-125%	80-120%	<20%
Chromium, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.0048	75-125%	80-120%	<20%
Iron, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.1	75-125%	80-120%	<20%
Magnesium, Dissolved	6 Months	EPA 200.7, 200.8 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.02	75-125%	80-120%	<20%
Manganese, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.02	75-125%	80-120%	<20%
Mercury, Dissolved	6 months	EPA 245.1, 245.2, 245.5, 31127470 and 7471	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.0002	70-130%	85-115%	<20%
Molybdenum, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.01	75-125%	80-120%	<20%
Nickel, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020 B	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.01	75-125%	80-120%	<20%
Potassium, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.5	75-125%	80-120%	<20%
Selenium, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.005	75-125%	80-120%	<20%
Sodium,	6 Months	EPA 200.7, 200.8, 6010 and	HNO_3 to pH	500 mL	Plastic	0.5	75-125%	80-120%	<20%

Parameters	**Max Holding Time**	**Analytical Method**	**Preservation**	**Sampling Container**	**Sampling Container Material**	**Target MRL (mg/L)**	**MS/MSD Limits (%REC)**	**LCS/LCSD Limits (% REC)**	**RPD Limits (%)**
Dissolved		6020	<2, ≤6°C						
Thallium, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.000121 (MDL)	75-125%	80-120%	<20%
Vanadium, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.01	75-125%	80-120%	<20%
LABORATORY ANALYSES – VOCS									
VOCs	14 days	EPA 8260	HCl pH <2, ≤6°C	40-mL VOA	Glass	Varies	Varies	Varies	Varies (LCS), <20% (LCS)
LABORATORY ANALYSES - SVOCS									
SVOCs	7 Days (Extraction) 40 days (Analysis)	EPA 8270C	≤6°C	1 L	Amber glass	Varies	Varies	Varies	Varies
LABORATORY ANALYSES – PAHS									
PAHs	7 Days (Extraction) 40 days (Analysis)	EPA 8270C	≤6°C	1 L	Amber glass	Varies	Varies	Varies	Varies
LABORATORY ANALYSES – WATER FORENSICS									
Compound Specific Isotope Analysis (CSIA) on water (hydrogen 2H/1H (δD)	4 Weeks After Extraction	CRDS and EA-IRMS	≤6°C	500 mL	Plastic	5% (per mil)	-	-	-
CSIA on water (oxygen 18O/16O (δ18O)	4 Weeks After Extraction	CRDS and EA-IRMS	≤6°C	500 mL	Plastic	5% (per mil)	-	-	-
CSIA on sulfate (34S/32S (δ34S)	4 Weeks After Extraction	CRDS and EA-IRMS	≤6°C	1 L	Plastic	5.0 % (per mil)	-	-	-
CSIA on sulfate	4 Weeks After	CRDS and EA-IRMS	≤6°C	1 L	Plastic	5.0 % (per mil)	-	-	-

Parameters	Max Holding Time	Analytical Method	Preservation	Sampling Container	Sampling Container Material	Target MRL (mg/L)	MS/MSD Limits (%REC)	LCS/LCSD Limits (% REC)	RPD Limits (%)
(18O/16O (δ18O))	Extraction								
TOC	28 days	EPA 415.1, 415.2, 5310, and 9060	HCl	4-40 mL vials	Amber glass	0.5	-	-	-
Coliform Bacteria	30 Hours	SM 9132, 9222, 9223	Sodium Thiosulfate ≤6°C	100 mL Sterile		1.0 MPN/mL	-	-	-

NA – Not Available

NS – Not Specified

Table 6 Surface Water Sampling - Parameters, Methods, Containers, Holding Times, and Reporting Limits Summary

Parameters	Max Holding Time	Analytical Method	Preservation	Sampling Container	Container Material	Target MRL (mg/L)	MS/MSD Limits (%REC)	LCS/LCSD Limits (%REC)	RPD Limits (%)
FIELD PARAMETERS									
pH	ASAP	EPA 150.1	NA	NA	NA	NA	-	-	-
Specific Conductance	ASAP	EPA 120.1	NA	NA	NA	NA	-	-	-
Temperature	ASAP	SM 2550 B	NA	NA	NA	NA	-	-	-
LABORATORY ANALYSES - GENERAL CHEMISTRY									
Alkalinity (bicarbonate)	14 Days	EPA 310 and 2320	≤6°C	500 mL	Plastic	1.0	80-120%	90-110%	<20%
Alkalinity (carbonate)	14 Days	EPA 310 and 2320	≤6°C	500 mL	Plastic	1.0	80-120%	90-110%	<20%
Alkalinity(total)	14 Days	EPA 310 and 2320	≤6°C	500 mL	Plastic	1.0	80%-120%	90-110%	<20%
Ammonia (Nitrogen, Ammonia (as N)) Total & Dissolved	28 Days	EPA 350 and SM4500-NH3C/D	≤6°C	250 mL	Plastic	0.2	80-120%	90-110%	<20%
Chloride	28 Days	EPA 300.0 and 9056	≤6°C	500 mL	Plastic	1.0	80-120%	90-110%	<20%
Fluoride	28 Days	EPA 300.0 and 9056A	≤6°C	500 mL	Plastic	0.5	80-120%	90-110%	<20%
Nitrate (as N)	48 hours	EPA 300, 353, 354, 4100, 4500, 9056, and 9200	≤6°C	500 mL	Plastic	0.10	80-120%	90-110%	<20%
Nitrite (as N)	48 hours	EPA 300.0, 353, 354, 4100, 4500, 9056, and 9200	≤6°C	500 mL	Plastic	0.10	80-120%	90-110%	<20%
Nitrate and Nitrite (as N)	48 hours	EPA 300.0, 353, 354, 4100, 4500, 9056, and 9200	≤6°C	500 mL	Plastic	0.10	80-120%	80-120%	80-120%

Parameters	Max Holding Time	Analytical Method	Preservation	Sampling Container	Container Material	Target MRL (mg/L)	MS/MSD Limits (%REC)	LCS/LCSD Limits (%REC)	RPD Limits (%)
Total Kjedahl Nitrogen (TKN)	7 days	EPA 351.2, 351.3, 351.4, 4500	≤6°C	500 mL	Plastic	0.5	90-110%	90-110%	<20%
Hardness (as $CaCO_3$)	28 days	EPA 130.2 and SM 2340B	HNO_3 to pH <2, ≤6°C	125 mL	Plastic	13	80-120%	90-110%	<20%
Phosphorus (as P), Dissolved	28 Days	EPA 365 and SM 4500	≤6°C	250 mL	Plastic	0.10	90-110%	82-117%	<20%
Phosphorus (as P), Total	28 Days	EPA 365 and SM 4500	≤6°C	250 mL	Plastic	0.10	90-110%	82-117%	<20%
Sulfate	28 Days	EPA 300.0, 375.4, 4110, 9038, and 9056	≤6°C	500 ml HDPE	Plastic	1.0	80-120%	90-110%	<20%
TDS	7 Days	EPA 160.1 and SM-2540C	≤6°C	500 mL HDPE	Plastic	10	-	77.4-122.6%	<10%
Total Organic Carbon (TOC)	28 Days	SM 5310B	≤6°C	3-40 mL vials	Amber Glass	2.0	85-115%	85-115%	<20%
Total Suspended Solids (TSS)		EPA 160.2 and SM 2540				25	80-120%	85-115%	<20%
LABORATORY ANALYSES – METALS									
Antimony, Dissolved	6 Months	EPA 200.7 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.002	75-125%	80-120%	<20%
Antimony, Total	6 Months	EPA 200.7 and 200.8	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.002	75-125%	80-120%	<20%
Arsenic, Dissolved	6 Months	EPA 200.7 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.000247 (MDL)	75-125%	80-120%	<20%
Arsenic, Total	6 Months	EPA 200.7 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.000247 (MDL)	75-125%	80-120%	<20%
Boron, Dissolved	6 Months	EPA 200.7200.8 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.75	75-125%	80-120%	<20%

Parameters	Max Holding Time	Analytical Method	Preservation	Sampling Container	Container Material	Target MRL (mg/L)	MS/MSD Limits (%REC)	LCS/LCSD Limits (%REC)	RPD Limits (%)
Barium, Total	6 months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.75	75-125%	80-120%	<20%
Beryllium, Total	6 Months	EPA200.7 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.002	75-125%	80-120%	<20%
Boron, Total	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.75	75-125%	80-120%	<20%
Cadmium, Dissolved	6 Months	EPA 200.7200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.0025	75-125%	80-120%	<20%
Cadmium, Total	6 Months	EPA 200.7 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.0025	75-125%	80-120%	<20%
Calcium, Dissolved	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	1.0	75-125%	80-120%	<20%
Calcium, Total	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	1.0	75-125%	80-120%	<20%
Chromium, Dissolved	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.0048	75-125%	80-120%	<20%
Chromium, Total	6 Months	EPA 200.7 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.0048	75-125%	80-120%	<20%
Iron, Dissolved	6 Months	EPA 200.7 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.1	75-125%	80-120%	<20%
Iron, Total	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.1	75-125%	80-120%	<20%

Parameters	Max Holding Time	Analytical Method	Preservation	Sampling Container	Container Material	Target MRL (mg/L)	MS/MSD Limits (%REC)	LCS/LCSD Limits (%REC)	RPD Limits (%)
Lead, Total	6 months	EPA 200.7, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.002	75-125%	80-120%	<20%
Magnesium, Dissolved	6 Months	EPA 200.7, and 200.8	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	1.0	75-125%	80-120%	<20%
Magnesium, Total	6 Months	EPA 200.7 and 200.8	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	1.0	75-125%	80-120%	<20%
Manganese, Dissolved	6 Months	EPA 200.7 and 200.8	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.02	75-125%	80-120%	<20%
Manganese, Total	6 Months	EPA 200.7 and 200.8	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.02	75-125%	85-115%	<20%
Mercury, Total	28 days	EPA 245.1, 245.2, 245.5, 3112, 7470, and 7471	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.00005 (MDL)	70-130%	80-120%	<20%
Molybdenum, Dissolved	6 Months	EPA 200.7, 200.8, 6010 and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.01	75-125%	80-120%	<20%
Molybdenum, Total	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.01	75-125%	80-120%	<20%
Nickel, Total	6 months	EPA 200.7 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.01	75-125%	80-120%	<20%
Potassium, Dissolved	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.5	75-125%	80-120%	<20%
Selenium, Dissolved	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.005	75-125%	80-120%	<20%
Selenium, Total	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.005	75-125%	80-120%	<20%
Silver, Total	6 months	EPA 200.7,	HNO_3 to pH	500 mL	Plastic	0.2	75-125%	80-120%	<20%

Parameters	Max Holding Time	Analytical Method	Preservation	Sampling Container	Container Material	Target MRL (mg/L)	MS/MSD Limits (%REC)	LCS/LCSD Limits (%REC)	RPD Limits (%)
		200.8, 6010, and 6020	<2, ≤6°C						
Sodium, Dissolved	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.5	75-125%	80-120%	<20%
Thallium, Dissolved	6 months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.01	75-125%	80-120%	<20%
Thallium, Total	6 Months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.01	75-125%	80-120%	<20%
Zinc, Total	6 months	EPA 200.7, 200.8, 6010, and 6020	HNO_3 to pH <2, ≤6°C	500 mL	Plastic	0.05	75-125%	80-120%	<20%

B3.0 SAMPLE HANDLING AND CUSTODY REQUIREMENTS

This Section sets forth the requirements and provisions for sample control, documentation and proper custody in the field, during transport, and in the laboratory.

Examples of the sample handling and COC documents discussed below are included in Appendix D.

B3.1 Purpose

The NV Energy Project does not involve enforcement action or other civil penalties that might result from data use and does not necessitate an upper level stringency of the custody procedure.

The transfer of sample custody will be limited between field personnel, the sample courier, and laboratory personnel. The primary objective of custody requirements for this Project is simply to track that samples are handled by authorized personnel and to document that handling occurred within the DQO of the QAPP.

In general, the outline for sample handling and custody will be as follows.

- The Project Manager, or designee, will brief sampling personnel on custody procedures.
- Samples will always be in the custody of the field team, prior to shipment to the laboratory.
- Samples will be delivered to the laboratory in person or via an overnight courier daily when necessary to meet analytical holding times.
- The laboratory will implement tracking and custody documentation.
- Post-analysis samples will be disposed of properly.
- Stanley Consultants will maintain COC documentation after reporting.

B3.2 Sample Custody Procedures

COC protocols will be adhered to during all phases of sample collection, storage, shipment, and analytical procedures.

B3.2.1 Mobilization

The Project Manager, or designee, will assemble and designate the Stanley Consultants' Project Leads to oversee OGI and others collecting data at the RGS. COC documents, forms, and labels will be assembled in advance of field work. The processes and procedures for sample handling and custody will be stressed in the pre-field briefing prior to field mobilization.

Original laboratory analytical reports and COC forms will be maintained with the Project files.

B3.2.2 Field Procedures

Maintaining the COC in the field will be the responsibility of the Field Team Leader, or designee. Field personnel will direct the collection, handling, field analysis, and shipment of all Project samples. Samples for laboratory analysis will be properly preserved and immediately prepared for shipment. The samples will remain in the custody of the field team until they are picked up by a Pace Analytical Services courier or dropped off at Pace Analytical's Service Center in Henderson, NV. Until received by the courier or Pace Analytical Services, samples will reside with the Field Team Leader, or designee, in a secure place (i.e., locked vehicle or Project trailer) with temperature control to maintain preservation. Each cooler or refrigerated unit will have a dated and signed custody seal across the lid/door to the cooler/unit when not under direct supervision by the Field Team Leader, or designee. Each time the lid of the cooler or door of the refrigerated unit is opened; the seal must be broken and documented in the field logbook. A new dated and signed custody seal will be placed on the cooler prior to shipping or delivering to Pace Analytical Services for analyses. Upon receipt of the coolers, Pace Analytical Services personnel will inspect the integrity of the custody seals and note their condition in their laboratory reports. Generic Field Forms are provided in Appendix D. Actual forms used in the field may vary depending on the recording media (i.e., paper or electronic).

All samples collected in the field will be placed in proper sample containers, labeled, and stored in an iced cooler from the time of collection through sample shipment. Any field screening activities will take place as soon as possible after collection and will not be preserved or placed on ice. Stanley Consultants, OGI, or others collecting samples at the RGS will place the samples selected for offsite laboratory analysis into laboratory-prepared containers per the SOPs and guidelines for commonly used investigation activities provided in Appendix B. The container labels will indicate:

- Time and date of collection,
- Name of person collecting the sample,
- Type of sample,
- Sample designation and depth,
- Preservative,
- Name of site,
- Project number, and
- Requested analysis.

Stanley Consultants, OGI, or others collecting data at the RGS will place the samples into an insulated cooler chilled by ice or a portable refrigeration unit while at the physical sampling location.

A COC record will accompany all samples from containerization through shipment to the analytical laboratory. Each COC record will be filled out and signed in permanent ink by

OGI, Stanley Consultants, or others collecting Project samples. For each sample that is submitted to the laboratory for analysis, an entry will be made on a COC form. COCs will be prepared for groups of samples collected at a given location on a given day.

An electronic copy of the COC is immediately sent to Stanley Consultants once the COC is completely filled out by the Field Team Leader and the original hard copy of the COC is sent with the courier. Once the COC is sent, the QC process for tracking samples begins. At Stanley Consultants, the COC is checked against the associated Work Plan for number of containers, sample locations, and parameters to be analyzed for each sample. The hard copy of the COC is checked, signed, assigned a sample delivery group (SDG), and scanned in by Pace Analytical Services in Las Vegas and sent to Stanley Consultants. A final copy of the COC is also included in the final Level II laboratory report provided to Stanley Consultants. The COC documents identity all personnel involved in sample transfer. The following information will be entered on the COC:

- Project name and number,
- Job or SDG,
- Project location,
- Sample numbers,
- Sampler's/recorder's signature,
- Date and time of collection,
- Number and type of containers,
- Sample matrix,
- Analyses requested for each sample,
- Preservation method,
- Name of person receiving the samples,
- Date and time of receipt of samples,
- Address of laboratory, and
- Additional remarks (e.g., special handling or analysis requirements).

Sampling team members will maintain custody of the samples until they are relinquished to laboratory personnel or a professional courier service. The COC form will accompany the samples from the time of collection until they are received by the laboratory. Each party in possession of the samples (except the professional courier service) will sign the COC form signifying receipt. The COC form will be placed in a plastic bag and shipped in the cooler with the samples. After the samples, ice, and COC forms are packed in the cooler, the cooler will be appropriately sealed with a custody seal before it is relinquished to the courier. A copy of the original completed form will be provided by the laboratory along with the report of results. Upon receipt, the laboratory will inspect the condition of the sample containers and report the information on a COC or similar form. The method of sample shipment will be noted on the COC. Strict COC procedures will be maintained during sample handling. A typical COC form is illustrated in Appendix D.

A sample is considered under custody if:

- It is in actual possession;
- It is in view after physical possession; and/or
- It is placed in a secure area (accessible by or under the scrutiny of authorized personnel only after in possession).

Whenever possible, samples will be removed from the RGS on a daily basis under the supervision of the field personnel and signed over to the designated Pace Analytical Services courier or delivered to the Pace Analytical Service Center in Las Vegas. This allows tracking of samples from the RGS to the laboratory. Pace Analytical Services will provide for Saturday receipt of samples when necessary.

Should non-time critical samples be taken which need not be shipped same day, samples will be held in a secured, cooled compartment under the supervision of OGI, Stanley Consultants, or others collecting Project data to maintain preservation until the next shipping day. Each COC documentation will reflect this retention.

B3.2.3 Documentation Procedures

In addition to completing the COC, sampling activities will be documented in the Project field logbook and/or on the Field Activity Summary Forms in Appendix D. Entries will be recorded with permanent marking pens (i.e. Sharpie®). Errors in documenting activities will be indicated by a single horizontal line through the entry and initialed by the author. Each page of the field logbook will be consecutively numbered, dated, and signed by the author. At the beginning of each day, site and weather conditions, onsite personnel and the reason for being onsite will be entered in the field logbook. Field Activity Summary Forms will also be signed and dated by the author and their completion noted in the field logbook, as appropriate. Generic Field Forms are provided in Appendix D as examples. Actual forms used in the field may vary depending on recording media (i.e., paper or electronic).

Field crews will be required to keep a field logbook for each sampling event. The following items should be recorded in the field logbook and/or Field Activity Summary Form for each sampling event:

- Date and time of sample collection;
- Sample ID numbers, including bottle ID numbers and unique IDs for any duplicate or blank samples;
- The results of any field measurements (e.g., temperature, pH, conductivity, turbidity) and the time that measurements were made;
- Make, model, and calibration of field instrumentation;

- Qualitative descriptions of relevant groundwater and surface water conditions (e.g., color, flow level, clarity) or weather (e.g., wind, rain) at the time of sample collection;
- Description of any unusual occurrences associated with the sampling event, particularly those that may affect sample or data quality;
- Sample collection location description or sketch (latitude, longitude, and Global Positioning System coordinates when available);
- Sample collection depth, matrix collected, and collection method;
- Digital photograph of sampling location (if appropriate and possible);
- Analyses to be conducted on sample(s);
- Laboratory name, address, and telephone number;
- Name of courier delivery service, air bill shipping number, pickup time, and type of delivery (i.e. Priority AM delivery, Saturday delivery, etc.); and
- Reference to QA/QC samples taken.

Appropriate pages from the field logbook and Field Activity Summary Forms will be photocopied and transmitted to the QAO, or designee, on a regular basis.

B3.2.4 Laboratory Procedures and Disposal

Upon receipt, the laboratory will implement tracking and custody documentation as set forth in Appendix C. Original copies of documentation signed by laboratory QA staff will be returned to the Project Manager, or designee, with the laboratory analytical reports.

The laboratory will provide sample disposal as specified in Appendix C.

B3.2.5 Post-Reporting Retention

The Project Manager, or designee, will maintain the original COC documentation in the Project file. Upon project completion, Stanley Consultants will maintain documents for a period of 5 years in archives.

B4.0 ANALYTICAL METHODS REQUIREMENTS

This Section identifies the detailed and specific criteria for conducting, maintaining, and checking the analytical process in the laboratory to provide useful, quality data. The laboratory QAM and QAP in Appendix C and applicable EPA analytical methods shown in Tables 4, 5 and 6 ensures the data obtained through the analytical methods is useful and representative of the conditions existing in the RGS study area. All environmental samples will be analyzed as specified in SOPs and guidelines for commonly used investigation activities provided in Appendix B and specific source area Work Plans. The most current and approved QAPP will be distributed to the analytical laboratory. Updates and modifications will be incorporated in the QAPP as addenda if necessary. Stanley Consultants' QAO, or designee, will be responsible for distributing the addenda to Pace Analytical's Project Manager.

B4.1 Purpose and Background

The data collected must be sufficient for NV Energy's need to characterize potential source areas for eliminating the need for corrective action, corrective action alternatives and closure. As a result of NV Energy signing the AOC with the NDEP, NV Energy agrees to conduct all laboratory analysis by EPA-approved methods and procedures listed in SOPs and guidelines for commonly used investigation activities provided in Appendix B and specific source area Work Plans. Any corrective actions that may be necessary will be the responsibility of the Laboratory Quality Manager. Pace Analytical's Laboratory Quality Manager will notify Stanley Consultants' QAO, or designee, of any corrective actions that are implemented. A copy of Pace Analytical Services QAM and Isotech Laboratories' QAP is provided in Appendix C.

B4.2 Preparation of Samples

Preparation of laboratory samples will be in accordance with EPA-approved procedures as described in Pace Analytical Services QAM and Isotech Laboratories' QAP in Appendix C, and applicable EPA analytical methods shown in Tables 4, 5, and 6. Specific method protocols will be within recommended procedures of standard methods. Environmental samples will be preserved and analyzed as outlined in SOPs and guidelines for commonly used investigation activities provided in Appendix B, specific source area Work Plans, and the laboratory QAM and QAP in Appendix C.

B4.3 Analytical Methods

Laboratory analysis of samples will be as described in Appendix C. All samples will be analyzed within standard turnaround time unless the NV Energy Project Coordinator deems "rush" analyses are necessary to meet project goals. Laboratory analyses will be in accordance with EPA-approved methods presented in SOPs and guidelines for commonly used investigation activities provided in Appendix B, specific source area Work Plans, and in the Pace Analytical Services ' QAM Isotech Laboratories' QAP in Appendix C and applicable EPA analytical methods shown in Tables 4,5 and 6.

B4.4 Corrective Actions

Corrective actions will be initiated whenever DQIs suggest that DQOs have not been met. Corrective actions will begin with identifying the source of the problem. Potential problem sources include failure to adhere to method procedures, improper data reduction, equipment malfunctions, or systemic contamination. The first level of responsibility for identifying the problems and initiating corrective action lies with the laboratory analyst personnel. The second level of responsibility lies with the data reviewer or Laboratory Quality Manager. Corrective actions may include more intensive staff training, equipment repair followed by a more intensive preventive maintenance program, or removal of the source of systemic contamination. Once resolved, the corrective action procedure will be fully documented and, if DQOs were not met, the samples in question must be re-collected and/or re-analyzed using a properly functioning system.

B5.0 QUALITY CONTROL REQUIREMENTS

This Section implements the quality controls necessary to monitor the data quality program process, both as affected in the field and the laboratory environment. Analytical QA/QC issues that should be documented include standard traceability, frequency, and results of Quality Control (QC) samples, such as method and instrument blanks, spiked samples, duplicates, calibration check standards, and detection limit studies. These, and other QC Checks, are described in Section B5.2 and Appendix C.

B5.1 Purpose

The purpose of quality control is to set up a series of checks to determine if the data quality process is being implemented within the bounds supportive of the decision process. The procedures should be in process and deliver information in a timely fashion appropriate to enact corrective actions.

The Project finds itself with numerous locations (study areas and potential source areas) to assess and characterize to determine the feasibility of a RGS remedy and closure relative to the AOC and NAC 445A (NAC, 2007a) regulatory framework. The NDEP BCA programs rely on EPA-approved SOPs to limit the instrumental and laboratory bias. This process will similarly rely heavily on that level of field QC checks and those of the Pace Analytical Services SOPs to mitigate instrumental and analytical bias.

The Project will be focused on monitoring and correcting human or operational errors in process. This will be done by comparing the analytical results between the blind and field duplicate samples with the corresponding field samples for precision of sampling techniques. If variances of greater than 20% for inorganics and 30% for organics, for aqueous samples are encountered, corrective action procedures will be implemented. Laboratory QA/QC samples will be prepared and analyzed by the laboratory to evaluate the accuracy of analytical procedures. The accuracy goals listed as percent recovery (%REC) can be found in Tables 4,5, and 6 of Section B2.5 above. A precision goal of 20% for inorganics and 30% for organics will be used for both blind duplicate and field duplicate aqueous sample analyses as discussed in Section A7.3.1. Duplicate soil samples may be collected as discussed in Section B5.2.2.1. Laboratory results outside these ranges will result in corrective action. Corrective actions could include evaluation of sampling procedures, inspection of sample matrix, review of field screening results, evaluation of sample preparation and analytical methods, and rerunning sample preparation and/or sample analysis. Laboratory QC statistics will be calculated per methods specified in the QAM and QAP in Appendix C and applicable EPA analytical methods shown in Tables 4, 5 and 6.

The decision regarding the need for corrective action, corrective action alternatives, and closure is a preliminary goal of the characterization of the study areas and potential source areas. The data quality need only be sufficient to these ends. The degree of field QC should be of a low-to-moderate level. The laboratory checks should be as extensive as recommended by published standard methods.

B5.2 Laboratory Quality Control Check Systems

The following QC requirements pertain to groundwater, surface water and soil samples. Not all sample types provide enough volume to satisfy the QC requirements listed below. Therefore, the Laboratory Quality Manager will judge QC requirements for other sample types on a case-by-case basis. Detailed procedures for preparation and analysis of QC samples are provided in the analytical method documents and described in Section B5.3. The QC checks and frequencies in which they will be performed are listed in Table 7.

Table 7 Quality Control Checks and Schedules

AOC Implementation Activity	Agency	Frequency of Activity
Field Split	NDEP	Discretionary
Field Blank	OGI, Stanley Consultants, or others collecting Project data	1 per day of on-site sampling activity or 5% per project mobilization
Equipment Rinsate Blank	OGI, Stanley Consultants, or others collecting Project data	1 per day of on-site sampling activity or 5% per project mobilization
Blind or Field Duplicate Sample	OGI, Stanley Consultants, or others collecting Project data	Aqueous samples at 1 per day of sampling activity or 5% per project mobilization. Solid samples will be at the discretionary
Trip Blank	Pace Analytical Services	As specified in Appendix C
Lab Method Blank	Pace Analytical Services	As specified in Appendix C
Matrix Spike/Matrix Spike Duplicate	Pace Analytical Services	As specified in standard method SOP, Appendix C
Lab Control Sample	Pace Analytical Services	As specified in the applicable EPA laboratory method

B5.2.1 Qualitative Objectives

The following sections describe the quality objectives for the Project:

B5.2.1.1 Comparability

Comparability of the data can be defined as the similarity of data generated by different monitoring programs. For the purpose of this Project, this objective is addressed primarily by using standard sampling and analytical procedures where possible. Additionally, comparability of analytical data is addressed by analysis of standard reference materials.

B5.2.1.2 Representativeness

Representativeness can be defined as the degree to which the environmental data generated by the monitoring program accurately and precisely represent actual environmental conditions. For this Project, this objective is addressed by the overall design of the monitoring program. Specifically, ensuring the representativeness of the data is addressed primarily by selecting appropriate locations, methods, times, and frequencies of sampling for each environmental parameter, and by maintaining the integrity of the sample after collection. Each of these is addressed elsewhere in this QAPP.

B5.2.1.3 Completeness

Data completeness is a measure of the amount of successfully collected and validated data relative to the amount of planned data to be collected for the Project. Completeness is usually expressed as a percentage value. A Project objective for percent completeness is typically based on the percentage of the data needed for the program or project to reach valid conclusions. A Project goal for data completeness, based on the planned sampling frequency, is 90 percent (90%). The formula for calculation of completeness is:

$$\%\text{Completeness} = 100 \times \frac{\textit{number of valid results}}{\textit{number of expected results}}$$

B5.2.2 Field Procedures

Field sampling SOPs and guidelines for commonly used investigation activities are provided in Appendix B. As previously discussed, a site-specific Work Plan will be generated for each study area or potential source area investigation. The details for the field procedures are presented in the SOPs and guidelines for commonly used investigation activities provided in Appendix B or the site-specific Work Plan.

For basic groundwater and surface water quality analyses, QC samples to be prepared in the field will consist of field blanks and duplicates. The number of duplicates and field blanks collected will be one per day of onsite sampling activity or five percent (5%) for all analyses for a particular parameter. Additional sample volumes required for QC analyses will be supplied to Pace Analytical by OGI, Stanley Consultants, or others collecting samples.

B5.2.2.1 Field Blanks and Field Equipment Blanks

A field blank is a sample that is prepared in the field by pouring deionized, distilled water into sample containers at the location the samples were collected. Field blank samples are analyzed to determine whether contamination has been introduced into a sample set either in the field while the samples were collected or during sample transport to the laboratory, or in the laboratory during sample preparation and analysis. To prevent inclusion of non-site-related contaminants in the data evaluation, the concentrations of the parameters detected in the blanks will be compared to the concentrations of the same parameters detected in the primary samples.

A field equipment (or rinsate) blank is a sample that is prepared in the field by pouring deionized, distilled water into clean sampling equipment. The water is then collected and analyzed as a sample. The field equipment blank gives an indication of contamination from field procedures (e.g., improperly cleaned sampling equipment or cross contamination). Field blanks and field equipment (or rinsate) blanks will be collected at a frequency of one per day of onsite sampling activity, or 5 percent (5%) per project specific mobilization when non-dedicated equipment is used, whichever is less. These samples should be analyzed using the same analyses requested for the associated primary samples collected. If disposable or dedicated sampling equipment is used, the frequency of field blanks will be one per sampling device.

If the field blank contains detectable concentrations of common laboratory contaminants (e.g., acetone, 2-butanone, methylene chloride, or phthalate esters), the primary sample results will be considered as positive results only if the concentrations in the primary sample exceed 10 times the maximum amount detected in any field blank. If the detected concentration of a common laboratory contaminant in a primary sample is less than 10 times the concentration detected in the field blank, then it will be concluded that the analytes was not detected in the primary sample above a quantitation limit equal to the field blank concentration.

If all samples contain levels of a common laboratory contaminant that are less than 10 times the level of contamination noted in the field blank, then the analyte may be eliminated from use in data evaluation. If the field blank contains detectable concentrations of analytes that are not common laboratory contaminants, then the above considerations apply; however, the primary sample concentrations are compared to five times the concentration detected in the field blank.

B5.2.2.2 Trip Blanks

The primary purpose of trip blanks is to detect potential additional sources of contamination that could influence contaminant values reported in primary samples, both quantitatively and qualitatively. Trip blanks serve as a mechanism of control for sample bottle preparation, blank water quality, and sample handling. Trip blanks are submitted to the laboratory with groundwater and surface water samples collected for analysis of volatile organic compounds (VOCs).

The water trip blank consists of a VOC sample vial filled in the laboratory with ASTM Type II reagent-grade water. The trip blank travels to the RGS with the empty sample bottles and returns from the RGS with the collected primary field samples in an effort to simulate sample handling conditions. One trip blank will be included in each shipping container transporting samples for VOC analysis. The following are potential sources of contamination in trip blanks:

- Laboratory reagent water,
- Sample containers,
- Cross-contamination during shipment,
- Ambient air or contact with analytical instrumentation during preparation and analysis at the laboratory, and
- Laboratory reagents used in analytical procedures.

When a trip blank is identified as contaminated, the appropriate validation flag, as described in the applicable validation procedure, will be applied to associated primary sample results.

B5.2.2.3 Blind and Field Duplicates

Duplicates are samples collected from the same location and submitted to the laboratory for analyses with a composition and identity known to the submitter, but not the laboratory analyst, in the case of a blind duplicate. Blind duplicates are assigned a fictitious identification and location (i.e. MW-13 is a blind duplicate of primary sample MW-3). Field duplicates are assigned the same identification and location as the field sample with a "DUP" designation following the sample ID (i.e. MW-3-DUP is a field duplicate of primary sample MW-3).

The purpose of analyzing duplicate samples is to demonstrate the precision of sampling and laboratory proficiency in execution of the measurement process. Duplicates will be collected for groundwater and surface water samples. Soil and sediment duplicates may be collected at the discretion of the QAO in consultation with NV Energy's Project Coordinator. Soils and sediments are generally too heterogeneous to assess the precision of sample collection, so duplicate soil samples from the same location are generally no different (statistically) from independent samples (NDEP, 2007). The spatial variability in soils and sediments is high and reproducibility from sample to sample is expected to be poor. The decision of whether to collect soil or sediment duplicate samples will be addressed on a case by case basis when drafting source area work plans. The relative percent difference (RPD) for soil and sediment duplicates will be 100 percent (%) for grad samples and 50% for composites.

Duplicate aqueous samples will be prepared at the rate of one per analytical method per project-specific mobilization or 5% of primary samples collected, whichever is less, and analyzed along with the associated primary samples. Duplicates will consist of two grab samples collected in succession from the same location. If the RPD of duplicate results is greater than 30 percent (30%) and the absolute difference is greater than the RL, both samples should be reanalyzed. If upon reanalysis, the RPD is still greater than 30 percent (30%) for sample results greater than 10 times the Method Detection Limit (MDL), results will be flagged "Field Variability." The sampling crew should be notified so that the source of sampling variability can be identified (if possible) and corrective measures taken prior to the next sampling event.

The RPD will be calculated as follows:

$$\text{RPD} = 100 \times \frac{|X_2 - X_1|}{\frac{X_2 + X_1}{2}}$$

where X_1 and X_2 are the two observed values.

B5.2.2.4 Field Split

A field split sample is two or more representative portions taken from one sample in the field and analyzed by different laboratories. The purpose of collecting split samples is to duplicate the measurement of the variable(s) of interest in demonstrating the precision of sampling and proficiency of the laboratory's analytical methods. Split samples will be provided upon request to the NDEP. Otherwise, split samples will not be collected as part of this Project. The precision goal for split samples will be 50 percent (50%) RPD for aqueous and solid samples.

B5.3 Laboratory Quality Control Samples

Detailed procedures for preparation and analysis of QC samples are provided in the analytical method documents provided in Appendix C and are describe in the following sections.

B5.3.1 Laboratory Analyses

For basic groundwater and surface water quality analyses, QC samples prepared in the contract laboratory(s) will typically consist of equipment blanks, method blanks, standard reference materials, laboratory duplicates, MSs, and MSDs.

B5.3.2 Analytical Instrument and Bottle Blanks

The purpose of analyzing instrument blanks is to demonstrate that analytical equipment is free from contamination. Prior to analyses, the laboratory responsible for cleaning and maintenance of the analytical instrumentation will prepare a subset of bottle blanks and sampler blanks.

The blanks will be analyzed using the same analytical methods specified for environmental field samples. If any analytes of interest are detected at levels greater than the established control limits (as specified in the cleaning SOPs or laboratory QAM/QAP) the source(s) of contamination will be identified and corrected and applicable EPA analytical methods shown in Tables 4, 5 and 6.
0
Bottle blanks will consist of one of each type of sample container filled with laboratory-prepared blank water, preserved like a regular sample for the analyte of interest, and allowed to stand for a minimum of 24 hours before analysis.

Sampler blanks will consist of laboratory-prepared blank water processed through the sampling equipment using the same procedures used for environmental samples.

B5.3.3 Method Blanks

The purpose of analyzing method blanks is to demonstrate that the analytical procedures do not result in sample contamination. Method blanks will be prepared and analyzed by the contract laboratory at a rate of at least one for every 20 samples or at least one per day, whichever is more frequent. Method blanks will consist of laboratory-prepared blank water processed along with the batch of environmental samples. If the result of the mean or standard deviation of the method is greater than the established control limit (as specified in the individual analytical SOP), then the source(s) of contamination will be corrected, and the associated samples will be reanalyzed. If reanalysis is not possible, the associated sample results will be qualified as below detection at the reported value considering the U.S. EPA 10 times and 5 times rule (*Standard Methods for the Examination of Water and Wastewater,* Section 1030E, 20th Edition, January 1999) (APHA, AWWA, and WEF, 1999).

B5.3.4 Laboratory Control Samples (Certified Reference Materials)

The purpose of analyzing LCSs is to demonstrate the accuracy of the analytical method. Laboratory control samples will consist of a certified reference material of the same matrix as the sample set and will be analyzed at the rate of one for every 20 samples or at least one per day, whichever is more frequent. The LCS will be prepared along with the sample batch using the same methods. If recovery of any analyte is outside the acceptable range for accuracy (as specified in the method SOP), the sample batch should be prepared again, and the laboratory control sample should be reanalyzed.

B5.3.5 Matrix Spikes and Matrix Spike Duplicates

The purpose of analyzing MSs and MSDs is to demonstrate the performance of the analytical method in a particular sample matrix and to demonstrate precision. Each MS and MSD will consist of an aliquot of laboratory-fortified environmental sample. MS samples will be spiked during the preparation phase and recorded as such. In some analytical methods, it is not effective to spike the sample at the preparation phase. In these cases, the sample should be spiked at the analytical phase and reported as an analytical spike. MSs and MSDs will be analyzed at the rate of one pair for every 20 samples or at least one per day, whichever is more frequent for primary measurements of concern.

The analyst's goal should be to spike samples at two to five times native sample concentration. If the sample is spiked too high (>5X native sample concentration), and the percent recovery is within the control limits, the data are considered valid. If the sample is mistakenly spiked too low (<2X native sample concentration), or the native sample is too variable, but the LCS and other QC criteria are in compliance, then only the MS/MSD requires reanalysis. The MS/MSD will be reanalyzed with the next batch of samples at a higher spiking level. If the MS/MSD is in compliance when reanalyzed, the previous data set is considered valid. If the MS/MSD is not within the control limits when reanalyzed, matrix interferences need to be investigated and all data flagged. Data will be flagged with a "high" or "low" bias.

If MSD RPD for any analyte is greater than the precision criterion, the results for that analyte have failed the acceptance criteria. The laboratory should attempt to correct the problem (by homogenization, dilution, or concentration) and reanalyze the samples and the MSDs. If the matrix problem cannot be corrected, the laboratory should qualify the results for that analyte as “not reproducible.”

B5.3.6 Laboratory (Digestion) Duplicates

The purpose of analyzing laboratory duplicates is to demonstrate the precision of preparation and analytical methods and will be prepared at the rate of one per analytical batch. Laboratory duplicates will consist of two aliquots from the same sample. If an RPD greater than 20 percent (>20%) for aqueous samples and 35 percent (>35%) for sediment/soil samples, for results greater than 10 times the MDL, is confirmed by reanalysis, environmental results will be flagged.

Laboratory precision will be assessed by LCSs, surrogate standards, matrix spikes, and initial and continuing calibrations of instruments. Laboratory accuracy is expressed as the percent recovery (%R). Accuracy limits are statistically generated by the laboratory or required by specified U.S. EPA methods. If the %R is determined to be outside of acceptance criteria, data will be qualified as described in the applicable validation procedure. The calculation of %R is provided below:

$$\%R = 100 \times \frac{X_s - X}{T}$$

where:

X_S is the measured value of the spiked sample
X is the measured value of the unspiked sample
T is the true value of the spike solution added

B5.3.7 Laboratory Method Blank

The purpose for analyzing laboratory method blanks is to detect and quantitate contamination introduced during sample preparation and analysis, and will be analyzed at the rate of one for every 20 samples or at least one per day, whichever is more frequent. Reagents used in sample preparation and analysis, without the target analyte or sample matrix, are introduced into the analytical procedure at the appropriate point and carried through all the subsequent steps to determine the contribution of the reagent(s) in the absence of the matrix. If the result of the mean or standard deviation of the method is greater than the established control limit as specified in the analytical SOP, the source(s) of contamination should be corrected, and the associated samples should be reanalyzed. If reanalysis is not possible, the associated sample results should be qualified as below detection at the reported value considering the U.S. EPA 10 times and 5 times rule (*Standard Methods for the Examination of Water and Wastewater, Section 1030E, 20th Edition, January 1999*) (APHA, AWWA, and WEF, 1999).

B6.0 INSTRUMENT TESTING, INSPECTION AND MAINTENANCE REQUIREMENTS

The equipment used to make measurements must be reliable and not present a potential source for data failure for the Project. Equipment and instrumentation involved are operated in the laboratory and field.

B6.1 Purpose

The QAPP must directly include or indirectly reference the procedures that will be used to verify that all instruments and equipment are maintained in sound operating condition and are capable of operating at acceptable performance levels.

B6.2 Testing, Inspection and Maintenance

The following describes the process to implement the stated purpose.

B6.2.1 Field Equipment

No field instruments will be used to make critical measurements relative to the decision process. Field instruments referenced in the Work Plan will be supplied and maintained in-house by field personnel or a contracted field equipment supplier.

Stanley Consultants, OGI, and others collecting Project samples, maintain and repair field-screening equipment in accordance with the manufacturer’s specifications. The original manufacturer performs, repairs, and provides certifications beyond the limits of Stanley Consultants, OGI, and others collecting Project samples.

Equipment is bench-tested for performance by Stanley Consultants, OGI, and others collecting Project samples prior to use in the field.

B6.2.2 Laboratory Equipment

Appendix C presents the laboratory instrumentation and equipment specific to laboratory analysis and the schedules of maintenance and testing.

B7.0 INSTRUMENT CALIBRATION AND FREQUENCY

This Section identifies instruments used to make measurements, critical and non-critical to the decision, which must be controlled to maintain quality of data.

B7.1 Field Instrument Identification

Instruments which may be used for making field environmental measurements must be checked against standards for acceptable performance as follows:

- Portable temperature/pH/conductivity meter for making non-critical measurements of aqueous solutions.
- Portable turbidity meter for making non-critical field measurements of aqueous solutions.
- Portable water level meter for making non-critical field measurements of depth to aqueous solutions.
- Portable dissolved oxygen (DO) meter for making non-critical field measurements of aqueous solutions.
- Portable pressure transducers and data logger for making non-critical field measurements of groundwater aquifer properties.
- Portable four gas monitor for making non-critical air measurements of carbon monoxide, hydrogen sulfide, and oxygen content as well as explosive limits of a work environment.
- Portable flame or photo-ionization detector for making non-critical measurements of ionizable volatile gases.

Laboratory analytical instruments used in conducting environmental measurements for which the response must be checked against standards for acceptable performance are identified in the Pace Analytical's QAM and Isotech Laboratories' QAP in Appendix C and applicable EPA analytical methods shown in Tables 4, 5 and 6.

B7.2 Calibration Methods

Measuring equipment will be routinely calibrated in accordance with the manufacturer's specifications. Calibration standards will be those recommended by the instrument manufacturer. The standards will be relied upon as certified and accepted by the industry.

B7.2.1 Field Equipment Bench Calibration

All field instruments will receive scheduled bench calibrations to verify the measurement response to accepted check standards. Calibration methods and results will be documented on calibration logs in Appendix D and placed in the Project File.

The calibration methods and materials for field equipment are included in their respective SOPs and the manufacturer’s manuals.

B7.2.2 Field Equipment: On-Site Calibration

All field instruments will receive regular and scheduled calibrations in the field to verify the measurement response to accepted check standards. Soil and groundwater sampling protocols will be identified in the Work Plan. Copies of the Work Plan will accompany the field personnel to the RGS. Field calibration activities will be recorded in the project field logbook or field forms in Appendix D.

B7.2.3 Laboratory Equipment Calibration

Calibration of laboratory analytical instrumentation is required for the generation of appropriate data to meet project DQOs. The laboratory will be responsible for the proper calibration and maintenance of laboratory analytical equipment. Calibration procedures, calibration frequency, and acceptance criteria are presented in contract laboratory’s QAM and QAP in Appendix C and applicable EPA analytical methods shown in Tables 4, 5 and 6.

B7.3 Calibration Apparatus

Calibrations will be conducted using manufacturer-recommended equipment and supplies.

B7.4 Calibration Standards

Calibration standards for field equipment will be as referenced in the manufacturer's manual and/or the respective SOPs.

Calibration standards for laboratory instrumentation will be prepared using the Reagents and Standards Section of the analytical method. General calibration standard procedures are described in the QAM/QAP in Appendix C and applicable EPA analytical methods shown in Tables 4, 5 and 6.

B7.5 Calibration Frequency

Field equipment will be calibrated on the schedule summarized in Table 8. The frequency meets the minimum requirements specified by the manufacturer, industry SOPs, and/or EPA guidance.

Table 8 Calibration Checks Frequency Summary for Field Equipment

Type of Field Measuring Instrument	**Calibration Checks Per Unit Manufacturer’s Specification**			
	1 Pre-Field Bench Check at Mobilization	**On-Site 1 Per Day of Onsite Use**	**On-Site 1 Per Each Week of Onsite Use**	**On-Site “Zero” to Ambient Prior to Each Use**
Temperature/pH Meter	X	X		
Specific Conductance Meter	X	X		
Type of Field Measuring Instrument	**Calibration Checks Per Unit Manufacturer’s Specification**			
	1 Pre-Field Bench Check at Mobilization	**On-Site 1 Per Day of Onsite Use**	**On-Site 1 Per Each Week of Onsite Use**	**On-Site “Zero” to Ambient Prior to Each Use**
Turbidity Meter	X		X	
Photo-Ionization Detector	X	X		X
Dissolved Oxygen Meter	X		X	
4 Gas Monitor	X		X	
Pressure Transducer/Data Logger	X			
Flow Tracker	X	X		

Calibration frequencies for laboratory instrumentation will be as presented in the applicable EPA analytical methods shown in Tables 4, 5 and 6.

B8.0 INSPECTION AND ACCEPTANCE REQUIREMENTS FOR SUPPLIES AND CONSUMABLES

The nature of the analytical laboratory demands that all material used in any of the procedures be of known quality. The procedures established to verify that critical laboratory supplies, and consumables meet relevant project quality objectives are identified in the QAM and QAP in Appendix C and applicable EPA analytical methods shown in Tables 4, 5 and 6.

Stanley Consultants, OGI, and others collecting Project data maintain centralized control of field sampling expendables, supplies, and materials for conducting environmental assessments. Only supplies and consumables that are of adequate quality to sustain confidence in the sample collection, processing, and laboratory analysis will be used. Purchased supplies and consumables will not be used until they have been inspected, calibrated, or otherwise verified to ensure compliance with standard specifications relevant to calibrations or tests being performed.

Only the Project Manager, or designee, is authorized to make purchases of approved supplies. Purchased materials will be stored in the Stanley Consultants, OGI or other facilities under the supervision of Stanley Consultants, OGI, or others collecting Project data.

B9.0 NON-DIRECT MEASUREMENTS

The use of data from non-direct measurement sources is essential in implementing characterization activities for the NV Energy Project. Proposed activities to be conducted under this Project rely heavily on previously collected site data. The calculation of site-specific standards and cleanup goals will be based on external data sources and research. This information may include:

- Existing sampling and analytical data from previous studies;
- Topographic, geologic, and historical maps;
- Aerial and site photographs;
- Information from published literature;
- Background data from the facility or regulatory agency; and
- Meteorological data.

The source of this data may include ASTM, EPA, NDEP, Southern Nevada Water Authority (SNWA), National Oceanic and Atmospheric Administration (NOAA), United States Geological Survey (USGS), professional organizations, society journals, publications, and local, state, and federal health agencies.

B10.0 DATA MANAGEMENT

This Section and Section A9 describe the process of managing field, laboratory, and reporting data from their generation to their final use or storage. Data will be maintained in a manner that supports Project activities by creating and retaining records that document Project activities in an accurate and transparent manner that will allow for reviews and data usability assessments. Sampling and training records will be maintained and may potentially include specialized training certificates, sampling procedures, the names of the persons conducting the activity, sample number, sample collection points, maps, diagrams and/or photographs, equipment/method used, climatic conditions, and unusual observations. Bound field logbooks, pre-printed forms, or computerized notebooks can serve as the recording media. Bound field logbooks are generally used to record raw data and to make references to prescribed procedures and necessitated changes made to address contingencies. Preferably, field logbooks will contain pre-numbered pages with date and name of person recording in the logbook.

The various data and information generated from this project will be stored and maintained at the Stanley Consultants' offices. Copies of field logbooks, COC forms, original preliminary and final laboratory reports, and electronic media reports will be sent to the Project QAO, or designee. The field team may retain original field logbooks or send them to one of the Stanley Consultants' offices for filing. The raw field data generated and stored on data loggers, notebooks/tablets and portable laptop computers will be transmitted to the Project QAO, or designee, and converted to a standard database format maintained on Stanley Consultants' servers. After data entry or data transfer procedures are completed for each field event, data will be inspected for data transcription errors, and corrected as appropriate. After the final QA checks for errors are completed, the data will be added to the final database. The data tables will be generated from this database. Stanley Consultants will potentially use the following computer software to process data: Access®, Adobe Acrobat®, ArcView GIS®, Aqtesolv®, AutoCAD®, AutoDesk®, Datatran®, DQO/DEFT®, Excel®, Earth Volumetric Studio, Photoshop®, Project®, Surfer®, VSP®, Win-Situ®, and Word®.

Data management will be in-keeping with end-use by NV Energy for comparison to standards. Stanley Consultants' Project Manager will be responsible for supervising administrative support personnel in maintaining the Project files for the duration of the Project. The Project files will be kept by Stanley Consultants while the Project remains active. Upon completion of the Project, Stanley Consultants will archive the Project files at a secure storage facility for a period of 5 years after the completion of the Project. After 5 years, the disposition of the Project files will be determined by NV Energy.

Laboratory data management will focus on a level requisite of EPA protocols and the standard methods set forth in Appendix C. Concentrations of chemicals and all numerical parameters will be calculated as described in Pace Analytical Services ' QAM and Isotech Laboratories' QAP in Appendix C and applicable EPA analytical methods shown in Tables 4, 5 and 6. In cases where environmental results are less than the RL for a parameter, the results will be reported as "less than" the RL. Pace Analytical Services will retain the original COC forms and the preliminary and final data reports.

SECTION C - ASSESSMENT AND OVERSIGHT

C1.0 ASSESSMENT AND RESPONSE ACTIONS

This Section lists and describes the assessment and response activities used to ensure the QAPP is implemented as prescribed.

C1.1 Purpose

This element describes the internal and external checks to provide that:

- All elements of the QAPP are correctly implemented;
- The quality of the data produced is sufficient to the DQO screening decision; and
- That corrective action, if needed, is done and effectiveness confirmed to the DQO.

The end-use of the data is commensurate with a site characterization level process by NV Energy for determination of the need for corrective action, corrective action alternative selection, and closure of the RGS. The end-use of the data will be comparison with standards and needs to be consistent with other technical and supporting efforts to meet the Nevada industry standard of care. Consistent with this purpose, this Project will not enact extensive assessments or audits relative to supporting management systems of subsidiary organizations or internal management programs. Site assessment will be limited to monitoring the completion of technical and evaluation assignments.

C1.2 Assessment Activities

To accomplish the objectives of C1.1, the items in Table 9 will be conducted:

Table 9 Quality Control and Assurance Assessment Activities

ASSESSMENT ACTIVITY	ORGANIZATION NAME	PROJECT POSITION	FREQUENCY OF ACTIVITY
Certified Environmental Manager	Stanley Consultants	Project Manager, Field Team Leader, Technical Advisor	Duration of project
Project Field Check	NDEP	Project Coordinator or designee	Minimum 1 per year, as appropriate
Field Check	NV Energy	Project Coordinator or designee	Minimum 1 per year, as appropriate
Technical/Field Methods Audit	Stanley Consultants or NV Energy	QAO, Project Manager, or designee	Minimum 1 per year, as appropriate
Project Files/Media Check	Stanley Consultants	Project Manager or designee	Minimum 1 per year, as appropriate
Nevada Laboratory Certification	Contracted Laboratory	QA Officer or designee	National Environmental Laboratory Accreditation Conference (NELAC) Proficiency Testing, Biannual On-site inspection/ Annual Proficiency Testing Series, Inspection every 2 years

C1.3 Assessment Criteria and Documentation

The following criteria will be used for evaluation as part of the assessments listed in C1.2.

C1.3.1 Project Field Check

The NDEP Project Coordinator, or designee, will conduct, at their discretion, site visits to meet with the Field Team and to observe field activities in progress. The resulting deliverable will be a trip report to NDEP supervisors with a copy to the NV Energy Project Coordinator. A minimum of one trip report will be generated per year of the project or as deemed necessary by the NDEP Project Coordinator.

C1.3.2 Field Check

The NV Energy Project Coordinator, or designee, will conduct an unannounced visit to the RGS study area to observe the in-progress activities and management of the Project. Findings and observations will be conveyed verbally to the Stanley Consultants' Project Manager, or designee, to be documented and kept with the Project files.

C1.3.3 Technical/Field Methods Audit

Stanley Consultants' Project Manager, QAO, or designee will conduct random and unannounced in-progress checks of field activities relative to performance of the specific activities in Sections A6, A7, A9, B1, B2, B3, and B7. These will result in the completion of checklists and/or forms in Appendix D delivered to the Project Manager and QAO within one week of the audit. The Project Manager copy will remain resident in the Project file. Generic Field Forms are provided in Appendix D as examples. Actual forms used in the field may vary depending on recording media (i.e., paper or electronic).

C1.3.4 Project Files/Media Check

Stanley Consultants' Project Manager, or designee, will conduct and document random and unannounced in-progress checks of resident hardcopy and electronic Project files relative to Section A9. This will result in completion of the checklists and/or forms in Appendix D delivered to the QAO and Project Manager within one week of the check. The auditor copy will remain resident in the Project file. Generic Field Forms are provided in Appendix D as examples. Actual forms used in the field may vary depending on recording media (i.e., paper or electronic).

C1.3.5 Laboratory Certifications

Where applicable, only Nevada-certified laboratories will be used. Any non-compliance or serious failure of the program, which revokes or impugns the accreditation necessary for this Project, will be immediately reported in writing to the NV Energy Project Coordinator or the Stanley Consultants' Project Manager.

C2 .0 REPORTS TO MANAGEMENT

Communication is essential in assessing the need for and the feasibility of the corrective action and closure of the RGS. Quality is enhanced when this communication is regular and routine. Stanley Consultants management will act promptly to understand the impact and assist in resolution of corrective action on a continuous basis.

C2.1 Project Reports

The reports described and submitted to parties and on schedules described in C1.3 will be made part of the permanent data quality record. Additional routine reports describing the Project activities, status, results of audits, corrective actions, need for resolution among participating parties, and schedule changes will be distributed electronically and in writing. These are summarized below in Table 10.

Table 10 Routine Reports

Document	Party	Preparer	Distribute	Frequency
Monthly Reports	NV Energy	Project Coordinator or designee	NDEP, Project Manager	Monthly throughout AOC implementation
Daily/Weekly Field Reports	Stanley Consultants	Project Lead, Field Team Leader, or designee	Project Manager	Weekly when field work in progress with logbook copies
Project / E-Status Reports	Stanley Consultants	Project Manager or designee	NV Energy	Monthly throughout AOC implementation

C2.2 Laboratory Reports

Laboratory quality is enhanced through a formalized process and management system of reporting relative to communication issues on data quality, identification/resolution of problems and corrective action. These will be accomplished to maintain Project laboratory data quality within the limits of the standard methods. Reporting occurs consistent with Appendix C.

The laboratory will deliver to Stanley Consultants Level II or Level IV data quality packages for analyses, as appropriate. Analytical records will include SOPs for sample receipt, preparation, analysis, and report generation, as well as the actual data reports with all specified supporting information (e.g., run logs, case narratives). The amount of supporting information is determined by data validation needs and the need for the documents to stand alone.

The following information will be supplied by laboratories as data deliverables to support Project activities, data validation, and the documentation of data quality:

- Case narrative, including a discussion of nonconformance and corrective actions;
- Sample identification, preparation date, analyses dates, and results;
- As appropriate, MDLs and/or RLs;
- QC data summary forms;
- Complete COC forms, sample receipt forms, logbook pages, shipping manifests;

- Verification of sample temperature on receipt; and
- Copies of temperature logs for coolers used to store samples.

Hand-entered field parameter data will, at a minimum, include:

- Sample dates,
- Observations,
- Units, and
- Parameters.

C2.3 Database and Data Validation Reports

Data validation reports will be generated for data that is used on the Project in accordance with NDEP requirements. These reports will be submitted on specific data sets and not on the entire database in one report. These deliverables must obtain NDEP approval.

C2.4 Public Reports

In addition to data quality reports, the NV Energy Project has an obligation to report technical data for decision-making through community outreach portions of the Project. The content of reports will be sufficient to meet the planning and feasibility needs of NV Energy and for future use relative to the AOC. These needs and deliverables are set forth in the NDEP-approved CRP.

SECTION D - DATA VALIDATION AND USABILITY

D1.0 DATA REVIEW, VERIFICATION, AND VALIDATION

The AOC implementation will be conducted with end comparison to NDEP's site-specific standards, which do not require the detailed statistical and numerical comparison of traditional Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or other enforcement activities. When considering the DQOs of Section A7 and NV Energy's end use of data for a preliminary level decision-making effort, this Project does not require the extensive validation procedures traditionally required of enforcement action or in support of civil litigation.

D1.1 Purpose

The primary purpose for data validation is to assess and summarize the quality and the defensibility of the laboratory's analytical data for the end user. The data validation process focuses on evaluating the laboratory's performance so that "analytical error" associated with a data set can be determined. It provides a technical judgment on the validity of the laboratory results as a first step in determining the data's overall usability and legal defensibility.

Data review is necessary to ensure that the laboratory data collected for this Project are of sufficient quality to support the decisions of the DQOs in Section A7. The field and laboratory data generated during the implementation of the AOC will be verified and validated according to the criteria and procedures described in Section D2.0. The focus will be on the completeness and accuracy of field methods, proper sample handling, and validation and verification of the laboratory operating methods and protocols.

D1.2 General

The resultant data and information produced through implementation of the QAPP will be reviewed in relation to the objectives set forth in Section A7. The review and verification will check that the stipulated methods were implemented and, where failures occurred, assess the relative impact to the DQOs and primary decision of Section A7.2. Qualified or corrected procedures and data for comparison to NAC 445A (NAC, 2007a) standards will likely be acceptable if consistent with and sufficient to meet the Decision Statement.

The Project QAO, or designee, will be responsible for conducting a full-package review of the field process and data produced for this Project. Pace Analytical's Laboratory Quality Manager will conduct validation and reporting consistent with the QAM and QAP in Appendix C, the Data Validation SOPs in Appendix E, and applicable EPA analytical methods shown in Tables 4, 5 and 6. Pace Analytical will deliver laboratory data packages to the Stanley Consultants' QAO, or designee, for validation to be performed by Ordway and Associates, LLC, as required by Work Plans.

D1.3 Data Qualifiers

Data review and validation procedures will review data and evaluate biases in the data and ascertain its value or usability. Data that does not meet the DQOs described in Section A7 are assigned qualifiers or flags. Qualifiers indicate the results are considered to be estimated or rejected. Rejected data is considered unusable in the decision-making process. Flagged data may be usable with limitations. Qualifiers to be used in this Project are per the *National Functional Guidelines for Organic Superfund Methods Data Review* EPA-540-R-2017-002, January 2017 (USEPA, 2017a) and *National Functional Guidelines for Inorganic Superfund Methods Data Review* EPA-540-R-2017-001, January 2017 (USEPA, 2017b) and are as follows:

U	The analyte was analyzed for but was not detected above the sample quantitation limit.
J	The analyte was positively detected; the associated concentration is estimated.
N	The analysis indicates the presence of an analyte for which there is presumptive evidence to make a tentative identification and is referenced as a "tentatively identified compound" or TIC.
NJ	The analysis indicates the presence of a TIC and the concentration is estimated.
UJ	The analyte was not detected above the reported quantitation limit (RQL). However, the RQL is estimated and may or may not represent the actual quantitation limit to accurately and precisely measure the analyte in the sample.
R	The sample results have been rejected due to serious deficiencies in the ability to analyze the sample and meet the QC criteria. The presence or absence of the analyte cannot be determined.

The application of nonstandard qualifiers may be necessary and used for special circumstances such as contamination of the sample from preservatives or an analyte that failed a quality check. Nonstandard qualifier definitions will be included in the database.

D2.0 DATA REPORTING, VALIDATION AND USABILITY

The data review process consists of three steps; Verification, Validation, and Usability Assessment. These reviews are conducted in part to ensure that data produced are of adequate quality usability for their intended purpose; meeting the DQOs outlined in Section A7.3 of this QAPP.

Analytical data verification by the QAO, or designee, will generally consist of a completeness check to confirm that all data requested from the laboratory has been received and complies with specified requirements. Analytical data validation by Ordway and Associates, LLC will generally consist of an analyte and sample-specific process for evaluating compliance of the laboratory data received with methods, procedures, or contract requirements. Analytical data usability assessment by the Project Manager, or designee, will generally consist of an evaluation of data based upon the results of data validation and verification for the decisions being made. The Project Manager, or designee, will assess whether the process execution and resulting data meet quality objectives based on criteria established in this QAPP.

Data validation is comprised of a technical review of the data based on method specifications and laboratory-developed performance criteria by adapting the procedures set forth in the *National Functional Guidelines for Organic Superfund Methods Data Review* EPA-540-R-2017-002, January 2017 (USEPA, 2017a) and *National Functional Guidelines for Inorganic Superfund Methods Data Review* EPA-540-R-2017-001, January 2017 (USEPA, 2017b).

D2.1 Data Reporting

Laboratory personnel will verify that the measurement process was “in control” (i.e., all specified DQOs were met or acceptable deviations explained) for each batch of samples before proceeding with the analysis of a subsequent batch. In addition, each laboratory will establish a system for detecting and reducing transcription and/or calculation errors prior to reporting data. Only data that have met DQOs, or data whose acceptable deviations have been explained, will be submitted by the laboratory. When QA requirements have not been met, the samples will be reanalyzed when possible and only the results of the reanalysis will be submitted, provided they are acceptable. Pace Analytical will provide the analytical data in an EDD with the appropriate fields formatted.

D2.2 Data Verification and Validation

Generally, samples are taken in the field based on the SOPs and guidelines for commonly used investigation activities provided in Appendix B. There are typically two data flows created as a result of the field sampling activities that require verification and validation.

1) Field data, including sample location information, will be sent to the Project Manager, QAO, or designee.
2) Samples and COC information will be sent to Pace Analytical Services.

The laboratory(ies) then analyzes the samples and reports the results according to the protocols specified in the QAPP and/or Work Plan. The laboratory analytical data package (with qualifiers noted by the laboratory itself) then may be sent to Ordway and Associates, LLC who will verify and validate the analytical data (or some percentage of it) using guidelines and/or requirements identified in specific national or regional analytical data validation guidance, NDEP requirements, analytical method(s) or this QAPP. The validated laboratory analytical data (with validation qualifiers) then will be merged with field data. Generally, the overall data quality and usability is then assessed based on the review of field procedures and conditions during sampling. Finally, any ultimate decisions made that rely on this data may be documented and stored in a data repository along with supporting field and laboratory data. When stored appropriately, these data may be re-used or considered in future site decisions. The need for data validation by Ordway and Associates, LLC will be specified in each Work Plan. Data validation SOPS are provided in Appendix E.

Stages of verification and validation are outlined in further detail in Section 3.1 of "Data Validation Memo of Understanding" written by Ordway and Associates, LLC dated 5 March 2010 (Appendix F). In general, the initial data package for each analytical method will be verified and validated in accordance with Stage 4 validation requirements. Once it is determined that the data report is acceptable and that no corrective actions will be needed on the part of the laboratory, the data review and validation process may be performed in accordance with Stage 2B validation requirements. In general, 10% of field samples and one (1) in every five (5) data packages will be validated in accordance with Stage 4 requirements with the remainder validated in accordance with Stage 2B requirements. The QAO, or designee, is responsible for determining which group of samples will undergo Stage 4 validation based on field observations and expected analytical results. Data validation requirements will be included in each Work Plan.

There are, however, quantitative and qualitative errors that would constitute upgrading a Stage 2B validation to Stage 4, such as:

- Inability to verify sample result;
- Not reporting an analyte that is present and vice-versa;
- Misidentification of compounds;
- Inappropriate manual integrations;
- Incorrect number of calibration points;
- Exclusion of inside calibration points in calculating acceptance criteria; and
- Improper regression parameters.

In general, Stage 2B is based on completeness and compliance checks of sample receipt conditions and both sample-related and instrument-related QC results. Stage 4 is based on completeness and compliance checks of sample receipt conditions, both sample-related and instrument-related QC results, recalculation checks, and review of actual laboratory instrument outputs.

D3.0 VALIDATION AND VERIFICATION METHODS

The Project decision is a preliminary screening-level activity for use in determining the need for corrective action, selection of a corrective action, and closure. The data will be compared with State and site-specific standards having wide margins of latitude incorporated into a conservative first order comparison for unrestricted land use. The level of supporting effort expended in validation procedures should be of a similar latitude and magnitude. For this Project, the general focus will be determining proper collection, preservation, and delivery of proper amounts of media under specific conditions to the laboratory for measurement and use in the final decision.

The data validation procedures were designed to review each data set and identify biases inherent to the data set and determine its usefulness. Data validation flags are applied to those sample results that fall outside specified tolerance limits and; therefore, do not meet the program's QA objectives. Data validation flags to be used for this Project are defined in the *National Functional Guidelines for Organic Superfund Methods Data Review* EPA-540-R-2017-002, January 2017 (USEPA, 2017a) and *National Functional Guidelines for Inorganic Superfund Methods Data Review* EPA-540-R-2017-001, January 2017 (USEPA, 2017b). Data validation flags will indicate whether results are considered anomalous, estimated, or rejected. Only rejected data are considered unusable for decision-making purposes; however, other qualified data may require further evaluation.

Corrective actions will be initiated whenever DQIs suggest that DQOs have not been met. Corrective actions will begin with identifying the source of the problem. Potential problem sources include failure to adhere to method procedures, improper data reduction, equipment malfunctions, or systemic contamination. The first level of responsibility for identifying the problems and initiating corrective actions lies with the analyst/field personnel. The second level of responsibility lies with any person reviewing the data. Corrective actions may include more intensive staff training, equipment repair followed by a more intensive preventive maintenance program, or removal of the source of systemic contamination. Once resolved, the corrective action procedure will be fully documented and, if DQOs were not met, the samples in question may be re-collected and/or re-analyzed using a properly functioning system.

The QAO will rely on standard methods conformance, the laboratory data packages, and data validation reports from Ordway and Associates, LLC to support valid analytical data.

D3.1 Field and Management

The QAO, or designee, will be responsible for validation of Project implementation by conducting a direct comparison of the Project records to the Work Plan and/or QAPP. This will be initiated upon completion of the field sampling activities.

Due to the limited nature of the validation, the QAO, or designee, will conduct a minimum of one review per year when field sampling is occurring. The QAO, or designee, will evaluate the implementation of the following relative to field and management procedures as they apply to the Project. Data resulting from assessment activities will be reviewed to evaluate conformance with the quality criteria set forth in the QAPP and Work Plan. These evaluations will include, but are not limited to:

- Conformance to the QAPP's DQOs listed in Section A7.2 for selection and implementation as point source conditions;
- Conformance to the proposed sampling plan as detailed in the individual Work Plan;
- Conformance with sample handling protocols and holding times;
- Results of QC checks listed in Table 7 as they relate to field influences on data quality; and
- Results of calibration of instruments at bench mobilization and in the field from instrument records and field logbooks.

The review will specifically evaluate the implementation of the Work Plan relative to field and management procedures as they apply to the Project. The quality of the resultant data will be evaluated in accordance with the following:

- Generic conformance to design parameters of the QAPP and DQOs;
- Sampling design as detailed in the Work Plan(s);
- Sample collection procedures will be in accordance with SOPs and guidelines for commonly used investigation activities provided in Appendix B and specific source area Work Plan(s) and compared to field documentation and audits of Section C1.2; also:
    - Sampling will be considered complete if 95% of all soil samples are obtained pursuant to the Work Plan design;
    - Sampling will be considered complete if 95% of all groundwater samples are obtained pursuant to the Work Plan design;
    - Sampling will be considered complete if 95% of all surface water samples are obtained pursuant to the Work Plan design;
    - Sampling will be considered accurate if 95% of the sampling SOPs stipulated were used and documentation supports proper use; and
    - Sampling will be considered representative if 70% of the sample interval for soil and 95% of the laboratory volume for groundwater and surface water was recovered and submitted;
- Sample handling protocols and COC will be reviewed and holding and transport times must be met for the sample to be considered valid;
- QC checks conducted as they relate to field influences on data quality; and
- Calibration of instruments at bench mobilization and in the field from instrument records and field logbooks.

D3.2 Laboratory Data

The Laboratory Quality Manager will be responsible for validation of laboratory results and procedures as part of the preparation of data packages submitted to the QAO, or designee. The QAO, or designee, will be responsible for submittal of the laboratory data packages to Ordway and Associates, LLC for an independent Stage 2B or Stage 4 evaluation.

A Stage 2B evaluation will generally be completed on laboratory data generated during the AOC implementation. Data validation requirements will be included in all Work Plans.

The usability of historical data is dependent upon the intended use of the data and the data quality. Data that have associated QA/QC (field and laboratory) sample results can be evaluated utilizing the QA criteria established for the current activity. Data without QA/QC information may be utilized as screening quality data, providing site personnel with information relative to the most likely contaminants and approximate concentration levels.

D4.0 RECONCILIATION WITH DATA QUALITY OBJECTIVES

The decision process by NV Energy is a planning evaluation to assess the feasibility of site cleanup and closure under the requirements of the AOC. The decision, and data to support the decision, are considered quantitative for technical implementation, but are preliminary relative to the end decision to actually do so. The characterization of the RGS area is the first step in moving the RGS towards closure.

Beyond the Project process, NAC 445A (NAC, 2007a) has incorporated screening levels based on public protection into the development of the respective standards for soil and groundwater. The NAC 445A (NAC, 2007a) process has incorporated acceptance of variability through the allowable methods of demonstrating compliance (e.g., statistical averaging of site concentrations to consider risk, acceptability of less than 100% compliance to a standard). This infers that some variability in the data set will still be useful to NV Energy's decision in Section A.7.

The Project has limited resources for site characterization and must maximize use of all resultant data, even if qualified, in making decisions. Data qualified as "estimated" will be used for its intended purpose and "flagged" appropriately. While this data is less accurate or precise than unqualified data, the QAO, or designee, will evaluate its effect on the overall quality of the characterization of the RGS.

A failure to validate full compliance of a field procedure will not likely remove the resultant data from use by NV Energy, it may merely qualify it for recognition and use by others beyond the primary decision.

With the increased reliance on laboratory systems to produce quality data, a significant failure to validate analytical results will be less likely to be used in the process. Laboratory data failures will be given more extensive consideration and result in a written opinion by the Project QAO, or designee, as to usability relative to the DQO by NV Energy and for comparison with standards. Key to the reconciliation will be the following considerations:

- Is the invalid or qualified data point the sole determinant?
- Does inclusion of the flawed method or qualified data point/set skew the resultant comparison with standards?

The resultant opinion of the QAO, or designee, will be incorporated as an element of uncertainty in the subsequent reports to be delivered to the Project Manager for submittal to NV Energy and NDEP.

REFERENCES

This QAPP has been prepared considering the following guidance:

APHA, AWWA, and WEF, 1999. *Standard Methods for the Examination of Water and Wastewater,* Section 1030E, 20th Edition, January 1999.

ASTM, 2015a. *Standard Guide for Risk-Based Corrective Action Applied to Petroleum Release Sites*, Designation E 1739-95 (Reapproved 2015), ASTM International, West Conshohocken, PA, 2015.

ASTM, 2015b. *Standard Guide for Risk-Based Corrective Action*, American Society of Testing and Materials (ASTM), Designation E 2081-00 (Reapproved 2015), ASTM, West Conshohocken, PA, 2015.

Clark County, 2018. *Assessor's Website*, Real Property Record Search, September 5, 2018. http://www.clarkcountynv.gov/assessor/Pages/RecordSearch.aspx

IDQTF, 2005. *Uniform Federal Policy for Quality Assurance Project Plans: Evaluating, Assessing, and Documenting Environmental, Data Collection and Use Programs, Part 1: UFP-QAPP Manual.* Final Version, (EPA 505-B-04-900A/DoD DTIC ADA 427785), Intergovernmental Data Quality Task Force, March 2005.

NAC, 2000. *Nevada Administrative Code (590*) – *Title 40: Public Health and Safety, Chapter 590: Motor Vehicle Fuel, Petroleum Products and Antifreeze,* Nevada Revised Statues (NRS), Nevada Legislator, 2000).

NAC, 2002. – *Nevada Administrative Code (534), Title 40: Public Health and Safety Chapter 534: Underground Water and Wells:* Nevada Revised Statues (NRS), Nevada Legislator, 2002.

NAC, 2007a. *Nevada Administrative Code (445A), Title 40: Public Health and Safety, Chapter 445A: Water Controls*, Nevada Revised Statues (NRS), Nevada Legislator, 2007.

NAC, 2007b. *Nevada Administrative Code (459), Title 40: Public Health and Safety, Chapter 459: Hazardous Materials*, Nevada Revised Statues (NRS), Nevada Legislator, 2007.

NDEP, 2007. *Final Quality Assurance Program Plan for the Nevada Brownfields Plan*. May 20, 2007.

NDEP, 2008. *Nevada Division of Environmental Protection, Administrative Order on Consent*, *Nevada Power Company, Final*, February 22, 2008.

Stanley Consultants, 2011. *Data Quality Objectives and Generic Quality Assurance Project Plan, Nevada Power Company, Reid Gardner Station, Moapa, Nevada, version 2.4*. November 2011.

Stanley Consultants, 2013. *Preliminary Source Area Identification and Characterization Report, NV Energy, Reid Gardner Station, Moapa, Nevada*. July 2013.

US Census, 2012. *Profile of General Population and Housing Characteristics: 2010 Demographic Profile Data (DP-1): Moapa Town CDP, Nevada*. U.S. Census Bureau, American Factfinder. Retrieved March 13, 2012.

USEPA, 1999a. *Contract Laboratory Program National Functional Guidelines for Organic Data Review* EPA/540/R/9/008*,* October 1999*.*

USEPA, 1999b. *Test Methods for Evaluating Solid Waste: Physical/Chemical Methods; Third Edition; Final Update III-A EPASW-846.3.3a*, March 1999.

USEPA, 2000. *Multi-Agency Radiation Survey and Site Investigation Manual (MAESSIM), NUREG-1575, EPA402-R-97-016, Final*, December 1997 – update to 2000 version.

USEPA, 2001. *EPA Requirements for Quality Assurance Project Plans* EPA QA/R-5, OEI, March 2001.

USEPA*,* 2002*. Guidance for Quality Assurance Project Plans* EPA QA/G-5, OEI, EPA/240/R-02/009, December 2002.

USEPA, 2004. *Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* EPA/540/R/04/004*,* October 2004*.*

USEPA, 2006*. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4*, February 2006*.*

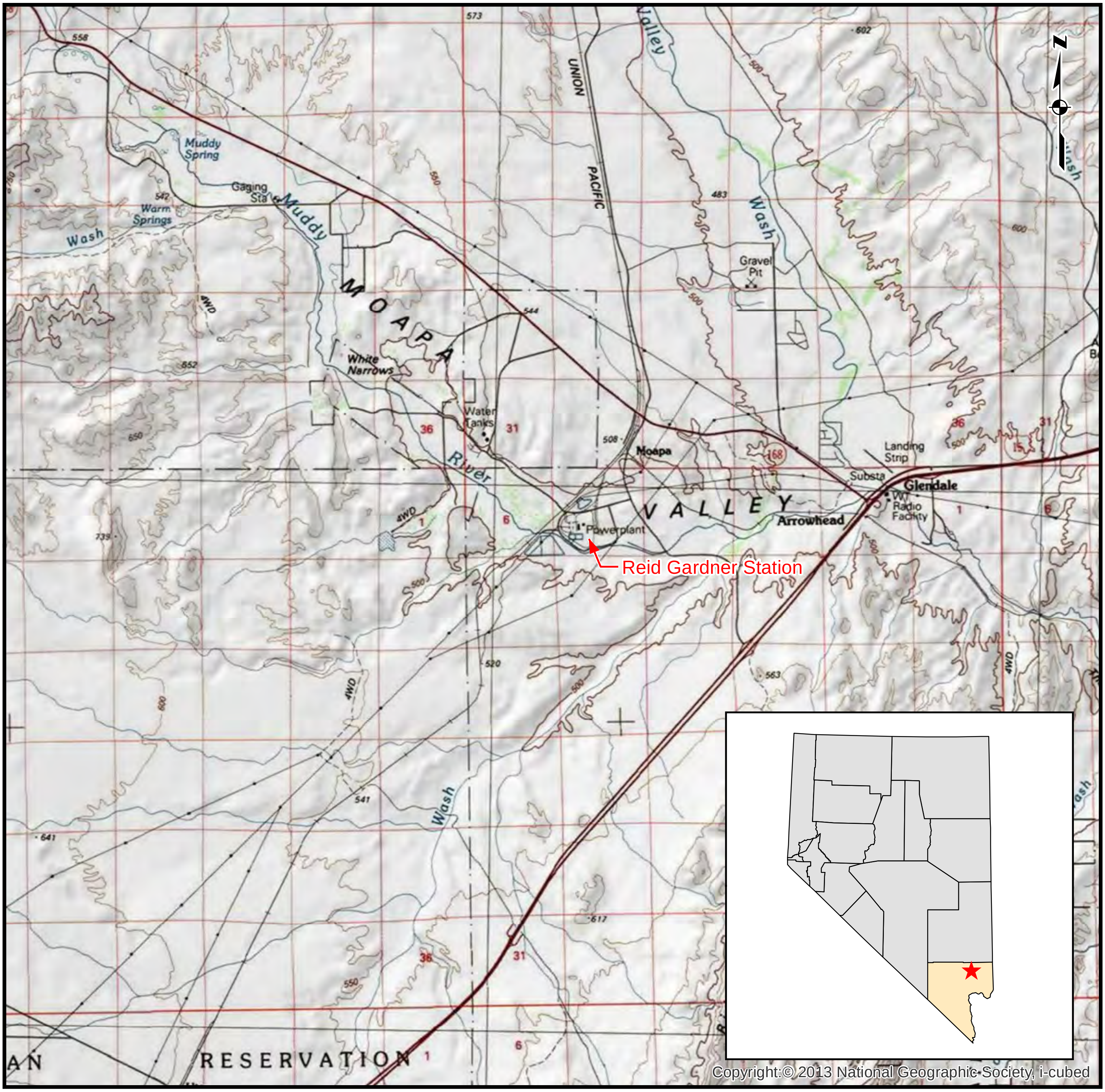
USEPA*,* 2012. *EPA Region 9 Guidance for Quality Assurance Program Plans*, R9QA/03.2, March 2012.

USEPA, 2017*. National Functional Guidelines for Organic Superfund Methods Data Review* EPA-540-R-2017-002, January 2017 (USEPA, 2017a)

USEPA 2017*. National Functional Guidelines for Inorganic Superfund Methods Data Review* EPA-540-R-2017-001, January 2017 (USEPA, 2017b)

APPENDIX A

PROJECT LOCATION MAPS



Copyright:© 2013 National Geographic Society, i-cubed

Notes:
1) Base map service displaying USGS topographic map tiles was compiled by National Geographic Society, copyrighted 2013.
2) Approximate date of USGS topographic map for Moapa West Quadrangle 7.5 Minute Series is 1983.

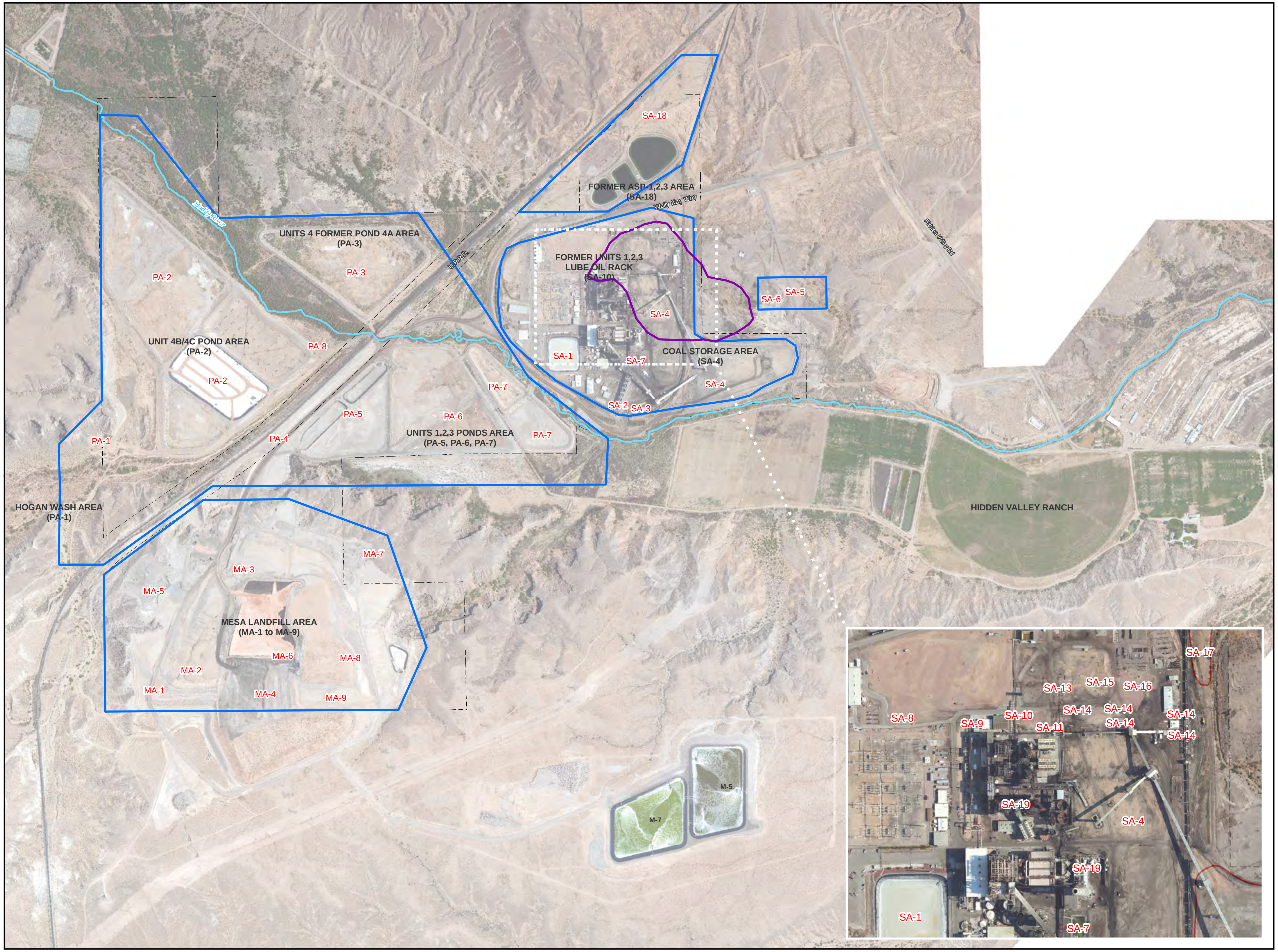
0 2.5 5 Miles

May 2020

SITE LOCATION
Generic Quality Assurance Project Plan
NV Energy
Reid Gardner Station
Moapa, NV
Figure 1

Stanley Consultants INC.

\\...\GIS\WorkingData\Mxd\QAP\QAP_Figure1.mxd © STANLEY CONSULTANTS



Legend

- - - - RGS Property Boundary
Muddy River
▢ Source Area Group
▢ Petroleum Source Area Group

Potential Source Areas		
	Source No.	Description
Potential Mesa Source Areas	MA-1	Closed Sanitary Landfill (WMU-1)
	MA-2	Special Asbestos Waste Cell (WMU-2) (Actively Permitted)
	MA-3	Disposal Area for Construction and Demolition Debris (WMU-3)
	MA-4	Class III (Industrial Waste) Landfill (WMU-4) (Active Permit)
	MA-5	Closed Ash Disposal Site (WMU-5)
	MA-6	Evaporation Ponds P1 - P5
	MA-7	Landfill Used for Industrial and Non-Industrial Waste (WMU-7)**
	MA-8	Disposal Area for Water Treatment Waste (WMU-9)
	MA-9	Former Mesa Dredge Pond (WMU-10)
	PA-4	Closed Fly Ash Fill Area Under Landfill Haul Road (WMU-6)
Potential Pond Source Areas	PA-1	Hogan Wash
	PA-2	Ponds 4B and 4C
	PA-3	Former Pond 4A
	PA-5	Former Pond D (West Pond)
	PA-6	Ponds E (East Pond, Pond C, Pond D)
	PA-7	Pond F and Former Pond G (Units 1,2,3 Laydown Ponds)
	PA-8	Hydrogen Peroxide Tank Release
Potential Petroleum Source Areas	SA-9	Units 1 and 2 Emergency Diesel Generator
	SA-10	Former Units 1,2,3 Lube Oil Rack
	SA-11	Former Gasoline UST (1000-gallon) and Warehouse 1
	SA-12	Former Diesel AST (850,000- gallon)
	SA-13	Former Diesel Fuel Unloading Area
	SA-14	Former Underground Product Piping, Petroleum Tanks
	SA-15	Free Product Recovery System
	SA-16	Vehicle Maintenance Area
Potential Station Source Areas	SA-1	Unit 4 Treated Water Pond
	SA-2	Unit 4 Cooling Tower
	SA-3	Unit 4 Cooling Tower Catch Basin
	SA-4	Coal Piles and Fly Ash Under Unit 4 Coal Pile (WMU-12)
	SA-5 and SA-6	Area of Previous Fly Ash Fill (WMU-13 and WMU-14)
	SA-7	Unit 4 Settling Pond (Foster Wheeler Pond)
	SA-8	Units 1, 2, 3 Catch Basin
	SA-17	Reported Previous Waste Disposal Area (WMU-8)
	SA-19	Units 1, 2, 3 Scrubbers and Unit 4 Absorber
Potential Northern Station Source Area	SA-18	ASP-1, ASP-2, ASP-3, Former Clear Wells, Former Fly Ash Disposal Area (WMU-11)

Notes:
1. Aerial LiDAR imagery provided by NV Energy; dated July 11-12, 2017.
2. Potential source area locations from July 2013 Preliminary Source Area Identification & Characterization Report.

1,000 500 0 1,000 2,000
Feet

Stanley Consultants INC.

May 2020

REV	No.	REVISION DESCRIPTION	DATE	DRWN	CHKD	APVD
C		Draft for NV Energy review	9/12/18	EW	BC	RLS
B		Draft for NV Energy review	5/18/17	CC	BC	RLS
A		Draft for NV Energy review	8/18/15	MT/CC	BC	RLS

0 1in.
At full size
1 inch = 1,150 feet

PRELIMINARY
FOR DISCUSSION
PURPOSES ONLY

20618.09.42

REV.
C

POTENTIAL SOURCE AREAS
Generic Quality Assurance Project Plan
NV Energy
Reid Gardner Station
Moapa, NV
Figure 2

\\...\GIS\WorkingData\Mxd\QAP\QAP_Figure2_RevC.mxd

APPENDIX B

COMPENDIUM OF FIELD STANDARD OPERATING PROCEDURES

APPENDIX B – REFERENCED STANDARD OPERATING PROCEDURES

TABLE OF CONTENTS

- 7.4 Nevada Division of Environmental Protection (NDEP) – Guidance Document for Design of Groundwater Monitoring Wells

CATEGORY 8: SOIL SAMPLING

- 8.1 US EPA Environmental Response Team Standard Operating Procedures – Soil Sampling
- 8.2 Standard Guide for Direct Push Soil Sampling for Environmental Site Characterization
- 8.3 Appendix B-1 Sample Collection Parameters for Metals and Classical Chemistry Parameters

CATEGORY 9: SONIC, HSA, USCS

- 9.1 Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
- 9.2 Standard Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices.
- 9.3 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

CATEGORY 10: SURFACE WATER SAMPLING, FLOW

- 10.1 Field Sampling Guidance Document #1225 Surface Water Sampling
- 10.2 Standard Operating Procedure for Streamflow Measurement
- 10.3 Standard Operating Procedure for Surface Water Sampling
- 10.4 MRI SOP

CATEGORY 11: SURVEYING

- 11.1 GPS Pathfinder Systems User Guide
- 11.2 GPS Site Surveying Standard Operating Procedure Manual – Attachment G

CATEGORY 12: UTILITY CLEARANCE

- 12.1 USA North’s California Excavation Manual
- 12.2 USA North 811 Ticket Form
- 12.3 USA North Color Brochure

CATEGORY 1: DIRECT PUSH AND DISCRETE GROUNDWATER SAMPLE

Section 1.1

Standard Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization

Designation: D6001 – 05 (Reapproved 2012)

Standard Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization[1]

1. Scope

1.1 This guide covers a review of methods for sampling groundwater at discrete points or in increments by insertion of sampling devices by static force or impact without drilling and removal of cuttings. By directly pushing the sampler, the soil is displaced and helps to form an annular seal above the sampling zone. Direct-push water sampling can be one time, or multiple sampling events. Methods for obtaining water samples for water quality analysis and detection of contaminants are presented.

1.2 Direct-push methods of water sampling are used for groundwater quality studies. Water quality may vary at different depths below the surface depending on geohydrologic conditions. Incremental sampling or sampling at discrete depths is used to determine the distribution of contaminants and to more completely characterize geohydrologic environments. These investigations are frequently required in characterization of hazardous and toxic waste sites.

1.3 Direct-push methods can provide accurate information on the distribution of water quality if provisions are made to ensure that cross-contamination or linkage between water bearing strata are not made. Discrete point sampling with a sealed (protected) screen sampler, combined with on-site analysis of water samples, can provide the most accurate depiction of water quality conditions at the time of sampling. Direct-push water sampling with exposed-screen sampling devices may be useful and are considered as screening tools depending on precautions taken during testing. Exposed screen samplers may require development or purging depending on sampling and quality assurance plans. Results from direct-push investigations can be used to guide placement of permanent groundwater monitoring wells and direct remediation efforts. Multiple sampling events can be performed to depict conditions over time. Use of double tube tooling, where the outer push tube seals the hole, prevents the sampling tools from coming in contact with the formation, except at the sampling point.

1.4 Field test methods described in this guide include installation of temporary well points, and insertion of water samplers using a variety of insertion methods. Insertion methods include: *(1)* soil probing using combinations of impact, percussion, or vibratory driving with or without additions of smooth static force; *(2)* smooth static force from the surface using hydraulic cone penetrometer (Guide D6067) or drilling equipment (Guide D6286), and incremental drilling combined with direct-push water sampling events. Under typical incremental drilling operations, samplers are advanced with assistance of drilling equipment by smooth hydraulic push, or mechanical impacts from hammers or other vibratory equipment. Direct-push water sampling maybe combined with other sampling methods (Guide D6169) in drilled holes. Methods for borehole abandonment by grouting are also addressed.

1.5 Direct-push water sampling is limited to soils that can be penetrated with available equipment. In strong soils damage may result during insertion of the sampler from rod bending or assembly buckling. Penetration may be limited, or damage to samplers or rods can occur in certain ground conditions, some of which are discussed in 5.6. Information in this procedure is limited to sampling of saturated soils in perched or saturated groundwater conditions. Some soil formations do not yield water in a timely fashion for direct-push sampling. In the case of unyielding formations direct-push soil sampling can be performed (Guide D6282).

1.6 This guide does not address installation of permanent water sampling systems such as those presented in Practice D5092. Direct-push monitoring wells for long term monitoring are addressed in Guide D6724 and Practice D6725.

1.7 Direct-push water sampling for geoenvironmental exploration will often involve safety planning, administration, and documentation.

1.8 *This guide does not purport to address all aspects of exploration and site safety. It is the responsibility of the user of this guide to establish appropriate safety and health practices and determine the applicability of regulatory limitations before its use.*

---

[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

Current edition approved Jan. 15, 2012. Published December 2012. Originally approved in 1996. Last previous edition approved in 2005 as D6001 – 05. DOI: 10.1520/D6001-05R12.

1.9 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D4448 Guide for Sampling Ground-Water Monitoring Wells
D4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well) (Withdrawn 2010)[3]
D5088 Practice for Decontamination of Field Equipment Used at Waste Sites
D5092 Practice for Design and Installation of Ground Water Monitoring Wells
D5254 Practice for Minimum Set of Data Elements to Identify a Ground-Water Site
D5314 Guide for Soil Gas Monitoring in the Vadose Zone
D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D5474 Guide for Selection of Data Elements for Groundwater Investigations
D5521 Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers
D5730 Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Groundwater
D5778 Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils
D5903 Guide for Planning and Preparing for a Groundwater Sampling Event
D6067 Practice for Using the Electronic Piezocone Penetrometer Tests for Environmental Site Characterization
D6089 Guide for Documenting a Ground-Water Sampling Event
D6235 Practice for Expedited Site Characterization of Vadose Zone and Groundwater Contamination at Hazardous Waste Contaminated Sites
D6452 Guide for Purging Methods for Wells Used for Groundwater Quality Investigations
D6517 Guide for Field Preservation of Groundwater Samples
D6564 Guide for Field Filtration of Groundwater Samples
D6634 Guide for the Selection of Purging and Sampling Devices for Ground-Water Monitoring Wells
D6724 Guide for Installation of Direct Push Groundwater Monitoring Wells
D6725 Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers
D6771 Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations (Withdrawn 2011)[3]
D6911 Guide for Packaging and Shipping Environmental Samples for Laboratory Analysis

2.2 *Drilling Methods:*[2]

D5781 Guide for the Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5782 Guide for the Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5783 Guide for the Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5784 Guide for the Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5875 Guide for the Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Explorations and Installation of Subsurface Water-Quality Monitoring Devices
D5876 Guide for the Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D6286 Guide to the Selection of Drilling Methods for Environmental Site Characterization

2.3 *Soil Sampling:*[2]

D4700 Guide for Soil Sampling from the Vadose Zone
D6169 Guide to the Selection of Soil and Rock Sampling Devices Used With Drilling Rigs for Environmental Investigations
D6282 Guide for Direct-Push Soil Sampling for Environmental Site Characterization

3. Terminology

3.1 Terminology used within this guide is in accordance with Terminology D653 with the addition of the following:

3.2 *Definitions in Accordance with Practice D5092:*

3.2.1 *bailer*—a hollow tubular receptacle used to facilitate removal of fluid from a well or borehole.

3.2.2 *borehole*—a circular open or uncased subsurface hole created by drilling.

3.2.3 *casing*—pipe, finished in sections with either threaded connections or beveled edges to be field welded, which is installed temporarily or permanently to counteract caving, to

---

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

advance the borehole, or to isolate the interval being monitored, or combination thereof.

3.2.4 *caving; sloughing*—the inflow of unconsolidated material into a borehole that occurs when the borehole walls lose their cohesive strength.

3.2.5 *centralizer*—a device that helps in the centering of a casing or riser within a borehole or another casing.

3.2.6 *jetting*—when applied as a drilling method, water is forced down through the drill rods or riser pipe and out through the end openings. The jetting water then transports the generated cuttings to the ground surface in the annulus of the drill rods or casing and the borehole. The term jetting may also refer to a well development technique.

3.2.7 *PTFE tape*—joint sealing tape composed of polytetrafluorethylene.

3.2.8 *well screen*—a filtering device used to retain the primary or natural filter pack; usually a cylindrical pipe with openings of uniform width, orientation, and spacing.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *assembly length*—length of sampler body and riser pipes.

3.3.2 *bentonite*—the common name for drilling fluid additives and well construction products consisting mostly of naturally occurring sodium montmorillonite. Some bentonite products have chemical additives that may affect water quality analyses (see 9.3.3).

3.3.3 *direct-push sampling*—sampling devices that are directly inserted into the soil to be sampled without drilling or borehole excavation.

3.3.4 *drill hole*—a cylindrical hole advanced into the subsurface by mechanical means; also, known as borehole or boring.

3.3.5 *effective screen length*—the length of a screen open or exposed to water bearing strata.

3.3.6 *effective seal length*—the length of soil above the well screen that is in intimate contact with the riser pipe and prevents connection of the well screen with groundwater from other zones.

3.3.7 *grab sampling*—the process of collecting a sample of fluid exposed to atmospheric pressure through the riser pipe with bailers or other methods that may include pumping; also known as batch sampling.

3.3.8 *incremental drilling and sampling*—insertion method where rotary drilling and sampling events are alternated for incremental sampling. Incremental drilling is often needed to penetrate harder or deeper formations.

3.3.9 *percussion driving*—insertion method where rapid hammer impacts are performed to insert the sampling device. The percussion is normally accompanied with application of static down force.

3.3.10 *push depth*—the depth below a ground surface datum that the end or tip of the direct-push water sampling device is inserted.

4. Summary of Guide

4.1 Direct-push water sampling consists of pushing a protected well screen to a known depth, opening the well screen over a known interval, and sampling water from the interval. A well point with an exposed screen can also be pushed with understanding of potential cross-contamination effects and purging requirements considered. A sampler with constant outside diameter is inserted directly into the soil by hydraulic jacking or hammering until sufficient riser pipe is seated into the soil to ensure a seal. Protected well screens can be exposed by retraction of riser pipes. While the riser is seated in the soil, water samples can be taken, and water injection or pressure measurements may be performed.

5. Significance and Use

5.1 Direct-push water sampling is an economical method for obtaining discrete groundwater samples without the expense of permanent monitoring well installation **(1-6)**.[4] This guide can be used to profile potential groundwater contamination with depth by performing repetitive sampling events. Direct-push water sampling is often used in expedited site characterization (Practice D6235). Soils to be sampled must be permeable to allow filling of the sampler in a relatively short time. The zone to be sampled can be isolated by matching well screen length to obtain discrete samples of thin aquifers. Use of these sampling techniques will result in more detailed characterization of sites containing multiple aquifers. By inserting a protected sampling screen in direct contact with soil and with watertight risers, initial well development (Guide D5521) and purging of wells (Guide D6452) may not be required for the first sampling event. Discrete water sampling, combined with knowledge of location and thickness of target aquifers, may better define conditions in thin multiple aquifers than monitoring wells with screened intervals that can intersect and allow for intercommunication of multiple aquifers **(4,6,7,9,13)**. Direct-push sampling performed without knowledge of the location and thickness of target aquifers can result in sampling of the wrong aquifer or penetration through confining beds.

5.2 For sites that allow surface push of the sampling device, discrete water sampling is often performed in conjunction with the cone penetration test (Test Method D6067) **(4-9)**, which is often used for stratigraphic mapping of aquifers, and to delineate high-permeability zones. In such cases, direct-push water sampling is normally performed close to cone holes. In complex alluvial environments, thin aquifers may vary in continuity such that water sampling devices may not intersect the same layer at equivalent depths as companion cone penetrometer holes.

5.3 Water sampling chambers may be sealed to maintain in situ pressures and to allow for pressure measurements and permeability testing **(6,9,12)**. Sealing of samples under pressure may reduce the possible volatilization of some organic compounds. Field comparisons may be used to evaluate any systematic errors in sampling equipments and methods. Comparison studies may include the need for pressurizing samples,

---

[4] The boldface numbers in parentheses refer to a list of references at the end of this guide.

or the use of vacuum to extract fluids more rapidly from low hydraulic conductivity soils (8.1.5.3).

5.4 Degradation of water samples during handling and transport can be reduced if discrete water sampling events with protected screen samplers are combined with real time field analysis of potential contaminants. In limited studies, researchers have found that the combination of discrete protected screen sampling with onsite field analytical testing provide accurate data of aquifer water quality conditions at the time of testing **(4,6)**. Direct-push water sampling with exposed screen sampling devices, which may require development or purging, are considered as screening tools depending on precautions that are taken during testing.

5.5 A well screen may be pushed into undisturbed soils at the base of a drill hole and backfilled to make permanent installed monitoring wells. Procedures to complete direct-push wells as permanent installations are given in Practice D6725 and Guide D6724.

5.6 In difficult driving conditions, penetrating to the required depth to ensure sealing of the sampler well screen may not be possible. If the well screen cannot be inserted into the soil with an adequate seal, the water-sampling event would require sealing in accordance with Practice D5092 to isolate the required aquifer. Selection of the appropriate equipment and methods to reach required depth at the site of concern should be made in consultation with experienced operators or manufacturers. If there is no information as to the subsurface conditions, initial explorations consisting of penetration-resistance tests, such as Test Method D6067, or actual direct-push testing trials can be performed to select the appropriate testing system.

5.6.1 Typical penetration depths for a specific equipment configuration depend on many variables. Some of the variables are the driving system, the diameter of the sampler and riser pipes, and the resistance of the materials.

5.6.2 Certain subsurface conditions may prevent sampler insertion. Penetration is not possible in hard rock and usually not possible in softer rocks such as claystones and shales. Coarse particles such as gravels, cobbles, and boulders may be difficult to penetrate or cause damage to the sampler or riser pipes. Cemented soil zones may be difficult to penetrate depending on the strength and thickness of the layers. If layers are present that prevent direct-push from the surface, the rotary or percussion drilling methods (Guide D6286) can be employed to advance a boring through impeding layers to reach testing zones.

5.6.3 Driving systems are generally selected based on required testing depths and the materials to be penetrated. For systems using primarily static reaction force to insert the sampler, depth will be limited by the reaction weight of the equipment and penetration resistance of the material. The ability to pull back the rod string is also a consideration. Impact or percussion soil probing has an advantage of reducing the reaction weight required for penetration. Penetration capability in clays may be increased by reducing rod friction by enlarging tips or friction reducers. However, over reaming of the hole may increase the possibility of rod buckling and may allow for communication of differing groundwater tables. Hand-held equipment is generally used on very shallow investigations, typically less than 5-m depth, but depths on the order of 10 m have been reached in very soft lacustrine clays. Intermediate size driving systems, such as small truck-mounted hydraulic-powered push and impact drivers, typically work within depth ranges from 5 to 30 m. Heavy static-push cone penetrometer vehicles, such as 20-ton trucks, typically work within depth ranges from 15 to 45 m, and also reach depth ranges on the order of 10^2 m in soft ground conditions. Drilling methods (Guide D6286) using drilling and incremental sampling are frequently used in all depth ranges and can be used to reach depths on the order of 103 m.

NOTE 1—Users and manufacturers cannot agree on depth ranges for different soil types. Users should consult with experienced producers and manufacturers to determine depth capability for their site conditions.

5.7 Combining multiple-sampling events in a single-sample chamber without decontamination (Practices D5088) is generally unacceptable. In this application, purging of the chamber should be performed to ensure isolation of the sampling event. Purging should be performed by removing several volumes of fluid until new chemical properties have been stabilized or elements are flushed with fluid of known chemistry. Purging requirements may depend upon the materials used in the sampler and the sampler design (Guide D6634).

6. Apparatus

6.1 *General*—A direct-push sampling system consists of a tip; well screen; chambers, if present; and riser pipes extending to the surface. Direct-push water sampling equipment can be grouped into two classes, either with a sealed protected screen or exposed screen (see 6.2). There are also two types of drive systems, single tube and double tube (see 6.4).

6.2 Samplers with sealed screens depend on the seal to avoid exposure of the sampling interval to soil or water from other layers. They can be considered as accurate point-source detectors. They are normally decontaminated between sampling events. Exposed-screen samplers may require purging and development and as such are considered as screening devices for profiling relative degrees of contamination.

6.2.1 *Exposed-Screen Samplers*—Some direct-push samplers may consist of a simple exposed well screen and riser pipe that allows grab sampling with bailers or pumps. An example of this arrangement is the simple push or well point shown in Fig. 1 **(14)**. The practice of jetting well points is often not acceptable due to the large quantities of water used for insertion and the resulting potential for disturbance and dilution in the aquifer. If water is used for insertion, knowing the chemical constituents in the water may be necessary. Bias may be possible if an exposed-screen sampler is pushed through multiple contaminated layers. If exposed-screen well points are pushed through predrilled holes the screen and riser may fill with water present in the drill hole and require purging before sampling. One form of exposed screen sampler has been developed for multiple sampling events as an exposed tip is advanced **(18,19)**. This multiple event "groundwater profiler" injects distilled water out of the ports in between sampling

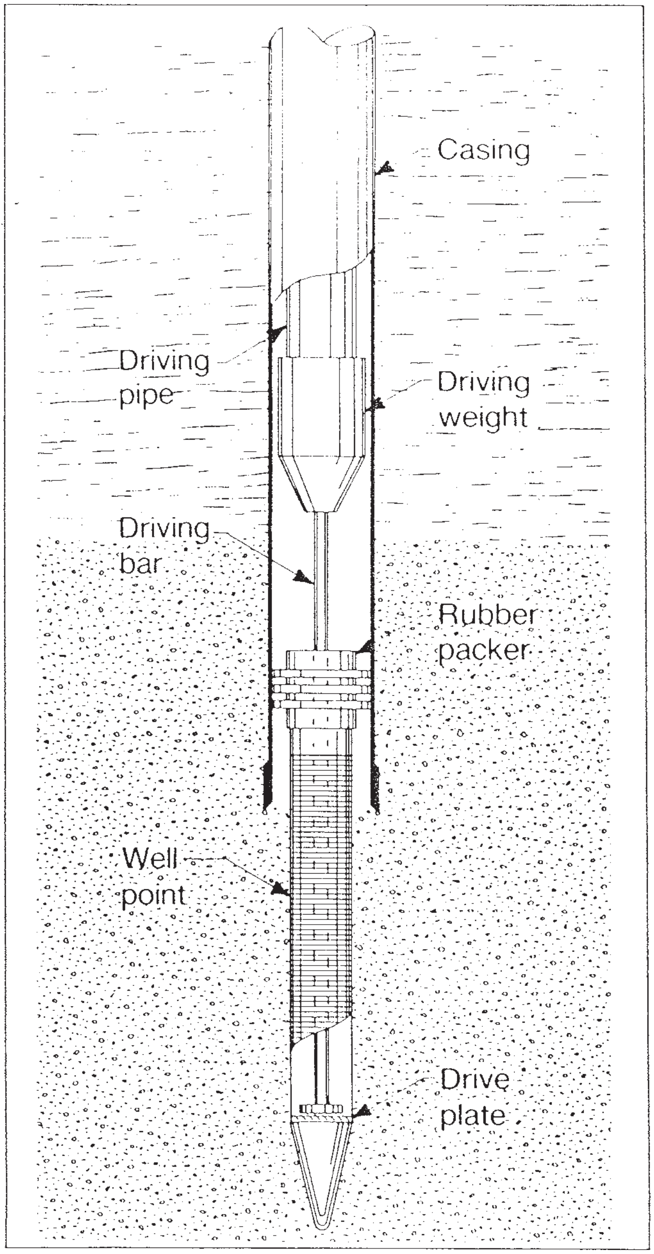


FIG. 1 Exposed-Screen Sampler—Well Point Driven Below the Base of a Borehole (**12**)

events which keep the port from clogging and purges the sampling line between sampling events.

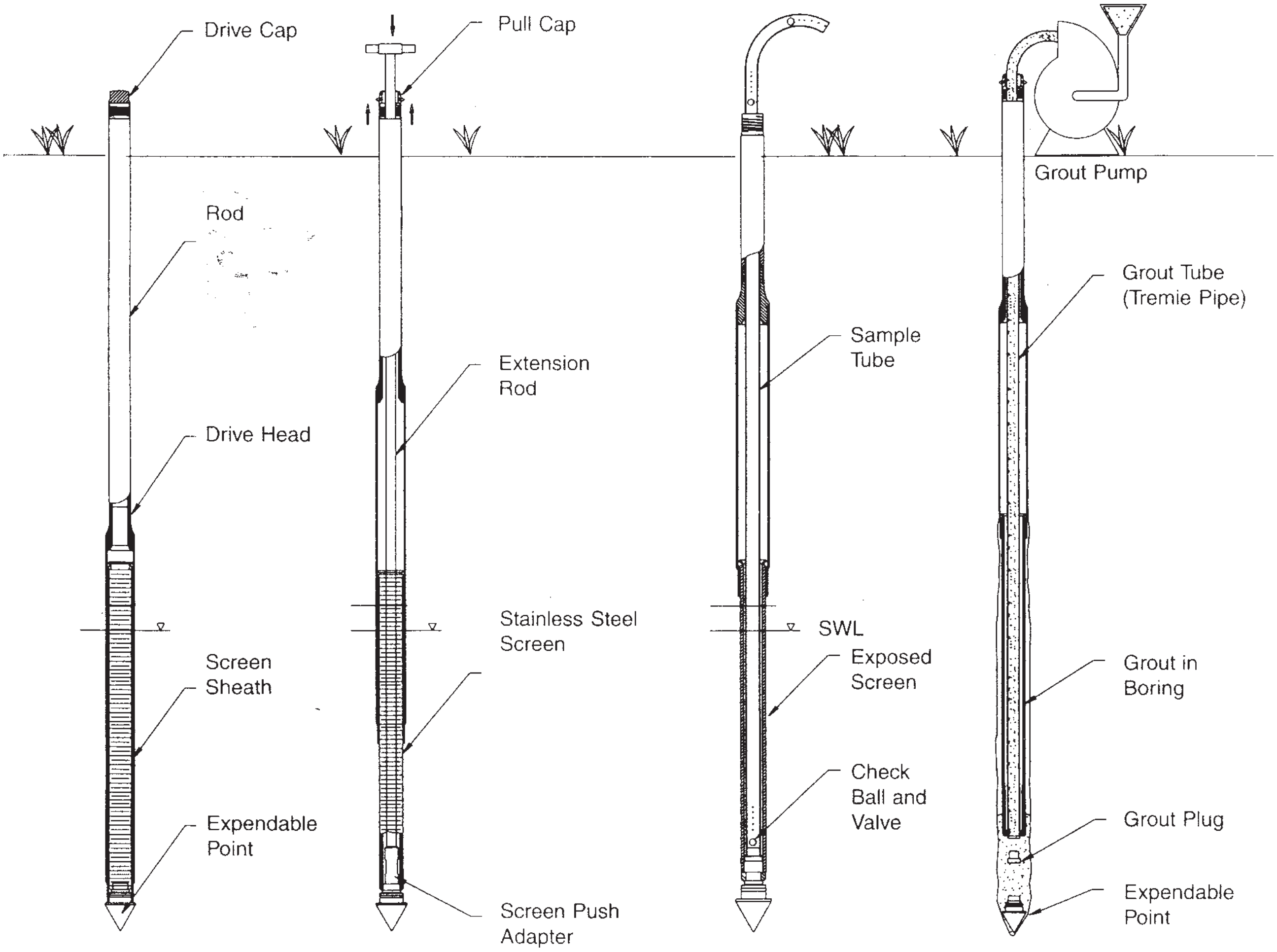
6.2.1.1 Another form of an exposed-screen sampler has been incorporated into cone penetrometer bodies (**8**). The cone penetrometers have sample chambers with measurement devices such as temperature and conductivity. Some cone penetrometers have been equipped with pumps for drawing in water samples into sample chambers or to the surface. Samplers equipped with chambers and subjected to multiple sampling events may require purging between sampling events.

6.2.2 *Sealed-Screen Samplers*—Protected well screen and simple riser pipes for grab sampling are also deployed. An example is shown in Fig. 2 (**15**). This simple well screen arrangement allows for grab sampling through the riser pipe without purging or development if there is no leakage at the screen seals and riser pipes. Fig. 3 shows a schematic of a direct-push water sampler with a protected screen and with the ability to work in the grab sampling mode or by allowing water to enter a sample chamber in the sampler body (**5**). Most simple sample chambers allow for flow through the chamber. When flow through chambered samplers is opened, it is possible that the groundwater from the test interval can fill into the rods above the chamber. In those cases, it may be advisable to add water of known chemistry into the rods prior to opening the screen. Some protected-screen samplers have sample chambers designed to reduce volume and pressure changes in the sample to avoid possible volatilization of volatile compounds (**6**,**9**,**12**). The need for pressurization is dependent on the requirements of the investigation program and should be evaluated by comparison studies in the field with simpler systems allowing the sample to equalize at atmospheric pressure. There are different approaches to pressurizing the sample chamber including use of inert gas pressure or using sealed systems. An example of a sealed vial-septum system is shown in Fig. 4 (**6**). In the sealed vial system, a septum is punctured with a hypodermic needle connected to a sealed vial. With this approach the vial will contain both a liquid and gas at aquifer pressure. The sealed vial-septum system has been used in an exposed-screen mode.

6.2.3 *Materials of Manufacture*—The choice of materials used in the construction of direct-push water sampling devices should be based on the knowledge of the geochemical environment to be sampled and how the materials may interact with the sample by means of physical, chemical, or biological processes. Due to the nature of insertion of these devices, the sampler body is typically comprised of steel, stainless steel, or metals of other alloys. The type of metal should be selected based on possible interaction effects with the fluid to be sampled. Well-screen materials can be selected from a variety of materials. Materials commonly used for well-screen elements include steel, stainless steel, rigid polyvinyl chloride (PVC), polytetrafluorethylene (PTFE), polyethylene (PE), polypropylene (PP), and brass. Sample chambers, pumps, and connector lines are also constructed with a variety of materials. Evaluating the possible interaction of materials that will be exposed to the water during the sampling event is important.

6.3 *Sampler Body*—The sampler body consists of a tip, and a barrel that consists of well screen, a protective sleeve if used, and a sampling chamber if used, with a connector assembly to attach to riser pipes or tubing. The sampler is normally constructed of steel to withstand insertion forces. The sampler barrel should be of constant outside diameter to ensure intimate contact with the soil to be tested. Protective sleeves shall be equipped with O-rings to prevent the ingress of water before the sampling event.

6.3.1 *Expendable Sampler Tips*—Some sampler tips are expendable and are left in the ground after the sampling event. The tip should be equipped with an O-ring seal to the sampler sleeve to prevent leakage into the riser pipe until the sampling depth is reached.



The assembled Sampler is driven to the desired sampling depth using standard rods.

Extension rods are used to hold the screen in position as the Casing Puller Assembly is used to retract the rods.

The tubing check valve can be used to sample groundwater.

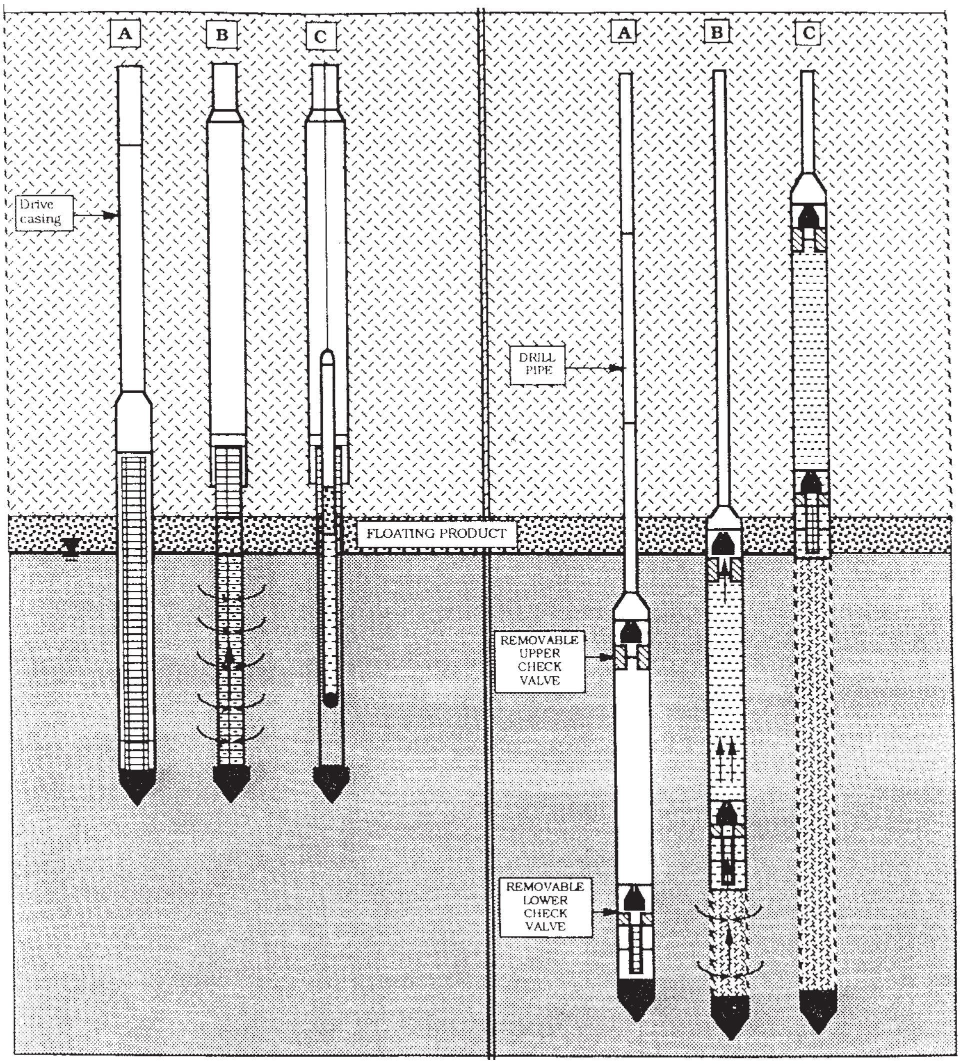
Abandonment grouting can be conducted to meet ASTM requirements.

FIG. 2 Simple Protected Screen Sampler (13)

6.3.1.1 Sampler tips are designed so that upon pull back of the sampler body and riser pipe, the tip is disconnected from the sampler. The required diameter, and the ability to expend the tip successfully, depends on the soils to be penetrated. The tip diameter can be set equal to, or slightly less than, the sampler body. If there are problems with tip retraction, tips can be designed with a diameter of 1 to 3 mm (⅛ to ¹⁄₁₆ in.) larger than the sampler body. The use of an enlarged diameter with a larger shoulder or tip may help in reaching greater depths because it acts as a friction reducer. An enlarged tip should not leave too large an annulus above the sampler body and riser pipes as to maintain a seal above the well screen and to prevent potential cross contamination.

6.3.1.2 Most sampler tips are made of steel to withstand pushing forces. With some samplers, after the sampling event, the tip may remain in the ground and the hole may be grouted. The user should consider if leaving the tips below the ground will adversely affect surrounding groundwater chemistry depending on site conditions.

6.3.2 *Well Screen*—Many materials for well screens are available for direct-push samplers. The material of manufacture should be selected with consideration of chemical composition of the groundwater to be sampled and possible interactive effects (see 6.2.3). Some samplers use simple mill slotted steel, or PVC tube. Steel or brass screen formed into a cylinder can be used to cover inlets. Continuous-wrapped, wire-wound well points are also commonly used. The effective opening size of the well screen material should be selected based on the material to be sampled, the time required to sample, and soil sediment that can be tolerated in the water sample. Methods to size well-screen and filter-pack materials are given in Practice D5092. Clean sands and gravels can be sampled with a screen with larger openings without producing excessive sediment. Clayey and silty soils containing fines may require finer openings. Typical openings of 10 to 60 µm are used. Finer openings will reduce sediment but may also slow ingress of fluid.



Legend: Grab Sampling

A Penetrometer closed while being driven into position.
B Tool opened and 5 foot screen telescopes into position for collection of hydrocarbon or water sample at the very top of the aquifer.
C Hydrocarbon sample being collected using bailer lowered through drive casing.

Legend: Water Sampling in Chamber

A Penetrometer closed while being driven into position.
B Cone separated and tool open to collect sample.
C Check valves closed as sample is retrieved within body of the tool.

FIG. 3 Protected Screen Sampler Capable of Working in Grab or Chamber Sampling Modes (1)

6.3.3 Some sampler inlets are not protected by well screen or slotting. The simplest form of sampler can be an open riser pipe with an expendable tip. The use of unprotected inlets has sometimes been useful to sample groundwater at soil/bedrock interface. If unprotected inlets are used, one must consider the amount of soil sediment that can be tolerated in the sample.

6.4 *Push Rod, Single Tube and Double Tube Systems and Riser Pipes***—**Also commonly referred to as "push rods" or "extension rods," drive tubes are normally constructed of steel to withstand pushing and impactforces. Most double tube systems use an outer casing and inner drive rods. The inner drive rods are removed when ready for sampling (Fig. 5). Double-tube systems are advantageous if multiple sampling events are required in a single push. The outer casing of a double tube system prevents cross contamination from different aquifers. Some systems may use a double-tube system with a small-diameter PVC riser pushed by the steel tube (Fig. 6) **(14)**. Other temporary systems may use a flexible tubing system connected to the well point (Fig. 7) **(14)**. Most double tube systems have larger outside diameter and required more driving power. Single rod systems (Fig. 2) sometime have a larger diameter sampling body in front of smaller diameter drive rods and can cause concern if the sampler has to be driven through multiple aquifers. The single rod system is generally used for one time sampling events in the same hole. The maximum rod diameter that can be used depends on the material to be penetrated and the driving system. Increased rod diameter causes increase in the required driving force required

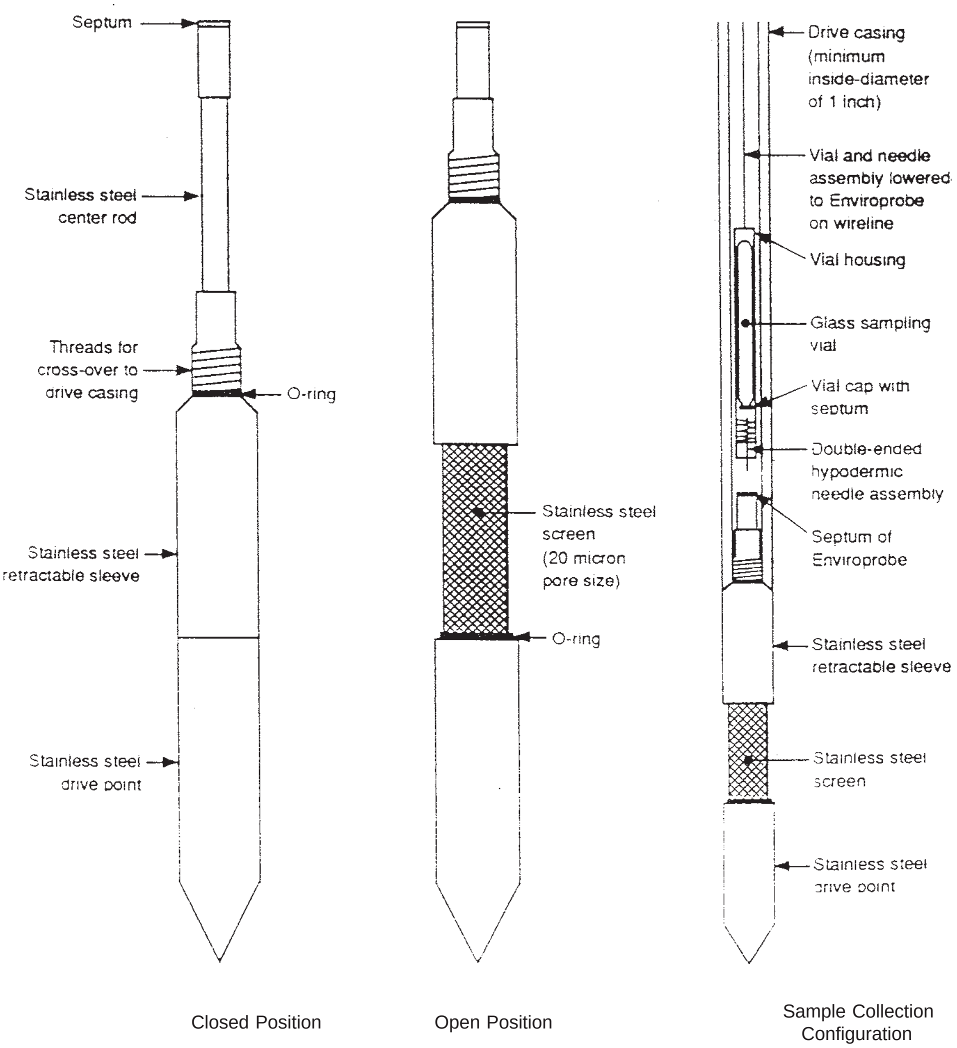


FIG. 4 Protected Screen Sampler with Sealed Vial System (4)

to penetrate a sufficient distance. Most surface direct-push riser pipes are less than 50 mm (2 in.) in diameter.

6.4.1 Cone penetrometer rods as specified in Test Method D5778 are sometimes used in sampling systems deployed with cone penetrometer equipment. Larger diameter rods, typically 45 mm (1.75 in.), are sometimes used with cone penetrometer equipment.

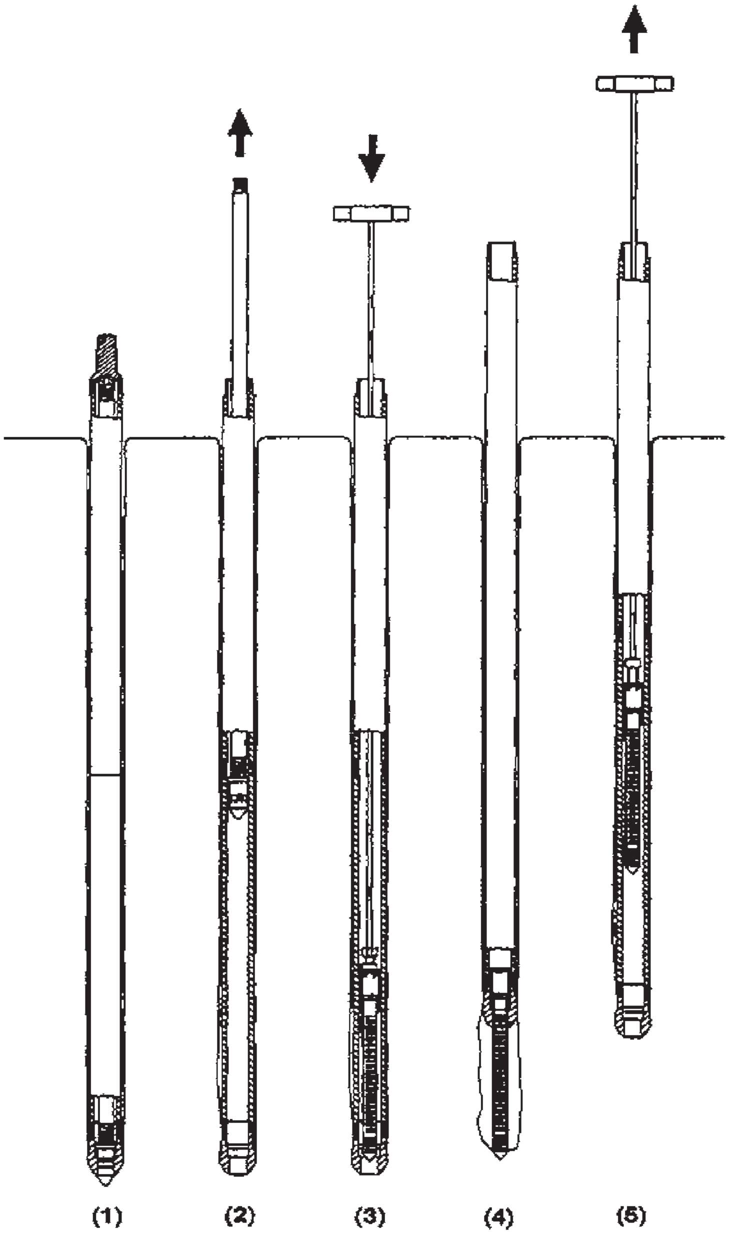
6.4.2 Standard drilling rods used for rotary drilling are normally used when sampling is done at the base of drill holes. Many drill rods are available (see Guide D6286).

6.4.3 For direct-push sampling systems that depend on the riser pipe for sampling within the riser, ensuring that joints are watertight will be necessary such that water enters through the well screen interval to be sampled. Rods should be wrench-tightened, and PFTE tape can be used on the threads to stop leakage. The quality checks discussed in Section 8 can be performed to evaluate possible leakage. Sometimes it may be necessary to equip rod joint shoulders with O-rings to prevent leakage. Cone penetrometer rods with precision tapered threads are normally watertight during short sampling events lasting up to 1 h if they are not damaged.

6.4.4 *Friction Reducers*—Friction reducers that have enlarged outside diameters of the riser pipe are sometimes employed to reduce thrust capacity needed to advance the well point or sampler. If friction reducers are used, they must be a sufficient distance above the sampling location to ensure that fluids from overlying layers cannot enter the sampling zone. If cross-contamination is possible, use of friction reducers should be avoided. In some cases the use of friction reducers can help in forming an annular seal. Donut-type reducers ream the hole smoothly. Lug-type reducers rip and remold the soil and may provide a better annular seal. The type and location of friction reducers should be documented in the project report.

6.4.5 *Mud Injection*—Some direct-push systems inject bentonite drill fluid along the drill rods to reduce friction. These systems normally inject the fluid behind friction reducers. These systems may provide better sealing above the sampler for the sampling process but are also more difficult to operate.

6.5 *Sampling Devices*—Consult Guide D6634 for selection of sampling devices. Due to the small diameter of most direct-push equipment, pump selection is limited. Bladder



(1) Advance outer casing to bottom of screen interval.
(2) Remove inner rod string leaving open outer casing.
(3) Lower screen to bottom of casing and hold in place with extension rods.
(4) Retract casing to expose screen to formation, remove extension rods.
(5) Retrieve screen after development, sampling, and slug testing.

FIG. 5 Double Tube Sealed Screen Sampler

pumps, gas-displacement pumps, peristaltic pumps, and inertial lift (tubing check valve) pumps may all be used for sampling.

6.6 *Sample Containers*—Sample containers for sampling groundwater are addressed in Guide D6911.

6.7 *Driving or Pushing Equipment*—Soil probing (percussion driving) systems, penetrometer systems, and rotary drilling equipment are used for inserting direct-push water sampling devices. The equipment should be capable of applying sufficient mechanical force or have sufficient reaction weight, or both, to advance the sampler or screen to a sufficient depth to ensure an effective seal above the area to be sampled. The advancement system must also have sufficient retraction force to remove the rods, which is often a more difficult task than advancing the rods. Simple advancement systems include hand-held rotary-impact hammers with mechanical-extraction jacks. Many systems use hydraulic- or vibratory-impact hammers operating at high frequency to drive rods into the

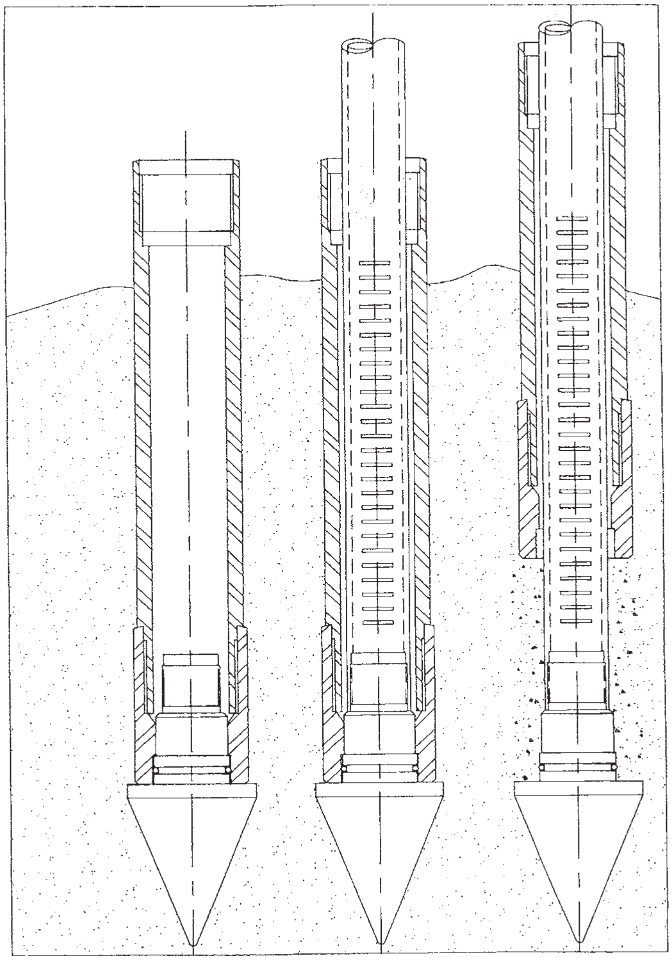


FIG. 6 Double-Tube Temporary Well Point System (14)

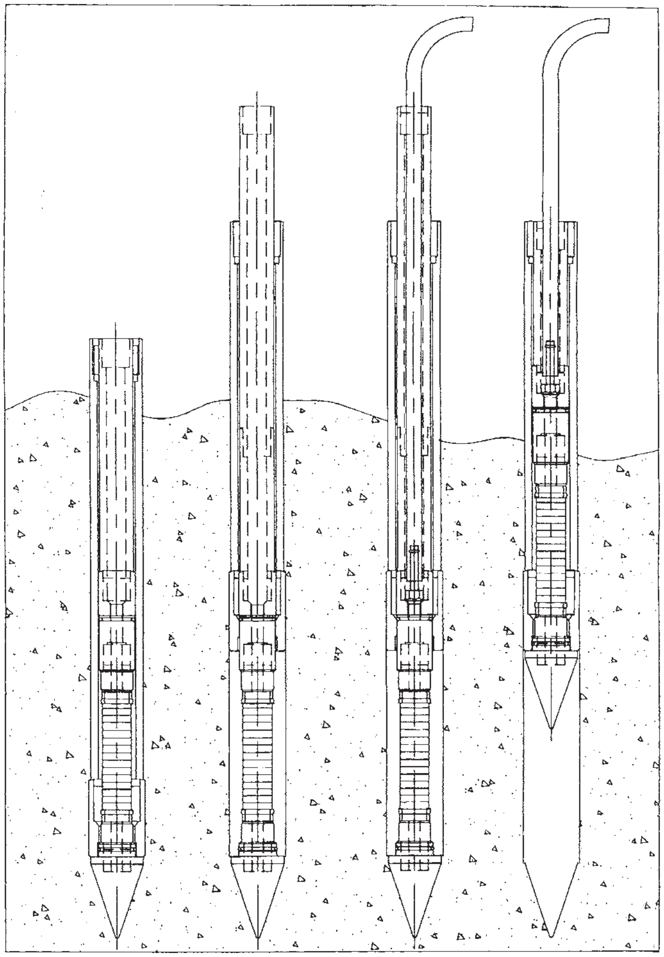


FIG. 7 Protected Screen Sampler with Sample Tubing (14)

sampling interval. Reaction force can be reduced if impact hammers are employed. Multipurpose driving systems such as those commonly deployed for soil gas sampling (Guide D5314) are frequently used in shallow explorations. Some vibratory drilling systems can provide vibration to the rods and easily penetrate cohesionless soils. On soft ground sites, cone penetrometer systems use hydraulic rams to push the sampler and riser pipe into the ground. Conventional rotary drilling rigs can use either hydraulic pull-down capability or hammers to drive the sampler to the required depth. Rotary drilling rigs are often used with the incremental drilling and sampling method. A140-lb SPT hammer (Test Method D1586) is available on most rotary drilling rigs and can be used to advance the sampler. Use of impact or vibration may allow for penetration of harder soils. If a significant length of rods whip during driving, they should be restrained to prevent damaging of the annular seal at the base of a borehole from lateral movement.

7. Conditioning

7.1 *Decontamination*—Sampling equipment that contacts groundwater to be sampled before and after the sampling event may require decontamination. Decontamination should be performed following the procedures outlined in Practices D5088 and the site-sampling plan. The sampler body normally requires complete decontamination before sampling. Well-screen components are sometimes expendable. Newly manufactured screens and sampler components may contain residues from manufacture and should be cleaned before the sampling event. Riser pipes should be decontaminated if sampling will be performed within the tube. In many cases it's advantageous to have several samplers on hand so one can be cleaned while the other is being used.

7.2 *Purging*—For exposed-screen sampling devices and sampling systems open to overlying groundwater, purging may be required before the sampling event. With both protected- and exposed-screen samplers, purging may be required if groundwater from overlying sources infiltrates into the riser pipes into the sampling area. Purging should consist of removal of overlying groundwater from the sampling system prior to the sampling event. Purging requirements are outlined in Guides D6452 and D6771.

8. Procedure

8.1 Two procedures are outlined depending on whether the sampling device is pushed directly from the surface or whether drilling is used to advance an open hole close to the sampling interval. In either event, the sampling screen should be advanced into undisturbed soil a sufficient distance to ensure that the sampling depth cannot be exposed to overlying groundwater, if present. Consult Guide D5903 prior to performing a groundwater sampling event.

8.1.1 *Incremental Drilling and Sampling*—In this method, advance a drill hole close to the sampling interval using drilling methods listed in 2.2. Of the drilling methods listed, the most commonly employed is rotary hollow-stem auger drilling because fluids are not introduced during the drilling process. If a rotary drilling method using drilling fluid or air is employed, the impact of the fluid or air to the sample quality and quality of the surrounding aquifer should be considered. If caving or sloughing occurs the use of protective casings may be required.

8.1.1.1 Stabilize the drill rig and erect the drill rig mast. Establish and document a datum for measuring hole depth. This datum may consist of a stake driven into a stable ground surface, the top of the surface casing, or the drilling deck. If the hole is to be later surveyed for elevation, record and report the elevation difference between the datum and the ground surface. Proceed with drilling until a depth is reached above the target sampling interval. Check and document the depth of the borehole and condition of the base of the hole. Establish the depth and condition of the base of the boring by resting the sampler at the base of the boring and checking depth to the sampler tip. If casing is used and heave occurs into the casing, remove this material and advance the hole deeper. Heave of soil into the casing may make it impossible to drive the water sampler without it carrying the casing along with the well point or sampler. If excessive heave, caving, or sloughing of soil occurs, consider using an alternative drilling method capable of maintaining stable soil conditions.

8.1.2 If the sampling event is to occur at the groundwater table and equipment depends on a dry-hole condition, that is, an exposed screen sampler with no purging requirements, test the drill hole to confirm that groundwater has not entered the hole. Water levels can be determined using Test Method D4750.

8.1.3 Attach the well point or sampler to riser pipes and lower into the borehole. Carefully record the assembly length as rod sections are added to the assembly. Centralizers may be used to maintain verticality of the assembly and to reduce rod whip. Rest the assembly on the base of the borehole. Determine and record the depth to the tip of the assembly.

8.1.4 Either push or drive the well point or sampler a sufficient distance below the base of the boring. This distance should be at least 1 m (3 ft), or the minimum to ensure an effective seal. For protected-screen samplers where a protective screen is exposed by pulling back the riser pipe, the withdrawal action may shear or crack soil, allowing connection to the base of the borehole. In these cases, adjust the insertion and retraction lengths according to soil conditions. In general, the sampler should be inserted at least three times the effective screen length from retraction. To check the seal in fluid filled holes, tracers can be introduced into the fluid in the base of the borehole. Document the final depth of insertion to the tip of the sampler and midpoint of the well screen. If the sampler is driven with hammer blows, accomplish the penetration without excessive vibrations that could reduce the effective seal of the riser pipe above the well screen. Normally, if smooth penetration is accomplished with each hammer blow, the seal should be intact.

8.1.4.1 The process of jetting well points is not preferred because of the addition of water, disturbance to the sampling zone, and lack of an effective seal above the screen. These installations are usually intended for permanent installations with the drill hole completed as a monitoring well. If jetting is used, document the approximate volume and chemical quality of water.

8.1.5 *Sampling*—The sampling process depends on the type of the sampling equipment used, that is, exposed- or protected-screen samplers.

8.1.5.1 *Sampling of Exposed-Screen Samplers*—Exposed-screen samplers can be sampled after fluids have been purged from the screen and riser pipes. Purge these systems in accordance with Guides D4448, D6452, and D6771.

8.1.5.2 *Sampling of Protected-Screen Samplers*—Test protected-screen samplers that are open to the surface through the riser for grab sampling for system leakage before exposing the screen for sampling. Before screen exposure, test the riser for presence of water that may have leaked through joints and connections using Test Method D4750. If water is present from unknown sources, this should be noted and either purging or abandoning of the test should be considered. After quality checks for leakage, the riser pipes may be pulled or twisted to expose the well screen to the aquifer.

8.1.5.3 Several methods for sampling water are available. If the sampling device uses head pressure available in the aquifer, sufficient time should be allowed for water to fill the sampling chamber or riser pipes. Some systems allow for connection of a sealed sampling chamber, or tubing, to a port in the sampler body after the screen is opened, allowing direct connections to the screened sampling area. By using these systems, one may avoid the necessity to check inside the riser pipes for leakage water. Use of sampling pumps to draw in the sample may be allowed, but consideration should be given to the changes in ambient pressures and temperatures that may change chemical compositions. With an open tube well screen using grab or pump sampling in low permeability soils, a vacuum is sometimes applied to the top of the riser pipe to accelerate groundwater inflow. The use of a vacuum and its effect on chemical composition should be considered and evaluated if site requirements dictate.

8.1.5.4 After a sufficient volume of the sample is obtained, place the samples in suitable containers for analysis and preserve them if required (Guides D6517 and D6911). The volume of a sample to obtained depends on the chemical composition of groundwater, testing protocols, and the data-quality objectives. Depending on the screen or porous filter used, samples may contain turbidity and/or sediment and may require filtering before placement of samples in containers. Certain testing procedures or regulations may require filtration of water samples. Consult Guide D6564 for filtering groundwater samples.

8.1.6 After sampling, either retrieve the sampler or leave it in place for permanent installation in accordance with Practice D5092 and Guide D6724. Some retrievable samplers leave a tip or a well screen element, or both, below the bottom of the boring. If repeated sampling events are to be performed in the same drill hole, drilling it through these pieces if present will be necessary. Depending on the drilling method, a pilot bit should be reinserted in the drill string and drilling continued to a depth exceeding the depth of the previous sampling event. Tips or screens from the previous sampling event, will be drilled through or moved to the side of the drill hole by drilling action before the next sampling event. Sometimes the presence of a tip or element, or both, can be detected by drilling action. If drilling action detects these pieces, note the location. Drilling continues to the next depth of concern and sampling may be repeated. The depth of the extended drill hole should equal or exceed the depth to the sampling tip of the previous interval.

8.1.7 After the drilling is completed, the drill hole should be completed following guidelines in drilling methods (Guide D6286) or those given in Section 9.

8.2 *Direct-Push from the Surface*—Well points and samplers may be advanced directly from the surface with multipurpose percussion driving systems, hand-held rotary percussion drills, cone penetrometer systems, or any other systems capable of supplying sufficient force to reach the depths of concern.

8.2.1 Stabilize and level the rig for testing. For some tire-mounted equipment, the rig can be raised off the ground and leveled with hydraulic rams to lift the rig from the tires to avoid shifting during difficult driving conditions. Establish and document a datum for measuring hole depth. If the hole is to be later surveyed for elevation, record and report the height of the datum to the ground surface.

8.2.2 The sampler body is connected to riser pipes along with any subassemblies such as friction reducers. Prior to driving, measure the length of the sampler assembly and riser pipes to determine the depth of sampling. Some temporary well systems drive a double tube or cased system, where riser pipe and casing are added as it is advanced. This allows for easy annulus grouting as the casing is retracted. The rods are then pushed using smooth quasi static push or impacts, or both. Additional riser pipes are added as pushing progresses. As driving progresses, operators should carefully record the rods added to ensure that sampling occurs at the correct depth.

8.2.3 *Sampling of Exposed-Screen Samplers*—Use the same procedures in accordance with 8.1.5.1.

8.2.4 *Sampling of Protected-Screen Samplers*—Use the procedure in accordance with 8.1.5.2 with the addition that the riser pipes should be periodically checked for leakage using Test Method D4750.

8.2.5 After sufficient volume of a sample is procured, place the samples in suitable containers and preserve them if required (Guides D6517 and D6911). The volume of the sample to obtained depends on the chemical composition of groundwater, testing protocols, and the data-quality objectives. Depending on the screen used, samples may contain turbidity and/or sediment and may require filtering before placement of samples in containers (Guide D6564).

8.3 After sampling, the sampler is either retrieved or left in place for permanent installation (Section 9). Some retrievable samplers leave a tip or a well-screen element, or both, at the bottom of the sounding. If repeated sampling events are to be done in the same hole, they must be done with samplers pushed to greater depths.

8.4 After the testing is finished, complete the borehole following the guidelines in Section 9.

9. Completion and Abandonment

9.1 *Permanent or Temporary Well Installations*—Wells inserted by either drilling methods or direct-push from the surface may be left in the ground as permanent or temporary installations. Refer to Guide D6724 for direct-push well installation. For wells inserted in drill holes, the drill hole will require completion with sealing materials to ensure a seal between the hole wall and riser pipes. Sealing procedures are given in Practice D5092.

NOTE 2—For wells installed by direct push from the surface, the need for sealing depends on the size of the annulus, groundwater quality, and the ability for cross-contaminating or accelerating contamination movements among aquifer(s). Temporary well points installed into the top of the first groundwater layer may only require surface sealing. If the annulus is very small, soil cave and squeeze may reduce effective vertical hydraulic conductivity. If the well riser intersects perched aquifers, cross-communication of aquifers may be possible if too large an annulus is left open. Communication can be evaluated by performing tracer tests, if necessary. Friction reducers used on cone penetrometer equipments may only increase hole diameters by 6 to 13 mm (¼ to ½ in.) of that of the steel pipes for pushing.

9.2 *Other Completion Methods*—Performing special completions with protective casings or other sealing methods may be necessary depending on the investigation requirements. For holes using rotary drilling methods and incremental sampling, the hole could be completed as a monitoring well (Practice D5092) or with grouted casings for other testing such as geophysical tests. Several methods are available for grouting of casings. The most desirable method is injection grouting, where injection is done at the base of the boring is most desirable and grouts are pumped up the annulus until they reach the surface showing a continuous seal.

9.3 *Hole Abandonment*—For test holes where there are no installations or other completion methods, the hole should be abandoned following program requirements. The need for and the method of sealing for abandonment depends on state and local regulations, site conditions, groundwater quality, and the ability for cross-contaminating or accelerating contamination movements among aquifer(s).

9.3.1 Large-diameter drill holes from rotary drill operation which intersect the groundwater often require sealing. State, federal, and local regulations may dictate abandonment requirements for boreholes intersecting the water table.

9.3.1.1 The need for sealing of holes is also dependent on geohydrologic conditions. If the hole intersects the top of the first groundwater table, complete sealing may not be required. Under a homogeneous single aquifer system, where there are no perched water table or artesian conditions, there will be little hydraulic gradient to move potential contaminants at differing elevations. The worst case for possible cross-communication of aquifers occurs under perched or confined groundwater conditions.

9.3.1.2 In most cases, direct-push holes intersecting groundwater tables will require complete sealing. In cases where the hole is to be backfilled completely, the condition of the hole should be evaluated and documented. Any zones of caving or blocking which preclude complete sealing should be documented. Displacement grouting may displace groundwater from the hole to the surface. If this water is considered contaminated then provisions must be made to collect these fluids at the surface. A minimum requirement for sealing should be that the surface of the hole is sealed to prevent hazards to those at the surface and to eliminate direct movement of surface contaminants to the water table through the hole.

9.3.2 *Completion of Drill Holes*—Completion of boreholes using drilling methods are addressed in Guides D5781, D5782, D5783, D5784, D5875, D5876, and also see 2.2.

9.3.3 *Completion of Surface Direct-Push Holes*—Several methods have been used successfully for sealing or grouting of surface direct-push holes **(17)**. The method of grouting depends on the types of equipment deployed and the subsurface conditions encountered.

9.3.3.1 *Retraction Grouting*—One method of grouting is retraction grouting directly through the sampler tip or friction reducer as the sampler is withdrawn after the sampling event. Tip retraction grouting is normally performed through small diameter tubes and a knockoff tip. Tip retraction grouting is the least frequently used due to difficulty in pumping grout mixtures without significant head loss through the tubing. Cement grouts for tip retraction grouting may require higher water content or additives to reduce viscosity.

(1) Retraction grouting is sometimes performed through grouting points above the sampler tip. This is normally accomplished using an enlarged diameter grouting port above the sampler as shown in Fig. 8.

9.3.3.2 *Reentry Grouting*—Reentry grouting may have an advantage of freeing pushing equipments for production while grouting operations follow. Reentry grouting allows temporary connection of aquifers between the removal and reinsertion process but is normally acceptable if grouting follows promptly minimizing exposure. The selection of retraction or reentry grouting is an economic decision and it depends on site conditions and depth of soundings.

(1) In reentry grouting, Figs. 9 and 10, the test string is completely withdrawn from the hole and a secondary grouting tube or tubing is reinserted to the complete depth of the hole. If the hole remains open after retraction of the test string, inserting flexible tubing or small-diameter PVC into the hole by hand directly after testing may be possible. In this case, reinserting the grout line is desirable close to the original depth of the hole. In some cases, depending on project needs, locations of water bearing strata, and soil stratigraphy, it may be acceptable if the grout line does not reach the bottom of the hole.

(2) Usually, with squeezing clays or caving sands, reaction equipment may be required to push rigid tubing of steel or plastic with a sacrificial or grouting tip to the complete depth of the hole (Figs. 9 and 10). The reentry string should follow the original hole alignment because it is the path of least resistance. If deviation is suspected, it should be reported. If a knockoff tip is to be retracted in high hydraulic conductivity sands it may be necessary to add grout into rods prior to tip retraction to avoid water filling the rods. Grout is then pumped through the hole until it rises to the surface, or tremie grouting is performed by maintaining a grout column in the rods as they are removed. Grouting is continued to maintain a full hole as tubing is withdrawn.

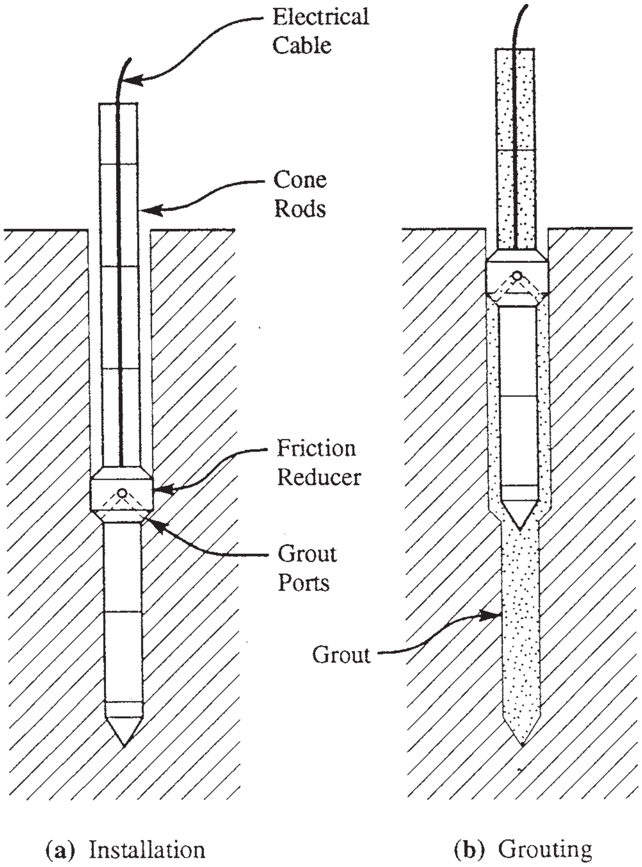
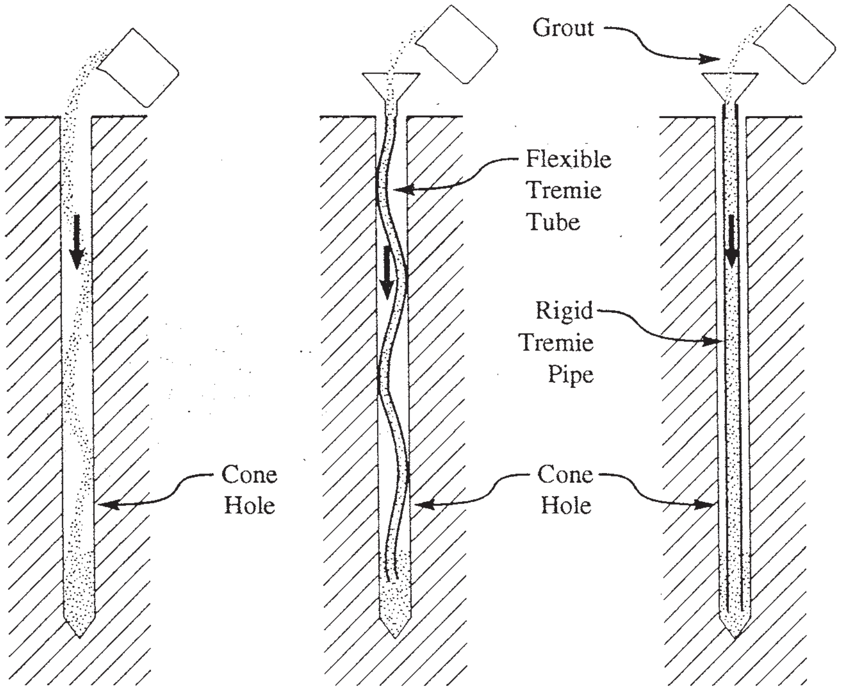


FIG. 8 Grouting Through Ports in Friction Reducers (15)

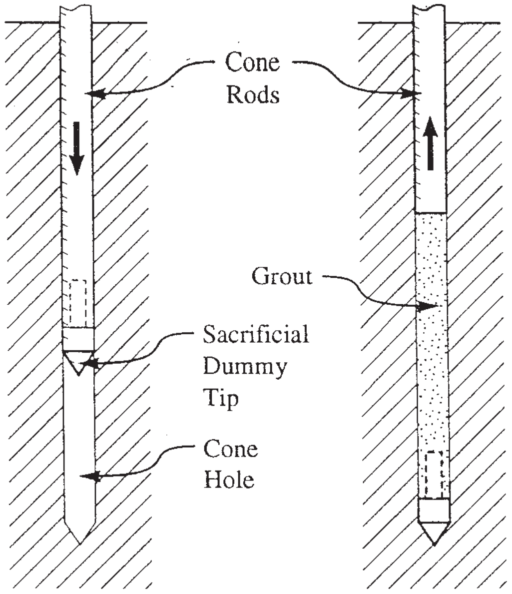
9.3.3.3 Direct-push water sampling holes can be grouted with either cement or bentonite grouts. The grout consistency may have to be wetter than standard mixes used for sealing boreholes (Practice D5092). There has been no research to confirm the best proportions. A typical mixture is 1 sack of Portland cement to 19 to 22 L (5 to 8 gal) of water. Bentonite is added in a small percentage, 2 to 5 %, to reduce shrinkage. Typical bentonite-based mixtures consist of 22.7 kg of dry powered bentonite to 50 to 200 L (24 to 55 gal) of water. It is difficult to mix dry high-yield bentonite without good circulation equipment and time to allow for mixing and hydration. Pre-hydrated bentonite is easier to mix. Some bentonites contain additives that may not be acceptable for grouting use and the user should check with regulators to ensure sealing products are acceptable.

9.3.3.4 Record the volumes of grout injected and compare them with theoretical hole volumes. Often the grouting pressure at depth is unknown due to head losses through pipes, grout tubing, and connections. Pressure grouting equipments should at a minimum include a pressure gage at the surface. To



(a) Surface Injection (b) Flexible Tremie Tube (c) Rigid Tremie Pipe

FIG. 9 Rigid Pipe with Internal Flexible Tremie Tube (15)



(a) Installation (b) Grouting

FIG. 10 Reentry with CPT Rods and Sacrificial Tip (15)

avoid excessive hydraulic fracturing of the units, downhole pressures should be restricted to ½ psi per foot of hole depth. Record any unusual changes in grouting pressures that may suggest the presence of obstructions, caved zones, or occurrence of fracturing.

9.3.3.5 *Dry Granular Bentonite*—The simplest method of sealing a direct-push hole in stable materials is to place dry materials by pouring or placing directly into the open hole after testing. This method is normally only acceptable in stable clay soils above the water table where the hole remains open after testing. This method is not acceptable if there are zones of hole caving or squeezing or there is appreciable presence of groundwater in the hole. The holes can be probed with small-diameter rods to evaluate these conditions. Small diameter granular bentonite is normally used in this application.

10. Field Report and Project Control

10.1 Report information recommended in Guide D5434 and Test Method D6034 and identified as necessary and pertinent to the needs of the exploration program. Information is normally required for the project, exploration type and execution, drilling equipment and methods, subsurface conditions encountered, groundwater conditions, sampling events, and installations. Some of the data collected during these investigations may be reported as data elements for describing groundwater sites (Practice D5254, and Guide D5474).

10.2 Other information besides that mentioned in Guide D5434 and Test Method D6034 should be considered if deemed appropriate and necessary to the needs of the exploration program. Additional information should be considered as follows:

10.2.1 *Drilling Methods*—If rotary drilling methods are used for predrilling holes, report information particular to the drilling methods as outlined in Guides D5781, D5782, D5783, D5784, D5875, D5876, and also see 2.2.

10.2.2 *Percussion Driving and Penetrometer Equipment*—For equipment used for surface direct-push, report the equipment type, make, model, and manufacturers. Report conditions during push of the sampler such as the occurrence of hard layers. Report datums established for monitoring depth of penetration. For combined cone penetrometers and water-sampling devices, report cone-penetration information in accordance with Test Methods D3441 and D5778.

10.3 *Sampling:*

10.3.1 *Equipment*—Report the types of sampling equipment used including materials of manufacture of the components. Provide dimensions of the equipment including outside diameter, screen length and diameter, and friction reducers. Report methods for cleaning of the equipment before and after sampling. Note materials left in the hole or discarded between sampling events. Report any purging or development actions taken before the sampling event.

10.3.2 When water sampling is performed at the base of the borehole, report the condition of the base of the hole before sampling, and report any slough or cuttings present in the recovered sample.

10.3.3 During insertion of the sampler or well point, note any difficulties in advancing the point and retraction of a protective sleeve. Report the retraction distance for protected-screen samplers. If the sampler cannot be advanced more than the minimum required distance of the sampler given in 8.1.4, report the distance driven. Note and record sampling depths including depths to the tip and midpoint of the well screen. Note any unusual occurrence during sampling such as fluid exposure, or evidence of cross-contamination contained in the samples recovered. Note and record the volume of the sample taken and other sample handling and preservation methods taken.

10.3.4 Report any measurements of water samples routinely performed in the field. These measurements may include temperature, PH, and conductivity. Report methods of testing, calibrations, and equipment used.

10.4 *Completion and Installations*—A description of completion materials and methods of placement, approximate volumes placed, intervals of placement, methods of confirming placement, and areas of difficulty or unusual occurrences.

11. Precision and Bias

11.1 The precision and bias of this method have not been established. Due to variability of subsurface conditions, comparative studies of differing approaches to direct-push sampling have not been statistically significant, because site spatial variability exceeded differences between methods **(2)**. Comparisons between water samples obtained from direct-push samples and standard-monitoring wells have been favorable **(11)**. Additional studies are needed and are actively pursued by Subcommittee D18.21.

12. Keywords

12.1 direct-push; groundwater; groundwater sampling; site characterization; well point

REFERENCES

(1) U.S. EPA, Expedited Site Assessment Tools for Underground Storage Tank Sites, A Guide for Regulators, EPA 510 B 97 001, U.S. EPA Office of Underground Storage Tanks, Washington DC, 1997.

(2) Applegate, J. L., and Fitton, D. M., "Rapid Site Assessment Applied to the Florida Department of Environmental Protection's Drycleaning Solvent Cleanup Program," *HazWaste World Superfund XVIII Conference Proceedings*, December, 1997, Washington D.C., pp. 695–703.

(3) Cordry, K., "Ground Water Sampling Without Wells," *Proceedings of the National Water Well Association, Sixth National Symposium on Aquifer Restoration and Ground Water Monitoring*, May 19–22, 1986, Columbus, OH, pp. 262–271.

(4) Zemo, D., et al, "Cone Penetrometer Testing and Discrete-Depth Groundwater Sampling Techniques: A Cost Effective Method of Site Characterization in a Multiple Aquifer Setting," *Proceedings of the National Ground Water Association*, Outdoor Action Conference, May 11–13, 1992, Las Vegas, NV, pp. 299–313.

(5) Smolley, M., and Kappemyer, J., "Cone Penetrometer Tests and Hydropunch™ Sampling—An Alternative to Monitoring Wells for Plume Detection," *Proceedings of the Hazmacon 1989 Conference*, April 18–20, 1989, Santa Clara, CA, pp. 71–80.

(6) Berzins, N. A., "Use of the Cone Penetration Test and BAT Groundwater Monitoring System to Assess Deficiencies in Monitoring Well Data," *Proceedings of the National Ground Water Association Outdoor Action Conference*, 1992, pp. 327–341.

(7) Strutynsky, A., and Bergen, C., "Use of Piezometric Cone Penetration Testing and Penetrometer Groundwater Sampling for Volatile Organic Contaminant Plume Detection," *Proceedings of the National Water Well Association Petroleum Hydrocarbons Conference*, Oct. 31–Nov. 2, 1990, Houston, TX, pp. 71–84.

(8) Woeller, D. J., Weemees, I., Kokan, M., Jolly, G., and Robertson, P. K., "Penetration Testing for Groundwater Contaminants," *ASCE Geotechnical Engineering Congress, Special Technical Publication*, June 1991.

(9) Klopp, R. A., Petsonk, A. M., and Torstensson," In-Situ Penetration Testing for Delineation of Ground Water Contaminant Plumes," *Proceedings of the Third National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods*, May 22–25, 1989, National Ground Water Association, Dublin, OH, pp. 329–343.

(10) Campanella, R. G., Davies, M. P., Boyd, T. J., and Everard, J. L., "In-Situ Teating Methods for Groundwater Contamination Studies," *Developments in Geotechnical Engineering*, Balasubramaniam et al (eds), Balkema, Rotterdam, pp. 371–379.

(11) Zemo, D. A., Pierce, Y. G., Gallinatti, J. D.," Cone Penetrometer Testing and Discrete-Depth Ground Water Sampling Techniques: A Cost Effective Method of Site Characterization in a Multiple Aquifer Setting," *Ground Water Monitoring Review*, Fall 1994, National Ground Water Association, Dublin, OH, pp. 176–182.

(12) Eckard, T. L., Millison, D., Muller, J., Vander Velde, E., and Bowallius, R. U., "Vertical Ground Water Monitoring Using the BAT Groundwater Monitoring System," *Proceedings of the Third National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods*, May 22–25, 1989, National Ground Water Association, Dublin, OH, pp. 313–327.

(13) Church, P. E., and Gvanato, G. E., "Bias in Ground-Water Data Caused by Well Bore Flow in Long Screen Wells," *Ground Water*, March–April 1996, Ground Water Publishing, Columbus, OH, 1996, pp. 262–273.

(14) Driscoll, F. G., *Groundwater and Wells*, Johnson Filtration Systems

Inc., St. Paul, MN, 55112, 1986.

(15) *Geoprobe Screen Point Ground Water Sampler—Standard Operating Procedure, Technical Bulletin No. 94-440*, Geoprobe Systems, April 1994.

(16) Schematic Drawings Courtesy of Diedrich Drilling Inc., LaPorte, IN.

(17) Lutennegger, A. J., and DeGroot, D. J., "Techniques for Sealing Cone Penetrometer Holes," *Canadian Geotechnical Journal*, Vol 32, No. 5, pp. 880–891.

(18) Pitkin, S., Ingleton, R. A., and Cherry, J. A., "Use of a Drive Point Sampling Device for Detailed Characterization of a PCE Plume in a Sand Aquifer at a Dry Cleaning Facility," *Proceedings, Eighth National Outdoor Action Conference and Exposition, National Ground Water Association*, Dublin, Ohio, 1994, pp. 395–412.

(19) Pitkin, S. E., Cherry, J. A., Ingleton, R. A., and Broholm, M., "Field Demonstrations Using the Waterloo Ground Water Profiler," *Ground Water Monitoring and Remediation*, Vol 19, No. 2, 1999, pp. 122–131.

CATEGORY 1: DIRECT PUSH AND DISCRETE GROUNDWATER SAMPLE

Section 1.2

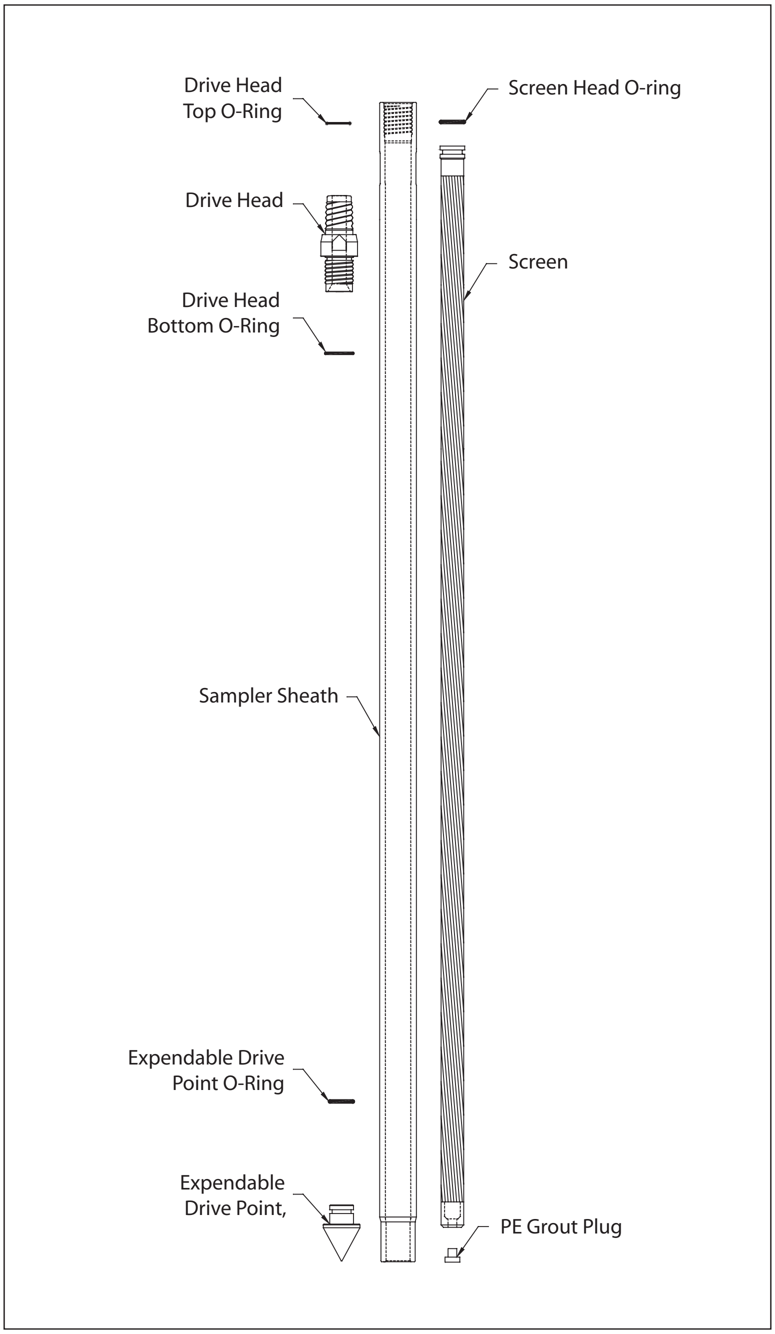
Standard Operating Procedure for Geoprobe Screen Point 16 Groundwater Sampler

GEOPROBE® SCREEN POINT 16 GROUNDWATER SAMPLER

STANDARD OPERATING PROCEDURE

Technical Bulletin No. MK3142

PREPARED: November, 2006



GEOPROBE® SCREEN POINT 16 GROUNDWATER SAMPLER PARTS

Geoprobe® and Geoprobe Systems®, Macro-Core® and Direct Image® are Registered Trademarks of Kejr, Inc., Salina, Kansas

Screen Point 16 Groundwater Sampler is manufactured under U.S. Patent 5,612,498

1.0 OBJECTIVE

The objective of this procedure is to drive a sealed stainless steel or PVC screen to depth, deploy the screen, obtain a representative water sample from the screen interval, and grout the probe hole during abandonment. The Screen Point 16 Groundwater Sampler enables the operator to conduct abandonment grouting that meets American Society for Testing and Materials (ASTM) Method D 5299 requirements for decommissioning wells and borings for environmental activities (ASTM 1993).

2.0 BACKGROUND

2.1 Definitions

Geoprobe®: A brand name of high quality, hydraulically powered machines that utilize both static force and percussion to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling and monitoring, soil conductivity and contaminant logging, grouting, and materials injection.

Screen Point 16 (SP16) Groundwater Sampler: A direct push device consisting of a PVC or stainless steel screen that is driven to depth within a sealed, steel sheath and then deployed for the collection of representative groundwater samples. The assembled SP16 Sampler is approximately 51.5 inches (1308 mm) long with an OD of 1.625 inches (41 mm). Upon deployment, up to 41 inches (1041 mm) of screen can be exposed to the formation. The Screen Point 16 Groundwater Sampler is designed for use with 1.5-inch probe rods and machines equipped with the more powerful GH60 Hydraulic Hammer. Operators with GH40 Series hammers may chose to use this sampler in soils where driving is difficult.

Rod Grip Pull System: An attachment mounted on the hydraulic hammer of a direct push machine which makes it possible to retract the tool string with extension rods or flexible tubing protruding from the top of the probe rods. The Rod Grip Pull System includes a pull block with rod grip jaws that are bolted directly to the machine. A removable handle assembly straddles the tool string while hooking onto the pull block to effectively grip the probe rods as the hammer is raised. A separate handle assembly is required for each probe rod diameter.

2.2 Discussion

In this procedure, the assembled Screen Point 16 Groundwater Sampler (Fig. 2.1A) is threaded onto the leading end of a Geoprobe® probe rod and advanced into the subsurface with a Geoprobe® direct push machine. Additional probe rods are added incrementally and advanced until the desired sampling interval is reached. While the sampler is advanced to depth, O-ring seals at each rod joint, the drive head, and the expendable drive point provide a watertight system. This system eliminates the threat of formation fluids entering the screen before deployment and assures sample integrity.

Once at the desired sampling interval, extension rods are sent downhole until the leading rod contacts the bottom of the sampler screen. The tool string is then retracted approximately 44 inches (1118 mm) while the screen is held in place with the extension rods (Fig. 2.1B). As the tool string is retracted, the expendable point is released from the sampler sheath. The tool string and sheath may be retracted the full length of the screen or as little as a few inches if a small sampling interval is desired.

There are three types of screens that can be used in the Screen Point 16 Groundwater Sampler. Two of the these, a stainless steel screen with a standard slot size of 0.004 inches (0.10 mm) and a PVC screen with a standard slot size of 0.010 inches (0.25 mm), are recovered with the tool string after sampling. The third screen is also manufactured from PVC with a standard slot size of 0.010 inches (0.25 mm), but is designed to be left downhole when sampling is complete. This disposable screen has an exposed screen length of approximately 43 inches (1092 mm). The two screens that are recovered with the sampler both have an exposed screen length of approximately 41 inches (1041 mm).

(continued on following page)

An O-ring on the head of the stainless steel screens maintains a seal at the top of the screen. As a result, any liquid entering the sampler during screen deployment must first pass through the screen. PVC screens do not require an O-ring because the tolerance between the screen head and sampler sheath is near that of the screen slot size.

The screens are constructed such that flexible tubing, a mini-bailer, or a small-diameter bladder pump can be inserted into the screen cavity. This makes direct sampling possible from anywhere within the saturated zone. A removable plug in the lower end of the screens allows the user to grout as the sampler is extracted for further use.

Groundwater samples can be obtained in a number of ways. A common method utilizes polyethylene (TB25L) or Teflon® (TB25T) tubing and a Check Valve Assembly (GW4210). The check valve (with check ball) is attached to one end of the tubing and inserted down the casing until it is immersed in groundwater. Water is pumped through the tubing and to the ground surface by oscillating the tubing up and down.

An alternative means of collecting groundwater samples is to attach a peristaltic or vacuum pump to the tubing. This method is limited in that water can be pumped to the surface from a maximum depth of approximately 26 feet (8 m). Another technique for groundwater sampling is to use a stainless steel Mini-Bailer Assembly (GW41). The mini-bailer is lowered down the inside of the casing below the water level where it fills with water and is then retrieved from the casing.

The latest option for collecting groundwater from the SP16 sampler is to utilize a Geoprobe® MB470 Series Mechanical Bladder Pump (MBP)*. The MBP may be used to meet requirements of the low-flow sampling protocol (Puls and Barcelona 1996, ASTM 2003). Through participation in a U.S. EPA Environmental Technology Verification study, it was confirmed that the MB470 can provide representative samples (EPA 2003).

**The Mechanical Bladder Pump is manufactured under U.S. Patent No. 6,877,965 issued April 12, 2005.*

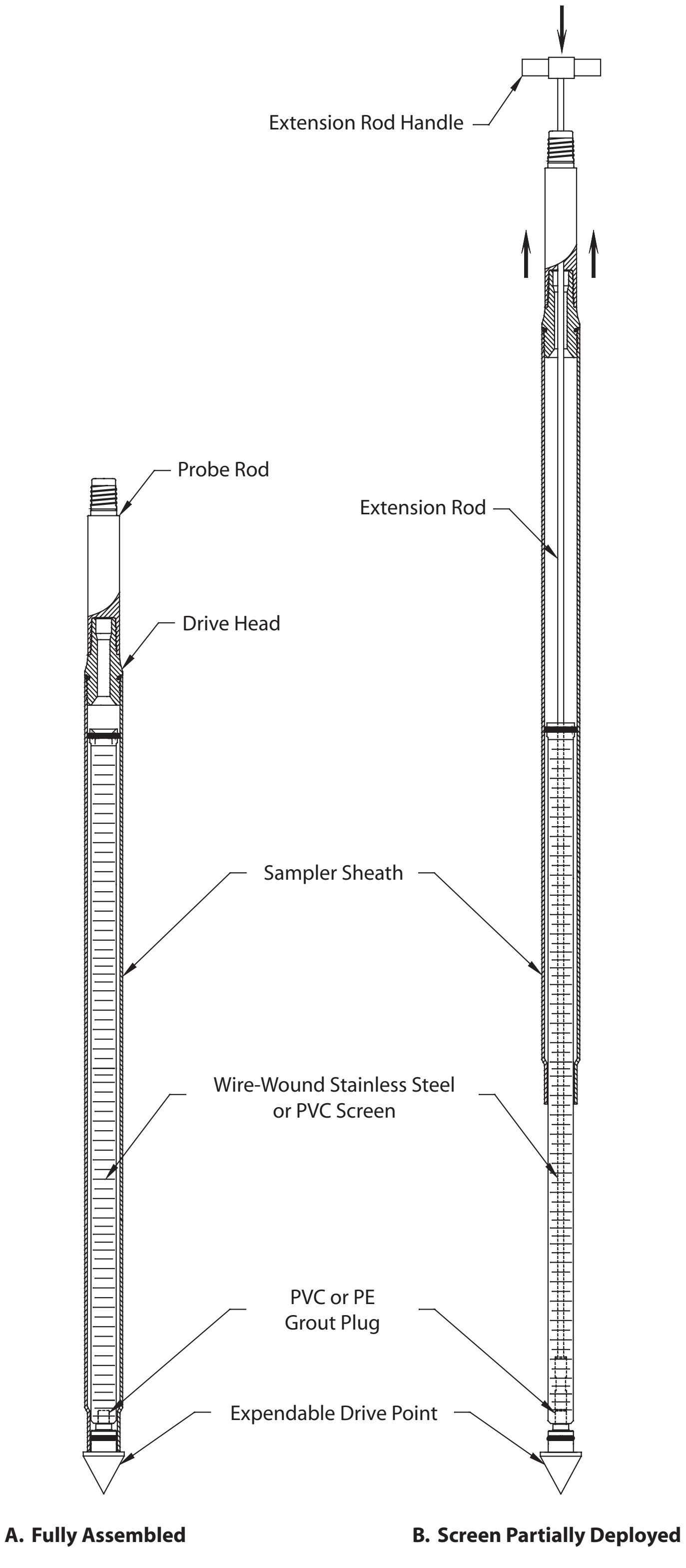


FIGURE 2.1
Screen Point 16 Groundwater Sampler

3.0 TOOLS AND EQUIPMENT

The following tools and equipment can be used to successfully recover representative groundwater samples with the Geoprobe® Screen Point 16 Groundwater Sampler. Refer to Figures 3.1 and 3.2 for identification of the specified parts. Tools are listed below for the most common SP16 / 1.5-inch probe rod configurations. Additional parts for optional rod sizes and accessories are listed in Appendix A.

SP16 Sampler Parts	**Part Number**
SP16 Sampler Sheath	15187
SP16 Drive Head, 0.5-inch bore, 1.5-inch rods*	18307
SP16 O-ring Service Kit, 1.5-inch rods *(includes 4 each of the O-ring packets below)*	15844
O-rings for Top of SP16 Drive Head, 1.5-inch rods only (Pkt. of 25)	*15389*
O-rings for Bottom of SP16 Drive Head (Pkt. of 25)	*13196*
O-rings for GW1520 Screen Head (Pkt. of 25)	*GW1520R*
O-rings for SP16 Expendable Drive Point (Pkt. of 25)	*GW1555R*
Screen, Wire-Wound Stainless Steel, 4-Slot*	GW1520
Grout Plugs, PE (Pkg. of 25)	GW1552K
Expendable Drive Points, steel, 1.625-inch OD (Pkg. of 25)*	GW1555K
Screen Point 16 Groundwater Sampler Kit, 1.5-inch Probe Rods *(includes 1 each of: 15187, 18307, 15844, GW1520, GW1535, GW1540, GW1555K, and GW1552K)*	15770

Probe Rods and Probe Rod Accessories	**Part Number**
Drive Cap, 1.5-inch probe rods, threadless, (for GH60 Hammer)	12787
Pull Cap, 1.5-inch probe rods	15090
Probe Rod, 1.5-inch x 60-inch*	11121

Extension Rods and Extension Rod Accessories	**Part Number**
Screen Push Adapter	GW1535
Grout Plug Push Adapter	GW1540
Extension Rod, 60-inch*	10073
Extension Rod Coupler	AT68
Extension Rod Handle	AT69
Extension Rod Jig	AT690
Extension Rod Quick Link Coupler, pin	AT695
Extension Rod Quick Link Coupler, box	AT696

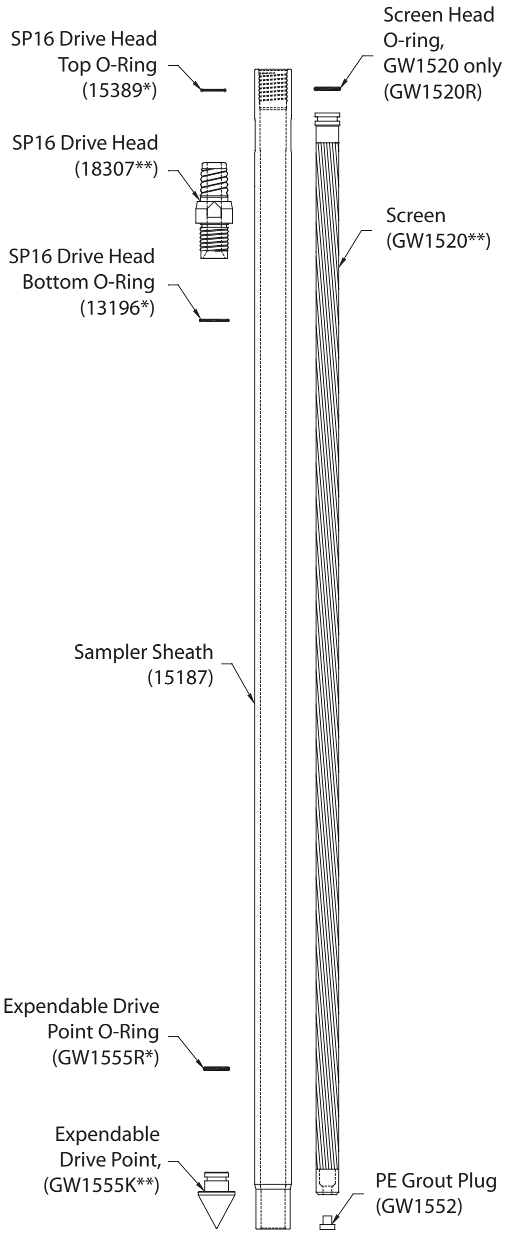
Grout Accessories	**Part Number**
Grout Nozzle, for 0.375-inch OD tubing	GW1545
High-Pressure Nylon Tubing, 0.375-inch OD / 0.25-inch ID, 100-ft. (30 m)	11633
Grout Machine, self-contained*	GS1000
Grout System Accessories Package, 1.5-inch rods	GS1015

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.375-inch OD, 500 ft.*	TB25L
Check Valve Assembly, 0.375-inch OD Tubing*	GW4210
Water Level Meter, 0.438-inch OD Probe, 100 ft. cable*	GW2000
Mechanical Bladder Pump**	MB470
Mini Bailer Assembly, stainless steel	GW41

Additional Tools	**Part Number**
Adjustable Wrench, 6.0-inch	FA200
Adjustable Wrench, 10.0-inch	FA201
Pipe Wrenches	NA

* See Appendix A for additional tooling options.

** Refer to the Standard Operating Procedure (SOP) for the Mechanical Bladder Pump (Technical Bulletin No. MK3013) for additional tooling needs.



* Included in the SP16 O-ring Service Kit (15844)

** Part numbers show most common tool configuration.
See Appendix A for alternative parts.

FIGURE 3.1
SP16 Sampler Parts

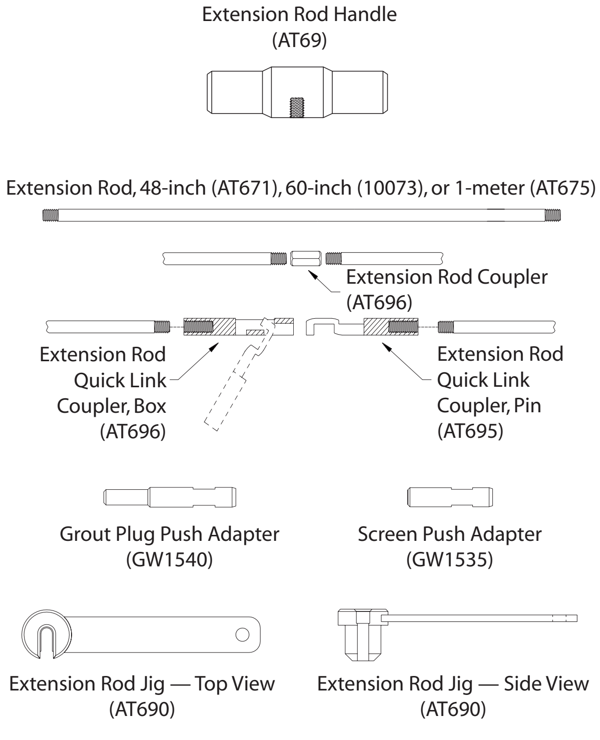


FIGURE 3.2
Geoprobe® Extension Rods and Accessories

4.0 OPERATION

4.1 Basic Operation

The SP16 sampler utilize a stainless steel or PVC screen which is encased in an alloy steel sampler sheath. An expendable drive point is placed in the lower end of the sheath while a drive head is attached to the top. O-rings on the drive head and expendable point provide a watertight sheath which keeps contaminants out of the system as the sampler is driven to depth.

Once the sampling interval is reached, extension rods equipped with a screen push adapter are inserted down the ID of the probe rods. The tool string is then retracted up to 44 inches (1118 mm) while the screen is held in place with the extension rods. The system is now ready for groundwater sampling. When sampling is complete, a removable plug in the bottom of the screen allows for grouting below the sampler as the tool string is retrieved.

4.2 Sampler Options

The Screen Point 15 and Screen Point 16 Groundwater Samplers are nearly identical. Subtle differences in the design of the SP16 sampler make it more durable than the earlier SP15 system. Operators of GH60-equipped machines should always utilize SP16 tooling. Operators of machines equipped with GH40 Series hammers may also choose SP16 tooling when sampling in difficult probing conditions.

A 1.75-inch OD Expendable Drive Point (17066K) and Disposable PVC Screen (16089) provide two useful options for the SP16 sampler. The 1.75-inch drive point may be used when soil conditions make it difficult to remove the sampler after driving to depth. The disposable PVC screen may be left downhole after sampling (when regulations permit) to eliminate the time required for screen decontamination.

4.3 Decontamination

In order to collect representative groundwater samples, all sampler parts must be thoroughly cleaned before and after each use. Scrub all metal parts using a stiff brush and a nonphosphate soap solution. Steam cleaning may be substituted for hand-washing if available. Rinse with distilled water and allow to air-dry before assembly.

4.4 SP16 Sampler Assembly (Figure 4.1)

Part numbers are listed for a standard SP16 sampler using 1.5-inch probe rods. Refer to Page 6 for screen and drive head alternatives.

1. Place an O-ring on a steel expendable drive point (GW1555K). Firmly seat the expendable point in the necked end of a sampler sheath (15187).

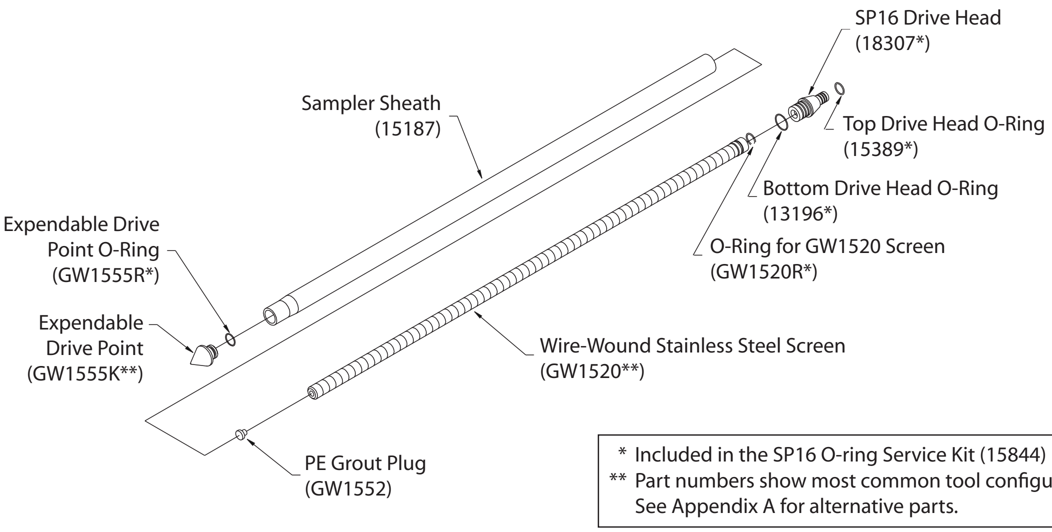
2. Install a PE Grout Plug (GW1552) in the bottom end of a Wire-wound Stainless Steel Screen (GW1520). Place a GW1520R O-ring in the groove on the top end of the screen.

3. Slide the screen inside of the sampler sheath with the grout plug toward the bottom of the sampler. Ensure that the expendable point was not displaced by the screen.

4. Install a bottom O-ring (13196) on a Drive Head (18307 or 15188). Thread the drive head into the sampler sheath using an adjustable wrench if necessary to ensure complete engagement of the threads. Attach a Drive Cap (12787 or 15590) to the top of the drive head.

   NOTE: The 18307 drive head should be used whenever possible as the smaller 0.5-inch ID provides a greater material cross-section for increased durability.

Sampler assembly is complete.



* Included in the SP16 O-ring Service Kit (15844)
** Part numbers show most common tool configuration. See Appendix A for alternative parts.

FIGURE 4.1
Screen Point 16 Groundwater Sampler Assembly

4.5 Advancing the SP16 Sampler

To provide adequate room for screen deployment with the Rod Grip Pull System, the probe derrick should be extended a little over halfway out of the carrier vehicle when positioning for operation.

1. Begin by placing the assembled sampler (Fig. 2.1.A) in the driving position beneath the hydraulic hammer of the direct push machine as shown in Figure 4.2.

2. Advance the sampler with the throttle control at slow speed for the first few feet to ensure that the sampler is aligned properly. Switch to fast speed for the remainder of the probe stroke.

3. Completely raise the hammer assembly. Remove the drive cap and place an O-ring in the top groove of the drive head. Distilled water may be used to lubricate the O-ring if needed.

   Add a probe rod (length to be determined by operator) and reattach the drive cap to the rod string. Drive the sampler the entire length of the new rod with the throttle control at fast speed.

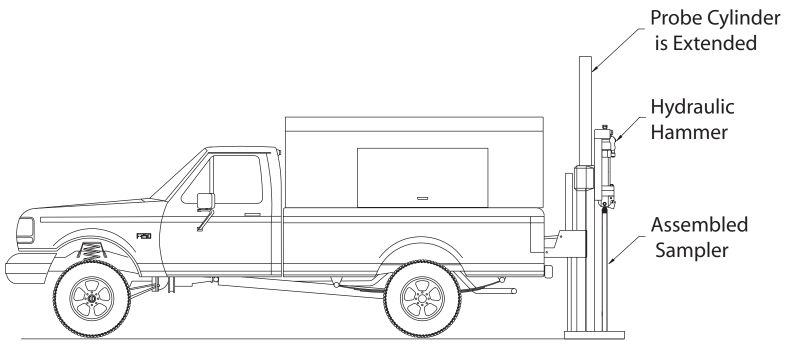


FIGURE 4.2
Screen Point 16 Groundwater Sampler in Driving Position

4. Repeat Step 3 until the desired sampling interval is reached. Approximately 12 inches (305 mm) of the last probe rod must extend above the ground surface to allow attachment of the puller assembly. A 12-inch (305 mm) rod may be added if the tool string is over-driven.

5. Remove the drive cap and retract the probe derrick away from the tool string.

4.6 Screen Deployment

1. Thread a screen push adapter (GW1535) on an extension rod of suitable length (AT671, 10073, or AT675). Attach a threaded coupler (AT68) to the other end of the extension rod. Lower the extension rod inside of the probe rod taking care not to drop it down the tool string. An extension rod jig (AT690) may be used to hold the rods.

2. Add extension rods until the adapter contacts the bottom of the screen. To speed up this step, it is recommended that Extension Rod Quick Links (AT695 and AT696) are used at every other rod joint.

3. Ensure that at least 48 inches (1219 mm) of extension rod protrudes from the probe rod. Thread an extension rod handle (AT69) on the top extension rod.

4. Maneuver the probe assembly into position for pulling.

5. Raise (pull) the tool string while physically holding the screen in place with the extension rods (Fig. 4.3.B). A slight knock with the extension rod string will help to dislodge the expendable point and start the screen moving inside the sheath.

   Raise the hammer and tool string about 44 inches (1118 cm) if using a GW1520 or GW1530 screen. At this point the screen head will contact the necked portion of the sampler sheath (Fig. 4.3.C.) and the extension rods will rise with the probe rods. Use care when deploying a PVC screen so as not to break the screen when it contacts the bottom of the sampler sheath.

   The Disposable Screen (16089) will extend completely out of the sheath if the tool string is raised more than 45 inches (1143 mm). Measure and mark this distance on the top extension rod to avoid losing the screen during deployment.

6. Remove the rod grip handle, lower the hammer assembly, and retract the probe derrick. Remove the top extension rod (with handle) and top probe rod. Finally, extract all extension rods.

7. Groundwater samples can now be collected with a mini-bailer, peristaltic or vacuum pump, tubing bottom check valve assembly, bladder pump, or other acceptable small diameter sampling device.

   When inserting tubing or a bladder pump down the rod string, ensure that it enters the screen interval. The leading end of the tubing or bladder pump will sometimes catch at the screen head giving the illusion that the bottom of the screen has been reached. An up-and-down motion combined with rotation helps move the tubing or bladder pump past the lip and into the screen.

4.7 Abandonment Grouting for GW1520 and GW1530 Screens

The SP16 Sampler can meet ASTM D 5299 requirements for abandoning environmental wells or borings when grouting is conducted properly. A removable grout plug makes it possible to deploy tubing through the bottom of GW1520 and GW1530 screens. A GS500 or GS1000 Grout Machine is then used to pump grout into the open probe hole as the sampler is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations.

1. Maneuver the probe assembly into position for pulling. Attach the rod grip puller to the top probe rod. Raise the tool string approximately 4 to 6 inches (102 to 152 cm) to allow removal of the grout plug.

2. Thread the Grout Plug Push Adapter (GW1540) onto an extension rod. Insert the adapter and extension rod inside the probe rod string. Add extension rods until the adapter contacts the grout plug at the bottom of the screen. Attach the handle to the top extension rod. When the extension rods are slightly raised and lowered, a relatively soft rebound should be felt as the adapter contacts the grout plug. This is especially true when using a PVC screen.

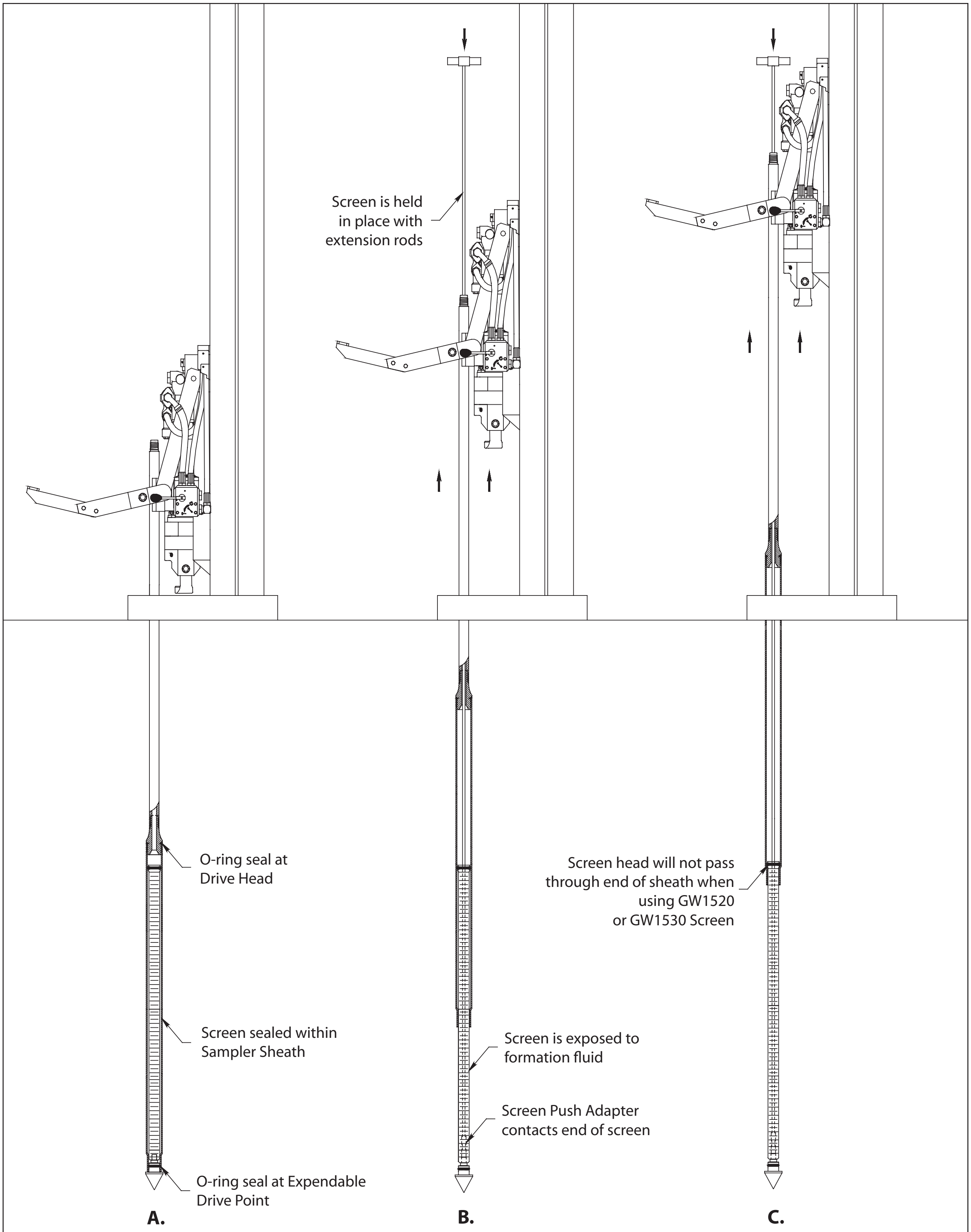


FIGURE 4.3

Screen Deployment for SP16 Sampler

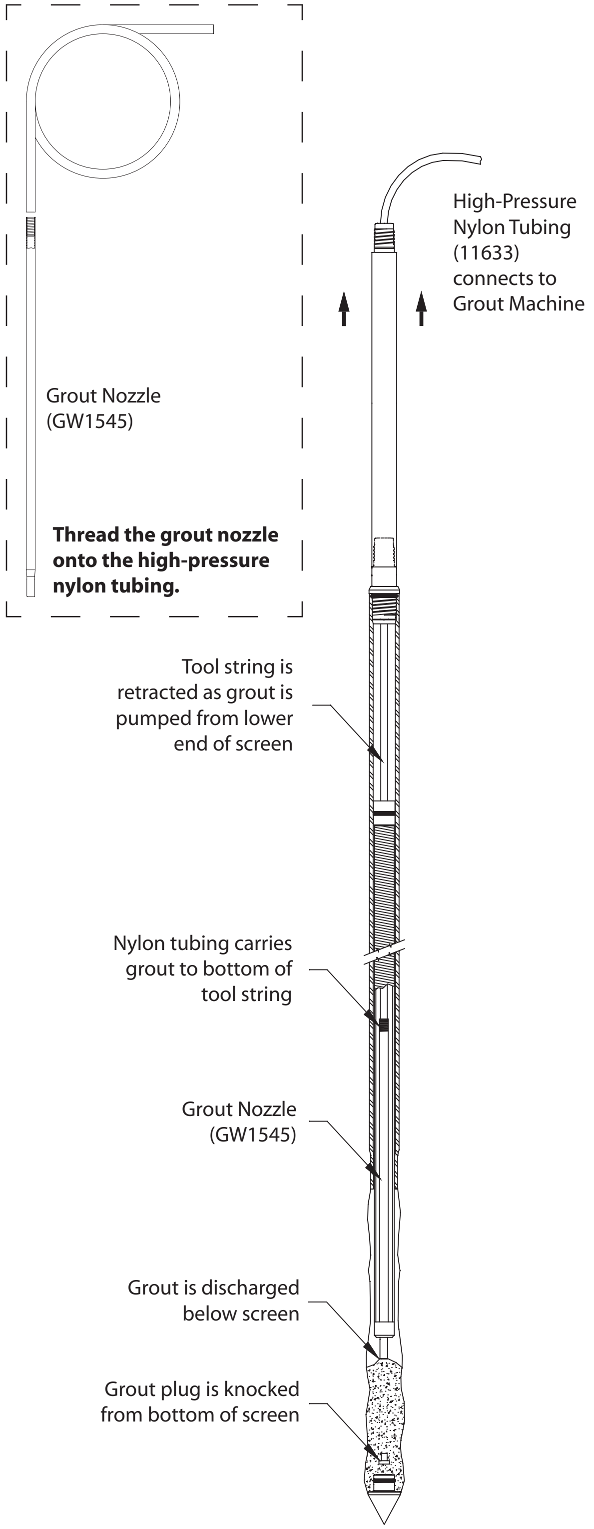


FIGURE 4.4
Grouting the SP16 Sampler With a GW1520 or GW1530 Screen

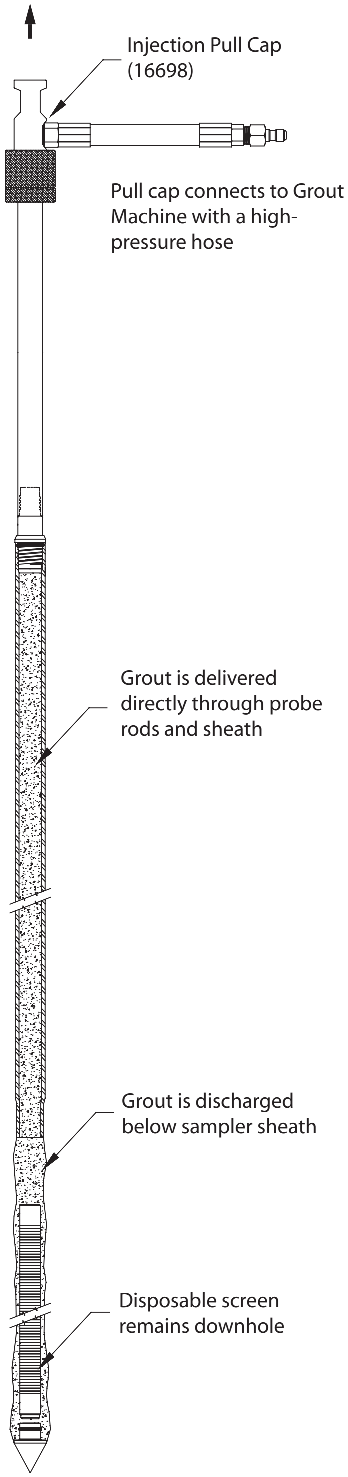


FIGURE 4.5
Grouting the SP16 Sampler With a 16089 Disposable Screen

3. Place a mark on the extension rod even with the top of the probe rod. Apply downward pressure on the extension rods and push the grout plug out of the screen. The mark placed on the extension rod should now be below the top of the probe rod. Remove all extension rods.

   Note: When working with a stainless steel screen, it may be necessary to raise and quickly lower the extension rods to jar the grout plug free. When the plug is successfully removed, a metal-on-metal sensation may be noted as the extension rods are gently "bounced" within the probe rods.

4. A Grout Nozzle (GW1545) is now connected to High-Pressure Nylon Tubing (11633) and inserted down through the probe rods to the bottom of the screen (Fig. 4.4). It may be necessary to pump a small amount of clean water through the tubing during deployment to jet out sediments that settled in the bottom of the screen. Resistance will sometimes be felt as the grout nozzle passes through the drive head. Rotate the tubing while moving it up-and-down to ensure that the nozzle has reached the bottom of the screen and is not hung up on the drive head.

   ***Note:** All probe rods remain strung on the tubing as the tool string is pulled. Provide extra tubing length to allow sufficient room to lay the rods on the ground as they are removed. An additional 20 feet is generally enough.*

5. Operate the grout pump while pulling the first rod with the rod grip pull system. Coordinate pumping and pulling rates so that grout fills the void left by the sampler. After pulling the first rod, release the rod grip handle, fully lower the hammer, and regrip the tool string. Unthread the top probe and slide it over the tubing placing it on the ground near the end of the tubing.

6. Repeat Step 5 until the sampler is retrieved. Do not bend or kink the tubing when pulling and laying out the probe rods. Sharp bends create weak spots in the tubing which may burst when pumping grout. Remember to operate the grout pump only when pulling the rod string. The probe hole is thus filled with grout from the bottom up as the rods are extracted.

7. Promptly clean all probe rods and sampler parts before the grout sets up and clogs the equipment.

4.8 Abandonment Grouting for the 16089 Disposable Screen

ASTM D 5299 requirements can also be met for the SP16 samplers when using the 16089 disposable screen. Because the screen remains downhole after sampling, the operator may choose either to deliver grout to the bottom of the tool string with nylon tubing or pump grout directly through the probe rods using an Injection Pull Cap (16698). A GS500 or GS1000 Grout Machine is needed to pump grout into the open probe hole as the sampler is withdrawn. The following procedure is presented as an example only and should be modified to satisfy local abandonment grouting regulations.

1. Maneuver the probe assembly into position for pulling with the rod grip puller.

2. Thread the screen push adapter onto an extension rod. Insert the adapter and extension rod inside the probe rod string. Add extension rods until the adapter contacts the bottom of the screen. Attach the handle to the top extension rod.

3. The disposable screen must be extended at least 46 inches (1168 mm) to clear the bottom of the sampler sheath. Considering the length of screen deployed in Section 4.7, determine the remaining distance required to fully extend the screen from the sheath. Mark this distance on the top extension rod.

4. Pull the tool string up to the mark on the top extension rod while holding the disposable screen in place.

   The screen is now fully deployed and the sampler is ready for abandonment grouting. Apply grout to the bottom of the tool string during retrieval using either flexible tubing (as described in Section 4.7) or an injection pull cap (Fig. 4.5). This section continues with a description of grouting with a pull cap.

5. Remove the rod grip handle and maneuver the probe assembly directly over the tool string. Thread an Injection Pull Cap (16698) onto the top probe rod and close the hammer pull latch over the top of the pull cap.

6. Connect the pull cap to a Geoprobe® grout machine using a high-pressure grout hose.

7. Operate the pump to fill the entire tool string with grout. When a sufficient volume has been pumped to fill the tool string, begin pulling the rods and sampler while continuing to operate the grout pump. Considering the known pump volume and sampler cross-section, time tooling withdrawal to slightly "overpump" grout into the subsurface. This will ensure that all voids are filled during sampler retrieval.

The grouting process can lubricate the probe hole sufficiently to cause the tool string to slide back downhole when disconnected from the pull cap. Prevent this by withdrawing the tool string with the rod grip puller while maintaining a connection to the grout machine with the pull cap.

4.9 Retrieving the Screen Point 16 Sampler

If grouting is not required, the Screen Point 16 Sampler can be retrieved by pulling the probe rods as with most other Geoprobe® applications. The Rod Grip Pull System should be used for this process as it allows the operator to remove rods without completely releasing the tool string. This avoids having the probe rods fall back downhole when released during the pulling procedure. A standard Pull Cap (15164) may still be used if preferred. Refer to the Owner's Manual for your Geoprobe® direct push machine for specific instructions on pulling the tool string.

5.0 REFERENCES

American Society of Testing and Materials (ASTM), 2003. D6771-02 Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations. ASTM, West Conshocken, PA. (www.astm.org)

American Society of Testing and Materials (ASTM), 1993. ASTM 5299 *Standard Guide for Decommissioning of Groundwater Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.* ASTM West Conshohocken, PA. (www.astm.org)

Geoprobe Systems®, 2003, *Tools Catalog, V.6.*

Geoprobe Systems®, 2006, *Model MB470 Mechanical Bladder Pump Standard Operating Procedure (SOP), Technical Bulletin No. MK3013.*

Puls, Robert W., and Michael J. Barcelona, 1996. Ground Water Issue: Low-Flow (Minimal Drawdown) Ground Water Sampling Procedures. EPA/540/S-95/504. April.

U.S. Environmental Protection Agency (EPA), 2003. Environmental Technology Verification Report: Geoprobe Inc., Mechanical Bladder Pump Model MB470. Office of Research and Development, Washington, D.C. EPA/600R-03/086. August.

Appendix A
ALTERNATIVE PARTS

The following parts are available to meet unique soil conditions. See section 3.0 for a complete listing of the common tool configurations for the Geoprobe® Screen Point 16 Groundwater Sampler.

SP16 Sampler Parts and Accessories	**Part Number**
SP16 Drive Head, 0.625-inch bore, 1.5-inch rods	15188
Expendable Drive Points, aluminum, 1.625-inch OD (Pkg. of 25)	GW1555ALK
Expendable Drive Points, steel, 1.75-inch OD (Pkg. of 25)	17066K
Screen, PVC, 10-Slot	GW1530
Screen, Disposable, PVC, 10-Slot	16089

Groundwater Purging and Sampling Accessories	**Part Number**
Polyethylene Tubing, 0.25-inch OD, 500 ft.	TB17L
Polyethylene Tubing, 0.5-inch OD, 500 ft.	TB37L
Polyethylene Tubing, 0.625-inch OD, 50 ft.	TB50L
Check Valve Assembly, 0.25-inch OD Tubing	GW4240
Check Valve Assembly, 0.5-inch OD Tubing	GW4220
Check Valve Assembly, 0.625-inch OD Tubing	GW4230
Water Level Meter, 0.375-inch OD Probe, 100-ft. cable	GW2001
Water Level Meter, 0.438-inch OD Probe, 200-ft. cable	GW2002
Water Level Meter, 0.375-inch OD Probe, 200-ft. cable	GW2003
Water Level Meter, 0.438-inch OD Probe, 30-m cable	GW2005
Water Level Meter, 0.438-inch OD Probe, 60-m cable	GW2007
Water Level Meter, 0.375-inch OD Probe, 60-m cable	GE2008

Grouting Accessories	**Part Number**
Grout Machine, auxiliary-powered	GS500

Probe Rods, Extension Rods, and Accessories	**Part Number**
Probe Rod, 1.5-inch x 1-meter	17899
Probe Rod, 1.5-inch x 48-inch	13359
Drive Cap, 1.5-inch rods (for GH40 Series Hammer)	15590
Rod Grip Pull Handle, 1.5-inch Probe Rods (for GH40 Series Hammer)	GH1555
Extension Rod, 48-inch	AT671
Extension Rod, 1-meter	AT675

Geoprobe Systems®

A DIVISION OF KEJR, INC.

Corporate Headquarters
601 N. Broadway • Salina, Kansas 67401
1-800-GEOPROBE (1-800-436-7762) • Fax (785) 825-2097
www.geoprobe.com

CATEGORY 2: FIELD DOCUMENTATION, DECONTAMINATION, AND WASTE

Section 2.1

Superfund Program Representative Sampling Guidance Volume 4: Waste

OSWER Directive 9360.4-14
EPA 540/R-95/141
PB96-963207
December 1995

SUPERFUND PROGRAM

REPRESENTATIVE SAMPLING GUIDANCE

VOLUME 4: WASTE

Interim Final

Environmental Response Team

Office of Emergency and Remedial Response
Office of Solid Waste and Emergency Response

U.S. Environmental Protection Agency
Washington, DC 20460

Notice

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication.

The policies and procedures established in this document are intended solely for the guidance of government personnel, for use in the Superfund Program. They are not intended, and cannot be relied upon, to create any rights, substantive or procedural, enforceable by any party in litigation with the United States. The Agency reserves the right to act at variance with these policies and procedures and to change them at any time without public notice.

For more information on Waste Sampling procedures, refer to the *Compendium of ERT Waste Sampling Procedures*, OSWER Directive 9360.4-07, EPA/540/P-91/008. Topics covered in this compendium include: sampling equipment decontamination; drum sampling; tank sampling; chip, wipe, and sweep sampling; and waste pile sampling.

Please note that the procedures in this document should only be used by individuals properly trained and certified under a 40-hour hazardous waste site training course that meets the requirements set forth in 29 CFR 1910.120(e)(3). It should not be used to replace or supersede any information obtained in a 40-hour hazardous waste site training course.

Questions, comments, and recommendations are welcomed regarding the *Superfund Program Representative Sampling Guidance, Volume 4 -- Waste*. Send remarks to:

Mr. William A. Coakley
Chairman, Representative Sampling Committee
U.S. EPA - ERT
Raritan Depot - Building 18, MS-101
2890 Woodbridge Avenue
Edison, NJ 08837-3679

Disclaimer

The following trade names are mentioned in this document:

Dräger is a trademark of National Draeger, Inc. of Pittsburgh, Pennsylvania

Sensidyne is a trademark of Sensidyne, Inc.

MSA is a trademark of Mine Safety Appliance Company of Pittsburgh, Pennsylvania

Teflon® and Tyvek® are registered trademarks of E.I. DuPont de Nemours and Company of Wilmington, Delaware

Contents

List of Figures

List of Tables

1.0 INTRODUCTION

1.1 OBJECTIVE AND SCOPE

This is the fourth volume in a series of guidance documents that assist Superfund Program Site Managers, On-Scene Coordinators (OSCs), Remedial Project Managers (RPMs), and other field staff in obtaining representative samples at Superfund sites. The objective of representative sampling is to ensure that a sample or a group of samples accurately characterizes site conditions. The representative sampling principles discussed in this document are applicable throughout the Superfund Program. The following chapters will help field personnel to assess available information, select an appropriate sampling approach, select and utilize field analytical screening methods and sampling equipment, incorporate suitable types and numbers of quality assurance/quality control (QA/QC) samples, and interpret and present the site analytical data.

As the Superfund Program has developed, the emphasis of this response action has expanded beyond addressing emergency response and short-term cleanups. Each planned response action must consider a variety of sampling objectives, including identifying threat, delineating sources of contamination, and confirming the achievement of clean-up standards. Because many important and potentially costly decisions are based on the sampling data, Site Managers and other field personnel must characterize site conditions accurately. To that end, this document emphasizes the use of cost-effective field analytical screening techniques to characterize the site and aid in the selection of sampling locations.

1.2 CHARACTERISTICS OF WASTE

Waste, in general terms, can include solid, liquid, and sludge material typically generated as a by-product of an industrial process. Assume that containerized wastes comprise high concentrations of hazardous substances, unless clearly indicated otherwise through previous sample analysis or other reliable documentation. Waste samples are often of high concentration and phased (e.g., light liquid, dense liquid, and sludge), an important point to consider when developing a sampling strategy. This document specifically addresses the sampling of wastes typically found in drums, tanks, lab packs, transformers, impoundments, waste piles, and on surfaces.

The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) definition for a hazardous substance includes "...any substance designated pursuant to section 311(b)(2)(A) of the Clean Water Act; any element, compound, mixture, solution, or substance designated pursuant to Section 3001 of the Solid Waste Disposal Act (but not including any waste the regulation of which under the Solid Waste Disposal Act has been suspended by an Act of Congress); any hazardous air pollutant listed under Section 112 of the Clean Air Act; and any imminently hazardous chemical substance or mixture with respect to which the EPA Administrator has taken action pursuant to Section 7 of the Toxic Substances Control Act. The term does not include petroleum including crude oil or any fraction thereof which is not otherwise specifically listed or designated as a hazardous substance..., and the term does not include natural gas, natural gas liquids, liquified natural gas, or synthetic gas usable for fuel (or mixtures of natural gas and such synthetic gas)." Pursuant to 40 CFR 261, Subpart C, a waste is considered hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity; or if it is a listed hazardous waste under 40 CFR 261.30, Subpart D. Asbestos and "mixed" waste (having radioactive and hazardous waste components), while included in this definition, require specialized sampling methods and techniques and will not be addressed in this document.

1.3 REPRESENTATIVE SAMPLING OBJECTIVES

Representative sampling applies to all phases of a Superfund response action. Representative sampling objectives for waste include:

- Identify the waste, including composition and characteristics, and determine if it is hazardous.

- Determine if there is an imminent or substantial threat to public health or welfare or the environment.

- Determine the need for long-term action.

- Develop containment and control strategies.

- Evaluate appropriate disposal/treatment options.

- Verify treatment goals or clean-up levels.

Determine Hazard and Identify Waste

One of the first objectives during a response action at a site is to determine the presence, identity, and potential threat of any hazardous materials. Use field screening techniques (discussed in Chapter 3) for rapid detection of wastes. Upon confirming the presence of hazardous materials, sample and/or continue screening to identify their compositions and determine their concentrations.

In addition to characterizing the waste sufficiently, conduct compatibility tests to help classify waste by composition and other physical characteristics into compatible waste streams (e.g., acid, base, or oxidizer). This will ensure safer handling, staging, bulking, storage, and transportation of wastes both on and off site.

Establish Threat

Establishing threat to the public or environment is a primary objective during a response action. The data obtained from characterizing the waste will help the Site Manager to determine whether an imminent or substantial threat exists and whether a removal action or other response action is necessary. The type and degree of threat determines the rate at which a response action is taken.

Determine Need for Long-Term Action

Site conditions may establish a long-term threat that is not imminent or substantial. Characterization of the waste can assist the Site Manager in setting a priority for long-term remediation evaluation and response. Waste characterization data are required to evaluate the site under the Hazard Ranking System and to identify sites eligible for inclusion on the National Priorities List (NPL). The NPL is the ranking list of those sites at highest national priority for long-term evaluation and remediation.

Develop Waste Containment and Control Strategies

Once the chemical constituents and threat have been established, many strategies for waste containment and control are available to the Site Manager. Analytical data indicating the presence of chemical hazards are not in themselves sufficient to select a containment or control strategy. Site reconnaissance and historical site research provide information on site conditions and the physical state of the waste sources; waste containment and control strategies are largely determined by this information. For example, site security measures (such as erecting a fence) may be sufficient to stabilize a site containing intact drums of solvents, and overpacking may be sufficient to contain a corroded drum of organophosphate pesticides. Unstable or explosive wastes, such as picric acid, may require immediate removal by demolition experts.

Identify Available Treatment/Disposal Options

The site contaminants should be identified, quantified, and compared to selected action levels. Where regulatory action levels do not exist, site-specific clean-up levels are determined by the EPA Region (often in consultation with the Agency for Toxic Substances and Disease Registry (ATSDR)). If action levels are exceeded, a series of chemical and physical tests may be required to evaluate possible treatment and/or disposal options. Each treatment or disposal method has a corresponding set of waste parameters that must be evaluated, e.g., ash content, British thermal unit (BTU) value, total metals concentration, total organic halides, cyanide, total chlorine and NOx are minimum requirements for incineration. It is important to test for treatment/disposal parameters as early as possible during the site assessment and characterization procedure. Relatively inexpensive tests such as total organic carbon (TOC), BTU, and pH should be considered early in the response action in order to contribute to later treatability studies. The test results will ultimately help to determine the most appropriate treatment or disposal option for meeting regulatory requirements.

Verify Treatment Goals or Clean-up Levels

After treatment or disposal, representative sampling results should either confirm that the response actions have met the site-specific treatment goals or clean-up levels, or indicate that further treatment or removal is necessary. Refer to the *Representative Sampling Guidance, Volume 1 -- Soil,* OSWER Directive 9360.4-10, for guidelines on soil sample collection and preparation for confirming cleanup.

Sampling to verify cleanup requires careful coordination with demobilization activities. After treatment of one area on a site, verification sampling can begin in that area by using field screening and on-site analysis. Meanwhile, other areas can be treated. Lab confirmation of the screening performed in the treated areas can help ensure accuracy of screening for subsequent areas to meet QA objectives (as discussed in Section 5.2).

1.4 CONCEPTUAL SITE MODEL

A conceptual site model is a useful tool for selecting sampling locations. It helps ensure that sources, pathways, and receptors throughout the site have been considered before sampling locations are chosen. The conceptual model assists the site manager in evaluating the interaction of different site features. Risk assessors use conceptual models to help plan for risk assessment activities. Frequently, a conceptual model is created as a site map (see Figure 1) or it may be developed as a flow diagram which describes potential migration of contaminants to site receptors (see Appendix A).

A conceptual model follows contaminants from their sources, to pathways (e.g., air, surface water), and eventually to the assessment endpoints. Consider the following when creating a conceptual model:

- The state(s) of each contaminant and its potential mobility
- Site topographical features
- Meteorological conditions (e.g., wind direction/speed, average precipitation, temperature, humidity)
- Human/wildlife activities on or near the site

The conceptual site model on the next page is an example created for this document. The model assists in identifying the following site characteristics:

Potential Sources:

Site (waste pile, lagoon); drum dump; sewage plant discharge

Potential Migration Pathways:

Soil -- Leachate from the waste pile or drum dump; soil in direct contact with solids in the waste pile or drum dump

Surface Water -- Liquid waste from the lagoon or sewage plant discharge (into the lake)

Sediments -- Liquid waste from the lagoon or sewage plant discharge (into the lake)

Air -- Release of vapors/particulates from the waste pile, drum dump or lagoon

Potential Exposure Routes:

Ingestion -- Particles from the waste pile or drum dump; liquid from the lagoon or lake (from sewage plant discharge)

Inhalation -- Vapors from the waste pile, drum dump, lagoon, or lake (sewage plant discharge)

Absorption/direct contact -- Contact with the waste pile, drum dump, lagoon, or lake (sewage plant discharge)

Potential Receptors of Concern (and associated potential exposure sources):

Human Population

Residents/Trespassers:

Soil -- Leachate from the drum dump; direct contact with soil from solids in the drum dump

Surface water -- Liquid waste from the lagoon into the river or sewage plant discharge into the lake

Air -- Vapors/particulates from the waste pile, drum dump, lagoon, or lake (sewage plant discharge)

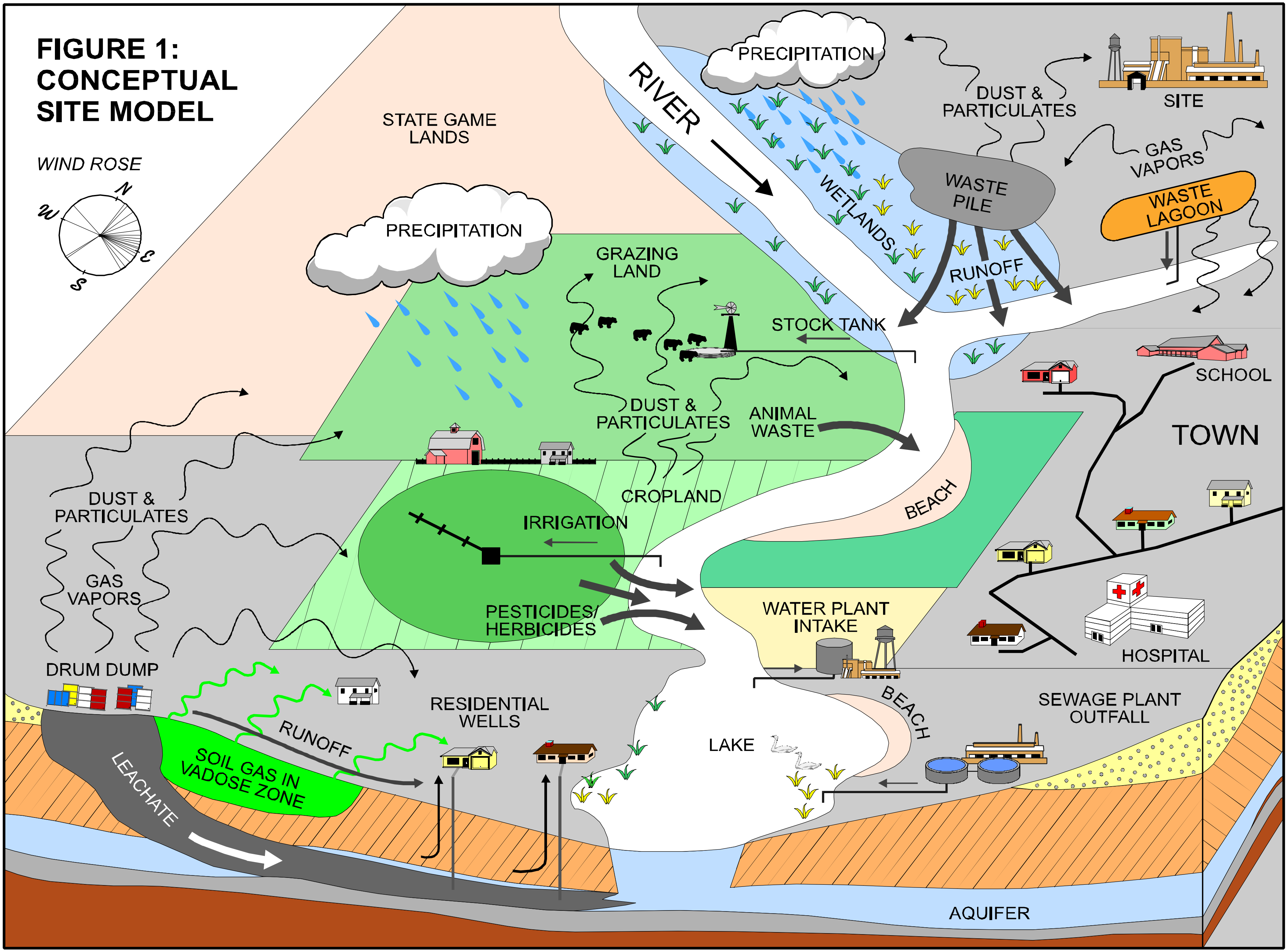


FIGURE 1: CONCEPTUAL SITE MODEL

Workers/Trespassers:

Soil -- Leachate from the waste pile; direct contact with soil from solids in the waste pile

Surface water -- Liquid waste in the lagoon or associated with the sewage plant discharge

Air -- Vapors/particulates from the waste pile, drum dump, lagoon, or sewage plant discharge

Biota

Threatened or endangered species or human food chain organisms known to frequent areas near the waste pile, drum dump, lagoon, or lake (sewage plant discharge)

Preliminary site information may provide the identification of the contaminant of concern and the level of the contamination. A sampling plan should be developed based upon the selected receptors of concern and the suspected sources and pathways. The model may assist in the selection of on-site and off-site sampling locations.

1.5 EXAMPLE SITE

An example site presented at the end of each chapter illustrates the development of a representative waste sampling plan that meets Superfund Program objectives for an early action.

2.0 SAMPLING DESIGN

2.1 INTRODUCTION

There is no universal sampling method for characterizing wastes because site characteristics vary widely. The sampling methods and equipment must be suited to the specific sampling situation. A properly developed waste sampling design defines the sampling purpose, protects site worker health and safety, effectively utilizes resources, and minimizes errors. The sampling design will vary according to the type of waste sampled (including type of containers or sources), and the characteristics of the site. When developing a sampling design, consider: prior actions at the site (e.g., sampling practices, compliance inspections); properties and characteristics of the wastes sampled; site waste sources (e.g., impoundments, waste piles, drums); topographic, geologic, hydrologic, and meteorologic conditions of the site; and flora, fauna, and human populations in the area.

Waste material may be liquid, solid, or sludge, and may be contained in drums, tanks, waste piles, surface impoundments, on surfaces (e.g., building structures, floors, equipment), in lab packs, or other sources. Sampling each waste stream may require a variety of sampling techniques, equipment, sample packaging, and sample analyses.

2.2 SAMPLING PLAN

Many site-specific factors are important in the development of a good sampling plan, including: data use and quality assurance objectives; sampling equipment; sampling design; standard operating procedures (SOPs); field analytical screening; analytical method selection; decontamination; sample handling and shipment; and data validation.

The U.S. EPA *Quality Assurance Sampling Plan for Environmental Response* (QASPER) was designed to develop sampling plans for response actions. QASPER is menu-driven software which prompts the user to input background information and to select prescribed parameters for development of a site-specific sampling plan. It also gives the user access to any previously developed site-specific sampling plans.

The following procedures are recommended for developing a thorough waste sampling plan. Many steps can be performed concurrently, and the sequence is flexible.

- Review the history of the site, including regulatory and reported spill history; note current and former locations of buildings, tanks, and process, storage, and disposal areas.
- Perform a site reconnaissance; categorize physical/chemical properties and hazardous characteristics of materials involved.
- Identify topographic, geologic and hydrologic characteristics of the site including surface water, groundwater, and soil characteristics, as well as potential migration pathways and receptors.
- Determine geographic and demographic information, including population size and its proximity to the site (e.g., public health threats, source of drinking water); identify threatened environments (e.g., potentially contaminated wetlands or other sensitive ecosystems).
- Select sampling strategies, considering field analytical screening and statistical applications, when appropriate.
- Determine data quality and quality assurance objectives for field analytical screening, sampling, and analysis. As the extent of contamination becomes quantified, the sampling plan can be modified to better assess sampling objectives throughout the action.

It is recognized that many of these steps (described in detail below) would not be applicable during a classic emergency response because of the lack of advance notice. Emergency response sampling nevertheless requires good documentation of sampling events.

2.2.1 Historical Data Review

The first step in developing a sampling plan is a review of historical site data, examining past and present site operations and disposal practices to provide clues on possible site contamination. Available sources of information include: federal, state and local agencies and officials; federal, state, and local agency files (e.g., site inspection reports and legal actions); deed or title records; current and former facility employees; potentially responsible parties (PRPs); local residents; and facility records or files.

A review of previous sampling information should include sampling locations, matrices, methods of collection and analysis, and relevant contaminant concentrations. Assess the reliability and usefulness of existing analytical data, including those which are not substantiated by documentation or QA/QC controls, but which may still illustrate general site trends.

Collect information that describes specific chemical processes, raw materials used, products and wastes, and waste storage and disposal practices. Review any available site maps, facility blueprints, and historical aerial photographs detailing past and present storage, process, and waste disposal locations. County property and tax records and U.S. Geological Survey (USGS) topographic maps are useful sources of information on the site and its surroundings.

2.2.2 Site Reconnaissance

A site reconnaissance can be conducted at an earlier date or immediately prior to sampling activities. It allows field personnel to assess site conditions, evaluate areas of potential contamination, evaluate potential hazards associated with sampling, and finalize a sampling plan. Site reconnaissance activities include: observing and photographing the site; noting site access routes and potential evacuation routes; noting potential safety hazards; recording label information from drums, tanks, or other containers; mapping process and waste disposal areas such as landfills, impoundments, and effluent pipes; making an inventory of the wastes on site; mapping potential contaminant migration routes such as drainage, streams, and irrigation ditches; noting the condition of animals and/or vegetation; and noting topographic and/or structural features. Field personnel should use appropriate personal protective equipment (PPE) when engaged in any site activities.

2.2.3 Physiographic and Other Factors

Other procedures, such as determining data quality and QA/QC objectives, utilizing field analytical screening techniques, identifying topographic, geologic and hydrologic characteristics, and determining geographic and demographic information are important steps of an overall sampling plan. Field analytical screening techniques and equipment are discussed in Chapter 3; QA objectives are discussed in Chapter 5. Since this document specifically pertains to waste sampling, the remaining procedures listed above will not be addressed in detail here. (Please refer to the *Representative Sampling Guidance, Volume 1 -- Soil*, OSWER Directive 9360.4-10.) The U.S. EPA is currently developing an ecological sampling guidance document that will contain a detailed checklist for collecting ecological data.

2.3 WASTE SAMPLE TYPES

Design sampling procedures to match sampling objectives. The type of sample collected may depend on suspected waste types and characteristics; size and accessibility of waste containers, impoundments and other media; target analytes; and health and safety requirements.

The following section describes and gives examples of the two types of waste samples.

2.3.1 Grab Sample

A *grab* sample is a discrete aliquot collected from one specific sampling location at a specific point in time, and may be considered representative of a homogeneous and stable waste. When obtaining grab samples from containers or from an impoundment having stratified layers, sample each phase or stratum separately; the separate aliquots are representative of their respective stratum. When sampling stratified sources, determine as many properties of the wastes as possible through historical data and site reconnaissance prior to sampling, and use caution because the individual phase components may be more concentrated than the original waste material.

2.3.2 Composite Sample

A *composite* sample is a non-discrete sample composed of two or more equal aliquots collected at various sampling points or times. There are four types of composite samples: *areal, vertical, flow proportional,* and *time.* An *areal composite* is comprised of individual aliquots collected over a defined area (e.g., surface of a waste pile). It is made up of aliquots of equal volume, each collected in an identical manner at the same horizon (depth). A *vertical composite* is composed of individual aliquots collected at different depths but along the same vertical line (e.g., borehole). It is made up of aliquots of equal volume which are collected in an identical manner. A *flow proportional composite* is a sample collected proportional to the flow rate during the compositing period by either a time-varying/constant volume or time-constant/varying volume method. A *time composite* is composed of a varying number of discrete, equal-volume aliquots collected at equal time intervals during the compositing period. (Both flow and time composite samples are appropriate for sampling wastewater or streams.)

By design, composite samples reflect an "average" concentration within the composite area, flow, or interval. Compositing is appropriate when determining the general characteristics or the representativeness of certain sources (e.g., a waste pile or impoundment) when considering methods of treatment or disposal. When compositing samples from a waste stream, note that resulting concentrations are representative of the waste stream's average concentration, but not of discrete areas within the waste stream.

Composite sampling should be performed only on like waste streams. Do not composite dissimilar waste streams or waste sources (e.g., drums with unknown contents or dissimilar materials) because of health and safety risks associated with possible reactions; in addition, the resulting sample will not define or represent the origin of the mixed contaminants. Composite aliquots from tanks, drums, or other containers only after adequate hazardous characterization screening to prevent mixing of incompatible wastes.

A result of sample compositing is the dilution of high concentration aliquots. To compensate for dilution, reduce the applicable detection limits accordingly. If the composite value is to be compared to a selected action level, then the action level must be divided by the number of aliquots that make up the composite in order to determine the appropriate detection limit. For example, if the action level for a particular substance is 40 ppb, a detection limit of 10 ppb should be used when analyzing a 4-aliquot composite.

When compositing waste, four aliquots per sample are recommended because two ounces of each aliquot can be added to an 8-ounce (or larger) jar. Individual aliquots in storage from any "hit" composites can be analyzed later to pinpoint contamination.

2.4 WASTE TYPES

The types of wastes encountered at a site greatly influence the development of the site sampling plan. The number of grab and composite samples, type of screening/sampling equipment used, and analytical methods all depend on the types of wastes present at the site. Waste solids can vary from granular or powdered materials to contaminated structural surfaces or demolition debris. Waste liquids can include solvents, acids, bases, process solutions, and lubricants, among others. Waste sludges have characteristics of both solids and liquids.

Each type of waste may be highly concentrated, consisting of virtually pure industrial products, raw or spent materials, chemicals, or process by-products. Methods for sampling and analyzing vary by waste type, and the sampling plan should specify appropriate sample collection and analysis methods.

Waste samples are often complex mixtures and may be difficult to analyze in the laboratory. Provide the analytical laboratory with as much information as possible to help minimize delays in analysis. The laboratory will find the following information helpful in expediting the analysis of waste samples:

- Whether the sample is pure waste or an environmental sample (e.g., oil as opposed to oily water).

- Viscosity, particle size, or an accurate description of the waste characteristics.

- Qualitative estimate of concentration (i.e., low, medium, high).

- Presence of extreme pH levels (i.e., less than 2 or greater than 12); some analytical methods will not yield successful results on such samples; it may be necessary to consult with a chemist to change the method.

- Presence of chlorinated dioxins, even if the samples are being analyzed for another parameter (e.g., metals). The Occupational Safety and Health Administration (OSHA) specifies special handling facilities for samples contaminated with dioxin; many laboratories are not set up to handle these samples.

- Presence of high concentrations of organic substances, particularly aromatics, in samples to be analyzed for metals (some methods for metals analysis are not compatible with high concentrations of organic materials).

Inform the laboratory in advance about important sample constituents of interest and QA/QC criteria. Waste samples typically must be diluted before analysis, which may prevent detection of these constituents. Also consult with the laboratory on how to prepare subaliquots of non-typical samples.

2.5 WASTE CHARACTERISTICS

Waste characteristics, including homogeneity, physical state, chemical stability, particle size (solids), and viscosity (liquids) are other factors that influence the number and types of samples collected.

2.5.1 Homogeneity

Wastes may be homogeneous or heterogeneous. The solubility, specific gravity, and mechanical mixing ability of the waste can affect its degree of homogeneity. A single grab sample per waste stream may be appropriate for a homogeneous material; however, heterogeneous and unclassified wastes often require more extensive sampling and analysis to ensure that the various phases and concentrations of the waste are represented in the samples. The sampling strategy should reflect the homogeneity, random heterogeneity, or stratification of the waste over space or time.

2.5.2 Physical State

The physical state of waste (i.e., solid, liquid, gas, or multiphasic) will influence the selection of sampling devices and many other aspects of the sampling effort. Variances in each physical state can also affect sampling. For example, free-flowing liquid would require a different sampling approach than a viscous liquid.

Sample containers with wide mouths are best for solid samples, sludges, and liquids with substantial amounts of suspended matter. Bottles with air-tight closures are needed for gas samples or gases adsorbed onto solids or dissolved in liquids.

The sampling strategy will vary if the physical state of the waste is subject to stratification (for example, liquid wastes with differing densities or viscosities, or those with suspended solids), homogenization, or random heterogeneity.

2.5.3 Chemical Stability

Waste materials can differ considerably in their inherent chemical stability. Exposure to the elements (e.g., sunlight, air, rain) and leaching may cause chemical degradation or reaction, thereby creating new compounds. Heterogenous materials may undergo physical separation, resulting in pockets or layers of different compounds. Sampling methods and shipping practices will vary according to the toxicity, ignitability, corrosivity, and reactivity of the waste.

2.5.4 Particle Size (solids)

Waste solids are often made up of materials with different particle sizes. This variation can influence analytical results by introducing either a negative or positive bias. For example, if large pieces of waste material (e.g., slag) are not collected and included with a sample, a negative bias of contaminants may result (analytical results may be lower than what is actually representative). Small particle size can also bias a sample. Some pollutants adsorb more readily onto small particles, so a small-fraction sample may result in a positive bias (analytical results may be higher than what is representative). If it is necessary to sample material that has unusual particle size characteristics, identify an approximate size distribution and consult the laboratory in advance to determine a method for representative analysis of the irregular materials. Sieving of waste is not usually recommended. If grinding or pulverizing large pieces is desired, make special arrangements with the laboratory.

2.5.5 Viscosity (liquids)

Viscosity is the internal friction of a fluid that produces a resistance to flow. The viscosity of waste liquids often greatly affects the effort required for sample collection and may indirectly determine the volume of sample required. Because viscosity can affect the representativeness of the sample, and can itself be a physical limitation for sampling, a sampling technique suited to the viscosity of the material must be selected. Very viscous materials (greater than 100,000 centipoise (cps)) must be scooped, while low viscosity materials may be aspirated, encapsulated, or poured. To collect a representative sample for viscosity testing, it is important to limit handling and contact time. The sample must be allowed to return to equilibrium before measurement. Without a viscometer, viscosity may be roughly determined by comparison to water (low viscosity), syrup (medium viscosity), and mayonnaise or taffy (high viscosity), as well as to other materials of known viscosity.

Several sampling devices have been designed to sample waste liquids within a specific viscosity range. Weighted bottle samplers, PACS grab samplers, and composite liquid waste samplers (COLIWASAs) are suited for sampling less viscous liquids and become difficult to use in very viscous liquids. The glass thief and bacon bomb sampler are suitable for sampling moderately to highly viscous materials. See Section 3.2 for a discussion of sampling equipment.

2.6 WASTE SOURCES

There are a variety of potential waste sources commonly found at waste sites. The type of waste source affects many aspects of the sampling design, such as sampling approach (e.g., judgmental or random), sampling equipment, and types/numbers of samples (including QA/QC samples). The type of source will also affect many logistical considerations, such as cost, level of effort, and duration of a response action. This section introduces the three categories of waste sources: containerized waste, uncontainerized waste, and surfaces and debris.

2.6.1 Containerized Waste

Containerized waste consists of solids, liquids, or sludges that are found in drums, bulk storage tanks, transformers, and lab packs. Evaluate container label information before making sampling decisions. It may be possible to identify numerous containers of similar material. Wherever possible, use screening techniques to substantiate label information. Screening results should be confirmed with laboratory test results prior to making any treatment or disposal decisions (affirming that screening was effective). Specialized equipment (e.g., forklift, grapple, manlift) may be needed to access drums and tanks safely.

The sampling objective determines which and how many containers need to be sampled. For example, if the objective is to establish threat, it may be most important to sample a few containers having visible leaks or spills. If the objective is to estimate the disposal cost, it may be appropriate to sample each of the largest volume containers to identify the predominant waste streams.

Drums can be of different volumes (typically from 30 to 90 gallons), varied construction (e.g., top bung, side bung, removable top, lined), and be made of a variety of materials (e.g., steel, polyethylene, fiber, combinations). Drums located at a waste site often vary in condition, sometimes showing deterioration, bulging, and/or damage. These physical criteria can be useful in making assumptions about a drum's contents. For example, strong acids, caustics, or other corrosives are typically stored in 30- to 55-gallon polyethylene or polyethylene-lined steel drums with top bung holes. While this is not a fool-proof method of determining drum contents, it gives the investigator an indication prior to sampling of the general types of materials to be encountered.

Bulk storage tanks include tank cars/trucks, vats, storage vessels, and transformers. They range in size from less than 100 gallons to millions of gallons. Like drums, bulk storage tanks are constructed of many different materials and are designed in many configurations.

Lab packs consist of small, individually-labelled containers of laboratory waste or unused reagents. The chemical containers are usually not more than five gallons each, and are often packaged or transported together in a larger Department of

Transportation (DOT) shippable container (these are typically 30- to 55-gallon drums). Be sure to screen lab packs for radioactivity, since radioactive substances (alpha, beta, and gamma emitters) are commonly found in lab packs.

Another type of waste that can be found on site is biological waste, also known as "red bag waste." Note that contaminated biological waste (dressings, syringes, etc.) may not always be found in the required red bag. It should be handled only by personnel specifically trained and authorized to deal with biological waste. If "red bag waste" is encountered at a site, notify the ATSDR, or local health authorities.

2.6.2 Uncontainerized Waste

Uncontainerized waste consists of solids, liquids, and sludges that are found in waste piles and surface impoundments.

Waste piles may be composed of solid wastes such as tank bottom solids, contaminated soil, ash, solidified sludges, or a mixture of liquid and solid chemical wastes. The shape and size of waste piles can vary greatly, depending on the generating process or facility. The sampling plan should take into account the chemical and physical characteristics of the waste pile. For example, contaminants can leach out of the surface layers of a waste pile, resulting in deceptively low or nonrepresentative concentrations at the top. The sampling plan should account for leaching by taking composite samples from various horizons within the pile to determine an "average" concentration.

Surface impoundments include lined and unlined lagoons, ponds, and trenches that contain predominantly liquids and sludges from site processes or surface runoff. The liquids may be homogeneous or stratified, depending on the chemical and physical properties of the wastes. Reactions may occur within the impoundment to alter or degrade the original chemicals. Do not compromise any existing liners when sampling bottom sludges.

2.6.3 Surfaces and Debris

Surfaces and debris require specialized sampling techniques. During a response action, it may be necessary to sample object and structural surfaces for contamination to determine the need for dismantling and eventual disposal. Virtually any surface on the site may have to be sampled, including walls and floors of buildings, process machinery, tanks, vats, air ducts, vehicles, and furniture. There are three methods for sampling surfaces: wipe sampling, chip sampling, and dust sampling. Each method is described further in Section 4.3.6.

Debris can be highly variable and includes demolition rubbish, construction and destruction materials, paint cans, empty 55-gallon drums, battery-casings, shredded automobiles, and other miscellaneous matrices such as process waste, tannery waste, and slag. Debris may be composed of plastic, metal, rubber, paper, concrete, wood, glass, masonry, and municipal waste. It can include contaminated waste sampling articles such as protective disposable clothing (e.g., Tyvek suits), sample collection jars, and disposable sampling equipment (e.g., plastic scoops).

2.7 QUALITY ASSURANCE CONSIDERATIONS

Quality assurance components are defined as follows:

- Precision -- measurement of variability in the data collection process
- Accuracy (bias) -- measurement of bias in the analytical process; the term "bias" throughout this document refers to the QA/QC accuracy measurement
- Completeness -- percentage of sampling measurements which are judged to be valid
- Representativeness -- degree to which sample data accurately and precisely represent the characteristics and concentrations of the waste contaminants
- Comparability -- evaluation of the similarity of conditions (e.g., sample depth, sample homogeneity) under which separate sets of data are produced

To ensure that the analytical samples are representative of site conditions, quality assurance measures must be associated with each sampling and analysis event. The sampling plan must specify these measures. QA measures include, but are not limited to: laboratory SOPs, sample bottle preparation, equipment decontamination, field blanks, replicate samples, performance evaluation samples, sample preservation and handling, and chain-of-custody requirements (see Chapter 5, Quality Assurance/Quality Control).

2.8 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) state the level of uncertainty that is acceptable for data collection activities and define the certainty of the data necessary to make decisions. When establishing DQOs for a particular project, consider:

- Decision(s) to be made or question(s) to be answered
- Why analytical data are needed and how the results will be used
- Time and resource constraints on data collection
- Descriptions of the analytical data to be collected
- Applicable model or data interpretation method used to arrive at a conclusion
- Detection limits for analytes of concern
- Sampling and analytical error

2.9 FIELD ANALYTICAL SCREENING AND GEOPHYSICAL TECHNIQUES

There are two types of analytical data that can be generated during a response action: field analytical screening data and laboratory analytical data. Field analytical screening instruments and techniques provide real-time or direct (or colorimetric) readings. They include: flame ionization detectors (FIDs), photoionization detectors (PIDs), colorimetric tubes, portable X-ray fluorescence (XRF) units, portable gas chromatography (GC) units, immunoassay tests, and hazard categorization kits. These screening methods can assist with the selection of sample locations or samples to be sent for laboratory analysis by narrowing the possible groups or classes of chemicals. They are effective and economical for gathering large amounts of site data. After an area or group of containers has been characterized using field screening techniques, a subset of samples can be sent for laboratory analysis to substantiate the screening results. Field analytical screening with laboratory confirmation usually generates more analytical data under a limited sampling budget than will sampling with off-site laboratory analysis alone. Whenever possible, use field analytical screening methods which provide detection limits below applicable action levels. If these methods are not available, field analytical screening can still be useful for waste sampling by detecting grossly contaminated areas as well as for on-site health and safety determination. Field analytical screening techniques to support waste sampling are discussed in more detail in Chapter 3.

Geophysical techniques may be utilized during a response action to locate potential buried drums or tanks, buried waste, and disturbed areas. Geophysical techniques include ground penetrating radar (GPR), magnetometry, electromagnetic conductivity (EM), and resistivity surveys. Refer to U.S. EPA *Representative Sampling Guidance, Volume 1 -- Soil*, OSWER Directive 9360.4-10, for a discussion of soil geophysical techniques that are also applicable for waste sampling.

2.10 ANALYTICAL PARAMETERS AND METHODS

Designing a representative waste sampling plan includes selecting analytical parameters and methods. Use data collected during the historical data review (e.g., past site processes, materials stored on site) to select appropriate analytical parameters and methods. If the historical data review reveals little information about the types of waste on site, select analytical parameters by initially characterizing the waste. Use applicable field screening methods and limited laboratory analysis to rule out the presence of high concentrations of certain contaminants, and to narrow the list of analytical parameters. Methods often used for characterization of waste include GC/MS (gas chromatography/mass spectroscopy) screening for tentatively identified compounds (TICs) in the volatile and semivolatile organic fractions, infrared spectroscopy (IR) for organic compounds, inductively coupled plasma (ICP) for inorganic substances, and product comparison. These methods are used to determine chemical percentages in waste samples. After characterization, future sampling and analysis efforts can focus on substances identified above the action level.

2.11 REPRESENTATIVE SAMPLING APPROACHES

Representative sampling approaches appropriate for waste sampling include judgmental, random, systematic grid, systematic random, and transect sampling. A representative sampling plan may use one or a combination of these approaches.

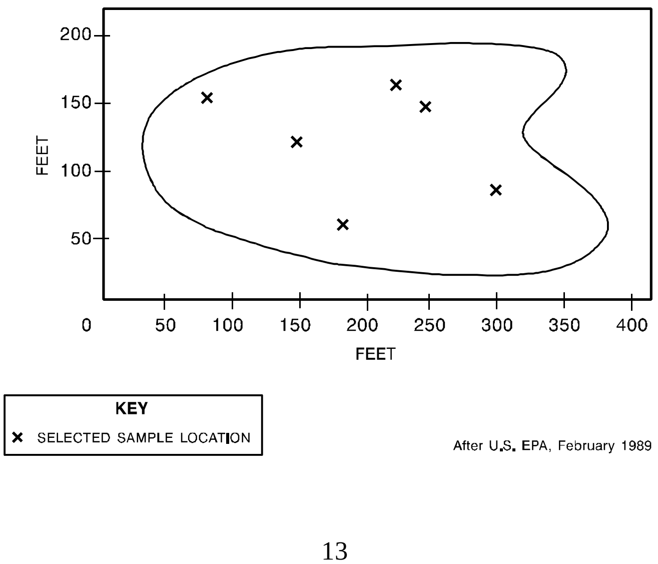
2.11.1 Judgmental Sampling

Judgmental sampling is the biased selection of sampling locations at a site, based on historical information, visual inspection, sampling objectives, and professional judgment. In waste sampling, three distinct situations prevail: 1) selecting locations within a large waste stream such as a waste pile or a stratum in an impoundment; 2) selecting a subset of containerized wastes when all containers cannot be sampled; and 3) sampling both containerized and non-containerized wastes in order to identify worst-case conditions and establish threat. If determining threat, the presence of certain site conditions such as leaking drums, spill areas, and large volume containers will indicate appropriate sampling locations if the source is known to be hazardous. Select drums to sample by existing labelling/markings or by container type, but not by random selection. When establishing threat, screen drums first to select a subset of drums containing hazardous materials or waste to be sent for analysis. This will avoid sampling drums of non-hazardous materials, which is not cost-effective. Judgmental sampling includes no randomization in the sampling strategy, precluding statistical interpretation of the sampling results.

2.11.2 Random Sampling

Random sampling is the arbitrary collection of samples having like contaminants within defined boundaries of the area of concern. Choose random sampling locations using a random selection procedure (e.g., a random number table). (Refer to Ford and Turina, July, 1984, for an example of a random number table.) The arbitrary selection of sampling points ensures that each sampling point is selected independently from all other points, so that all locations within the area of concern have an equal chance of being sampled. Randomization is necessary in order to make probability or confidence statements about the sampling results. The key to interpreting these statements is the assumption that the site or waste stream is homogeneous with respect to the parameters being monitored. The higher the degree of heterogeneity, the less the random sampling approach will adequately characterize true conditions. The use of random sampling on a subset of containers is not appropriate if different waste streams or concentrations might be present. Random sampling of waste piles and impoundments is often appropriate because of their large areal extent and relative homogeneity. Use random sampling to confirm the attainment of treatment levels of contaminated waste. (Refer to U.S. EPA, *Methods for Evaluating the Attainment of Cleanup Standards*, Volume 1 -- *Soils and Solid Media*, EPA/230/02-89/042, pages 5-3 to 5-5 for guidelines on selecting sample coordinates for random sampling.) Figure 2 illustrates a random sampling approach.

Figure 2: Random Sampling



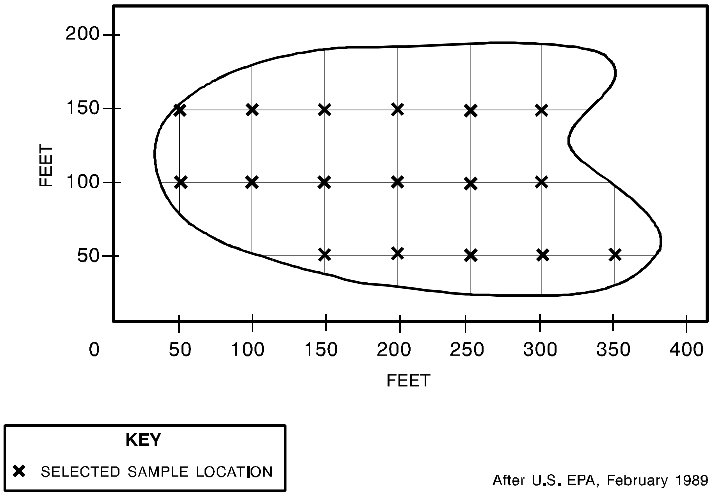
After U.S. EPA, February 1989

2.11.3 Systematic Grid Sampling

Systematic grid sampling involves subdividing the area of concern by using a square or triangular grid and collecting samples from the nodes (intersections of the grid lines). Select the origin and direction for placement of the grid using an initial random point. From that point, construct a coordinate axis and grid over the source. Generally, the more samples collected (and the smaller the grid spacing), the more reproducible and representative the results. Shorter distances between sampling locations also improve representativeness.

Systematic grid sampling can be used to characterize a waste pile, impoundments, or loose tank bottom solids. Systematic grid sampling is not applicable to sampling individual small containers or drums. (Refer to U.S. EPA, *Methods for Evaluating the Attainment of Cleanup Standards*, Volume 1 -- *Soils and Solid Media*, pages 5-5 to 5-12 for guidelines on selecting sample coordinates for systematic grid sampling.) Figure 3 illustrates a systematic grid sampling approach.

Figure 3: Systematic Grid Sampling



After U.S. EPA, February 1989

2.11.4 Systematic Random Sampling

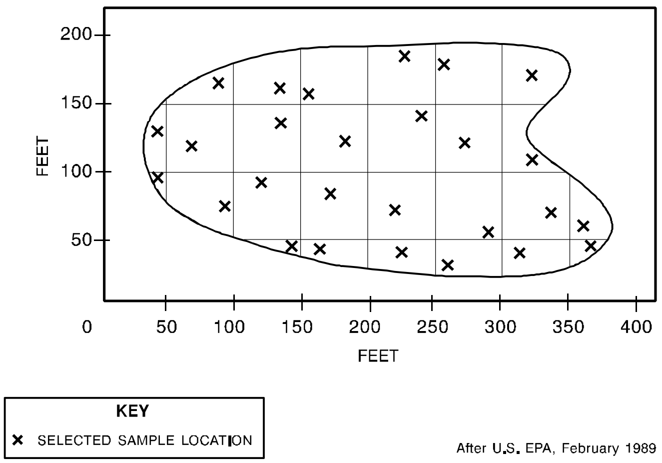
Systematic random sampling is a useful and flexible design for estimating the average pollutant concentration within grid cells. Subdivide the area of concern using a square or triangular grid (as mentioned above) then collect samples from within each cell using random selection procedures. Systematic random sampling allows for the isolation of cells that may require additional sampling and analysis. Like systematic grid sampling, systematic random sampling can be used to characterize a waste pile, loose tank bottom solids, or impoundments, but not small containers or drums. Figure 4 illustrates a systematic random sampling approach.

2.11.5 Transect Sampling

Transect sampling involves establishing one or more transect lines across a surface. Collect samples at regular intervals along the transect lines at the surface and/or at one or more given depths. The length of the transect line and the number of samples to be collected determine the spacing between sampling points along the transect. Multiple transect lines may be parallel or non-parallel to one another. If the lines are parallel, the sampling objective is similar to systematic grid sampling. The primary benefit of transect sampling versus systematic grid sampling is the ease of establishing and relocating individual transect lines.

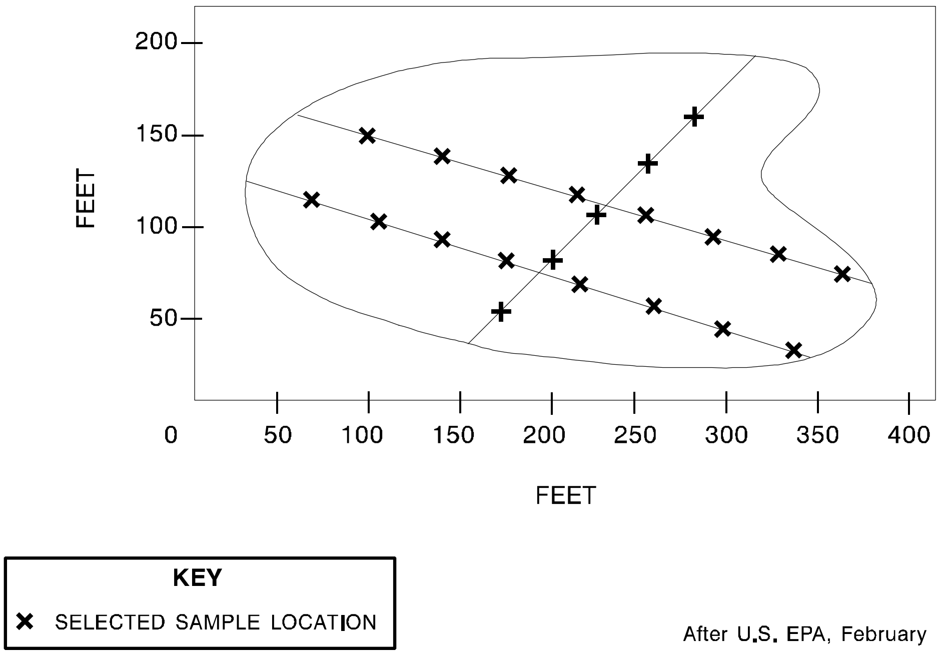
Transect sampling is applicable to waste piles or impoundments. Figure 5 illustrates a transect sampling approach.

Figure 4: Systematic Random Sampling



After U.S. EPA, February 1989

Figure 5: Transect Sampling



After U.S. EPA, February 1989

2.12 SAMPLING LOCATIONS AND NUMBER

The locations and number of samples to be collected must be carefully selected to obtain samples that are truly representative of the material being sampled, as well as of the general site area. The sampling objectives, waste type, container/source type, sampling approach, and other factors determine where and how many samples are collected. For example, a judgmental sampling approach can establish threat or identify the presence of wastes with a few carefully selected samples. A larger number of samples are needed to characterize wastes, and sampling locations should be selected using random, systematic grid, and systematic random sampling techniques. Field screening techniques are valuable for selecting sampling locations. In situations where there is a very large waste area or numerous containers of potentially different wastes, field screening techniques may identify similar waste streams. These wastes can be segregated into general chemical classes (e.g., strong acids, halogenated solvents) and then samples can be collected for confirmation by laboratory analysis.

Sampling locations which pose a severe chemical or physical hazard to sampling teams (e.g., cylinders of hydrofluoric acid, hydrogen cyanide, or nerve agents) should be avoided or sampled remotely. Sampling cylinders requires specially trained and authorized personnel.

2.13 EXAMPLE SITE

2.13.1 Background

ABC Plating, a multi-purpose specialty plating facility in northern Pennsylvania operating from 1947 to 1982, stored and treated its plating wastes by placing them in a series of unlined and unpermitted impoundments. State RCRA personnel cited the owner/operator for the operation of an unpermitted treatment system and ordered the owner to submit a remediation plan for state approval. Before the state could follow up on the order, the impoundments were partially backfilled with the wastes in place. The facility was later destroyed by a fire of suspicious origin. The owner abandoned the facility and could not be located by enforcement authorities. The state contacted U.S. EPA for an assessment of the site for a possible federally funded response action.

U.S. EPA initiated a removal assessment with the following primary sampling objectives:

- To establish the identities and volumes of hazardous materials present on the site to determine the potential threat to the surrounding population and the environment.
- To develop site stabilization strategies.

After federal funds were obtained and the site was stabilized, EPA addressed two additional objectives:

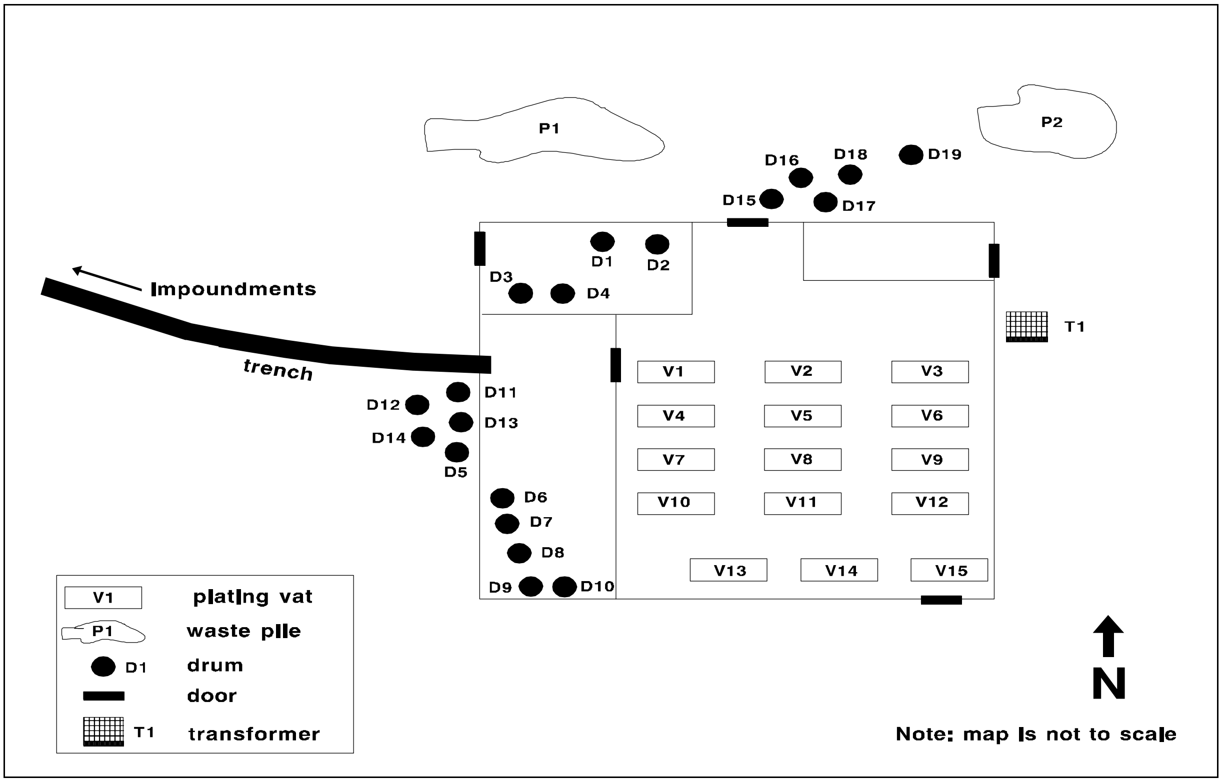
- To identify treatment and disposal options for the wastes on site.
- To verify that established clean-up levels are met.

2.13.2 Site Entry

Within four hours of the initial request for assistance from the state, an EPA On-Scene Coordinator (OSC) and other response personnel mobilized to the site with equipment to perform multi-media sampling. The next day, the OSC met with the township manager, representatives from the county health department and the Pennsylvania Department of Environmental Resources (PA DER), and the township Fire Chief. The OSC reviewed PA DER enforcement reports and aerial photographs which indicated the presence and locations of chromium, copper, and zinc plating process areas. The OSC interviewed local residents and performed a walk-through, donning Level B personal protective equipment (PPE), to survey the general site conditions. A site sketch was generated (Figure 6), indicating the locations and container types of the wastes. A total of nineteen 30- and 55-gallon fiber and metal drums, fifteen 250- to 500- gallon plating vats, two 10- to 15- cubic yard waste piles, a feeder trench leading to two 80 feet x 20 feet x 7 feet partially filled impoundments, and a transformer were located and noted in the site sketch. Some rooms of the building could not be entered because of unsafe structural conditions caused by the fire.

The OSC and PA DER reviewed all available information to formulate a sampling plan for the drums, vats, impoundments, and waste piles. The entry team used a judgmental sampling approach during the initial assessment, first collecting samples from containerized wastes for screening and possible analysis (suspecting that the containerized concentrated material posed the greatest potential hazard).

Figure 6: ABC Plating Site Sketch



2.13.3 Site Inventory

During this phase of the response, a field entry team in Level B personal protective equipment (PPE) inventoried drums, plating vats, waste piles, impoundments, and a transformer found at the site.

Drums

The entry team numbered each drum and noted drum type, size, condition, and label information on a drum inspection log (Figure 7). The chemical properties of constituents listed on labelled drums were researched. Typical hazardous materials used at plating facilities were determined from the references available; these substances include strong acids and bases, heavy metal solutions and solids, and cyanide-bearing compounds.

Vats

The plating vats were inspected, numbered, and noted on the site sketch. An estimate of the volume was documented for each of the vats. All vats were covered with non-reactive polyethylene sheeting to prevent rain water from collecting in them and increasing the waste stream volume.

Waste Piles

The waste piles were inspected and noted on the site sketch. Transects were established along the longest horizontal axis of each pile. The transects were also noted on the site sketch. The samples will be collected and screening will be conducted along each transect.

Impoundments

The OSC determined that the contents of the impoundments posed a potential direct contact hazard to the surrounding population. In preparation for sampling, a transect was established from the entry point of the feeder trench across each impoundment. During site operation, wastes flowed from the feeder trench into the impoundments. Suspended solids were suspected to be present in a gradient decreasing with distance from the feeder trench.

Transformer

The OSC was concerned that the single transformer outside the plating building could contain PCB dielectric fluid. Inspection of the transformer determined that it was disconnected by first responders during the facility fire. The maximum transformer volume, the type of oil used, the date of manufacture, and the manufacturer's name were indicated on the metal plate on the side of the unit, and this information was noted. The unit was not leaking, so it was numbered and noted on the site sketch for future screening or sampling.

Information obtained from the site inventory and data review was used to create a site-specific conceptual model. Sources (e.g., vats, drums), pathways (e.g., vapors from the impoundments, soil under leaking drums), and potential receptors (e.g., local residents) were detailed to assist the selection of sampling approaches, objectives, and locations.

2.13.4 Selecting Analytical Parameters

Analytical parameters were selected based on research of plating chemistry and the initial site screening. Plating facilities generally use either an acid bath or basic cyanide bath to achieve the desired coating on their metal products. Based on the researched information and the measured pH of the liquid wastes on site, the following compounds were suspected to be present:

- Sodium and zinc cyanide salts and sodium hydroxide (highly basic, grey to green color) from zinc plating practices

- Chromic acid and sulfuric acid/sodium sulfate (acidic, yellow or dulled color) from chromium plating practices

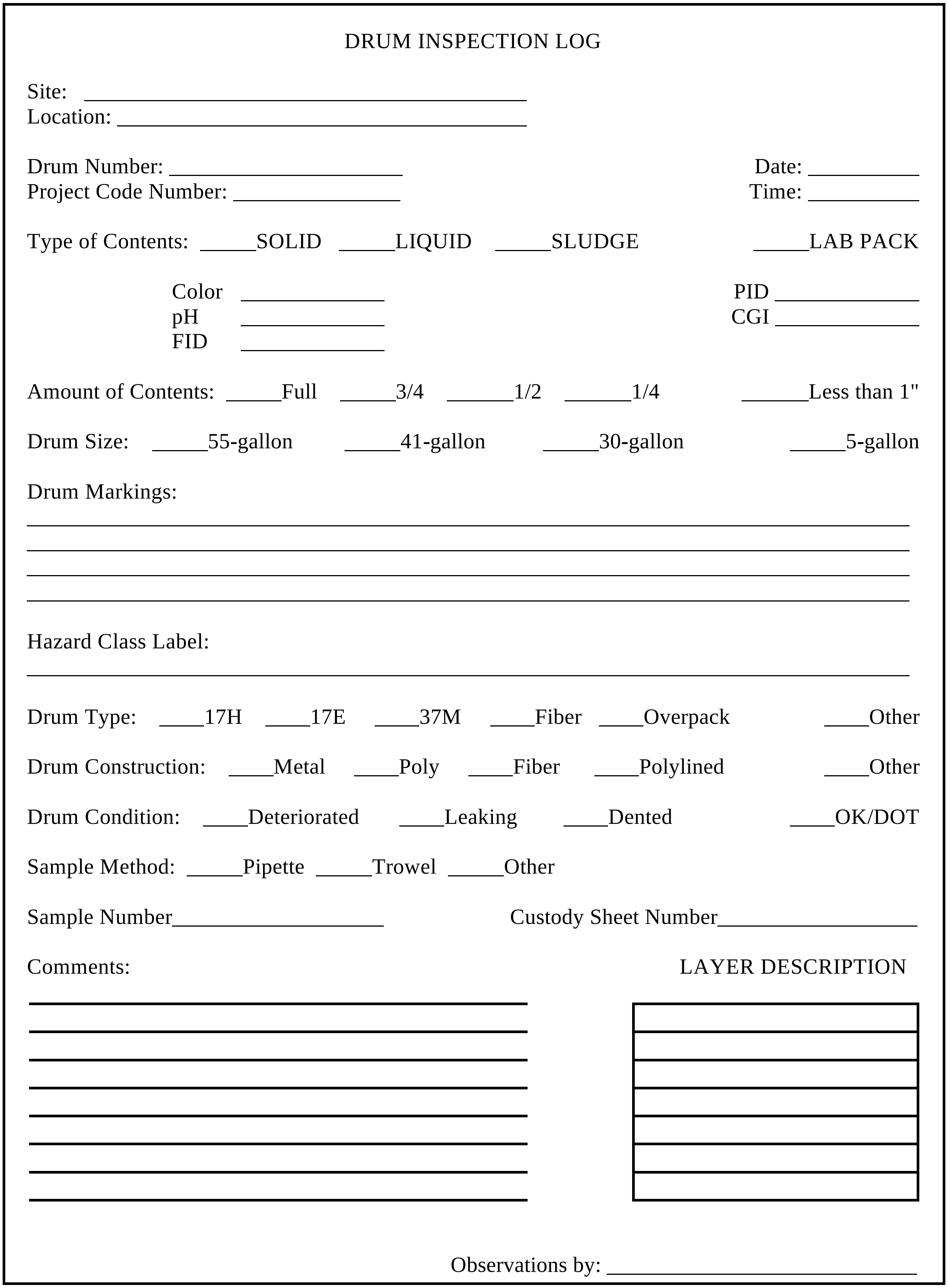
- Copper sulfate and sulfuric acid (acidic, blue/green color) from copper plating practices.

During the assessment, liquid vat samples underwent field screening to assist in the selection of analytical parameters. Samples from all highly basic solutions were shipped to a laboratory for analysis of metals and cyanide. Acidic samples were sent for analysis of metals only. The composition of some of the drummed materials was initially unknown. In addition to the plating chemicals listed above, other possible drum contents included various cleaners, oils, fuels, and solvents. Many of the drums still had labels identifying their contents, and field screening was used to confirm content composition. Acids and bases were easily identified with pH paper, which was by far the most useful and inexpensive screening tool.

The waste piles were thought to include plating vat sludge waste. Samples collected from the piles were sent for laboratory metals and cyanide analyses.

Initial samples from impoundment liquids and solids (large-volume unsecured waste streams) were sent for full target analyte list (TAL), hexavalent chromium, pH, and total and amenable cyanide analyses. These analyses were conducted to fully characterize the liquid impoundment wastes for evaluation of the various on-site water treatment system needs. This information was later used to select optimum pH conditions and flocculent type for maximum settling efficiency. A local industrial wastewater treatment facility agreed to accept the liquid wastes if the heavy metal and cyanide levels were within their permit parameters. In addition to evaluating off-site treatment and disposal options, the impoundment bottom samples were characterized using target compound list (TCL), hexavalent chromium, total and amenable cyanide, pH, and total alkalinity analyses to allow evaluation of possible on-site stabilization, solidification and treatment techniques.

Figure 7: Example of a Drum Inspection Log



DRUM INSPECTION LOG

Site: ____
Location: _____________________________________

Drum Number: _____________________ Date: __________
Project Code Number: _______________ Time: __________

Type of Contents: _____SOLID _____LIQUID _____SLUDGE _____LAB PACK

Color _____________ PID _____________
pH _____________ CGI _____________
FID _____________

Amount of Contents: _____Full _____3/4 ______1/2 ______1/4 ______Less than 1"

Drum Size: _____55-gallon _____41-gallon _____30-gallon _____5-gallon

Drum Markings:
____
____
____
____

Hazard Class Label:
____

Drum Type: ____17H ____17E ____37M ____Fiber ____Overpack ____Other

Drum Construction: ____Metal ____Poly ____Fiber ____Polylined ____Other

Drum Condition: ____Deteriorated ____Leaking ____Dented ____OK/DOT

Sample Method: _____Pipette _____Trowel _____Other

Sample Number___________________ Custody Sheet Number__________________

Comments: LAYER DESCRIPTION

Observations by: ____________________________

3.0 FIELD ANALYTICAL SCREENING AND SAMPLING EQUIPMENT

3.1 INTRODUCTION

Field analytical screening techniques and equipment may provide valuable information for developing sampling strategies. Field analytical screening can determine chemical classes of wastes and in some cases can identify particular substances of concern. Real-time or direct-reading capabilities narrow the possible groups or classes of substances which aids in selecting the appropriate laboratory analytical method. These screening techniques are useful and economical when gathering large amounts of site data. Some of the commonly used screening methods for waste analysis are presented in this chapter in the general order that they would initially be used at a waste site, although site-specific conditions may mandate a different sequence. This chapter focuses on site-screening methods, but the instruments described below have specific health and safety applications as well. Refer to the *Compendium of ERT Waste Sampling Procedures,* OSWER Directive 9360.4-07, for specific information about most of the following techniques or equipment. Refer to Standard Operating Safety Guides for each instrument, and the *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities* (NIOSH Pub. 85-115) for site entry information.

3.1.1 Combustible Gas Indicator

The combustible gas indicator (CGI) measures the concentration of a flammable vapor or gas in the air, registering the results as a percentage of the lower explosive limit (LEL) of the calibration gas. The CGI is often combined with an oxygen meter; some contemporary models also have built-in compound-specific detectors (e.g., hydrogen sulfide, sulfur dioxide, carbon monoxide, and hydrogen cyanide). CGIs are particularly useful for entry into unknown and/or confined space atmospheres.

There are several factors that must be considered when using a CGI for waste site work. The accuracy of the reading is temperature dependent; the CGI must be calibrated at ambient temperatures. The sensitivity of the CGI is also a function of the physical and chemical properties of the calibration gas versus those of the unknown atmosphere. Oxygen concentrations that are less than or greater than normal may cause erroneous readings. Leaded gasoline vapors, halogens, silicates, and sulfur compounds can decrease sensitivity. As a sample screening tool, the CGI is of limited value because it yields non-qualitative results for flammable vapors.

3.1.2 Radiation Screening Instruments

Screening for ionizing radiation is mandatory for all Superfund assessments, primarily for health and safety reasons. Since gamma rays and X-rays have high penetration capabilities even at extended distances, radiation screening instruments are generally used during the initial site entry. As containerized wastes are opened, alpha and beta radiation which was not detected during the initial walk-through screening may be encountered.

Most of the commonly used radiation screening instruments have gamma or beta/gamma detecting probes. Pure alpha detectors are not commonly used on site because the probes are too fragile and because pure alpha emitters are rare. However, an alpha/beta/gamma probe is suggested for screening wastes in lab packs, research facilities, laboratories, and on military installations where radioactive waste may be present (e.g., Department of Defense (DOD) and Department of Energy (DOE) installations).

3.1.3 Flame Ionization Detector

The flame ionization detector (FID) detects and measures the level of total organic compounds (including methane) in the ambient air or in a container headspace. The FID is used to evaluate existing conditions, identify potential sample locations and extent of contamination, and support health and safety decisions. The FID uses the principle of hydrogen flame ionization for detection and measurement. It is especially effective as an ethane/methane detector when used with an activated charcoal filter because most organic vapors are absorbed as the sample passes through the filter, leaving only ethane and methane to be measured.

The FID operates in one of two modes: the survey mode, or the gas chromatography (GC) mode. In the survey mode, the FID provides an approximate total concentration of all detectable organic vapors and gases measured relative to the calibration gas (usually methane). The GC mode identifies and measures specific components, some with detection limits as low as a few parts per million (ppm), using known standards run concurrently in the field. Since the GC mode requires standards to identify classes of compounds, before sampling it is necessary to have an idea of which compounds might be present on site. Advantages of the FID are that it is portable, relatively rugged, and provides real-time results.

The FID does not respond to inorganic substances. It has positive or negative response factors for each compound depending on the selected calibration gas standard. The FID does not recognize and may be damaged by acids; use pH paper to screen acids. Ambient air temperatures less than 40 degrees Fahrenheit will cause slower responses; relative humidity of greater than 95 percent can cause inaccurate and unstable responses. Low ambient oxygen levels can cause the flame to go out; use a CGI/oxygen meter in conjunction with an FID in confined space applications. Interpretation of readings (especially in the GC mode) requires training and experience with the instrument.

3.1.4 Photoionization Detector

Another portable air monitoring instrument frequently used for field screening is the photoionization detector (PID). Like the FID, the PID provides data for real-time total organic vapor measurements evaluating existing conditions, identifying potential sample locations and extent of contamination, and supporting health and safety decisions. The PID works on the principle of photoionization. Unlike the FID, the PID can be used to detect gross organic, and some inorganic vapors depending on the substance's ionization potential (IP) and the selected probe energy. It is portable and relatively easy to operate and maintain in the field.

The PID detects total concentrations and is not generally used to quantify specific substances. PIDs cannot detect methane; however, methane is an ultraviolet (UV) light absorber, and false negative instrument readings may register in methane-rich environments. The PID cannot detect substances with IPs greater than that of the UV light source. Readings can be affected by high wind speeds, humidity, condensation, dust, power lines, and portable radios. Dust particles and water droplets (humidity) in the sample may collect on the light source and absorb or deflect UV energy, causing erratic responses in PIDs not equipped with dust and moisture filters.

3.1.5 Colorimetric Tubes

Colorimetric indicator tubes (e.g., Dräger, Sensidyne, MSA) provide real-time results in environments where a specific gas or vapor is suspected to be present. In waste sampling, they are useful for situations such as screening drums, where drum labels provide limited information on the contents of only some of the drums.

Colorimetric tubes consist of a glass tube filled with silica gel or a similar material impregnated with an indicator reagent which changes color in the presence of specific contaminants. The tube is attached to an intrinsically safe piston-syringe or bellows-type pump which slowly pulls a measured volume of air through the tube. The contaminant then reacts with the indicator chemical within the tube producing a color change proportional to the concentration of the chemical.

Although the indicator tubes are usually chemical or class specific, interferences can occur. Common interferences are noted in the directions for the specific tube. The tubes have a limited shelf life, and cannot be reused. Results can be misinterpreted due to cross-sensitivity, and there exists a potential for error in reading the end point of color change. Errors result if the limit of the tube has been exceeded (in very concentrated environments). High humidity may reduce tube sensitivity.

3.1.6 Hazard Categorization

Hazard categorization (haz-catting) is performed as an initial screen for hazardous substances to provide identification of the classes/types of substances present in individual waste streams. Haz-catting tests for general chemical characteristics or the presence of specific ions to determine chemical class; it is not compound-specific. The information from haz-catting is useful for determining compatibility of unknown wastes.

Various indicators and wet chemistry tests characterize the wastes according to their chemical/physical properties (e.g., solubility, combustibility), and indicate the presence of sulfides, oxidizers, and cyanide. The haz-catting procedure requires numerous chemical reagents and interpretation of results. Common haz-cat tests include the *char* test for differentiating organic from inorganic substances; *chlorine hot wire* test to detect chlorine in organic solvents; *combustibility* test; *cyanide* test for cyanide salts; *flame* test for identifying cations and some anions; *iodine* crystal test for solvent classification; *oxidizer* test; *sulfide* test; *water solubility* test; and *pH* test.

3.1.7 Immunoassay Tests

Immunoassay tests can be used on site to screen for certain organic compounds such as pentachlorophenol (PCP), PCBs, and pesticides. Immunoassay tests are used for locating and mapping the extent of contamination, and for screening samples in the field prior to laboratory analysis.

Immunoassay tests utilize semi-quantitative, colorimetric methods. Some of the commonly used tests utilize tubes coated with a chemical that specifically binds to the contaminant. These types of tests utilize highly selective antibodies and sensitive enzyme reactions to yield qualitative, semi-quantitative, and quantitative results for a specific compound or for a closely related series of compounds (e.g., PCP, PCBs, and 2,4,D-pesticides). Antibodies can be either coated on the test tube, or attached to microparticulates or reaction well/ plates, depending on the brand. Other types of immunoassay tests utilize enzyme-linked, immunosorbent assays (ELISAs) and magnetic particles to bind to the contaminants.

The concentration range of a sample is determined by comparing the color change of the sample with that of duplicate standards of known concentrations. The color intensity in each tube decreases as the contaminant concentration increases. Photometers are available to "read" and digitally display, print, and store the color difference between the prepared sample and the standards. Since the results are compared to standards, the accuracy achievable is a contaminant range (e.g., greater than 100 ppm but less than 1,000 ppm). Laboratory confirmation is required when using these tests in the semi-quantitative and qualitative modes. Performance evaluation spikes determine the efficiency of the test. Some training is needed to effectively run and interpret immunoassay tests.

3.1.8 X-Ray Fluorescence

Field analytical screening using X-ray fluorescence (XRF) is a cost-effective and time-saving method to detect and classify lead and other heavy metals in wastes. XRF screening provides immediate semi-quantitative results. The principle behind XRF is the detection and measurement of the X-rays released from an atom when it is ionized. The measure of energy released identifies the atom present.

Results of XRF analysis help determine the presence of metals and are often used to assess the extent of soil contamination at a site. For waste sampling, the XRF can be used for screening waste piles and for assessing metals in certain liquids such as paint. XRF use requires a trained operator and may require numerous site-specific calibration samples.

3.1.9 Gas Chromatograph

Although many FIDs are equipped with a GC mode, an independent, portable GC can also be used on site to provide a chromatographic profile of the occurrence and intensity of unknown volatile organic compounds (VOCs). The GC is useful as a screening tool to determine "hot spots," potential interferences, and semi-quantitation of VOCs and semi-volatile organic compounds (semi-VOCs).

Compounds with high response factors, such as benzene and toluene, produce large response peaks at low concentrations, and can mask the presence of compounds with lower response factors. However, recent improvements in GCs, such as pre-concentrator devices for lower concentrations, pre-column detection with back-flush capability for rapid analytical time, and the multi-detector (PID, FID, and electron capture detector (ECD)), all enable better detection of compounds. The GC is highly temperature-sensitive. It requires set-up time, many standards, and operation by trained personnel.

3.2 SAMPLING EQUIPMENT

Representative waste sampling requires an understanding of the capabilities of the sampling equipment, since the use of inappropriate equipment may result in biased samples. Select appropriate sampling equipment based on the sample type and matrix, physical location of the sample point, and other site-specific conditions. Consideration must be given to the compatibility of the waste with the design and composition of the sampling device. Follow SOPs for the proper use and decontamination of sampling equipment. This section provides descriptions of drum opening and sampling equipment descriptions, and other information to assist in selecting appropriate equipment. Refer to the *Compendium of ERT Waste Sampling Procedures,* OSWER Directive 9360.4-07, for expanded guidelines on the use of the equipment discussed below.

3.2.1 Drum Openers

Closed drums need to be opened for sampling. Tools suitable for opening drums include: universal bung wrench, drum deheader, backhoe spike, hydraulic drum opener, and pneumatic bung remover. Each of these devices has specific applications based on the drum type, composition, condition, location, and suspected contents.

Follow ERT SOP #2009 (Drum Sampling) in the *Compendium of ERT Waste Sampling Procedures*, OSWER Directive 9360.4-07, for guidelines on opening drums and the operating instructions for the particular equipment used. Always use non-sparking instruments to open drums and comply with proper health and safety protocols. Note that the use of a non-sparking tool does not completely eliminate the possibility of a spark being produced. Drums should be grounded to decrease the chance of static charges and sparks. Stage drums by suspected compatibility type prior to opening and sampling to decrease the risk of chemical reaction between incompatible substances.

3.2.2 Liquid Samplers

The following samplers are useful for collecting waste liquids from various sources: composite liquid waste sampler (COLIWASA), glass thief, bailer, and bacon bomb. Each has specific applications for use depending on the type and nature of the waste and the type of source.

COLIWASA

The COLIWASA is a tool typically used for sampling stratified liquids in drums and other similar containers. It is a transparent or opaque glass, PVC, or Teflon tube approximately 60 inches in length and 1 inch in diameter. A neoprene stopper at the bottom of the tube can be opened and closed via a rod that passes through the length of the sampler.

The COLIWASA is difficult to decontaminate in the field but is versatile and simple to operate. Because of the relatively high cost of the COLIWASA, COLIWASA-type glass thieves have been developed which utilize neoprene or ground glass stopper mechanisms. Before conducting multiphased sampling, make sure that the physical and chemical properties of the container's contents and phases are understood.

Glass Thief

Another commonly used drum sampling device, the glass thief, is a hollow glass tube 40 to 48 inches in length and commonly 10 mm to 19 mm in diameter. The larger diameter tubes are used to collect more viscous materials. The glass thief is simple to operate, versatile, and disposable, eliminating the need for decontamination.

Conduct the sampling carefully in order to avoid sample spillage. Low viscosity liquids, thin-layered phases, and partially filled containers may be difficult to sample with a hollow glass thief. In those cases, use the COLIWASA-type glass thief, whose stopper mechanism prevents the sample from leaking out of the thief as it is removed from the container.

Bailer

A bailer is used to sample waste liquids in vessels (wells, tanks, or deep containers) where the liquid surface is far below the sampling entry access (i.e., too far for a glass thief or COLIWASA). The bailer consists of a hollow tube (constructed of relatively inert materials such as stainless steel, glass, or Teflon) with a bottom ball-check valve, usually suspended from a wire or rope for sampling. Bailers are good for sampling VOCs because of the relatively low surface-to-volume ratio which reduces off-gassing.

Most bailers cannot obtain discrete depth or phased samples, so their use is primarily limited to homogeneous liquids or shallow (length of bailer) sampling. As with any sampling device, the construction material should not interfere with the wastes or the desired analytical parameters.

Bacon Bomb

The bacon bomb sampler is used to collect waste liquid samples from various levels within storage tanks or surface impoundments. Storage tank and impoundment wastes are often stratified, and the bacon bomb is useful when a discrete sample is needed from any level in the tank or impoundment. The bacon bomb consists of a cylindrical body with an internal tapered plunger for sampling. A separate line attached to the top of the plunger opens and closes the bottom valve at the desired depth or stratum. A removable top cover attaches the sample line and has a locking mechanism to keep the plunger closed after sampling. The bacon bomb is usually constructed of chrome-plated brass and bronze or stainless steel. A rubber O-ring acts as the plunger sealing surface.

Transfer of the sample to sample containers is sometimes difficult and tends to aerate the sample, resulting in loss of volatile constituents. The bacon bomb sampler can be more difficult to decontaminate than a bailer.

3.2.3 Sludge Samplers

The following devices are useful for sampling waste sludges: Ponar/Ekman dredge, sludge judge, and PACS grab sampler.

Ponar/Ekman Dredge

Ponar/Ekman dredges are clamshell-shaped scoops that are used to extract waste sludge samples from the bottom of impoundments, lakes, or other standing water bodies. The Ponar dredge's jaws are latched open and the unit is slowly lowered to the bottom of the area being sampled. When tension is eased on the lowering cable, the latch releases, and the lifting action of the cable on the lever system closes the dredge around a sample of sludge. The Ekman dredge operates similarly but it closes by using a messenger or depressing a button on the upper end of the handle.

The substrate depth to which both dredges can sample usually does not exceed 4 to 6 inches, and they are not capable of collecting an undisturbed sample. As a result, material in the top inch of sludge cannot be separated from material at lower depths. The sampling action of the dredges causes agitation currents which may temporarily re-suspend some settled solids, especially the fine fraction.

Dredges are normally used from a boat or dock. Because the dredges are heavy, a boom is frequently used to ease the raising and lowering of them. Dredges are not usually effective in sampling hard or stony bottom material. Bottom vegetation will also limit dredge effectiveness.

Sludge Judge

The sludge judge is a long narrow tube with a check valve on the bottom, used primarily to obtain cores of waste sludge, or waste liquids mixed with sludge, from drums, tanks, or similar sources. Sludge judges are useful for determining the physical state of a tank's contents or its volume of settled sludge. The sludge judge is constructed of PVC which can limit its use because of potential interference with the contaminants of concern. The device is difficult to decontaminate and not recommended for use with very thick sludges.

PACS Grab Sampler

The PACS grab sampler is used to collect sludge samples at discrete depths from surface impoundments such as ponds and lagoons and also from certain types of containers. The PACS grab sampler consists of a 1000-ml wide-necked bottle with a control valve which screws on to the end of a 2-meter long handle. Large openings in the bottle facilitate sample collection. The control valve is operated from the top of the handle once the sampler is at the desired depth. Depth of sampling is limited by the length of the pole handle. The device is not useful in very viscous sludges, and it can be difficult to decontaminate.

3.2.4 Solids Samplers

The following devices are used to collect samples from waste piles and other sources of solid waste: scoop/trowel, bucket auger, sampling trier, waste pile sampler, cork screw auger, and split-barrel sampler.

Scoop/Trowel

Scoops or trowels are useful for collecting solid or sludge samples from waste piles. Collection is usually limited to near-surface and depends on the length of the scoop or trowel. These instruments are available in a variety of materials, including stainless steel and plastic. Stainless steel scoops and trowels are appropriate for VOC sample collection but require decontamination between sampling stations. Plastic scoops and trowels are suitable for metal analyses and are disposable, which eliminates the need to decontaminate between sampling stations. Do not use trowels with painted or chromium-plated surfaces, because the paint or plating can chip off into the sample.

Bucket Auger

Bucket augers are typically composed of stainless steel and are used to collect solid or sludge samples from waste piles or surface impoundments. The auger is effective for subsurface sampling, but tends to destroy horizons during sampling, making VOC collection difficult. The bucket auger is therefore not recommended for VOC collection; use a split-barrel sampler instead. Bucket augers can be used for sludge sampling in a surface impoundment, depending on accessibility.

Bucket augers provide uniform sampling diameter and good depth control, and are easy to decontaminate. Their effectiveness is reduced in rocky or hard solids, heavy clays, or very sandy solids.

Sampling Trier

A sampling trier is used to collect powdered or granular materials from bags, fiber or metal drums, sacks, or similar containers. A typical sampling trier is a long tube with a slot which extends almost its entire length. The tip and edges of the tube slot are sharpened so that when rotated after insertion into the material, the trier cuts out a sample core. Sampling triers range from 24 to 40 inches in length and from 1/2 to 1 inch in diameter, and are usually made of stainless steel (or a similar composition) with wooden handles. Triers are relatively easy to use and to decontaminate.

Waste Pile Sampler

The waste pile sampler is essentially a large sampling trier used for sampling large waste piles (with cross-sectional diameters greater than 1 meter). It can also be used for sampling granular or powdered wastes, and material in large bins or barges.

The waste pile sampler is commercially available, but one can be easily and inexpensively fabricated from sheet metal or plastic pipe. The sampler does not collect representative samples when the diameters of the solid particles are greater than one-half the diameter of the tube.

Cork Screw Auger

The cork screw auger is a hand-driven sampler used to sample bulk solid wastes such as waste piles. The auger tip resembles a large drill bit ranging from 3/4 to 1-1/2 inches in diameter. The auger is used for sampling at depth by adding rod extensions. It is effective in soft to hard materials, although saturated waste may be difficult to sample. Decontamination of the auger is relatively easy. The cork screw auger disturbs the waste profile and thus has limited utility for VOC sampling.

Split-Barrel Sampler

The split-barrel sampler (also called a split-spoon sampler) is used to collect waste samples from the bottom of boreholes. The split-barrel sampler consists of a hollow tube with a circular chisel or cutting shoe threaded onto one end and a driving head or collet threaded onto the other end. The sample tube is split lengthwise into two halves to facilitate sample removal and decontamination. A drilling rig is required to use the split-barrel sampler. The sampler is attached to the end of the drilling rod and is driven into the bottom of the borehole with a specially designed, 140-lb. drive hammer. The split-barrel sampler can be used to determine the relative density of the material that is being cored or drilled by counting the number of drive hammer blows it takes to drive the barrel 18 inches below the bottom of the borehole.

The split-barrel sampler is useful for collecting relatively undisturbed waste samples from great depths. Because split-barrel samplers do not disturb the sample, they are suitable for sampling VOCs. They can be used to sample deep into large waste piles, subsurface wastes, or dry lagoon beds, but they are not effective in rocky or very consolidated materials.

3.3 EXAMPLE SITE

After conducting proper site entry procedures (health and safety monitoring), the OSC utilized field screening techniques to the greatest extent possible. This allowed for the rapid collection of information to support the decision-making process and to limit the need for laboratory analysis. All waste streams were screened (as discussed below) to determine which laboratory analyses would be necessary, and to provide a logical basis for selecting a limited number of analytical parameters. All waste streams were also screened for radiation; none was detected.

3.3.1 Drum Screening and Sampling Equipment

Each of the closed drums appeared to be in relatively good condition, showing no signs of internal pressure or other instability, and were opened using a spark-proof bung wrench. Five drums were already open to the elements. After each drum was opened, samples were collected for screening using a glass thief. All drums were screened using haz-catting procedures. All haz-catting information was recorded in the field on a Hazard Categorization Data Sheet (illustrated in Figure 8). The first haz-catting procedure conducted was for pH. Four drums were found to contain strong acids; five drums contained strong bases. Various colorimetric tubes were used in an attempt to identify specific acids; however, all the tubes exhibited positive reactions due to interferences from the presence of similar strong acids. Since cyanide-bearing solutions are typically basic, all basic solutions were screened for the presence of cyanide to prevent the potential generation of hydrogen cyanide gas (HCN) during handling. As a result of screening, three drums containing basic solutions were tentatively determined to contain cyanide. Additional haz-cat screening (PID, FID, solubility, chlorine, and peroxide) was conducted for the ten drums exhibiting relatively neutral pH. From this additional screening, three drums of oil, one drum of halogenated solvents, and one drum of kerosene were tentatively identified. Two drums were suspected to contain rainwater. The screening results were inconclusive for three drums.

The drums containing strong acids and bases were, by definition, RCRA hazardous characteristic wastes. Because of the risks associated with strong acids and bases, there was no need for further data analysis to establish imminent threat. The entry team separated incompatible materials to reduce the risk of a chemical reaction/release.

3.3.2 Plating Vat Screening and Sampling Equipment

Some plating vats were already open; others had large, easy-to-open lids similar to that of a trash dumpster. The vat liquids and bottom solids were screened separately in the same manner as the drums, using a COLIWASA-style glass thief to collect the samples and haz-catting to identify the wastes. The samplers were long enough to reach the bottom of the vats, providing a sample of the entire vertical column of liquid. A hollow glass thief was then used to collect a single grab sample from the bottom solids in each vat.

The vat contents were tentatively identified as strong acids, strong bases, and cyanide bases. Haz-catting results were inconclusive for four vats. No volatile organic compounds were detected using PID and FID instruments.

3.3.3 Waste Pile Screening and Sampling Equipment

The piles contained blue and green solids that were assumed to be bottom solids cleaned from the plating vats. Screening samples from the waste piles were collected using a corkscrew auger and stainless steel trowels (because of the hardened texture of the piles). Waste pile samples were haz-catted in the same manner the samples from drums and vats. However, since haz-cat tests are better suited to liquid matrix waste streams, the two waste piles were difficult to classify into general hazard categories.

Screening results indicated that the wastes were not water reactive, flammable, combustible, or chlorine-bearing; organic compounds were not detected. Results of the cyanide test were positive. Sample color and other visual signs of contamination were documented as the screening samples were collected.

3.3.4 Impoundment Screening and Sampling Equipment

Screening samples were collected from both surface impoundments. Waste liquids were sampled using a bacon bomb sampler, and waste bottom sludges were sampled using a Ponar dredge. Waste liquid samples were taken from the center of each impoundment at depths of 0 to 2 feet, and 2 feet to bottom. Five waste sludge samples were collected from the bottom of each impoundment at 20 foot intervals along a transect established across each impoundment. A small rowboat with stabilizing lines was moved along the transects to collect screening samples.

Impoundment liquids were screened by haz-catting. The results indicated that impoundment liquids contained water and were slightly acidic, possibly cyanide-bearing, non-flammable, and non-chlorinated. The PID and FID did not detect any organic vapors, suggesting a non-organic wastewater classification. A chemical test kit was used to identify low levels of specific metals in the impoundment liquids. Screening of the bottom sludge had similar results, except for a higher metals content and the positive presence of cyanide.

3.3.5 Transformer Screening and Sampling Equipment

The transformer top was removed using a standard socket wrench. A transformer fluid screening sample was collected using a makeshift sampling device consisting of a clean, 4-oz sampling jar on a string. The transformer was screened for PCBs using a PCB screening kit. A grab sample was collected and the test was performed on site following the directions provided with the kit. The potential interferences listed in the directions were determined not to apply to this sampling event. The test indicated that the transformer contained less than the 50 ppm total PCBs action level (based on a colorimetric interpretation). The sample fluid was placed back into the transformer and the vessel was resealed.

Figure 8: Example of a Hazard Categorization Data Sheet

HAZARD CHARACTERIZATION DATA Page ___ of ___

Site: ______________________________ Date: ______________

Sampler(s): _________________________ Sample ID Number: _________

Phase: All Top Bottom N/A Sample Collected?: Yes No

HAZARD CHARACTERIZATION RESULTS

Soluble: Yes (dissolves/emulsifies in water) Heavier (than water) Lighter (than water)

pH: _______ (if using instrument, round to nearest whole number)

Flammable: Yes No

Chlorine: Yes No

Oxidizer: Yes No

Cyanide: Yes No

Sulfide: Yes No

Other Test A: ____

Other Test B: ____

Action Taken: Overpacked Staged (location __________________) Bulked Other __________

Sort Class: _____________ (optional--specify 2 character alphanumeric designator to assign user sort class)

SAMPLE DESCRIPTION

Color(s): Colorless White Yellow Blue Red Green Purple Brown Black Other ________

Clarity: Clear Cloudy Turbid (suspended solids) Opaque N/A (if solid)

Viscosity: Water Light Oil Heavy Oil Sludge N/A (if solid)

Impurities: ____

Comments:

____

____

____

Observations by: ____________________________

4.0 FIELD SAMPLE COLLECTION AND PREPARATION

4.1 INTRODUCTION

During a response action, proper field sample collection and preparation is as important as proper sampling equipment selection. Sample collection refers to the physical removal of a portion of waste material from its source for the purpose of either screening or laboratory analysis. Field sample preparation refers to all aspects of sample handling from collection to the time the sample is received by the laboratory. This chapter provides information on sample collection and preparation for various waste types and sources.

4.2 SAMPLE VOLUME

The volume of a sample should be sufficient to perform all required laboratory analyses with an additional amount remaining for analysis of QA/QC samples (including replicate analyses). However, because waste samples are generally of high concentration, sample volumes should be kept to a minimum (to minimize disposal costs). The EPA method description and the laboratory receiving the sample should be consulted for specific volume requirements for each parameter.

Make an initial estimate of the volume or area of waste represented by each sample. When obtaining representative samples from waste which appears to be relatively homogeneous, note the total waste volume in cubic yards or gallons.

4.3 SOURCE SAMPLING

The following sections provide general information on sampling several types of waste sources, including drums, bulk storage tanks, lab packs, surface impoundments, waste piles, surfaces, and debris. For specific sampling information on these waste types, refer to the *Compendium of ERT Waste Sampling Procedures,* OSWER Directive 9360.4-07.

4.3.1 Drum Sampling

Each drum can have different contents and concentrations, so each must be considered a unique waste source. A site-wide representative sampling approach is not appropriate. Screening techniques should be used on the contents of each drum to determine compatibility. This haz-cat information can help determine whether bulking of wastes is technically and economically feasible.

Drums may be sampled in place or staged in rows prior to sampling, depending on their condition and accessibility. If drums are stacked, a forklift or grapple may be needed to move them for sampling. (If drums cannot be safely moved, sample only accessible drums.) When moving drums, document on a site sketch their original locations. Number all drums and record their label information on a drum log sheet (see Chapter 2, Figure 6). Research all label information to determine health and safety precautions, including use of appropriate PPE. It does not necessarily follow that the labels affixed to the drums represent their actual contents. (Drums are often reused without regard to proper rinsing and relabelling procedures.) Further categorization is necessary to determine or confirm drum contents accurately. Be particularly cautious with drums that have crystalline deposits or a precipitate around the bung or lid. Some chemicals form a potentially shock-sensitive, explosive, or reactive phase as they degrade or react over time (e.g., picric acid forms shock-sensitive crystals). Do not move drums in this condition!

Bulging or misshapened drums and those with unknown contents should be opened remotely. Rough handling can trigger reactions which may cause them to rupture. Open unknown or unstable drums remotely. If drums contain a combination of solid, liquid, or sludge wastes, separate sampling of each phase may be necessary using chemically compatible sampling equipment (e.g., COLIWASA or glass thief). Where wastes are stratified, sample the top stratum first to avoid mixing strata. Since each drum may contain a different type of waste, it is usually not possible to make composites from separate drums until the contents have been screened. As with most containers, drums should be sampled through upper bungs or openings whenever possible. Document contents, physical characteristics (e.g., color, viscosity) and field screening readings (e.g., FID, PID, CGI).

Refer to Section 2.11.1 for a discussion of judgmental sampling as it applies to drum sampling.

4.3.2 Bulk Storage Tank and Transformer Sampling

Bulk storage tank sampling involves many of the procedures and precautions noted for drum sampling. Number and document each tank, noting National Fire Protection Association (NFPA) 704 markings, if present. Document available information on vessel construction, tank location (e.g., in a tank farm), and the presence of any secondary containment. Estimate maximum tank volume using mathematical volume equations ($V=Br^2h$) or tank charts. Measure the content volume using exterior level indicators, if present.

Perform sampling through top hatches whenever possible; avoid using bottom valves because a spill is possible if the valve does not reseal. When there is more than one phase, identify the distinct phases and associated volumes. The objective is to identify volume in gallons (liquids) or cubic yards (solids) to determine the total waste volume that each sample represents. Sample each phase separately, including tank bottom sludges (use a bacon bomb sampler, PACS grab sampler, or a sludge judge). Obtain a sample from each compartment in multicompart-ment tanks.

When sampling specialized tanks or transformers, it may be necessary to use a manlift to gain access. Be certain that transformers are "off-line" and de-energized. Exercise spill control measures and ensure secondary containment is in place around a transformer before opening it. Access a transformer through the top and collect a stratified sample.

4.3.3 Lab Pack Sampling

Initial inspection of lab packs may uncover packing slips listing contents and associated volumes. The packing slips may be affixed to the outside of the drum or under the drum lid. If the labels on individual containers are legible, inventory the containers and repackage them in inert cushioning and absorbent materials in accordance with 49 CFR 100-199. If the label is illegible or missing, the lab pack should be treated as an unknown. Unknowns are generally not manually opened because of the potential health and safety risks (exposure and reactivity). A safer approach is to use remote opening or crushing techniques and collecting the crushed containers and their contents in an absorptive medium, which is then sampled using a representative composite sampling method.

4.3.4 Surface Impoundment Sampling

When sampling a surface impoundment, consider its characteristics, which include size, depth, flow, liquid viscosity, bottom composition and whether a liner is present. The bottom sludges and liquid phases may be homogeneous or stratified.

Surface impoundments are often stratified by depth; each phase should be sampled separately. Transect sampling at various depths (including bottom sludge sampling) is generally recommended. Horizontal concentration gradients in the bottom sludges may be present from the point where liquids enter the impoundment. Vertical gradients may also be present in bottom sludges. The logistics and health and safety concerns of sampling large impoundments usually dictate the use of manlifts, boats, and safety lines. If a liner is present, take care to maintain its integrity.

4.3.5 Waste Pile Sampling

Waste pile sample collection techniques will depend upon the sampling objective. If the objective is to determine threat, grab sampling from the surface using a waste pile sampler or a scoop/trowel might be sufficient. If the objective is to obtain an average concentration value for the entire pile for treatment/disposal estimates, then the sampling should include grab samples or composite aliquots collected from the interior (using a waste pile sampler or an auger) and the surface of the pile. Composite aliquots collected at a given depth from several sides and the top of the pile can be used to obtain an estimate of the average pile concentration. The number of aliquots collected will depend on many site-specific factors, including the size, composition, and accessibility of the waste pile, as well as on budget considerations.

The surface of a pile continually weathers chemically and physically. Depending on the size of the pile, it may be divided into sections for compositing at various depths. This will define an average concentration for each section of the pile. For large piles (e.g., large impoundment dredge or slag piles), a three-foot depth is generally adequate to reach the more representative materials. Extensive sampling of a pile for both chemical and physical characteristics is conducted during the evaluation of treatment and disposal options. If the pile has been stabilized (e.g., cover, liner), do not collect samples that might breach the integrity of the pile containment.

4.3.6 Surface Sampling

Special situations may present the need to sample surfaces such as floors, walls, or equipment. When sampling surfaces for contamination, choose sampling points based on site history, manufacturing processes, personnel practices, obvious contamination, and available surface area. Where possible, collect comparable media background samples from surfaces unlikely to have been contaminated. This is especially important when sampling for naturally occurring substances such as metals.

Surface sampling includes wipe, chip, and dust sampling. Analytical results for dust sampling are reported in weight/weight; wipe sampling results are reported in weight per unit area. Note that there are very few action levels or health standards reported in weight of contaminant per unit area to assist a Site Manager in decision-making.

The methods of sampling described below are appropriate for surfaces contaminated with non-volatile species of analytes (e.g., PCBs, PCDD, PCDF, metals, pesticides, cyanide). Detection limits are analyte-specific. Determine sample size based upon the detection limit desired, amount of sample requested by the analytical laboratory, and sampling locations and configuration.

Wipe Sampling

Wipe sampling is a method for collecting non-volatile species of analytes from relatively smooth, non-porous surfaces. It is appropriate for sampling walls, floors, ventilation ducts and fans, empty transformers, process equipment, and vehicles. Wipe sampling can be used to confirm cleanup after steam cleaning or decontamination of smooth building walls.

To collect a wipe sample, use a piece of sterile medical gauze soaked in pesticide grade solvent (e.g., hexane, water, methanol, nitric acid). The type of solvent used depends on the target analytes. When requested in advance, analytical laboratories will often prepare the gauze and sample jars. Use caution and maintain proper safety protocols when handling hexane and other solvents.

Several wipe sampling techniques were developed for use in OSHA enforcement and industrial hygiene decision-making to evaluate potential sources of ingestion and direct contact exposures. Most of these techniques recommend a uniform wipe area of at least 100 cm^2, but larger areas may need to be wiped to collect enough sample for the analytical method detection limit. Disposable cardboard templates (or glass or stainless steel templates which can be decontaminated) are recommended to ensure a uniform surface area. Very few approved standards or action levels are available to compare with the wipe sampling results (this supports qualitative rather than quantitative conclusions). Wipe sampling is typically used to determine if decontamination has been effective or to select the type of disposal facility (e.g. hazardous vs. non-hazardous). A blank consisting of a solvent-soaked pad is required for each batch of samples.

Sampling locations are typically judgmental selections. They are chosen because they are areas of highest suspected contamination (for disposal decisions), or areas of suspected direct contact (for exposure and hygiene evaluations).

Chip Sampling

Chip sampling is a method for collecting non-volatile species of analytes from porous surfaces such as cement, brick, or wood. Sample points include floors near process areas, storage tanks, and loading dock areas. Chip sampling is usually performed with a hammer and chisel or with an electric hammer. It is important to ensure that the chipping device does not bias the integrity of the sample. Stainless steel tools allow for easy decontamination and preparation for reuse.

To collect the sample, chip the desired sampling area to a suitable depth (e.g., 1/8 inch). Gather the chips and place them in a sample container using forceps, a small scoop, or a dust pan. Make advance arrangements with the analytical laboratory prior to sampling to determine acceptable preparation and analysis procedures. The laboratory may require special grinding or extraction procedures.

Chip sampling is most often used to determine the necessity or effectiveness of decontamination, or the necessity for demolishing and disposing of a wall or building. As with wipe sampling, existing action levels may not be available for each application. Make appropriate decisions based on precedents and Regional guidelines.

Dust Sampling

Dust sampling is a method for collecting metal and semi-volatile contaminants in residue or dust found on porous or non-porous surfaces. Dust sampling techniques are used where a solvent cannot be used or where too much residue exists for a wipe sample to be easily collected. Dust sampling is used in industry to assess potential exposure of airborne contaminants to workers. For example, dust sampling would be effective in a bagging, processing, or grinding area where powdery contaminants and dust may have accumulated.

To collect a dust sample, select and sweep an appropriate area using a dedicated brush and dust pan. Transfer the sample to a sample container. Dust sampling can also be conducted using a cellulose fiber filter attached to a high-volume pump. Dust/residue is vacuumed onto the filter.

Dust sampling results are reported in mg/kg (weight/weight). The size of the area to be swept is dependent on the sample volume needed for the desired analysis and detection level. Dust sampling is often used to assess potential respiratory, direct contact, and ingestion hazards to workers and the public. It may also be used to determine the need and method for building decontamination.

4.3.7 Debris Sampling

The purpose of sampling waste debris is to select a disposal option. Since debris often consists of irregular pieces of material, it is a difficult matrix to analyze in the laboratory. Provide the laboratory with instructions to guide it in preparing a representative subaliquot of debris samples for analysis.

Currently there are no standardized methods that reliably conserve VOCs during the grinding of large objects, nor are there good methods for extracting non-polar organic contaminants from plastic matrices without dissolving the plastic.

Use a judgmental sampling approach to sample debris, selecting sampling locations by matrix and physical properties. Use a chip sampling technique for porous materials and wipe sampling for non-porous materials. It is difficult to collect a representative sample of debris because of its heterogeneous composition. Compositing large objects will not result in meaningful data, and obtaining a sample of different components of debris is not always practical. Only if feasible, separate debris into components (e.g., metal, plastic, wood) and collect a representative surface sample of each.

4.3.8 Compressed Liquid/Gas Cylinders

Although dealing with compressed liquid/gas cylinders is outside the scope of this document, they are often found at waste sites. Compressed liquids and gases are stored in a variety of low- and high-pressure vessels or cylinders. Though the liquids or gases in the cylinders are rarely considered to be waste, the original cylinder may have been weakened by exposure to heat, pressure, or outside contamination. Cylinders represent a chemical, explosion/fire, and projectile hazard. Compressed liquids and gases, especially those in cylinders, should be sampled only by specialists.

4.4 SAMPLE PREPARATION

Sample preparation depends on the sampling objectives and analyses to be performed. Proper sample preparation and handling maintain sample integrity. Improper handling can render samples unsuitable for analysis. For example, homogenizing and compositing samples result in a loss of volatile constituents and are thus inappropriate when volatile contaminants are of concern. Sample preparation for waste may include, but is not limited to:

- Removing extraneous material
- Homogenizing
- Splitting
- Final preparation

Another field preparation technique is compositing of samples, which requires that each discrete aliquot be equal, and that the aliquots be thoroughly homogenized. Compositing waste samples is discussed in detail in Section 2.3.2.

4.4.1 Removing Extraneous Material

During sample collection, identify and discard materials from the sample which are not relevant or vital for characterizing the site, since their presence may introduce an error into the sampling or analytical procedures. Examples of extraneous material include pieces of glass, twigs, or leaves. However, not all external materials are extraneous. For example, when sampling at a junkyard, lead-contaminated battery casing pieces should not be removed from a sample if the casing comprises more than 10 percent of the sample volume. (For such a sample to be representative, it must incorporate the lead from the casing.) Collect samples of any material thought to be a potential source of contamination. Discuss any special analytical requirements for extraneous materials with the project team (project management, geologists, and chemists), and notify the laboratory of any special sample handling requirements or method changes.

4.4.2 Homogenizing

Homogenizing is the mixing or blending of a grab or composite sample to distribute contaminants uniformly within the sample. Ideally, proper homogenizing ensures that all portions of the sample are equal or identical in composition and are representative of the total sample collected. Incomplete homogenizing can introduce sampling error. Homogenizing requires additional handling of the waste and is not appropriate for all wastes. Unless layered, liquid wastes can be assumed to be homogeneous and do not require additional mixing. If they occur in phases, treat each phase as a unique homogeneous medium and sample each separately, as discussed in Section 2.3.1. Solid samples that will be composited should be homogenized after all aliquots have been combined. Manually homogenize solid and sludge samples using a stainless steel spoon or scoop and a stainless steel bucket or pyrex bowl, or use a disposable plastic scoop and pan, depending on the analyses. Do not homogenize samples for VOC analysis.

4.4.3 Splitting

After collection and field preparation, samples are split into two or more equivalent parts when two or more portions of the same sample need to be analyzed separately. Split samples are most often collected in enforcement actions to compare sample results obtained by EPA with those obtained by the potentially responsible party. Split samples also provide measures of sample variability and analytical error. Before splitting, follow the homogenization techniques outlined above. Fill two sample collection jars at the same time, alternating spoonfuls (or scoopfuls) of homogenized sample between them. Samples for VOC analysis should not be homogenized; instead, collect two uniform samples concurrently from the same location (collocated).

4.4.4 Final Preparation

Select sample containers on the basis of compatibility with the material being sampled, resistance to breakage, and capacity. Appropriate sample volumes and containers will vary according to the parameters being analyzed. Actual sample volumes, appropriate containers, and holding times are specified in the U.S. EPA *Quality Assurance/Quality Control (QA/QC) Guidance for Removal Activities,* EPA/540/G-90/004, April 1990, in 40 CFR 136, and in the *Compendium of ERT Waste Sampling Procedures,* OSWER Directive 9360.4-07. Package all samples in compliance with current International Air Transport Association (IATA) or Department of Transportation (DOT) requirements, as applicable. Packaging should be performed by someone trained in current DOT shipping procedures.

Specific handling techniques may be required for physical parameters such as permeability or particle size distribution. Preservation of the original sample conditions will determine in part the representativeness of the analytical results. Permeability is affected by evaporation and by thermal variations; particle size is affected by handling. In general, cooling samples can help maintain original conditions; however, wastes are often of such high concentration that cooling a sample is not necessary.

4.5 EXAMPLE SITE

Table 1 is a sample log for the ABC Plating site, illustrating the parameters used by the analytical laboratory to evaluate each waste source. The analytical results provided preliminary information on waste composition plus data necessary to begin clean-up strategy and treatment/disposal planning. The sampling objective of the initial assessment was to establish threat.

4.5.1 Source Sampling

The following is a detailed description of the sampling activities listed in Table 1.

Drum Sampling

Samples were collected from three drums tentatively identified from screening results as containing cyanide bases. They were sent for laboratory analysis of free and total cyanide, TCL organic compounds, and metals. Each sample was collected using a COLIWASA sampler which preserved phase layers that were present.

Vat Sampling

Samples were collected from two vats which were tentatively identified as containing cyanide bases. They were sent for laboratory analysis of free and total cyanide and metals. Vat samples were assumed to be relatively homogeneous and were collected using a COLIWASA-style glass thief.

Waste Pile Sampling

Two composite samples were collected (one from each waste pile) for laboratory analysis of free and total cyanide and metals. For each pile, four aliquots were collected from 12-inch depths at equally-spaced points located along the previously established transect. Sample aliquots were collected with a corkscrew auger and a hard plastic scoop. Aliquots from each pile were composited in separate disposable plastic trays.

Impoundment Sampling

Two waste liquid samples and five waste bottom sludge samples were collected from each impoundment. Waste liquids were analyzed in the laboratory for full TAL substances and the waste sludges were laboratory analyzed for full TCL substances. Sample locations and techniques were identical to those chosen for initial screening (Section 3.3.4). Waste liquid samples were collected using a bacon bomb sampler and waste sludge samples were collected with a Ponar dredge.

Surface Sampling

Non-porous walls and the concrete slab floor in the plating building were wipe and chip sampled, respectively. A one-square foot template was used to mark each area for wipe sampling. Sterile gauze pads soaked in hexane were used to collect four samples from non-porous walls. Four chip samples were collected from the floor using block hammers and chisels. Wipe and chip samples were analyzed for metals and cyanide to determine if the facility block walls and concrete floor needed to be sent to a secure or sanitary chemical landfill.

4.5.2 Sample Preparation

Removing Extraneous Material

Drum, vat, and impoundment liquid samples did not contain extraneous material. Stones and small pieces of stainless steel wire were removed from solid samples collected from the waste pile, but clumps of blue-green solid material were not removed. Based on screening data and knowledge of plating processes, the clumps were suspected to be plating solids containing high concentrations of metals and possibly cyanide. Sticks and other extraneous materials (e.g., plastic and metal objects) were discarded from dredged impoundment sludge samples. The presence of extraneous materials was documented for later consideration during treatment/disposal technology evaluation.

Homogenizing Samples

Homogeneity was assumed for most liquid samples, since plating processes require homogenous solutions to promote for even ion movement and uniformity of the coating. The liquid samples which appeared to be uniform were not homogenized. Several drums containing liquid materials had distinct phases present which were visible in the glass thieves during sampling. Each phase was sampled separately using a COLIWASA. The solid waste piles and impoundment sludge samples were homogenized after screening results indicated a lack of volatile organic compounds. Since metals were a primary concern at the site, pyrex mixing bowls (instead of disposable aluminum pans) were used to homogenize samples.

Splitting Samples

At the request of the State, all initial containerized and impoundment waste samples were split during the removal assessment. The split samples were preserved and labelled, then chain of custody papersand samples were signed over to an on-site state representative.

Table 1: ABC Plating Sample Log

Sampling Locations	Number of Samples	Analytical Parameters
Plating Vats	2	metals, cyanide
Drums	3	metals, cyanide, full TCL substances
Waste Piles	2	metals, cyanide
Impoundment Liquids	4	full TAL substances
Impoundment Sludges	10	full TCL substances
Surfaces	8	metals, cyanide

5.0 QUALITY ASSURANCE/QUALITY CONTROL

5.1 INTRODUCTION

The goal of representative sampling is to obtain analytical results that accurately depict site conditions during a given time. The goal of quality assurance/quality control (QA/QC) is to implement correct methodologies which limit the introduction of error into the sampling and analytical procedures, and ultimately into the analytical data.

QA/QC samples evaluate three types of information: 1) the degree of site variation; 2) whether samples were cross-contaminated during sampling and sample handling procedures; and 3) whether a discrepancy in sample results is a result of laboratory handling and analysis procedures.

5.2 DATA CATEGORIES

EPA has established data quality objectives (DQOs) which ensure that the precision, accuracy, representativeness, and quality of environmental data are appropriate for their intended application. Superfund DQO guidance defines two broad categories of analytical data: *screening* and *definitive*.

Screening data are generated by rapid, less precise methods of analysis with less rigorous sample preparation. Sample preparation steps may be restricted to simple procedures such as dilution with a solvent, rather than elaborate extraction/digestion and cleanup. At least 10 percent of the screening data are confirmed using the analytical methods and QA/QC procedures and criteria associated with definitive data. Screening data without associated confirmation data are not considered to be data of known quality To be acceptable, screening data must include the following: chain of custody, initial and continuing calibration, analyte identification, and analyte quantification. Streamlined QC requirements are the defining characteristic of screening data.

Definitive data are generated using rigorous analytical methods (e.g., approved EPA reference methods). These data are analyte-specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data (e.g., chromatograms, spectra, digital values) in the form of paper printouts or computer-generated electronic files. Data may be generated at the site or at an off-site location, as long as the QA/QC requirements are satisfied. For the data to be definitive, either analytical or total measurement error must be determined. QC measures for definitive data contain all of the elements associated with screening data, but also may include trip, method, and rinsate blanks; matrix spikes; performance evaluation samples; and replicate analyses for error determination.

For further information on these QA/QC objectives, please refer to EPA's *Quality Assurance/Quality Control Guidance for Removal Activities* or EPA's *Data Quality Objectives Process for Superfund.*

5.3 SOURCES OF ERROR

The four most common potential sources of data error in waste sampling are:

- Sampling design
- Sampling methodology
- Sample heterogeneity
- Analytical procedures

5.3.1 Sampling Design

Waste samples are often heterogeneous. Waste components separate into phases or layers by specific gravity and solubility. For example, an impoundment may have an oily layer on top and relatively contaminant-free water below. Failure to account for differences in composition of multiple phases can introduce sampling error. The sampling design must account for all phases and strata which may contain hazardous substances.

The sampling design should utilize approved SOPs and previously approved sampling designs to ensure uniformity and comparability between samples. The actual sample collection process should be determined prior to sampling. All samples should be collected using a uniform surface area and/or depth to ensure data comparability. Sampling equipment must be standardized for like sampling situations.

The sampling design should fulfill sampling and data quality objectives. The QA objectives selected should be built into the sampling design, including all necessary QA/QC samples.

5.3.2 Sampling Methodology

Sampling methodology and sample handling procedures have possible sources of error, including: cross-contamination from inappropriate use of sample collection equipment; unclean sample containers; improper sampling equipment decontamination; and improper shipment procedures. Procedures for collecting, handling, and shipping samples should be standardized to allow easier identification of any source(s) of error, and to minimize the potential for error. Use SOPs to ensure that all given sampling techniques are performed in the same manner, regardless of the individual sampling team, date, or location of sampling activity. Use field blanks, replicate samples, trip blanks, and rinsate blanks to identify errors due to improper sampling methodology and sample handling procedures.

Site screening and haz-catting often employ kits or "cookbook" procedures requiring interpretations based on chemical reactions which produce a color change. The degree of subjectivity inherent in interpretation, and the complexity of some of the procedures, introduce a significant source of potential error.

5.3.3 Sample Heterogeneity

Wastes may become heterogeneous through vaporization, settling, solubility, migration, or addition of new wastes over time. Identify heterogeneity by obtaining several samples or composite aliquots from various depths.

Waste sources vary both in type and in concentration level. Incorporate representative sampling techniques into the sampling design to identify and define this variation accurately. Collect a grab sample of each phase or stratum suspected of containing contaminants of concern; the samples will be relatively homogeneous and representative of their respective phases. For example, if an impoundment has three liquid phases and sludge on the bottom, collect one sample of each liquid phase and a sample of the bottom sludge.

5.3.4 Analytical Procedures

Analytical procedures may introduce errors from: laboratory cross-contamination; inefficient extraction; and inappropriate methodology. High concentration waste samples tend to foul analytical equipment, which can lead to poor data reproducibility. Matrix spike, laboratory duplicate, performance evaluation, and laboratory control samples help to distinguish analytical error from sampling error.

5.4 QA/QC SAMPLES

QA/QC samples are collected at the site or prepared for or by the laboratory. Analysis of the QA/QC samples provides information on the variability and usability of waste sampling data, indicates possible field sampling or laboratory error, and provides a basis for future validation and usability of the analytical data. The most common field QA/QC samples are field replicate, background, and rinsate blank samples. The most common laboratory QA/QC samples are performance evaluation, matrix spike (MS), and matrix spike duplicate (MSD) samples. QA/QC results may suggest the need for modifying sample collection, preparation, handling, or analytical procedures if the resultant data do not meet site-specific quality assurance objectives.

Waste is typically characterized by high concentrations of contaminants, making precision and accuracy less important than for samples with lower concentrations (e.g., water, air). This eliminates the need for frequent field blanks. In addition, contaminant concentrations in waste samples are often several orders of magnitude higher than the concentrations of standard laboratory QA/QC mixes, which may render them useless in measuring laboratory error. The laboratory spikes are not detected because of masking caused by the high sample concentrations. Fouling of analytical equipment associated with high concentration samples may occur. Analytical error in waste sampling can be measured by performance evaluation samples and laboratory control samples, which are not subject to matrix interferences.

Refer to data validation procedures in U.S. EPA *Quality Assurance/Quality Control (QA/QC) Guidance for Removal Activities,* EPA/540/G-90/004, April 1990, for guidelines on utilizing QA/QC analytical results. The following sections briefly describe the types of QA/QC samples appropriate for waste sampling.

5.4.1 Field Replicate Samples

Field replicates, also referred to as field duplicates and split samples, are field samples obtained from one sampling point, homogenized (where appropriate), divided into separate containers, and treated as separate samples throughout the remaining sample handling and analytical processes. Use replicate samples to assess error associated with sample heterogeneity, sample methodology, and analytical procedures. Field replicates can also be used when determining total error for critical samples with contamination concentrations near the action level. In such a case, a minimum of eight replicate samples is recommended for valid statistical analysis. Field replicates may be sent to two or more laboratories or to the same laboratory as unique samples. For total error determination, samples should be analyzed by the same laboratory.

5.4.2 Collocated Samples

A collocated sample is collected from an area adjoining a field sample to determine local variability of the waste. Collocated samples of solids, such as waste pile samples, are situated side by side. Collocated samples of liquids, such as vat samples, are collected from the same location and depth. Collocated samples are collected and analyzed as discrete samples; they are not composited. Because of the non-homogeneous nature of many waste sources, collocated samples should not be used to assess variability within a large source and are not recommended for assessing error. Determine the applicability of collocated samples on a site-by-site and source-by-source basis.

5.4.3 Background Samples

Waste sampling typically involves containerized or relatively immobile waste streams. Background sampling, which is appropriate when sampling soil, surface water, groundwater, and air, has less application to waste sampling. In some cases (e.g., uncontainerized waste) soil samples from uncontaminated areas can serve as background samples for waste sampling. Background samples are appropriate for some surface sampling applications, as discussed in Section 4.3.6.

5.4.4 Performance Evaluation/ Laboratory Control Samples

A performance evaluation (PE) sample evaluates the overall error contributed by the analytical laboratory and detects any bias in the analytical method being used. PE samples contain known quantities of target analytes manufactured under strict quality control. They are usually prepared by a third party under an EPA certification program. The samples are usually submitted "blind" to analytical laboratories (the sampling team knows the contents of the samples, but the laboratory does not). Laboratory analytical error may be evaluated by the percent recoveries and correct identification of the components in the PE sample.

A blind PE sample may be included in a set of split samples provided to the PRP. The PE sample will measure PRP laboratory accuracy, which may be critical during enforcement litigation.

A laboratory control sample (LCS) also contains known quantities of target analytes in certified clean water. In this case, the laboratory knows the contents of the sample; the LCS is usually prepared by the laboratory. PE and LCS samples are not affected by waste matrix interference, and thus can provide a clear measure of laboratory error.

5.4.5 Matrix Spike/Matrix Spike Duplicate Samples

Matrix spike and matrix spike duplicate samples (MS/MSDs) are field samples that are spiked in the laboratory with a known concentration of a target analyte(s) in order to determine percent recoveries in sample extraction. The percent recovery from MS/MSDs indicates the degree to which matrix interferences will affect the identification of a substance. MS/MSDs can also be used to monitor laboratory performance. When four or more pairs of MS/MSDs are analyzed, the data obtained may also be used to evaluate error due to laboratory bias and precision. Analyze one MS/MSD pair to assess bias for every 20 samples, and use the average percent recovery for the pair. To assess precision, analyze at least 8 matrix spike replicates from the same sample, and determine the standard deviation and the coefficient of variation. See pages 9-10 of the *U.S. EPA Quality Assurance/Quality Control (QA/QC) Guidance for Removal Activities*, April 1990, for directions on calculating analytical error. MS/MSDs are recommended for screening data and are required as one of several methods for determining analytical error for definitive data. Since the MS/MSDs are spiked field samples, provide sufficient volume for three separate analyses. Because the spiking solutions used in MS/MSDs are often obscured by high concentrations of contaminants or by matrix effects, the usefulness of MS/MSDs for high concentration samples may be limited.

5.4.6 Rinsate Blank Samples

A rinsate blank is used to assess cross-contamination from improper equipment decontamination procedures. Rinsate blanks are samples obtained by running analyte-free water over decontaminated sampling equipment. Any residual contamination should appear in the rinsate sample data. Analyze the rinsate blank for the same analytical parameters as the field samples collected that day. Handle and ship the rinsate like a low-concentration field sample. Where dedicated sampling equipment is not utilized, collect one rinsate blank per sampling batch per day.

5.4.7 Field Blank Samples

Field blanks are samples prepared in the field using certified clean water or sand which are then submitted to the laboratory for analysis. A field blank is used to evaluate contamination or error associated with sampling methodology, preservation, handling/shipping, and laboratory procedures. For high-concentration samples, the usefulness of field blanks is limited. Parts per billion (ppb) or low parts per million (ppm) error has little significance when identifying high concentration wastes or addressing action levels in the hundreds of ppm. If available and appropriate, submit one field blank per day.

5.4.8 Trip Blank Samples

Trip blanks are samples prepared prior to going into the field. They consist of certified clean water or sand, and are not opened until they reach the laboratory. If available, utilize trip blanks to meet QA objectives for volatile organic analyses only. Handle, transport, and analyze trip blanks in the same manner as the other volatile organic samples collected that day. Trip blanks are used to evaluate error associated with sampling methodology, shipping and handling, and analytical procedures, since any volatile contamination of a trip blank would have to be introduced during one of those procedures. Since waste samples are often high concentration, trip blanks are not typically used during waste sampling.

5.4.9 Laboratory Duplicate Samples

A laboratory duplicate is a sample that undergoes preparation and analysis twice. The laboratory takes two aliquots of one sample and analyses them as separate samples. Comparison of data from the two analyses provides a measure of analytical reproducibility within a sample set. Discrepancies in duplicate analyses may indicate poor homogenization in the field or other sample preparation error, either in the field or in the laboratory. The benefit of laboratory duplicates in waste sampling may be limited. High concentration waste samples may foul analytical equipment and result in unavoidably poor reproducibility. Laboratory duplicates of high concentration waste samples should not be used to measure laboratory performance.

5.5 EVALUATION OF ANALYTICAL ERROR

Analytical error becomes significant in decision-making as sample results approach the action level. The acceptable level of error is determined by the intended use of the data and litigation concerns. Definitive data require quantitative measurement of analytical error with PE samples and replicates. The other QA samples identified in this section can indicate a variety of qualitative and quantitative sampling errors. As discussed earlier, error in the ppb or low ppm range may not be of concern when analyzing high concentration wastes.

5.6 CORRELATION BETWEEN FIELD SCREENING RESULTS AND LABORATORY RESULTS

A cost-effective approach for evaluating wastes and waste sources is to compare inexpensive field screening data and other field measurements (e.g., XRF) with laboratory results. This relies in part on statistical correlation, which involves computing an index called the correlation coefficient (r) that indicates the degree and nature of the relationship between two or more sets of values. The correlation coefficient ranges from -1.0 (a perfect inverse or negative relationship), through 0 (no relationship), to +1.0 (a perfect direct or positive relationship). The square of the correlation coefficient, called the coefficient of determination, R^2, is an estimate of the proportion of variance in one variable (the dependent variable) that can be accounted for by the independent variables. An acceptable R^2 value depends on the sampling objectives and intended data uses. As a rule, statistical relationships should have an R^2 value of at least 0.6 to determine a reliable model. For health or risk assessment purposes, the acceptable R^2 value may be more stringent (e.g., 0.6). Analytical calibration regressions have an R^2 value of 0.98 or greater. Once a reliable regression equation has been derived, the field screening data can be used to predict laboratory results. These predicted values can then be located on a base map and contoured (mapping methods are described in Section 6.4). The contour maps can illustrate the estimated extent of contamination (for certain waste sources) and the adequacy of the sampling program.

5.7 EXAMPLE SITE

5.7.1 QA Objectives

Screening data, which generate non-definitive, unconfirmed results (e.g., total hydrocarbons, total halogens, cyanide, PCBs) were used to select analytical parameters. Samples were sent to the analytical laboratory under protocols which provided definitive data. The rigorous laboratory analyses provided definitive identification and quantitation of contaminants (e.g., 50 ppm benzene, 110 ppm total chromium, 75 ppm total cyanide).

5.7.2 Sources of Error

All direct reading instruments were maintained and calibrated in accordance with their instruction manuals. Many of these instruments are class-specific (e.g. volatile organic vapors) with relative response rates that are dependent on the calibration gas selected. Instrument response to ambient vapor concentrations may differ by an order of magnitude from response to calibration standards. If compounds of interest are known, site-specific standards may be prepared; they are most applicable for field gas chromatographs (GCs). These standards can be prepared on site in a gas bag or flask, but have limited holding times. Preparation of standards on site introduces its own potential error. For sites of long duration, specialty mixtures may be ordered from a specialty gas company or an analytical laboratory.

The number and location of initial field samples were based on observation and professional judgment (as outlined in Section 2.8). Liquid wastes in the vats, impoundments, and transformers were assumed to be homogeneous because there were no visible phases. (An erroneous observation could introduce significant error into the sampling design.)

Field standard operating procedures, documented in the site sampling plan, established consistent screening and sampling procedures among all samplers. This reduced the chances for variability and error during sampling. Site briefings were conducted prior to all sampling and screening events to review the use of proper screening and sampling techniques.

Other steps taken to limit error included proper sample preparation, adherence to sample holding times, and the use of proper shipment procedures. All off-site laboratory sample analyses were performed using EPA standard methods and protocols.

5.7.3 Field QA/QC Samples

Few field QA/QC samples were collected during waste sampling at the ABC Plating site. For the low-concentration impoundment liquids, a PE sample for metals was sent to the laboratory. (The PE sample is not affected by matrix interferences.) Field and trip blanks were not applicable since they are used to determine cross-contamination of low concentration samples. Cross-contamination that may occur during storage and shipping is minimal compared to the high ppm or percent level concentrations which are typically found in plating wastes. Nevertheless, suspected high concentration samples were shipped separately from the low level samples. One rinsate blank sample was collected from the impoundment sampling equipment (dredge and bacon bomb samplers) to check for cross-contamination during equipment decontamination.

5.7.4 Laboratory QA/QC Samples

Instructions on matrices, target compounds, and QA/QC criteria of particular interest were provided to the laboratory to help ensure that analytical results met the required objectives. The laboratory was instructed to run a duplicate of LCS samples for each batch of high concentration liquid vat samples to check reproducibility of the laboratory results. A matrix spike was not requested because the level of error measured by the standard low/medium spiking mixtures did not apply to the expected high concentrations in the samples. The laboratory analyzed the metals using the methods of inductively coupled plasma (ICP) spectrometry and atomic absorption (AA). The presence of cyanide was confirmed in the laboratory using total and amenable cyanide analyses (colorimetric manual method, SW-846 Method 9010).

PE sample results indicated low recoveries for some metals. The difference between LCS duplicate results was within the acceptable range, so these results were used as estimates with a low bias. The confirmation by a second method on 10 percent, or one per batch, of the high concentration samples indicated acceptable accuracy.

The waste pile was thought to be vat bottom materials of high contaminant concentrations, therefore a matrix spike was not requested. An LCS duplicate was used to evaluate the reproducibility of the results and to establish if the solid samples were homogeneous. Agreement between the LCS duplicates indicates good laboratory precision. When results of the LCS and LCS duplicate correlate, but the field replicates do not, two possible errors are indicated: either the matrix interfered with recovery, or there was poor sample homogenization in the field. The laboratory does not homogenize samples unless specified in the analytical method.

For the impoundment samples, matrix spike and LCS duplicate samples were used. Matrix spikes are applicable since the impoundment samples have a lower concentration than the vat samples. Matrix spike recoveries for certain metals were low. However, LCS results were within control limits, indicating good laboratory performance.

6.0 DATA PRESENTATION AND ANALYSIS

6.1 INTRODUCTION

Data presentation and analysis techniques are performed with analytical, field screening, or geophysical results. The techniques discussed below can be used to compare analytical values, to evaluate numerical distribution of data, and to reveal the location of "hot spots" and the extent of contamination at a site. The appropriate methods to present and analyze sample data depend on the sampling objectives, the number of samples collected, the sampling approaches used, and other considerations.

6.2 DATA POSTING

Data posting involves placement of sample values on a site base map or cross-section. Data posting is useful for displaying the distribution of sample values, visually depicting the location of wastes with associated assessment data. Data posting requires each sample to have a specific location (e.g., *x*, *y*, and sometimes *z* coordinates). Ideally, the sample coordinates are surveyed values or inventoried and numbered containers, facilitating placement on a scaled map. Data posting is useful for depicting concentration values of non-containerized wastes and surfaces, but has limited application to containerized wastes.

6.3 CROSS-SECTION/FENCE DIAGRAMS

Cross-section diagrams (two-dimensional) and fence diagrams (three-dimensional) depict layers or phases of wastes in sources such as tanks and impoundments. Two-dimensional cross-sections may be used to illustrate vertical profiles of waste concentrations in containerized wastes or impoundments. For solid wastes in waste piles, three-dimensional fence diagrams are often used to interpolate data between sampling locations. Solid wastes in waste piles do not usually form horizontal layers, so fence diagrams based on a few sampling points may not be representative. Both cross-sections and fence diagrams can provide useful visual interpretations of contaminant concentrations.

6.4 CONTOUR MAPPING

Contour maps are useful for depicting contaminant concentration values in waste piles or impoundments. Contour mapping requires an accurate, to-scale basemap of the site. After data posting sample values on the basemap, insert contour lines (or isopleths) at a specified contour interval, interpolating values between sample points. Contour lines can be drawn manually or can be generated by computer using contouring software. Although the software makes the contouring process easier, computer programs have a limitation: as they interpolate between data points, they attempt to "smooth" the values by fitting contour intervals to the full range of data values. This can result in a contour map that does not accurately represent general site contaminant trends. Typical waste sites have low concentration/non-detect areas and "hot spots." If there is a big difference in concentration between the waste "hot spot" and the surrounding area, the computer contouring program, using a contour interval that attempts to smooth the "hot spots," may eliminate most of the subtle site features and general trends. For waste sampling, contouring may apply only to large waste piles and impoundments.

6.5 STATISTICAL GRAPHICS

If using statistical interpretation, the distribution or spread of the data set is important in determining which statistical techniques to use. Common statistical analyses, such as the t-test, rely on normally distributed data. The histogram is a statistical bar graph which displays the distribution of a data set. A normally distributed data set takes the shape of a bell curve, with the mean and median close together about halfway between the maximum and minimum values. A probability plot depicts cumulative percent against the concentration of the contaminant of concern. A normally distributed data set, when plotted as a probability plot, would appear as a straight line. A histogram or probability plot can be used to see trends and anomalies in the data from a waste source (e.g., impoundment) prior to conducting more rigorous forms of statistical analysis. As with contour mapping, statistical data interpretation applications for waste are limited.

6.6 RECOMMENDED DATA INTERPRETATION METHODS

The data interpretation methods chosen depend on project-specific considerations, such as the number of sampling locations and their associated range in values. Data which are dissimilar in composition (e.g., drums with different chemicals or different waste media) should not be compared using statistical interpretation methods. Data posting, screening, and sampling data sheets, and cross-section/fence diagrams may be appropriate. A site feature depicting extremely low data values (e.g., non-detects), together with significantly higher values (e.g., 5000 ppm) from neighboring "hot spots" with little or no concentration gradient in between, does not lend itself to contouring.

6.7 EXAMPLE SITE

Figure 9 illustrates a transect of impoundment No.1 in a two-dimensional cross-section. The sampling intervals are indicated by the twenty foot markings along the transect of the cross-section. Analytical results were data posted on the cross-section to illustrate contaminant trends. Contaminant volume can be visualized by depicting both the sludge layer and impoundment bottom. The bottom sludges contained 300 to 427 ppm total chromium; other parameters exhibited a similar concentration gradient range.

Table 2 presents the haz-catting results of all containerized waste and waste piles on site. This table was generated as the initial step in analyzing the data prior to posting on the base map and lists results from several different tests. These data were then posted on the base map.

Figure 9: Posted Total Chromium Data for Impoundment No. 1

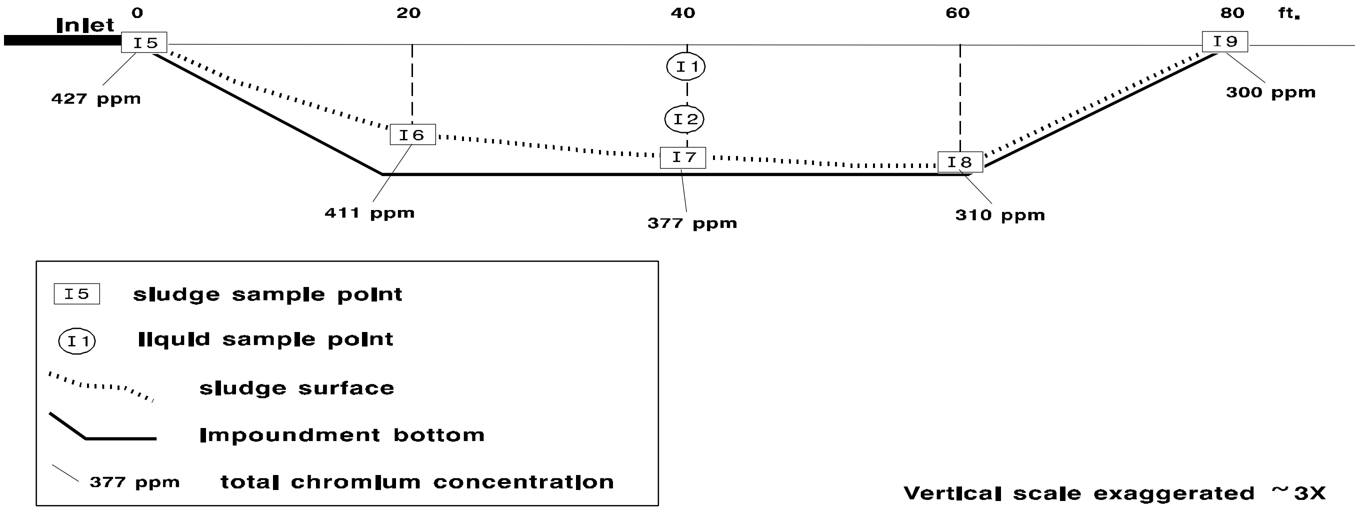


Table 2: Haz-Cat Results
ABC Plating Site
(page 1 of 2)

Container	Rad	pH	CN	PID	FID	Solubility in water	Chlorine Test	Peroxide Test	Phase	Cu^+	Comments
D1	ND	12	Y	N/A	N/A	Y	N	N	L	N	cyanide base
D2	ND	>12	Y	N/A	N/A	Y	N	N	L	N	cyanide base
D3	ND	>12	Y	N/A	N/A	Y	N	N	L	N	cyanide base
D4	ND	>12	N	N/A	N/A	Y	N	N	L	N	base
D5	ND	6	N/A	4	2	Y	N	N	L	N	inconclusive
D6	ND	7	N/A	18	35	N Floats	N	N	L	N	oil
D7	ND	7	N/A	26	70	N Floats	N	N	L	N	oil
D8	ND	7	N/A	14	39	N Floats	N	N	L	N	oil
D9	ND	7	N/A	45	128	N Sinks	N	N	L	N	halogenated solvent
D10	ND	N/A	N	18	26	Y	N	N	L	N	kersosene
D11	ND	5	N/A	6	11	Y	N	N	L	N	open; rain water?
D12	ND	5	N/A	8	6	Y	N	N	L	N	open; rain water?
D13	ND	5	N/A	ND	ND	Y	N	N	L	N	inconclusive
D14	ND	5	N/A	ND	ND	Y	N	N	L	N	inconclusive
D15	ND	<2	N/A	N/A	N/A	Reacts	N	N	L	N	strong acid
D16	ND	<2	N/A	N/A	N/A	Reacts	N	N	L	N	strong acid
D17	ND	<2	N/A	N/A	N/A	Reacts	N	N	L	N	strong acid
D18	ND	<2	N/A	N/A	N/A	Reacts	N	N	L	N	strong acid
D19	ND	>11	N	N/A	N/A	Y	N	N	S	N	caustic soda

Table 2: Haz-Cat Results (Cont'd)
ABC Plating Site
(page 2 of 2)

Container	Rad	pH	CN	PID	FID	Solubility in water	Chlorine Test	Peroxide Test	Phase	Cu^+	Comments
V1	ND	>12	Y	N/A	N/A	Y	N	N	L	N	cyanide base
V2	ND	>12	Y	N/A	N/A	Y	N	N	L	N	cyanide base
V3	ND	9	N	ND	ND	Y	N	N	L	N	inconclusive
V4	ND	2	N	N/A	N/A	Y	N	N	L	N	acid
V5	ND	2	N	N/A	N/A	Y	N	N	L	N	acid
V6	ND	8	N	ND	ND	Y	N	N	L	N	inconclusive
V7	ND	2	N	N/A	N/A	Y	N	N	L	N	acid
V8	ND	2	N	N/A	N/A	Y	N	N	L	N	acid
V9	ND	8	N	ND	ND	Y	N	N	L	N	inconclusive
V10	ND	<2	N	N/A	N/A	Reacts	N	N	L	Y	strong acid
V11	ND	<2	N	N/A	N/A	Reacts	N	N	L	Y	strong acid
V12	ND	8	N	ND	ND	Y	N	N	L	N	inconclusive
V13	ND	<2	N	N/A	N/A	Reacts	N	N	L	N	strong acid
V14	ND	<2	N	N/A	N/A	Reacts	N	N	L	N	strong acid
V15	ND	>12	N	N/A	N/A	Y	N	N	L	N	strong base
P1	ND	N/A	Y	ND	ND	N	N	N/A	S	N/A	inconclusive
P2	ND	N/A	Y	ND	ND	N	N	N/A	S	N/A	inconclusive

ND -- none detected
NA -- not applicable

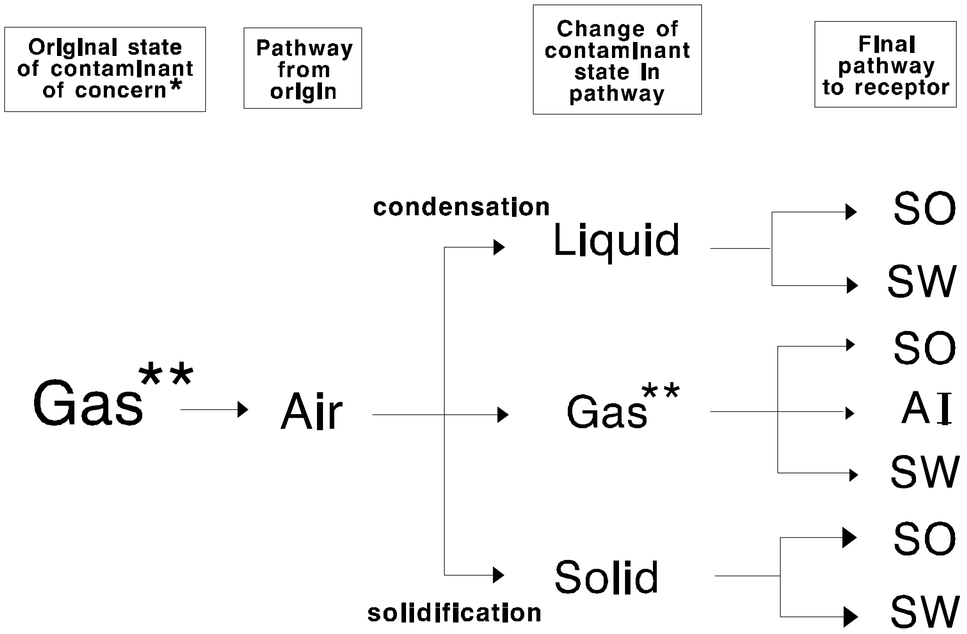
L -- liquid
S -- solid

Y -- yes
N -- no

APPENDIX A -- Example of Flow Diagram For Conceptual Site Model

Figure A-1

Migration Routes of a Gas Contaminant from Origin to Receptor



Receptor		
Human	Ecological Threat	
	Terrestrial	Aquatic
G,D	G,D	N/A
G,D	G,D	G,D
I,D	I,D	N/A
I,D	I,D	N/A
G,D	I,D	G,D
G,D	G,D	N/A
G,D	G,D	G,D

* May be a transformation product
** Includes vapors

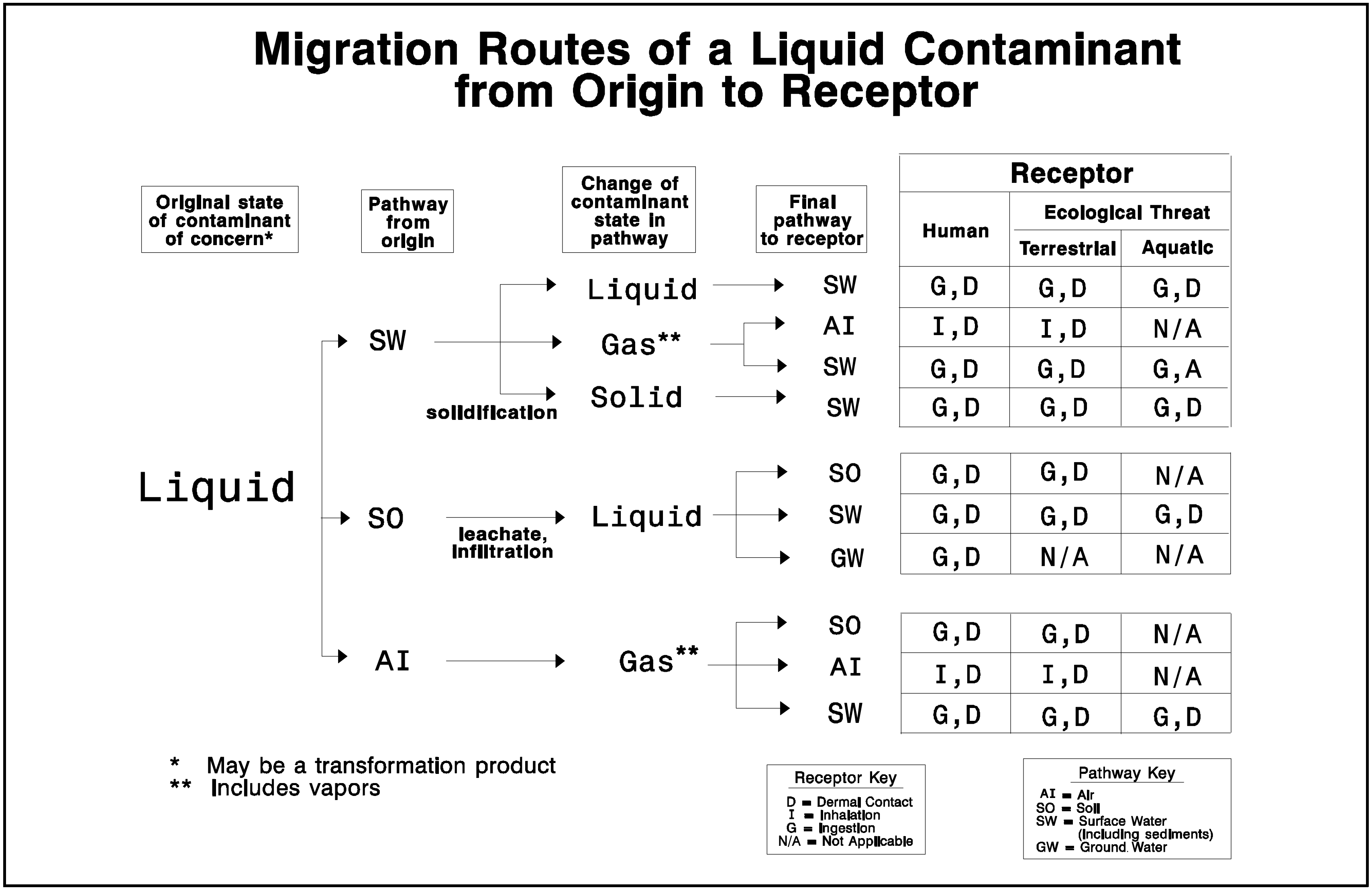
Receptor Key

D = Dermal Contact
I = Inhalation
G = Ingestion
N/A = Not Applicable

Pathway Key

AI = Air
SO = Soil
SW = Surface Water (including sediments)
GW = Ground Water

Figure A-2



Migration Routes of a Liquid Contaminant from Origin to Receptor

Original state of contaminant of concern*	Pathway from origin	Change of contaminant state in pathway	Final pathway to receptor	Receptor		
				Human	Ecological Threat	
					Terrestrial	Aquatic
Liquid	SW	Liquid	SW	G,D	G,D	G,D
		Gas**	AI	I,D	I,D	N/A
			SW	G,D	G,D	G,A
	solidification	Solid	SW	G,D	G,D	G,D
	SO	leachate, infiltration Liquid	SO	G,D	G,D	N/A
			SW	G,D	G,D	G,D
			GW	G,D	N/A	N/A
	AI	Gas**	SO	G,D	G,D	N/A
			AI	I,D	I,D	N/A
			SW	G,D	G,D	G,D

* May be a transformation product
** Includes vapors

Receptor Key

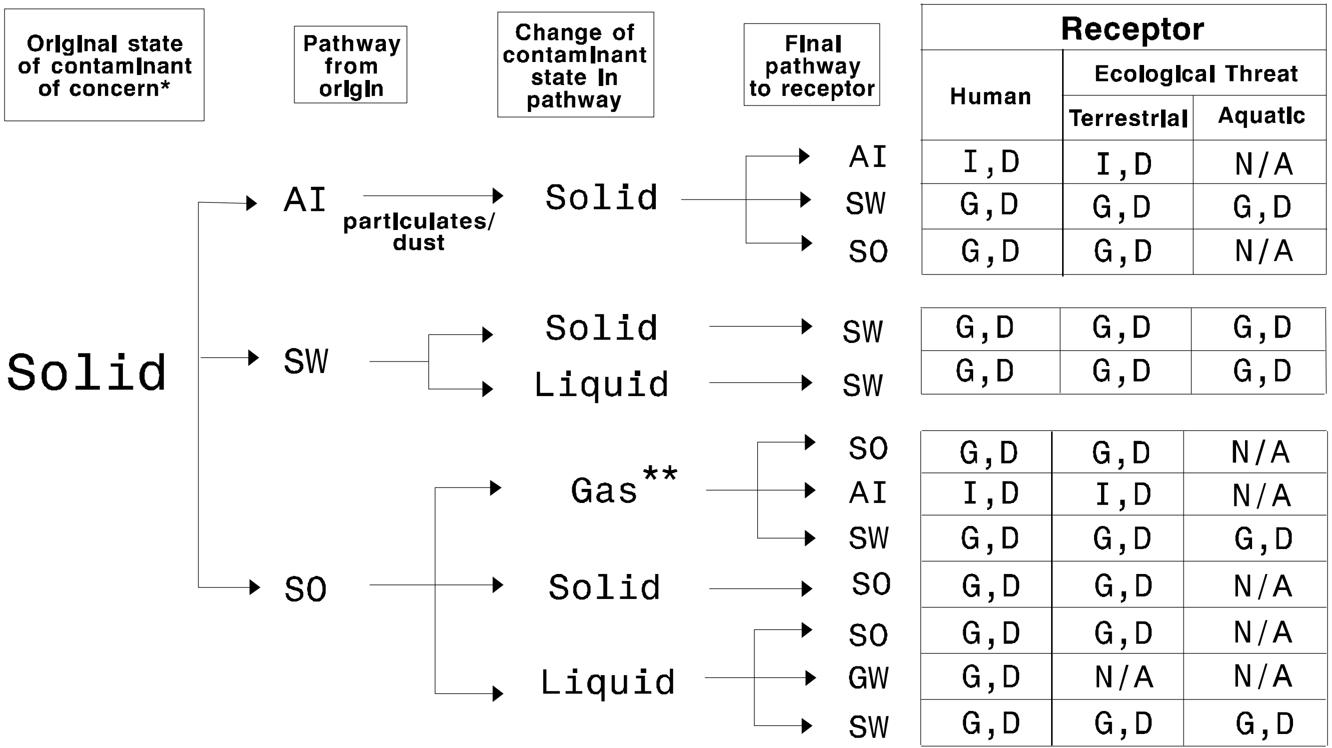
D = Dermal Contact
I = Inhalation
G = Ingestion
N/A = Not Applicable

Pathway Key

AI = Air
SO = Soil
SW = Surface Water (including sediments)
GW = Ground Water

Figure A-3

Migration Routes of a Solid Contaminant from Origin to Receptor



Original state of contaminant of concern*	Pathway from origin	Change of contaminant state in pathway	Final pathway to receptor	Receptor		
				Human	Ecological Threat	
					Terrestrial	Aquatic
Solid	AI	Solid (particulates/dust)	AI	I,D	I,D	N/A
			SW	G,D	G,D	G,D
			SO	G,D	G,D	N/A
	SW	Solid	SW	G,D	G,D	G,D
		Liquid	SW	G,D	G,D	G,D
	SO	Gas**	SO	G,D	G,D	N/A
			AI	I,D	I,D	N/A
			SW	G,D	G,D	G,D
		Solid	SO	G,D	G,D	N/A
		Liquid	SO	G,D	G,D	N/A
			GW	G,D	N/A	N/A
			SW	G,D	G,D	G,D

* May be a transformation product
** Includes vapors

Receptor Key

D = Dermal Contact
I = Inhalation
G = Ingestion
N/A = Not Applicable

Pathway Key

AI = Air
SO = Soil
SW = Surface Water (including sediments)
GW = Ground Water

References

Chavalitnitikul, C. et al. 1984. A Laboratory Evaluation of Wipe Testing Based on Lead Oxide Surface Contamination. American Industrial Association J.45(5):311-317.

Esposito, M.P., et al., June 1985. *Guide for Decontamination of Buildings, Structures, and Equipment at Superfund Sites*. EPA/600/S2-85/028. U.S. Environmental Protection Agency, Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio.

Ford, Patrick J. and Paul J. Turina. July 1984. *Characterization of Hazardous Waste Sites -- A Methods Manual. Volume I -- Site Investigations*. EPA/600/S4-84/075. U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

Haztech Systems, Incorporated. 1990. *Hazcat Chemical Identification System*. New Jersey Department of Environmental Protection, Hazardous Waste Programs. February 1988. *Field Sampling Procedures Manual*.

Rupp, Gretchen, et al. July 1990. *Debris Sampling at NPL Sites, Draft Interim Report*. University of Las Vegas-Nevada, Las Vegas, Nevada.

National Oil and Hazardous Substances Pollution Contingency Plan (40 CFR Part 300). October 1994.

U.S. Environmental Protection Agency. 1992. *Guidance for Performing Site Inspections Under CERCLA*. Directive 9345.1-05, Interim Final. Office of Solid Waste and Emergency Response.

U.S. Environmental Protection Agency. November 1991. *Removal Program Representative Sampling Guidance, Volume 1 -- Soil*. OSWER Directive 9360.4-10.

U.S. Environmental Protection Agency. January 1991a. *Compendium of ERT Toxicity Testing Procedures*. OSWER Directive 9360.4-08.

U.S. Environmental Protection Agency. January 1991b. *Compendium of ERT Waste Sampling Procedures*. OSWER Directive 9360.4-07.

U.S. Environmental Protection Agency. April 1990. *Data Quality Objectives Process for Superfund*. EPA/540/G-90/004.

U.S. Environmental Protection Agency. February 1989. *Methods for Evaluating the Attainment of Cleanup Standards, Volume 1 -- Soils and Solid Media*. EPA/230/02-89/042.

U.S. Environmental Protection Agency. September 1988a. *Field Measurements*. EPA/530/UST-90-003.

U.S. Environmental Protection Agency. September 1988b. *Field Screening Methods Catalog, User's Guide*. EPA/540/2-88/005.

U.S. Environmental Protection Agency. July 1988. *Standard Operating Safety Guidelines*. Office of Emergency and Remedial Response, Emergency Response Division.

U.S. Environmental Protection Agency. 1987. *A Compendium of Superfund Field Operations Methods*. EPA/540/P-87/001.

U.S. Environmental Protection Agency. November 1986. *Test Methods for Evaluating Solid Waste. Volume II: Field Manual Physical/Chemical Methods.* SW-846. Office of Solid Waste and Emergency Response.

U.S. Department of Health and Human Services. October 1985. *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*.

U.S. Environmental Protection Agency. April 1985. *Petitions to Delist Hazardous Wastes* -- *A Guidance Manual*. Office of Solid Waste, EPA/530/SW-85/003.

CATEGORY 2: FIELD DOCUMENTATION, DECONTAMINATION, AND WASTE

Section 2.2

Field Sampling Guidance Document #1230 Sampling Equipment Decontamination

U.S.EPA REGION 9 LABORATORY

RICHMOND, CALIFORNIA

FIELD SAMPLING GUIDANCE DOCUMENT #1230

SAMPLING EQUIPMENT DECONTAMINATION

TABLE OF CONTENTS

SOP #109

SAMPLING EQUIPMENT DECONTAMINATION

1.0 SCOPE AND APPLICATION

This Standard Operating Procedure (SOP) describes methods used for preventing or reducing cross-contamination, and provides general guidelines for sampling equipment decontamination procedures at hazardous waste sites. Preventing or minimizing cross-contamination in sampled media and in samples is important for preventing the introduction of error into sampling results and for protecting the health and safety of site personnel.

Removing or neutralizing contaminants that have accumulated on sampling equipment ensures protection of personnel from permeating substances, reduces or eliminates transfer of contaminants to clean areas, prevents the mixing of incompatible substances, and minimizes the likelihood of sample cross-contamination.

2.0 METHOD SUMMARY

Contaminants can be physically removed from equipment, or deactivated by sterilization or disinfection. Gross contamination of equipment requires physical decontamination, including abrasive and non-abrasive methods. These include the use of brushes, air and wet blasting, and high-pressure water cleaning, followed by a wash/rinse process using appropriate cleaning solutions. Use of a solvent rinse is required when organic contamination is present.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

This section is not applicable to this SOP.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

- The use of distilled/deionized water commonly available from commercial vendors may be acceptable for decontamination of sampling equipment provided that it has been verified by laboratory analysis to be analyte free.

- An untreated potable water supply is not an acceptable substitute for tap water. Tap water may be used from any municipal water treatment system for mixing of decontamination solutions.

- Acids and solvents utilized in the decontamination sequence pose the health and safety risks of inhalation or skin contact, and raise shipping concerns of permeation or degradation.

- The site work plan must address disposal of the spent decontamination solutions.

- Several procedures can be established to minimize contact with waste and the potential for contamination. For example:

    - Stress work practices that minimize contact with hazardous substances.
    - Use remote sampling, handling, and container-opening techniques when appropriate.
    - Cover monitoring and sampling equipment with protective material to minimize contamination.
    - Use disposable outer garments and disposable sampling equipment when appropriate.

5.0 EQUIPMENT/APPARATUS

- appropriate personal protective clothing
- non-phosphate detergent
- selected solvents
- long-handled brushes
- drop cloths/plastic sheeting
- trash container
- paper towels
- galvanized tubs or buckets
- tap water
- distilled/deionized water
- metal/plastic containers for storage and disposal of contaminated wash solutions
- pressurized sprayers for tap and deionized/distilled water
- sprayers for solvents
- trash bags
- aluminum foil
- safety glasses or splash shield
- emergency eyewash bottle

6.0 REAGENTS

There are no reagents used in this procedure aside from the actual decontamination solutions and solvents. In general, the following solvents are utilized for decontamination purposes:

- 10% nitric acid(1)

- acetone (pesticide grade)[(2)]
- hexane (pesticide grade)[(2)]
- methanol

(1) Only if sample is to be analyzed for trace metals
(2) Only if sample is to be analyzed for organics

7.0 PROCEDURES

As part of the health and safety plan, develop and set up a decontamination plan before any personnel or equipment enter the areas of potential exposure. The equipment decontamination plan should include:

- the number, location, and layout of decontamination stations
- which decontamination apparatus is needed
- the appropriate decontamination methods
- methods for disposal of contaminated clothing, apparatus, and solutions

7.1 Decontamination Methods

All personnel, samples, and equipment leaving the contaminated area of a site must be decontaminated. Various decontamination methods will either physically remove contaminants, inactivate contaminants by disinfection or sterilization, or do both.

In many cases, gross contamination can be removed by physical means. The physical decontamination techniques appropriate for equipment decontamination can be grouped into two categories: abrasive methods and non-abrasive methods.

Abrasive Cleaning Methods

Abrasive cleaning methods work by rubbing and wearing away the top layer of the surface containing the contaminant. The following abrasive methods are available:

- Mechanical cleaning methods are brushes of metal or nylon. The amount and type of contaminants removed will vary with the hardness of bristles, length of brushing time, and degree of brush contact.
- Air blasting is used for cleaning large equipment, such as bulldozers, drilling rigs or auger bits. The equipment used in air blast cleaning employs compressed air to force abrasive material through a nozzle at high velocities. The distance between the nozzle and the surface cleaned, as well as the pressure of air, the time of application, and the angle at which the abrasive strikes the surface, determines cleaning efficiency. Air blasting has several disadvantages: it is unable to control

the amount of material removed, it can aerate contaminants, and it generates large amounts of waste.

- Wet blast cleaning, also used to clean large equipment, involves use of a suspended fine abrasive delivered by compressed air to the contaminated area. The amount of materials removed can be carefully controlled by using very fine abrasives. This method generates a large amount of waste.

Non-Abrasive Cleaning Methods

Non-abrasive cleaning methods work by forcing the contaminant off of a surface with pressure. In general, less of the equipment surface is removed using non-abrasive methods. The following non-abrasive methods are available:

- High-Pressure Water: This method consists of a high-pressure pump, an operator-controlled directional nozzle, and a high pressure hose. Operating pressure usually ranges from 340 to 680 atmospheres (atm) which relates to flow rates of 20 to 140 liters per minute.
- Ultra-High-Pressure Water: This system produces a pressurized water jet (from 1,000 to 4,000 atm). The ultra-high-pressure spray removes tightly-adhered surface film. The water velocity ranges from 500 m/sec (1,000 atm) to 900 m/sec (4,000 atm). Additives can enhance the method. This method is not applicable for hand-held sampling equipment.

Disinfection/Rinse Methods

- Disinfection: Disinfectants are a practical means of inactivating infectious agents.
- Sterilization: Standard sterilization methods involve heating the equipment. Sterilization is impractical for large equipment.
- Rinsing: Rinsing removes contaminants through dilution, physical attraction, and solubilization.

7.2 FIELD SAMPLING EQUIPMENT CLEANING PROCEDURES

Solvent rinses are not necessarily required when organics are not a contaminant of concern and may be eliminated from the sequence specified below. Similarly, an acid rinse is not required if analysis does not include inorganics.

1. Where applicable, follow physical removal procedures specified in section 6.1
2. Wash equipment with a non-phosphate detergent solution.
3. Rinse with tap water.
4. Rinse with distilled/deionized water.
5. Rinse with 10% nitric acid if the sample will be analyzed for trace organics.

6. Rinse with distilled/deionized water.
7. Use a solvent rinse (e.g., pesticide grade methanol or hexane) if the sample will be analyzed for organics.
8. Air dry the equipment completely
9. Rinse again with distilled/deionized water.

Selection of the solvent for use in the decontamination process is based on the contaminants present at the site. Use of a solvent is required when organic contamination is present on-site. Typical solvents used for removal of organic contaminants include acetone, hexane, or water. An acid rinse step is required if metals are present on-site. If a particular contaminant fraction is not present at the site, the nine-step decontamination procedure listed above may be modified for site specificity. The decontamination solvent used should not be among the contaminants of concern at the site.

Table 1 lists solvent rinses that may be required for elimination of particular chemicals. After each solvent rinse, the equipment should be air dried and rinsed with distilled/deionized water.

Sampling equipment that requires the use of plastic tubing should be disassembled and the tubing replaced with clean tubing before commencement of sampling and between sampling locations.

8.0 CALCULATIONS

This section is not applicable to this SOP

9.0 QUALITY ASSURANCE/QUALITY CONTROL

One type of quality control sample specific to the field decontamination process is the rinseate blank. The rinseate blank provides information on the effectiveness of the decontamination process employed in the field. When used in conjunction with field blanks and trip blanks, a rinseate blank can detect contamination during sample handling storage and sample transportation to the laboratory.

A rinseate blank consists of a sample of analyte-free (i.e., deionized) water which is passed over and through a field decontaminated sampling device and placed in a clean sample container.

Rinseate blanks should be run for all parameters of interest at a rate of 1 per day for each parameter, even if samples are not shipped that day. Rinseate blanks are not required if dedicated

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA and specific health and safety procedures.

Decontamination can pose hazards under certain circumstances even though performed to protect health and safety. Hazardous substances may be incompatible with decontamination methods. For example, the decontamination solution or solvent may react with contaminants to produce heat, explosion, or toxic products. Decontamination methods may be incompatible with clothing or equipment; some solvents can permeate or degrade protective clothing. Also, decontamination solutions and solvents may pose a direct health hazard to workers through inhalation or skin contact, or if they combust.

Table 1: Recommended Solvent Rinse for Soluble Contaminants

SOLVENT	SOLUBLE CONTAMINANTS
Water	• Low-chain hydrocarbons • Inorganic compounds • Salts • Some organic acids and other polar compounds
Dilute Acids	• Basic (caustic) compounds • Amines • Hydrazines
Dilute Bases -- for example, detergent and soap	• Metals • Acidic compounds • Phenol • thiols • Some nitro and sulfonic compounds
Organic Solvents (1) - for example, alcohols, ethers, ketones, aromatics, straight-chain alkanes (e.g., hexane), and common petroleum products (e.g., fuel, oil, kerosene)	• Nonpolar compounds (e.g., some organic compounds)

(1) - WARNING: Some organic solvents can permeate and/or degrade protective clothing.

The decontamination solutions and solvents must be determined to be compatible before use. Any method that permeates, degrades, or damages personal protective equipment should not be used. If decontamination methods pose a direct health hazard, measures should be taken to protect personnel or the methods should be modified to eliminate the hazard.

CATEGORY 2: FIELD DOCUMENTATION, DECONTAMINATION, AND WASTE

Section 2.3

Standard Operating Procedure for Chain of Custody of Samples

.

STANDARD OPERATING PROCEDURE
FOR CHAIN OF CUSTODY OF SAMPLES

The Office of Environmental Measurement and Evaluation
EPA New England - Region 1
11 Technology Dr
North Chelmsford, MA 01863

Prepared by: ______________________ ________
Daniel Granz, Env. Engineer Date
Investigations & Analysis Unit

Reviewed by: ________________________ ________
Jerry Keefe, Team Leader Date
Investigations & Analysis Unit

Approved by: __________________________ ________
Robert Maxfield, Chief Date
Investigations &Analysis Unit

Revision Page

Date	**Rev#**	**Summary of Changes**	**Sections**
	1	**Initial Approval**	

Table of Contents

Attachments:

1.0 Scope & Application:

1.1 This Standard Operating Procedure is applicable to the sample control procedures used for chain of custody of representative samples collected from various locations. It includes samples collected from both ambient and source locations.

1.2 A sample is physical evidence collected from a facility or from the environment. An essential part of all enforcement investigations is that evidence gathered be controlled. To accomplish this, the following sample identification and chain of custody procedures are established.

2.0 Summary of Method:

2.1 The method of sample identification depends on the type of measurement or analyses performed. When in-situ measurements are made, the data are recorded directly in logbooks or Field Data Cards with identifying information, field observations, and remarks. Examples of in-situ measurements are pH, temperature, D.O., conductivity, and flow measurement. Samples other than in-situ measurements, are identified by a sample tag or label. These samples are removed from the sample location and transported to a laboratory for analyses. Before removal, however, a sample is often separated into portions depending upon the analyses to be performed. Each portion is preserved in accordance with applicable procedures and each sample container is identified by a sample tag / label.

2.2 Sample tags / labels shall be completed for each sample, using waterproof ink, unless prohibited by weather conditions. For example, a logbook notation would explain that a pencil was used to fill out the sample tag because a ball point pen would not function in freezing weather. The information recorded on the sample tag/label includes:
Station Number - a number assigned by the project coordinator
Date - a six digit number indicating the year, month, day of collection
Time - a four digit number indicating military time of collection. e.g. 0954
Station Location - sampling station description
Samplers - each sampler is identified
Sample Number - a unique sample # established from the Field Data Card for each set of samples collected at one time and place
Parameter/pres. - the analysis to be conducted for the sample /sample preservation
Remarks - the samplers record pertinent observations affecting analyses, if any

2.3 A Field Data Card which assigns a unique number to each set of samples, must be completed for each sampling event. The field data card used for samples contains an appropriate place for designating the sample as a grab or a composite, and identifying the type of sample collected for analyses.

2.4 Due to the evidentiary nature of samples collected during enforcement investigations, possession must be traceable from the time the samples are collected until they are introduced as evidence inn legal proceedings. To maintain and document sample possession, chain of custody procedures are followed. A sample is under custody if:

- It is in your possession, or
- It is in your view, after being in your possession, or
- It was in your possession and then you then locked it up to prevent tampering, or
- It is in a designated secure area.

2.5 In collecting samples for evidence, collect only that number which provides a good representation of the media being sampled. To the extent possible, the quantity and types of samples and sample locations are determined prior to actual field work. As few people as possible should handle samples. The field sampler is personally responsible for the care and custody of the samples collected until they are transferred or dispatched properly.

2.6 Samples are accompanied by a chain of custody record. When transferring the possession of samples, the individuals relinquishing and receiving will sign, date, and note the time on the record. This record documents sample custody transfer from the sampler, often through another person, to the analyst at the laboratory. The samples are typically transferred to the sample receiving custodian at the laboratory.

3.0 Definitions:

3.1 Bottle Blank: Analyte-free water is collected into a sample container, of the same lot as the containers used for the environmental samples. This evaluates contamination introduced from the sample container(s) from a common lot.

3.2 Equipment/Rinse/Rinsate Blanks: A sample that is collected by pouring over or running analyte-free water through the sample collection equipment after decontamination and before sample collection. The sample is collected in the appropriate sample container with the proper preservative, identical to the samples. This represents background contamination resulting from the field equipment, sampling procedure, sample container, preservative, and shipment.

3.3 Field Blank: In the field, analyte-free water is collected into a sample container with preservatives. The sample containers are the same lot used for the environmental samples. This evaluates contamination introduced from the sample container(s) with applicable preservatives. Field blanks are not used for volatile samples.

3.4 Field Replicates/Duplicates: Two or more samples collected at the same sampling location. Field replicates should be samples collected side by side or by collecting one sample and immediately collecting the second sample. Field replicates represent the precision of the whole method, site heterogeneity, field sampling and the laboratory analysis.

3.5 Field Split Samples: Two or more representative subsamples taken from one environmental sample in the field. Prior to splitting, the environmental sample is homogenized to correct for sample heterogeneity that would adversely impact data comparability. Field split samples are usually analyzed by different laboratories (interlaboratory comparison) or by the same laboratory (intralaboratory comparison). Field splits are used to assess sample handling procedures from field to laboratory and laboratory's comparability.

3.6 Filter Blank: In the field, analyze-free water is passed through a filter and collected into in the appropriate sample container. The filter blank is then preserved. This procedure is identical to the sample collection.

3.7 Laboratory Quality Samples: Additional samples will be collected for the laboratory's quality control: matrix spike, matrix spike duplicate, laboratory duplicates, etc.

3.8 Proficiency Testing (PT)/Performance Evaluation Sample (PES): A sample, the composition of which is unknown to the laboratory or analyst, provided to the analyst or laboratory to assess the capability to produce results within acceptable criteria. This is optional depending on the data quality objectives.

3.9 Shipping Container Temperature Blank: A water sample that is transported to the laboratory to measure the temperature of the samples in the cooler.

4.0 Trip Blanks: A sample collected at the laboratory using analyte free water in the appropriate sample container with the proper preservative, taken out to the field, and returned to the laboratory for analysis without being opened. Trip blanks are generally for volatile organic compounds, low level metals, and gasoline range hydrocarbon samples. Used to assess contamination introduced during sample transport.

4.0 Health and Safety Warnings:

4.1 When working with potentially hazardous materials or situations, follow EPA, OSHA, and specific health or safety procedures.

4.2 All proper personal protection clothing and equipment is to be worn.

4.3 When sampling lagoons or surface impoundments containing known or suspected hazardous substances, take adequate precautions. The sampling team member collecting the sample should not get too close of the edge of the impoundment, where bank failure may cause them to lose their balance.

4.4 Follow the Boat Safety SOP when conducting sampling from a boat.

4.5 Some samples may contain biological and chemical hazards. These samples should be handled with suitable protection to skin, eyes, etc.

5.0 Interferences:

5.1 Interference may result from using contaminated equipment, solvents, reagents, sample container, or sampling in a disturbed area.

5.2 Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of the sampling equipment is necessary.

5.3 All sampling equipment must be routinely demonstrated to be free from contaminants under the conditions of the analysis by running equipment blanks.

6.0 Personnel Qualifications:

6.1 All field samplers working at Superfund sites are required to take a 40 hour health and safety training course and a refresher course prior to engaging in any field activities.

6.2 The field sampler should be trained by an experienced sampler before initiating the procedure.

6.3 All personnel shall be responsible for complying with all quality assurance/quality control requirements that pertain to their organizational/technical function.

7.0 Equipment and Supplies:

7.1 log book, field data cards, custody seals, and chain of custody form

7.2 Zip lock plastic bags, large plastic bags, tape

7.3 Cooler(s) or other container(s) for securing samples

7.4 Padlock(s) (optional)

8.0 Sample Collection:

8.1 Sample control procedures, chain of custody procedures, are used in the collection of any type of samples. The level of control is strict for enforcement (evidence) samples and may be less for screening samples or water quality type samples.

8.2 The above (section 2.1 to 2.6) section address chain of custody procedures for enforcement type samples. Enforcement samples will also have custody seals placed on each individual sample container. Any automatic composite sampler will be secured with custody seals or padlocks to control access to the sample during collection.

8.3 All samples must have a unique field sample number that will identify it with a specific collection location/date/time and cannot be reused for the project. The field sample numbers may be generated during planning/preparation for the sampling or during sampling and can consist of up to 12 characters.

8.4 The sample containers may be pre-labeled (sample tagged) before sample collection or labeled (sample tagged) immediately after collection. The sample identification can consist of sample tags, labels, or indelible writing directly on the sample container. The required identifying sample information for any sample are:
-unique field sample number
-parameter(s) to be analyzed and sample preservation
-date & time of sample collection
-station number / location
-samplers

8.5 A chain of custody form will be used to transfer custody of samples to the laboratory. The form used may be as identified in the attachment or other chain of custody forms provided the same in formation is provided. Any alternative form used must at a minimum have a unique field sample number identifying each sample to be analyzed, parameter for analyses, sample collection date & time, sampler, custody transfer signature area.

9.0 Sample Handling, Preservation, and Storage:

9.1 Transfer the sample or collect directly a suitable labeled sample container.

9.2 Preserve the sample or use pre-preserved sample bottles, when appropriate.

9.3 Cap the container, use a custody seal if the sample is for enforcement and then place the container in a zip-lock plastic bag.

9.4 Place sample containers into cooler(s) ensuring that the bottles are in the ice but not totally immersed in water. Samples not requiring refrigeration do not need to be placed on ice.

9.5 Record all pertinent data in the logbook and on the field data card or sheet.

9.6 Complete the chain of custody form.

9.7 Samples may require short term storage in field locations prior to delivery to the laboratory for analyses. The storage may be in vehicles or lodging locations. The samples must be secured to limit access to them. A locked vehicle is considered controlled access. However, simply a locked lodging room is not secure due to potential custodial access. If an unattended lodging room is used for sample storage, the samples must be further secured. This may entail a padlock on the ice chest, samples in an ice chest secured in an inner bag with a custody seal on it, Ice chest taped shut with custody seal on the outside of it.

9.7 Attach the custody seals to the cooler prior to shipment if for investigation or shipment to another laboratory. If the samples are shipped, put the chain of custody form in a Zip-lock bag and tape to the inside cover of the cooler. Samples must be packaged to prevent breakage and leakage of any melted ice from the shipping container. The chain of custody form should have the courier name listed as receiving the samples for transport, however there will be no signature from the courier.

9.8 A list for the laboratory's containers and preservatives for the various analytes is located on the EPA Region 1 homepage under OEME.

9.10 Whenever samples are split with a source or other government agency, a separate chain of custody form should be completed for the samples and the relinquisher (sampler) and recipient should sign. If a representative is unavailable or refuses to sign for the samples, this can be noted in the "remarks" area of the form . When appropriate, as in the case where the representative is unavailable, the custody record should contain a statement that the samples were delivered to the designated location at the designated time. A copy of the chain of custody form for split samples must be kept with the project file.

10.0 Data and Records Management:

10.1 All data and information is to follow the Field Data Management SOP.

10.2 The chain of custody form is signed over to the laboratory. A copy is kept with the sampling records.

10.3 The sampling data is stored at US EPA - NE, 11 Technology Dr, North Chelmsford, MA for at least 3 years.

11.0 Quality Control and Quality Assurance:

11.1 Representative samples are required. The sampler will evaluate the site specific conditions to assure the sample will be representative.

11.2 All sampling equipment must be decontaminated prior to use and after each discrete sample following the General Field Equipment - Cleaning, Preparation, and Decontamination SOP.

11.23 All field QC samples requirements in the SAP or QAPP must be followed. These may involve trip blanks, equipment blanks, field duplicates and the collection of extra samples for the laboratory's quality control.

12.0 Waste Management and Pollution Prevention:

12.1 During field sampling and analysis events there may be hazardous waste produced from the sample collection. The waste must be handled and disposed of in accordance with federal, state, and municipal regulations. Dispose of the hazardous waste produced at the site where the work was performed, if the operating site has proper disposal available. If there is no disposal that meets regulatory requirements, the waste must be transported back to EPA-NE and transferred to the hazardous waste manager for disposal. The sample volume should be minimized to reduce unnecessary waste.

12.2 This SOP for sample chain of custody will not generate any waste

CATEGORY 2: FIELD DOCUMENTATION, DECONTAMINATION, AND WASTE

Section 2.4

Standard Guide for Documenting a Ground-Water Sampling Event

Designation: D 6089 – 97 (Reapproved 2003)

Standard Guide for Documenting a Ground-Water Sampling Event[1]

This standard is issued under the fixed designation D 6089; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers what and how information should be recorded in the field when sampling a ground-water monitoring well. Following these recommendations will provide adequate documentation in most monitoring programs. In some situations, it may be necessary to record additional or different information, or both, to thoroughly document the sampling event. In other cases, it may not be necessary to record all of the information recommended in this guide. The level of documentation will be based on site-specific conditions and regulatory requirements.

1.2 This guide is limited to written documentation of a ground-water sampling event. Other methods of documentation (that is, electronic and audiovisual) can be used but are not addressed in this guide. The specific activities addressed in this guide include documentation of static water level measurement, monitoring well purging, monitoring well sampling, field measurements, ground-water sample preparation, and ground-water sample shipment.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)[2]

D 5088 Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites[2]

D 5608 Practice for Deontamination of Field Equipment Used at Low-Level Radioactive Waste Sites[2]

D 5903 Guide for Planning and Preparing for a Ground-Water Sampling Event[3]

2.2 *Government Document:*

40 CFR 261.4 (d) (ii)[4]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this guide, refer to Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *chain of custody*—the process of maintaining accountability of the samples for the purpose of identifying potential breaches in sample integrity.

3.2.2 *chain of custody record*—a record of all individuals who possess the samples from the time of collection until analysis.

4. Significance and Use

4.1 When sampling ground-water monitoring wells, it is very important to thoroughly document all field activities. Sufficient field data should be retained to allow one to reconstruct the procedures and conditions that may have affected the integrity of a sample. The field data generated are vital to the interpretation of the chemical data obtained from laboratory analyses of samples. Field data and observations may also be useful to analytical laboratory personnel.

5. Documentation Methods

5.1 Field records should be generated by a member of the sampling team. It is important to record procedures used and measurements immediately after they have been accomplished and are fresh in the memory. In general, notes should not be taken after returning from the field.

---

[1] This guide is under the jurisdiction of ASTM Committee D 18 on Soil and Rock and is the direct responsibility of Subcommittee D 18.21 on Ground Water and Vadose Zone Investigations.

Current edition approved May 10, 1997. Published January 1998.

[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 04.09.

[4] Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

5.2 The format of the documentation is discretionary, but should be consistent from well to well and in accordance with regulatory requirements. Forms are often used for consistency and to reduce the chance of failing to record needed information. It may be desirable for records to be entered with indelible ink in a hard cover, stitch-bound book for credibility in litigation.

6. Documentation Content

6.1 *General:*

6.1.1 Record the facility or site name, or both, and the well identification.

6.1.2 Record the weather conditions.

6.1.3 Record the names of all sampling team members.

6.1.4 Record any instrument calibration details to include instrument identification and date and time of last calibration.

6.1.5 Note any changes in the physical condition of the well.

6.1.6 Note changes in land use or physical conditions of the site.

6.1.7 Record wellhead observations and measurements (for example, odor, organic vapor measurements).

6.1.8 Record any quality control samples collected or prepared in the field.

6.1.9 Describe decontamination procedures for non-dedicated equipment (See Practice D 5088 and D 5608).

6.1.10 Record any deviations from the sampling and analysis plan.

6.2 *Static Water Level Measurement*:

6.2.1 Record the depth to water in the well from a reference point of known elevation. Optimally, there will be a mark or notch on the well casing to indicate the exact reference point (See Test Method D 4750).

6.2.2 Record the reference point from which the measurement was taken (that is, ground surface, top of well casing, top of protective casing).

6.2.3 Document the presence and estimated thickness of an immiscible layer.

6.2.4 Record the total depth of the well from either historical records or actual measurement.

6.2.5 Record the units of the measurement (that is, feet or metres).

6.2.6 Record the method or equipment (include serial number) used for measuring the depth to water in the well.

6.2.7 Record the date and time that the water level is measured.

6.2.8 Record any other relevant information (for example, were any nearby wells being pumped).

6.3 *Monitoring Well Purging*:

6.3.1 Briefly describe the purging method used.

6.3.2 Record the calculated purge volume (if applicable).

6.3.3 Record the volume of water removed from the well. Indicate if the well was purged to dryness.

6.3.4 Record all measurements taken during purging (that is, water levels, indicator parameter levels, organic vapor monitoring data).

6.3.5 Record the pumping rate, if known.

6.3.6 Record the type of equipment used to purge the well. Include the materials of construction of the equipment used.

6.3.7 Record the length of time spent purging the well.

6.3.8 Record the appearance of the water before and after purging.

6.3.9 Record the date and time that well purging is completed.

6.3.10 Briefly describe management of purged water.

6.4 *Monitoring Well Sampling*:

6.4.1 Record the analytes for which samples are being collected.

6.4.2 Record the order, by analyte, that sample containers are filled.

6.4.3 Record the volume, material of construction, and number of sample containers.

6.4.4 Record the equipment used to collect the samples. This should include a description of any component materials used that contact the ground water (for example, tubing, pump parts, bailer material, etc.).

6.4.5 Record the pumping rate, if applicable.

6.4.6 Record the date and approximate time that the sampling is accomplished.

6.4.7 Record the general appearance of the sample (that is color, clarity).

6.4.8 Note any problems or unusual events during the sampling.

6.4.9 Record the name of the person collecting the sample.

6.5 *Field Measurements*:

6.5.1 Record all field measurement data.

6.5.2 Record the units of measurement for each measurement taken.

6.5.3 Record all of the equipment/instrumentation used for field measurements and any calibration activities to include calibration standard information and date and time of calibration.

6.5.4 Record the date and time that field measurements are taken.

6.6 *Ground-Water Sample Preparation*:

6.6.1 Record the method of ground-water sample filtration, filter type and medium, and for which analytes filtration is performed.

6.6.2 Record any chemical preservatives used.

6.6.3 Record the manner of storage and shipment of samples (that is, refrigeration and packaging methods)

6.6.4 Record the name of the person who performs the sample preparation.

6.7 *Sample Container Labeling*—Ground-water samples should be labeled such that they will be intact and legible even if wet. The labels should contain, at a minimum, the following information: sample identification number, name of collector, date and time of collection, site identification, parameter(s) requested, and preservation methods.

6.8 *Ground-Water Sample Shipment*:

6.8.1 Record the method of shipment.

6.8.2 Record the type and number of shipping containers.

6.8.3 Note if a temperature check sample is included in the shipping container.

6.8.4 Provide a chain of custody record in each shipping container identifying the exact contents of that container. At a minimum, the chain of custody records should list the site identification, the sample identifiers and analyses required, container sizes and types, chemical preservatives used, sampling dates, shipping date, and the samples preparer's name.

6.8.5 Other information that must accompany each shipping container as required in 40 CFR 261.4(d)(ii) follows: "the sample collector's name, mailing address, and telephone number; the laboratory's name, mailing address, and telephone number; the quantity of the sample; the date of shipment; and a description of the sample".

6.9 *Analytical Request Forms*—The analytical laboratory will need a written request for analytical support. The request is usually generated before the sampling event; however, a copy of the request or other forms for laboratory use may need to be included in the sample shipment. The laboratory will instruct the project manager on the forms to be submitted for their use. Analytical request forms may include project manager's name, organization and phone number; project number or identifier; project location; brief description of the project objectives; any known contaminants associated with the project site, when sample containers and preservatives are needed; date samples will arrive; number and types of samples for each analyte; date results needed; desired detection limits and analytical methods; and, remarks or other special requirements.

7. Keywords

7.1 documentation; ground-water sampling; monitoring well

CATEGORY 2: FIELD DOCUMENTATION, DECONTAMINATION, AND WASTE

Section 2.5

Appendix B-3 Field QC and Laboratory QC Sample Collection and Documentation Requirements

Appendix B-3
Field QC and Laboratory QC Sample Collection and Documentation Requirements

SAMPLE TYPE	PURPOSE	COLLECTION [1]	SAMPLE NUMBER
Field Duplicate [2]	To check reproducibility of laboratory and field procedures. To indicate non-homogeneity.	Collect from areas that are known or suspected to be contaminated. Collect one sample per week or 10% (projects may vary) of all field samples per matrix, whichever is greater.	Assign two separate (unique) sample numbers (i.e. one number to the primary sample and one to the duplicate). Submit blind to the lab.
Field Blanks	To check cross-contamination during sample collection, sample shipment, and in the laboratory. Also to check sample containers.	Collect for each group of samples of similar matrix per day of sampling. Organics - Use water (demonstrated to be free of the contaminates of concern). Inorganics - Use metal-free (deionized or distilled) water.	Assign separate sample numbers to the trip blanks. Submit blind to the lab.
Volatiles Trip Blank	To check contamination during sample handling and shipment from field to laboratory.	Prepare one sample using water demonstrated to be free of the contaminates of concern (DI water is appropriate). Place this sample in the cooler used to ship volatile samples.	Assign separate sample numbers to the equipment blanks. Submit blind to the lab.
Equipment Blank or Rinse Blank	To check field decontamination procedures.	Collect when sampling equipment is decontaminated and reused in the field or when a sample collection vessel (bailer or beaker) will be used. Use blank water (water decontamination to be organic-free, deionized or distilled for inorganics) to rinse water into the sample containers.	Assign separate sample numbers to the equipment blanks. Submit blind to the lab.
Matrix Spike and Matrix Spike Duplicate [3]	Required by laboratory's contract to check accuracy and precision of organic analyses.	Collect triple volume for one water sample per 20 water samples. The triple volume water sample should be collected in the first shipment of organics samples.	Assign the primary sample, extra volume, matrix spike and matrix spike duplicates the same sample number. Label the extra volume "Lab QC".
Spike and Lab Duplicate[3]	Required by laboratory's contract to check accuracy and precision of inorganic analyses.	Collect double volume for one water sample per 20 water samples. The double water volume samples should be collected in the first shipment of inorganic samples.	Assign the primary sample, extra volume, spike and duplicate the same sample number. Label the extra volume "Lab QC."

1 Consult Regional or Project Manager guidance for field QC sample frequencies; laboratory QC sample frequencies are generally fixed in the laboratory subcontracts or specified in analytical methods.

2 A true split for sediment, sludge, and soil samples (and other heterogenous samples such as highly turbid waters) is typically not feasible under field conditions. A split of this type of sample should generally be considered a duplicate.

3 No extra volume is required for the soil/sediment matrix; however, the sample to be used for laboratory QC must be designated on the Traffic Report/Chain-of-Custody Record.

CATEGORY 3: FIELD MEASUREMENTS

Section 3.1

A Compendium of Superfund Field Operation Methods

United States
Environmental Protection
Agency

Office of Emergency and
Remedial Response
Washington DC 20460

EPA/540/P-87/001
(OSWER Directive 9355.0-14)
December 1987
PB88-181557

Superfund

EPA

A Compendium of Superfund Field Operations Methods

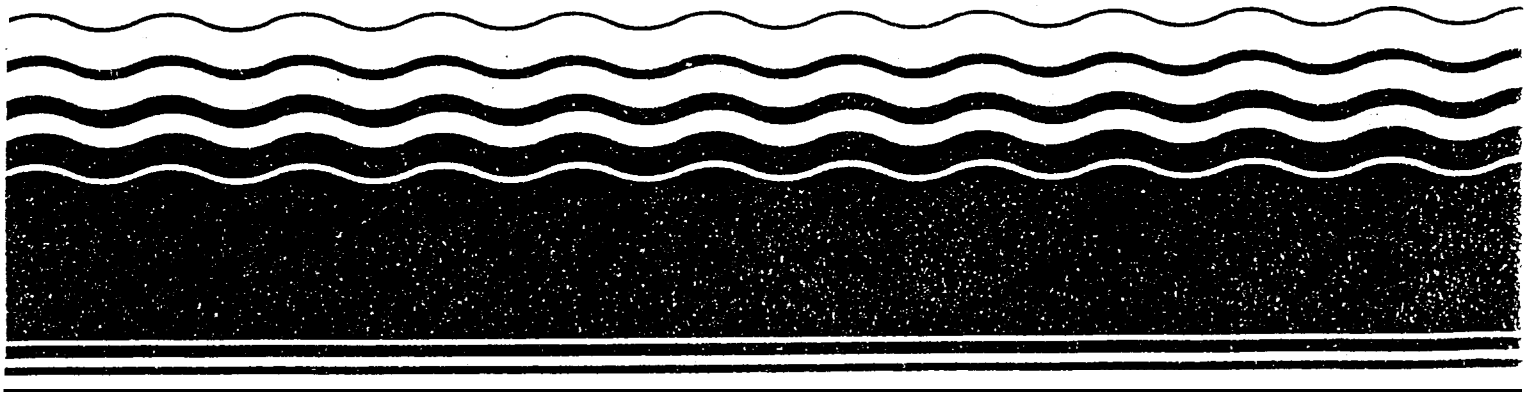


Table of Contents

SECTION 6

SECTION 7

APPENDIX 7A

SECTION 8

APPENDIX 8.4A

SECTION 10

SECTION 11

SECTION 16

SECTION 17

SECTION 20

A GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AA	atomic adsorption
AAM	Algal Assay Medium
AC	alternating current
ACS	American Chemical Society
AGI	American Geological Institute
API	American Petroleum Institute
AR	authorized requester
ARAR	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
ATM	atmosphere
BNA	base neutral acids
CAA	Clean Air Act
CCS	Contract Compliance Screening
CDC	Center for Disease Control
CDP	common-depth-point profiling
CE	current electrode
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980 (PL 96-510)
CERCLIS	CERCLA information System
CFR	Code of Federal Regulations
CIR	color Infrared
CLP	Contract Laboratory Program
COC	chain of custody
COD	Chemical Oxygen Demand
COE	U.S. Army Corps of Engineers
CRDL	Contract Required Detection Limits
CWA	Clean Water Act
d.b.h	diameter breast height
DC	direct current
DO	dissolved oxygen
DOJ	Department of Justice
DOT	Department of Transportation
DQO	data quality objectives
DRI	Direct Reading Instrument
ECD	electron capture detector
EDMI	electronic distance meter instrument
Eh	oxygen-reduction potential
EM	electromagnetic
EMSLLV	Environmental Monitoring System Laboratory-Las Vegas
EOS	equivalent opening size
EP	toxidty-extraction procedure toxicity
EPA	Environmental Protection Agency
EPIC	Environmental Photographic Interpretation Center
ER	electrical resistivity
ERP	Emergency Response Plan
ERT	EPA Emergency Response Team
ERTS	Earth Resources Technology Satellite
EROS	Earth Resources Observation Systems
ESB	EPA Environmental Services Branch
ESD	Environmental Services Division
EST	Eastern Standard Time
EV	electron volt
FAA	Federal Aviation Administration
FIT	Field Investigation Team
FS	Feasibility Study
FSP	Field Sampling Plan
GC	Gas Chromatography
GC/MS	Gas Chromatrography/Mass Spectrometer

GEMS	Graphical Exposure Modeling System
gpm	gallons per minute
GPR	Ground Penetrating Radar
GSC	a company name
GT	greater than
HASP	Health and Safety Plan (see also Site Safety Plan)
HAZMAT	Hazardous Materials Team
HEP	Habitat Evaluation Procedure
HEPA	High Efficiency Particulate Air
HNU	indicates a photoionization device
HR	heart rate
HRS	Hazard Ranking System
HSCD	EPA Headquarters Hazardous Site control Division
HSI	habitat suitability index
HSL	Hazardous substance List (previous term for Target Compound List)
HSO	Health and Safety Officer (see also SSC, SSHO and SS0)
HSWA	Hazardous and Solid Waste Amendments
HU	habitat unit
IATA	international Air Transport Association
ICAO	international Civil Aviation Regulations
ICP	inductively coupled Plasma
ICS	Incident Command System
ID	inside diameter
IDL	instrument Detection Limit
IDLH	immediately dangerous to life and health
IFB	invitation for bid
IP	ionization potential
ISCO	instrumentation Specialists Company
ITD	Ion Trap Detector
LEL	lower explosive limit
LL	liquid limit
LOO	limits of detection
LOQ	limit of quantitation
LSC	liquid sample concentration
LT	less than
LUST	leaking underground storage tank
LVZ	low-velocity layer
MAD	maximum applicable dose
MDL	Method Detection Limit
m/sec	meters per second
MHz	megahertz
MS/MS	Mass Spectrometer/Mass Spectrometer
NBS	National Bureau of Standards
NCDC	National Climatic Data Center
NCIC	National Cartographic information Center
NCP	National Contingency Plan
NEIC	National Enforcement investigation Center
NGVD	National Geodetic Vertical Datum
NIOSH	National institute for Occupational Safety and Health
NMO	normal moveout
NOAA	National Oceanographic and Atmospheric Administration
N.0.S	not otherwise specified (used in shipping hazardous material)
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NRC	Nuclear Regulatory Commission

NSF	National Sanitation Foundation
NTIS	National Technical Information Service
NWS	National Weather Service
OD	outside diameter
OERR	EPA Office of Emergency and Remedial Response
OSHA	Occupational Safety and Health Administration
OSWER	EPA Office of Solid Waste and Emergency Response
01	oral temperature
OVA	Organic Vapor Analyzer (onsite organic vapor monitoring device)
OWPE	EPA Office of Waste Programs Enforcement
PARCC	Precision, Accuracy, Representativeness, Completeness, Comparability
PCBS	polychlorinated biphyenyls
PDS	personnel decontamination station
PE	potential electrode
PEL	permissible exposure limtt
PHC	principal hazardous constituents
PI	plasticity Index
PID	photo ionization detector
PL	plastic limit
PO	EPA Headquarters Project Officer
POTWs	publically owned treatment works
ppb	parts per billion
PPE	personal protective equipment
ppm	parts per million
PRP	Potentially Responsible Party
psig	pounds per square Inch gauge
PVC	polyvinyl chloride
QA	quality assurance
QA/QC	quality assurance/quality control
QAMS	Quality Assurance Management staff
QAPjP	Quality Assurance Project Plan (see QAPP)
QAPP	former abbreviation for Quality Assurance Plan (see QAPjP)
QC	quality control
RA	remedial action
RAS	Routine Analytical Service
RCRA	Resource Conservation and Recovery Act of 1978 (PL 94-580)
RD	remedial design
RDCO	Regional Document Control Officer
REM	Remedial Planning
REM/FIT	Remedial Planning/Field investigation Team
RI	Remedial Investigation
ROD	Record of Decision (previous title for Remedial Project Manager)
RPM	EPA Remedial Project Manager
RSPO	Remedial Site Project Officer
RSCC	Regional Sample Control Center
RTDs	resistance temperature detectors
SARA	Superfund Amendments and Reauthorization Act of 1986 (PL 99-499)
SAS	Special Analytical Service
SDL	Sample Detection Limit
SI	Site Inspection
S1 units	International System of Units
SIM	Selected Ion Monitoring
SCBA	self-contained breathing apparatus
SCS	Soil Conservation Service
SDWA	Safe Drinking Water Act

SMCRA	Surface Mining Control and Reclamation Act
SMO	sample Management Office
SM	Site Manager
SOPS	standard operating procedures
SP	spontaneous potential
SPM	Site Project Manager (previous title for Site Manager)
SRM	Standard Reference Material
SSC	Site Safety Coordinator (see also SSHO, SS0, and HSO)
SSHO	Site Safety and Health Officer (see also SSC, SS0, and HSO)
SSO	Site Safety Officer (see also SSC, SSHO. and HSO)
STAPPA/ALAPCO	the State and Territorial Air Pollution Program Administrators and the Association of Air Pollution Control Officials
STAR	Stability Array
TAL	Target Analyte List
TAT	technical assistance team
TCDD	2,3,7,8-tetrachlorodibenzo-pdioxin
TEGD	Technical Enforcement Guidance Document
TDD	Technical Directive Documents
TDs	total dissolved solids
TIC	Tentatively Identified Compounds
TLD	thermoluminescent detector
TLD badge	Thermoluminescent detector badge
TLV	threshold limit value
TOC	Total Organic Carbon
TOH	Total Organic Halogen
TOX	Total Organic Halides
TR	traffic report
TSCA	Toxic Substances Control Act
TSDF	Treatment, Storage, and Disposal Facility
UEL	upper explosive limit
UNAMAP	User's Network for Applied Modeling of Air Pollution
U.S. EPA	U.S. Environmental Protection Agency
USCS	Unified Soil Classification System
USDI	U.S. Department of Interior
USGS	U.S. Geological Survey
USPS	U.S. Postal Service
UV	ultraviolet
VOA	volatile organic analysis
VOC	Volatile Organic Compound
WAS	Work Assignments
WP	work plans

ACKNOWLEDGMENTS

This document was developed for the Office of Solid Waste and Emergency Response (OSWER) with assistance from the following individuals:

- Lisa Woodson Feldt (Hazardous Site Control Division, OERR)
- James B. Moore (CH2M HILL)
- Bob Steclk (NUS)
- Jim Adams (Region V, Environmental Services Division)
- Lisa Gatton-Vidulich (Region VI, Environmental Services Division)
- Duane Geuder (Hazardous Response Support Division, OERR)
- Rolly Grabble (Region VIII, Environmental Services Dtvlsion)
- AJ Hanke (Region IV, Waste Management Division)
- Eric Johnson (Region VIII, Waste Management Division)
- Doug Lair (Region IV, Environmental Services Division)
- Steve Lemmons (Region Vi, Environmental Services Division)
- Stove Ostradka (Region V, Waste Management Division)
- Steve Serian (Region 1, Waste Management Division)
- Ed Sheener (Region Ill, Waste Management Division)
- Tim Travers (Region Ill, Waste Management Division)
- Lee Tyner (OGC)

The following lndlvlduals were largely responsible for the technical content of the compendium:

- Artemas Antipas (CH2M HILL)
- Steve Paquette (CDM)
- Dick Crim (CH2M HILL)
- Larry Fftzgeraid (E.C. Jordan)
- Jody Goaron (CH2M HILL)
- Jane Gendron (CH2M HILL)
- Joseph Boros (NUS)
- Don Heinle (CH2M HILL)
- Katie Brady (NUS)
- Gary Helms (CH2M HILL)
- Patrick Byrne (NUS)
- Larry Holm (CH2M HILL)
- Paul Clay (NUS)
- Don Johnson (CH2M HILL)
- Jeffrey Orient (NUS)
- Mike Keating (CH2M HILL)
- Hala Roffman (NUS)
- Davld Lincoln (CH2M HILL)
- Matthew Soltis (NUS)
- Craig Rightmire (CH2M HILL)
- Denise Taylor (NUS)

- Larry Well (CH2M HILL)
- Robert Tubach (NUS)
- Mark Ulintz (NUS)

Helpful suggestions and comments on the draft document were provided by the following, as well as other EPA and contractor staff:

- Mike Amdurer (EBASCO)
- Paul Beam (Hazardous Site Control Division, OERR)
- Linda Boornazian (CERCLA Enforcement Division, OWPE)
- Ken Jennings (CERCLA Enforcement Division, OWPE)
- Doug Mundrick (Region IV, Environmental Services Division)
- Julie Pfeffer (CH2M HILL)
- Andrew Szilagyi (CDM)

The compendium could not have been completed without the selfless dedication of these people:

- Diane Anderson (CH2M HILL)
- Cacey Combs (CH2M HILL)
- Barbara Hart (CH2M HILL)
- Cindy Howe (CH2M HILL)
- Craig Ripple (CH2M HILL)
- Betty Toms (CH2M HILL)
- Pam Feikema (Blue Pencil)
- Jeanie Massey (Blue Pencil)
- Pat Petretti-Velikov (Blue Pencil)

The camera-ready copy was prepared by Ebon Research Systems, 1173 Spring Centre South Boulevard, Altamonte Springs, Florida 32714.

SECTION 1

USE OF THE COMPENDIUM

1.1 SCOPE AND PURPOSE

Webster's Third New International Dictionary **(Unabridged) defines "compendium" as:**

- **A. A brief compilation or composition consisting of a reduction and condensation of the subject matter of a larger work**
- **B. A work treating in brief form the important features of a whole field of knowledge or subject matter category**

While the reader may take exception to the use of the word "brief" to describe this compendium, the two volumes represent an astoundingly reduced version of the many field operations methods that have been used during remedial response activities at hazardous waste sites. This compendium focuses primarily on techniques and methods used during the fieldwork phase of a remedial Investigation. Exhibits 1-2 and 1-3 emphasize this orientation, and provide the reader with a guide to the applicability of the various sections to the Remedial Investigation / Feasibility Study (RI/FS) process. The compendium also provides some limited information on those subjects for which extensive guidance exists elsewhere, such as project planning and management, quality control, decontamination, and health and safety issues. These latter subjects are addressed only briefly, primarily to guide the reader into an appreciation of how the various facets of project management and execution are interrelated.

The compendium was written primarily to assist the Site Manager (SM). The SM is the individual who is responsible for the successful execution of a work assignment, and who maybe an employee of the EPA, state agency, Potentially Responsible Party (PRP), or contractor. Generally, the compendium addresses the SM as a contractor's employee who is working with an EPA Remedial Project Manager (RPM) at the regional project level on a Superfund program, such as Field Investigation Team (FIT) or Remedial Planning Activities (REM II, Ill, or IV). The EPA management structure Includes a Regional Project Officer, who oversees implementation of a program at the EPA regional level, and a Project Officer at EPA Headquarters, who is responsible for program guidance Agency-wide. Management structures vary with the contractors' organization.

This compendium is one of a series of guidance and technical documents of which the Site Manager and, to a lesser degree, task leaders and field workers should be aware before beginning fieldwork. These documents are listed in Exhibit 1-1.

The list of applicable guidance is far from complete; a more detailed (but still Incomplete) list of guidance and technical resource documents, and their relationship to RI/FS phases and tasks is contained in Appendix 1A. Subsequent sections of the compendium will list other helpful references under the heading "Information Sources."

Exhibit 1-1
GUIDANCE AND TECHNICAL DOCUMENTS

- *Guidance on Remedial Investigations Under CERCLA* **(EPA 540/G-85/002)**
- *Guidance on Feasibility Studies Under CERCLA* **(EPA 540/G-85/003)**
- *Superfund Remedial Design and Remedial Action Guidance* **(OSWER Directive 9355.04A)**
- *Superfund Public Health Evaluation* Manual **(OSWER Directive 9285.4-1)**
- *Superfund ExposureAssessment Manual* **(OSWER Directive 9285.5-1)**
- *Standaed Operating Safety Guides* **(OSWER Directive 9285.1-1 B)**
- *Occupational Sqfety and Health Guidance Manual for Hazardous Waste Site Activities* **(DHHS (NIOSH) Publication 85-1 15)**
- *Data Quality Objectives for Remedial Response Activities* **(OSWER Directive 9355.O-7B)**
- *Samplers and Sampling Procedures for Hazardous Waste Sources* **(EPA 800/2-80-01 8)**
- *User's Guide to the Contract Laboratory Program* **(OERR, December 1988)**
- *EPA Regional Standard Operating Procedures, Guidelines and Directives*

The purpose of this compendium is to provide the reader with a summary of field techniques to use as references during preparation of project planning documents. The compendium does not contain a series of standard operating procedures to use as references in their entirety, but rather it may be used as a reference to a series of methods with project and site-specific modifications added. For example, a quality assurance project plan could present techniques for gathering data on chemical concentrations in fish tissues as shown in the following Example Citation.

Example Citation

TASK 1. BIOTA EVALUATIONS

Subtask 1. A. Electrofishing in Mung Creek

- **A. Limitations and Application - Subsection 12.6.3.3, Aquatic (Freshwater) Field Methods Summary, pp. 1 2-24 and 12-25, Section 12, Revision No. O, *Compendiumof Field Operations Methods* (COFOM #O).**

- **B. Sampling Techniques - Subsection D2, Electrofishing, Appendix 12A, pp. 12A-32 through 12A-35, COFOM #O.**

  Modifications - Only carp will be collected. Specimens smaller than 8 Inches in length and 2 pounds in weight will be released. Any specimens caught below 14th Street Bridge will be released. See site safety plan for boating and collection safety procedures.

- **C. Laboratory Techniques- Subsection 12.6.3.3, pp. 12-23 and 12-24, Subsection E4, Appendix 12A pp. 12A-41 through 12A-46, COFOM #O.**

  Modifications - See CLP SAS in Task 4, Sample Analysis

The compendium will be available to every EPA region and contractor and can serve as a common source for methods citation, as indicated above.

1.2 DEFINITIONS AND ABBREVIATIONS OR ACRONYMS

Each section of the compendium defines terms specific to that section and deciphers abbreviations or acronyms when they are first used. A glossary is furnished in the beginning of each volume. The most frequently used abbreviation is defined below.

Site Manager (SM)

The individual who is responsible for the successful execution of a work assignment. SM usually refers to a contractor's employee.

Exhibit 1-2

RELATIONSHIP AMONG STANDARD RI/FS TASKS AND THE COMPENDIUM

Description of Standard RI/FS Tasks and Subtasks	Applicable Sections and Subsections of the “Compendium of Field Operations Methods”*
Project Planning	2,3.2,3.3,3.4,4,5,6, 16 17,18,19,20
Community Relations	Not directly applicable
Field investigations	
Project management	2,3, 17,18, 19,20
Quality Control	Throughout procedure specific
Fieldwork, air	7,11,15
Fieldwork, biota	12
Fieldwork, close support laboratories	5.2,”7,15
Fieldwork, RI-derived waste disposal	3.2,5.2.6.4,8.1 .6.3
Fieldwork, son gas	
Fieldwork, support	3,17, 18,19,20
Fieldwork Well logging	8.1,8.3
Fieldwork, mapping and survey	14
Fieldwork, geophysical	8.4
Fieldwork, well installation	8.1,8.5
Fieldwork, groundwater	8.5
Fieldwork, soil	8.1,8.2,8.3
Fieldwork, source testing	7, 13,15
Fieldwork, surface water	10
sample Analysis	
Fieldwork, close support laboratory	5.2,15
Data validations	16
sample management	4,5,6
Data Evaluation	16
Assessment of Risk	Not directly applicable
Treatability Study/Pilot	9 (soils engineering data)
Remedial investigation Reports	Not directly applicable
Remedial Alternatives Screening	Not directly applicable
Remedial Alternative Evaluation	Not directly applicable
Feasibility Study RI/FS Reports	Not directly applicable
Post RI/FS Support	Not directly applicable
Enforcement Support	Not directly applicable
Miscellaneous Support	Not directly applicable
ERA Planning	Not directly applicable

---

*See Exhibit 1-3 for titles.

Exhibit 1-3

TITLES OF SUBJECTS IN "COMPENDIUM OF FIELD OPERATIONS METHODS"

Section and Subsection

1. Use of the Compendium
2. Preparation of Project Description and Statement of Objectives
3. Implementing Field Activities
   - 3.1 General Considerations
   - 3.2 Control of Fieldwork-Generated Contaminated Material
   - 3.3 Organization of the Field Team
   - 3.4 Decontamination
   - 3.5 General Health and Safety Considerations
4. Sample Control, Including Chain of Custody
5. Laboratory Interface
   - 5.1 National Contract Laboratory Program
   - 5.2 Noncontract Laboratory Program
     - 5.2.6.4 Residual samples and Analytical Wastes
6. Sample Containers, Preservation, and Shipping
   - 6.1 Sample Containers and Preservation
   - 6.2 Packaging, labeling, and Shipping
7. Field Methods for Rapid Screening for Hazardous Materials
8. Earth Sciences
   - 8.1 Geologic Drilling
   - 8.2 Test Pits and Excavations
   - 8.3 Geological Reconnaissance and Geological i-egging
   - 8.4 Geophysics
   - 8.5 Groundwater Monitoring
9. Earth Sciences Laboratory Procedures
   - 9.6.2 Laboratory Selection
   - 9.6.3 Physical Properties
   - 9.6.4 Chemical Properties of Soil and Rock
   - 9.6.5 Compatibility Testing
   - 9.6.6 Laboratory and Analysis Records
10. Surface Hydrology
    - 10.1 Flow Measurement
    - 10.2 Sampling Techniques
11. Meteorology and Air Quality

Exhibit 1-3
(continued)

12. BiologyEcdogy
    - 12.6.1 Presence of Toxic Substances
    - 12.6.2 Field Collection Techniques-General
    - 12.6.3 Field Methods-Specific
        - 12.6.3.2 Terrestrial Field Methods Summary
        - 12.6.3.3 Aquatic (Fresh Water) Field Methods Summary
        - 12.6.3.4 Marine Field Methods Summary
    - 12.6.4 Laboratory Tests and Analyses

13. Specialized Sampling Techniques
    - 13.1 Wipe Sampling
    - 13.2 Human Habitation Sampling
    - 13.3 TCDD sampling
    - 13.4 Container sampling

14. Land Surveying, Aerial Photography, and Mapping

15. Field Instrumentation

16. Data Reduction, Validation, Repotting, Review, and Use

17. Document Control

18. Corrective Action

19. Quality Assurance Audit Procedures

20. Quality Assurance Reporting

1.3 APPLICABILITY

The techniques presented in this compendium maybe used in remedial response activities conducted for or by the EPA. Other entities (state agencies, other federal agencies, or private concerns) may also find the techniques useful. All of the methods presented have been used by EPA contractors in executing fieldwork. Some of EPA's region-specific standard operating procedures, which are referenced in each section of this compendium, may take precedence over these more general methods (see Subsection 1.6).

The procedures are written for the trained, experienced professional who should realize that every hazardous waste site is discrete and every work assignment is different. Every hazardous waste site requires a degree of personal protection, a monitoring system to detect hazards, and an adaptation of work procedures to site conditions. The user should realize that not all procedures are suitable for use, or can even be accomplished, with every level of personal protection. The amount of time spent executing a procedure and the number of trained, experienced people needed to accomplish the work will increase dramatically as the need for personal protection increases.

1.4 RESPONSIBILITY

The Site Managers bear prime responsibility for selection of the proper methods to accomplish the goals and objectives of their work assignments. The SM uses the capabilities of various technical specialists and the data quality objectives to precisely determine the methods used. Senior management and the clients provide quality assurance and quality control (QA/QC), and overall direction.

1.5 UPDATES

The compendium represents a snapshot of methods and techniques that, in the rapidly evolving field of remedial response, will undergo changes as new procedures are defined. Additionally, methods that were not included in this compendium because of a lack of demonstrated success at the time of writing may rapidly emerge as methods of choice. EPA’s intent is to provide periodic updates presenting newly evolved methods and improvements on “old” methods. Comments, suggestions, and recommended procedures are solicited from the users. Please address such material to:

Ms. Lisa Woodson Feldt
U.S. EPA (WH548E)
401 M Street, SW
Washington, DC 20460

1.6 REGION-SPECIFIC VARIANCES

As stated, these procedures have been used by EPA contractors during remedial response activities. Variances specific to the various EPA regions are listed in. each section. These variances were updated using information supplied by the regions for this version and were current at publication. However, because performance requirements vary among EPA contracts, among EPA regions, within EPA regions, and even among tasks on the same work assignments, users of this compendium are strongly urged to consult the appropriate EPA official to obtain the most current variations to the methods listed in this compendium. Some regions, such as the Engineering Support Branch in Region IV, have published a detailed standard operating procedure for use by persons executing fieldwork.

Appendix 1A

INTERREL4TIONSHIP AMONG POLICY GUIDANCE, TECHNICAL RESOURCE DOCUMENTS, AND THE RI/FS PHASES AND TASKS

RI/FS Phases/Tasks	Primary or Policy Guidance (SARA & NCP for All)	Secondary or Technical Resource Documents
Scoping		
Collection and Analyses of Existing Data	Data Quality Objectives for Remedial Response Activities (EPA, 3/87)	
	Data quality Objectives for Remedial Response Activities (EPA, 3/87)	Management of Hazardous Waste Leachate, SW 871 (EPA. 1982)
	Gudiance Document for Cleanup of Surface Tank and Drum Sites (EPA, 5/85)	Leachate Plume Management (EPA, 11/85)
Identification of Preliminary Remedial Action Altematives	Guidance Documents for Cleanupd Surface Impoundment Sites (EPA, 6/86)	
	Handbook on Remedial Action on Waste Disposal Sites (EPA, t 0/85)	
	Other draft documents not yet In circulation (e.g., groundwater remediation guidance, landfill guidance, etc.)	
Identification on ARARs	CERCLA Compliance with other Environmental Statutes (EPA, 10/85)	
Identification of Data Needs and Sampling Strategles Activities	Data Quality Objectives for Remedial Response (EPA, 3/87)	
Health and Safety Planning	Occupational Safety and Health: Guidance Manual for Hazardous Waste Site Activities (NIOSH, 10/85)	Standard Operation Safety Guides (EPA 11/84)
SAP (QAPjP/FSP)	A Compendium of Field Operations Methods (3/84)	Sediment Sampling Quality Assurance Users Guide (EPA, 7/85)
		Soil Sampling Quality Assurance Users Guide (EPA 5/84)
Work Plans		Federal-Lead Remedial Project Management Handbook (EPA, 12/88)
		State-Lead Remedial Project Management Handbook (EPA, 1/86)

Go to RI phase
and FS Phase 1

Appendix 1A
(continued)

RI/FS Phases/Tasks	Primary or Policy Guidance (SARA & NCP for All)	Secondary or Technical Resource Documents
<u>RI Phase</u>		
Field Investigation	A Compendium of Field Operations Methods (3/34)	Test Methods for Evaluation of Solid Waste, 2nd Edition (EPA 6/86) Geophysical Methods for locating Abandoned Wells (5/84) Geophysical Techniques for Sensing Buried Wastes and Waste Migration (EPA 1964) Practical Guide for Groundwater Sampling (EPA 9/95)
Sample Analysts	A Compendium 01 Field Operations Methods (3/64) User's Guide to the CLP	
Risk Assessment	Superfund Public Health Evaluation Manual (EPA 12/85) Superfund Exposure Assessment Manual (EPA. 5/86)	
Other Data Evaluation Methods		Modeling Remedial Actions at Uncontrolled Hazardous Waste Sites (EPA 4/65)
Refinement of Remedial Action Objectives	Data Quality Objectives for Remedial Response Activities (EPA, 3/87)	

Go to FS Phase I

Appendix 1A
(continued)

RI/FS Phases/Tasks	Primary or Policy Guidance (SARA & NCP for All)	Secondary or Technical Resource Documents
Identification of Potential Technologies	Guidance Document for Cleanup of Surface Tank and Drum Sites (EPA, 5/85) Handbook on Remedial Actions al Uncontrolled Hazardous Waste Sites (4/85)	Management of Hazardous Waste Leachate, SW 871 (EPA, 1982) Leachate Plume Management (EPA 11/85) Mobile Treatment Technologies for Superfund Wastes (EPA 9/88) Review of In-place Treatment Techniques for Contaminated Surface Soils (EPA 7/84) Treatment Technology Briefs Alternatives to Hazardous Waste landfills (EPA 7/88) Handbook for Stabilization/Solidification d Hazardous Wastes (EPA 9/88) System to Accelerate In Situ Stabilization of Waste Disposal (EPA 9/88) Slurry Trench Construction for Pollution Migration Control (EPA 2/84)
Technology Screening	Handbook of Evaluating Remedial Action Technology Plans (EPA, 8/83) Directory of Commercial Hazardous Waste Treatment and Recycling Facilities (EPA. 12/85)	
Assembly of Alternatives		

Go to FS Phase II

Appendix 1A
(continued)

RI/FS Phases/Tasks	Primary or Policy (Guidance (SARA & NCP for All)	Secondary or Technical Resource Documents
ES PHASE III		
Alternative Evaluation		
- Efftectiveness	Modeling Remedial Actions at Uncontrolled Hazardous Waste Sites (EPA 4/65) Superfund Public Health Evaluation Manual (EPA 12/85)	
- Implementability		Directory of Commerical Hazardous Waste Treatment and Recycling Facilities (EPA 12/85) Petitions to Delist Hazardous Waste A Guidance Manual (EPA 4/85)
- cost	Costs of Remedial Response Actions at Uncontrolled Hazardous Waste Sites (EPA 1981) Remedial Action Costing Procedure Manual (EPA, 9/65)	
Alternative Screening		
Go to RI Phase II or FS Phase III		
RI Phase II		
Bench-Scale Testing		
Pilot Testing	Practical Gukte-Trial Burns for Hazardous Waste Incinerators-- Project Summary (EPA 7/86)	
Go to FS Phase III		

Appendix 1A
(continued)

RI/FS Phases/Tasks	Primary or Policy Guidance (SARA & NCP for AU)	Secondary or Technical Resource Documents
FS PHASE III		
Detailed Evaluation:		
- Effectiveness	Modeling Remedial Actions at Uncontrolled Hazardous Waste Sites (EPA, 4/85) Superfund Public Health Evaluation Manual (EPA, 12/85) Superfund Remedial Design and Remedial Action Guidance (EPA, 2/85)	
- Implementabilit y		Directory d Commercial Hazardous Waste Treatment and Recycling Facilities (EPA 12/85) Petitions to Delist Hazardous Waste: A Guidance Manual (EP44/85)
- cost	Costs of Remedial Response Actions at Uncontrolled Hazardous Waste Sites (EPA 1981) Remedial Action Costing Procedures Manuel (EPA, 9/85)	
Summery		
COMMUNITY RELATIONS	Community Relations in Superfund: A Handbook (EPA. 3/88)	

SECTION 2

PREPARATION OF PROJECT DESCRIPTION AND STATEMENT OF OBJECTIVES

2.1 SCOPE AND PURPOSE

This section describes the information that should be addressed in the "project description and statement of objectives" section of a field activities plan. The information discussed below Is applicable to all such plans, but it should be modified to meet the needs of a specific project.

A section entitled "project description and statement of objectives" should be Included in all response activity plans; such a section is required in the quality assurance and sampling plans for remedial investigations and in work plans for Field Investigation Team (FIT) operations. Project descriptions are also used as input to the site safety plan. The project description defines the goals of the project and describes how the information necessary to meet the project goals will be obtained. The project description should provide the reader with enough information to judge the appropriateness and adequacy of the quality assurance, work, or sampling plans. The project description and statement of objectives are integral elements in the development of data quality objectives, which are qualitative and quantitative statements that outline the decision-making process for remedial responsibilities and specify the data required to support those decisions. Extensive guidance on development of data quality objectives exists (OSWER Directive 9355.0-7B) and will not be repeated within this document.

2.2 DEFINITIONS

Analytical Parameters

Chemical constituents and levels of detection required for sample analysis. Parameters also include field measurements (e.g., pH, groundwater levels), engineering soils data (e.g., soil permeability, particle size analysis), and Contract Laboratory Program (CLP) Special Analytical Services (SAS) components.

Quality Assurance Project Plan (QAPjP)

The policies, organization, objectives, functional activities, and specific QA and Quality Control (QC) activities designed to achieve the data quality goals of the specific project(s) or continuing operation(s).

Sample Matrix

Media from which the sample is collected (e.g., soil, groundwater, surface water).

Sampling Plan

A program of action that is developed prior to field activities and that describes the methods and procedures for obtaining representative portions of the environment being investigated.

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

2.3 APPLICABILITY

Remedial response activities, such as field investigation and sample collection, require a written plan that should include a project description. The description should be included in its entirety and may not be referenced from another document.

2.4 RESPONSIBILITIES

The Site Manager or designated person who is responsible for writing the work plan, sampling plan, or quality assurance project plan is also responsible for the section on project description and statement of objectives.

2.5 RECORDS

The project description and statement of objectives constitute the record. Pertinent information that is used to develop the project description should be recorded and maintained by the SM.

Such information would include results of previous site investigations; any environmental permits associated with the site; tax records results of inspections by other state, local, or federal agencies; newspaper accounts records from community relations interviews; aerial photography (such as those typically available from the Environmental Photographic Interpretation Center); and any other data that will assist the SM in developing the project description and statement of objectives. It is important, particularly on projects involving enforcement activities, that adequate records be kept to document the process by which project objectives were derived. Project objectives determine sampling strategy and are directly related to the final costs of the response activities, the adequacy of the feasibility study, and the success of the remedial alternative. Meeting notes, telephone conversation records, assumptions regarding interpretations of work assignments, and other records pertaining to the development of the project description and statement of objectives should be maintained in a manner that will allow the SM and project team to reconstruct the decision-making process that led to the stated project objectives.

2.6 PROCEDURES

The project description should be site-specific and include at least the following items:

- Site description and history
- Schedule of activities
- Intended data usage
- Identification of sample matrices and parameters
- Sample design description and rationale

Each of these items are described below.

2.6.1 Site Description and History

The site description should include all pertinent physical and land use information. Maps, drawings, and photographs should be included, if available. The following information should be provided:

- Size, including area within facility boundaries and the extent of contamination above defined thresholds, if known (See also Section 17 for discussion of background levels used as a defined threshold.)

- Specific location description inclding directions and distances from nearby towns

- Surrounding geography (e.g., town, city, county, or state boundaries and jurisdictions; power lines; railroads; roads; and topography)

- Physical description including the following:

  Geologic conditions
  Soil types and depths
  Surface water hydrology
  Groundwater hydrology
  Flora
  Fauna
  Terrain

- Onsite conditions (e.g., the presence of pits, ponds, tanks, drums, standing water, buildings, and wells)

- Climatological description for the region and for site-specific parameters, such as wind speed and direction, precipitation patterns, and freezing conditions

- Demographics and surrounding land use (e.g., agricultural, industrial, or residental; populace at risk; and transportation patterns)

Relevant historic facts about the site “should be included in the project description. Following are examples of useful historic information:

- Past and present uses of the site

- Identification of onsite facilities and description of activities at these facilities, including any facilities that have been demolished and any subsurface facilities (e.g., tanks, utilities, and vaults)

- Onsite disposal and materials handling practices
    - Areas used for disposal and methods of disposal (tanks, drum, pit, pond, lagoon, landfill, land treatment, etc.)
    - Material storage or transfer facilities and areas onsite, including spills or dumps
- Description of wastes onsite
    - Quantity
    - Physical state
    - Chemical identification, If known
    - Location
- Prior complaints or agency actions concerning the site including any permits held by the site (Permit applications are also of interest, even if no permit was awarded,)
- Prior sampling activities onsite or near the site, and the resultant data (This information should be evaluated in terms of the confidence held in the data and of the Intended usage of that data.)
- Prior remedial or response activities
- Prior accidents or incidents onsite, such as fires, explosions, or chemical releases

A detailed site history should be completed before initiating any activities onsite. A brief summary of the site history, which includes information that may affect sampling plans, work plans, the site safety plan, or the quality assurance plan, should be included in the project description. The reliability of the information should be assessed, and the acceptability of the existing data for intended use should be determined.

2.6.2 Schedule of Activities

The project schedule should include project milestones, such as the startup date for the project, field investigation dates, the data review period, and dates when reports are due. The activity(s) addressed by quality assurance and work sampling plans should be identified. The expected start and finish dates for the project and the field work must be stated. A diagram. flow chart, or critical path chart should be included to help the reader understand the project.

2.6.3 Intended Data Usage

To determine whether the work, sampling, and quality assurance plans will generate data that meet the project objectives, it is necessary to define the types of decisions that will be made, identify the intended use of the data, and design a data collection program. Data quality objectives (DQO) are defined as “an integrated set of thought processes which define data quality requirements based on the identified end use of the database” (OSWER Directive 9355.0-76). The DQOS are useful in developing a sampling plan and analytical plan so that sufficient data of known, defensible quality are obtained to assist the decision-makers in arriving at sound decisions concerning remedial response activities. The DQO, based on the intended use of the data, will assist in determining the appropriate detection limits, analytical methods, and sample handling procedures (chain-of-custody requirements, as well as preservation and holding times).

Possible uses for the data are listed below:

- Confirm suspected contaminants or concentrations of contaminants.
- Qualitatively assess the nature and extent of contamination.
- Design additional sampling campaigns.
- Implement operable units involving cleanup and removal.
- Compare with established criteria (e.g., drinking water standards and National Pollution Discharge Elimination System (NPDES) requirements).
- Assess exposure, endangerment, and risks.
- Screen or select remedial alternatives.
- Use as input to the conceptual design of remedial technologies.
- Use in future enforcement actions and litigation. The applicable legislation (CERCLA, RCRA, TSCA, etc.) should be identified.

The specific purpose of the site investigation should be stated. The use of the data as a qualitative or quantitative measure should be specified. Discrete quantitative requirements for the data, such as a level of detection required for comparison with health criteria, should also be specified.

2.6.4 Identification of Sample Matrices and Parameters

Identification of the appropriate sample matrices and parameters should be included in the project description. A table similar to Exhibit 2-1 may suffice. A listing of compounds should be included. Any special sample handling requirements (e.g., filtering and dry weight analyses) should be identified in this section. Parameters for special analytical services and Geotechnical and hydrogeological investigations should also be identified.

2.6.5 Sampling Design Description and Rationale

A brief description of the sampling design and rationale should be included in the project description. DQO guidance addresses sampling design description and rationale. If DQO guidance is followed, a single scoping section covering anticipated remedies, data requirements, and sampling should result. The sampling design description should include potential sampling locations and parameters. A rationale for choosing the sampling points, number of samples, medium of sample (air, soil, or water), sampling methods, amounts, presentation techniques and chemical parameters should be discussed. Sample containers, preservation techniques, and shipping methods should be selected in accordance with the latest

Exhibit 2-1
SAMPLING FOR XYZ SITE

	Target Compound List Organics (No x Freq = Total	Target Compound List Inorganics[a] Tasks I &ii Metals Task III Cyanide (No. x Free. = Total	Special X naiyticai Services (No. x Freq. = Total
Groundwater			
Monitoring Well	19x2=38	19 x 2= 38	
Residential Wells[b]	10 x 2 =2O	5 x 2 = 1O	5 x 2 = 1O
Surface Water			
Water	6 x 1=6	6 x 1 =6	
Sediment	6 x 1=6	6 x 1 =6	
Soils			
Chemical	46 x 1 = 46	46 x 1 = 46	
Physical			25 x 1 = 25[c]

---

[a] Groundwater sample to be analyzed for total cyanide and total metals will not be filtered before analysis. An aliquot will be filtered in the field before sample preservation, and will be analyzed for soluble metals and soluble cyanide. Detection limit requirements are specified in "QAPjP for XYZ Site, Appendix A, Analytical Requirements."

[b] SAS will be used to analyze residential well samples for ammonia, nitrates and nitrites.

[c] 10 Atterberg limits, 15-grain-size distribution.

EPA and Department of Transportation (DOT) requirements. Sections 4,5, and 6 of this compendium contain information on these procedures; however, consultation with EPA and DOT is strongly recommended.

2.7 REGION-SPECIFIC VARIANCES

No specific regional variances have been Identified; however, ail future variances will be incorporated in subsequent revisions to this compendium. Information on van'antes may become dated rapidly. Thus, users should contact the regional EPA RPMs for full details on current regional practices and requirements.

2.8 INFORMATION SOURCES

U.S. Environmental Protection Agency. "*Data* Quality Objectives: *Development Guidance for Uncontrolled Hazardous Waste Site Remedial Response Activities.* " OSWER Directive 9355.0-7B, Sections B, C, D, and F. Washington, D. C.: Hazardous Site Control Division. 1 April 1987.

U.S. Environmental Protection Agency. *Guidance for Preparation"on of Quality Assurance Project Plans.* QAMS, *005/80.* Washington, D.C.

U.S. Environmental Protection Agency. *Guidance for the Development of a Quality Assurance Plan.* Prepared by Regional Team: Juanita Hill mar (Region. Vlll), Ho L. Young (Region IX), and Barry Towns (Region X).

U.S. Environmental Protection Agency. *Preparation of State-Lead Remedial Investigation Qualify Assurance Project Plans for Region V; Guidance.* Quality Assurance Office. Chicago, Illinois.

SECTION 3

IMPLEMENTING FIELD ACTIVITIES

3.1 GENERAL CONSIDERATIONS

3.1.1 Scope and Purpose

Section 3 addresses several areas including the control of contaminated materials generated during fieldwork, organization of the field team, decontamination, and general health and safety considerations. This section provides general information on those topics in individual subsections that identify their relevant scope and purpose, definitions, and applicability. The section lists information sources for specific guidance. Fieldwork encompasses the activities associated with preliminary assessments/ site inspections (PAN), site investigations, remedial investigations (Rl), feasibility study, pilot or bench tests, and Resource Conservation and Recovery Act (RCRA) inspections. Guidance on these activities is voluminous and will not be presented here. The Site Manager (SM) must also be guided by the state and local laws, codes, rules, regulations, and ordinances, as well as by any site-peculiar guidance such as consent decrees.

3.1.2 Definitions

Office of Safety and Health Administration (OSHA) 1910.120
OSHA Interim Final Rule on Hazardous Waste Operations and Emergency Response. OSHA Standard 29 CFR 1910.120 as released on 19 December 1986 in the *Federal Register.*

Site Manager (SM)
The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

3.1.3 Applicability

The procedures contained in Section 3 are applicable to field activities that involve hazardous materials (as defined by the OSHA standard) and area potential for personnel exposure.

3.1.4 Responsibilities

Activities that fall under the scope of OSHA 29 CFR 1910.120, as defined in that standard, must comply with the requirements of that standard. The SM is responsible for coordinating all efforts with the assigned Health and Safety Officer (HSO) [also known as Site Safety Coordinator (SSC) or Site Safety and Health Officer (SSHO)] to achieve and maintain compliance.

3.1.5 Records

The documents required by OSHA 29 CFR 1910.120 must be completed, maintained, and made available as described in that standard. These records include medical surveillance documents, health and safety plans, and all other required documentation. The retention time for these documents is significant – 30 years or more. Site Managers must rely on the administrative personnel associated with their corporate or agency health and safety programs to provide for retention of records. These procedures should be clearly delineated within the program.

3.1.6 Procedures

Appropriate procedures are specified in the subsequent subsections.

3.2 CONTROL OF FIELDWORK-GENERATED CONTAMINATED MATERIAL

3.2.1 Scope and Purpose

Field investigation activities often result in the production or migration of contaminated materials (Investigation derived waste) that must be properly managed to protect the public and the environment, as well as to meet legal requirements. This subsection dads with the proper management of contaminated materials.

The objective of this guideline is to provide general reference information on the control of con taminated materials.

3.2.2 Definitions

Contaminated Material

Any of the field investigation's by-products that are suspected of being contaminated or are known to be contaminated with hazardous substances. These by-products include such materials as decontamination solutions, disposable equipment, drilling muds and cuttings, welldevelopment fluids, well-purging water, and spill-contaminated materials.

3.2.3 Applicability

The SM should assume that hazardous wastes generated during an investigation will require compliance with federal requirements for generation, storage, transportation, or disposal. in addition, there may be state regulations that govern the disposal action.

The work plan for a site investigation must include a description of control procedures for contaminated materials. This plan should assess the type of contamination, estimate the amounts that would be produced, describe containment equipment and procedures, and delineate storage or disposal methods. Adequate budget must be allocated for these purposes. As a general policy, it Is wise to select investigation methods that minimize the generation of contaminated materials. The handling and the disposing of potentially hazardous materials are expensive; however, the consequences and penalties for improper handling are significant.

3.2.4 Responsibilities

The Site Manager or designee is responsible for identifying as contaminated, any material that was generated onsite and for implementing the procedures used to control and dispose of such material.

3.2.5 Records

If onsite or offsite testing is conducted on the contaminated material, appropriate chain-of-custody and sample analysis forms must be prepared as described in other sections of this compendium. If it is determined that wastes generated onsite are hazardous, the appropriate RCRA manifest and disposal forms must be completed as discussed In Subsection 3.2.6.2. The SM must determine who will be designated as the generator of the contaminated material. Typically, an EPA official should be designated as the person to sign items such as manifests.

3.2.6 Procedures

Provided below is a broad description of the sources of contaminated material that can be generated onsite, plus a general discussion of the current procedures used to control and dispose of contaminated materials that are fieldwork generated.

3.2.6.1 Sources of Contaminated Materials and Containment Methods

Decontamination Solutions: Decontamination solutions and rinses must be assumed to contain the hazardous chemicals associated with the site, unless there are analytical or other data to the contrary. The solution volumes could vary from a few gallons to several hundred gallons in cases where large equipment requires cleaning.

Small amounts of rinse solutions, such as those generated by the personnel decontamination station (PDS), are best stored in 55-gallon drums (or equivalent containers) that can be sealed until ultimate disposal at an approved facility. As a rule of thumb, use of a temporary PDS will generate 55 to 110 gallons of decontamination solution per day for every five persons using it. The addition of showers and clothes washing machines, associated with a more permanent facility, will generate as much as 1,000 gallons per day per every five persons. If the amounts generated by a PDS exceed one or two 55-gallon drums each day, a larger capacity above ground storage vessel, such as a fiberglass tank or collapsible rubber bladder, should be considered. If Individual drums are used, they should be marked with sufficient information so that personnel can determine what contaminants may be present. This Information should be based on the analytical results from the sampling campaign. Alternately, samples can be analyzed from each drum. However, the cost of analysis may exceed the cost of disposal. Larger containers may be sampled and analyzed in a cost-effective manner. If the suspected contamination is acceptably low, the fluids can be allowed to drain back onsite or can be released to local sewers - with the permission of the appropriate authorities. In some rare instances, contaminated fluids maybe released back to the site.

Larger equipment, such as backhoes and tractors, must be decontaminated In an area that has a method of controlling and collecting the spent fluids. A decontamination area for large equipment can consist of a shallow depression lined with plastic, which is covered with clean sand or gravel, or the area may be a bermed concrete pad with a floor drain leading to a holding tank. The amounts generated by typical equipment cleaning devices (steam jenny and hydro-blaster) usually exceed 500 gallons per cleaning. Spill prevention and containment measures should be implemented for the larger fluid containers, or if many drums of fluid are left onsite. Protection from vandals is also needed.

Disposable Equipment: Disposable equipment that could be contaminated during a site investigation typically includes tools, rubber gloves, boots, broken sample containers, and chemically resistant clothing. These items are small and can easily be contained in 55-gallon drums with removable lids. Secure containment within the containers is provided by sealing them at the end of each work day and upon project completion. Additionally, containers are labeled in accordance with the applicable Department of Transportation (DOT) regulations on hazardous materials under 49 CFR 172.304. Adequate protection from vandals, theft, and adverse weather must be provided for all containers.

Drilling Muds and Well-Development Fluids: Drilling muds and well development fluids are materials used when installing groundwater monitoring wells. Their use could result in the surface accumulation of contaminated liquids and solids that require containment. Monitoring wells are often placed in uncontaminated areas to determine if hazardous chemicals have migrated below ground. Materials from these wells require especially careful management since they threaten contamination of otherwise clean property.

The volume of drilling and well-development fluids requiring containment will depend on the number of wells, diameters and depths, groundwater characteristics, and geologic formations. There are no simple mathematical formulas available for accurately predicting these volumes. It is best to rely on the experience of hydrogeologists and/or reputable well drillers who are familiar with the local conditions and the well installation techniques selected. These individuals should be able to estimate the volume of contaminated fluid to be contained. Since rough estimates may be involved, managers shall always be prepared to halt drilling or other well-development operations if more containment capacity is needed. For example, over one million gallons of contaminated fluids have been generated during pump tests of monitoring wells.

Drilling fluid (mud) is mixed and stored in a container commonly referred to as a mud pit. This mud pit consists of a suction section from which drilling fluid is withdrawn and pumped through hoses down the drill pipe to the bit and then backup the hole to the settling section of the mud pit. In the settling section, the fluid velocity is reduced by a screen and by several flow-restriction devices, thereby allowing the well cuttings to settle out of the fluid.

The mud pit may be either a portable aboveground tank, commonly made of steel, or a stationary pit that is in the ground. The aboveground tanks have a major advantage over pits in the ground because the tanks isolate the contaminated fluids from the surface environment. The tanks are also portable and can usually be cleaned easily.

As the well is drilled, the sediments that accumulate in the settling section must be removed. Removal is best done by shoveling sediments into drums or other similar containers. When the drilling is complete, the contents of the above ground tank are likewise shoveled or pumped into drums, and the tank is cleaned and made available for reuse.

If in-ground pits are used, they shall not extend into the natural water table. They shall also be lined with a bentonite-cement mixture followed by a layer of flexible impermeable material such as plastic sheeting. To maintain its impermeable seal, the material used must be nonreactive with the contaminants. An advantage of the in-ground pit is that well cuttings do not necessarily have to be removed periodically during drilling because the pit can be made deep enough to contain them. Depending on site conditions, the in-ground pit may have to be totally re-excavated and refilled with uncontaminated natural soils when the drilling operation is complete.

When the aboveground tank or the in-ground pit is used, a reserve tank or pit should be located at the site as a backup system for leaks, spills and overflows. In either case, surface drainage shall be such that any excess fluid can be controlled within the immediate area of the drill site. In-ground pits must also be barricaded and lighted to prevent accidents.

The containment procedure for well-development fluids is similar to that for drilling fluids. The volume and weight of contaminated fluid will be determined by the method of development. When a new well is bailed to produce clear water, substantially less volume and weight of fluid will result, than when backwashing or high-velocity jetting is used.

Spill-Contaminated Materials: A spill is always possible when a site investigation involves opening and moving containers of liquids. Contaminated sorbents and soils resulting from spills will have to be contained and cleaned up. Small quantities of spill-contaminated materials are usually best contained in drums, while larger quantities can be placed in lined pits or in other impermeable structures. In some cases, onsite containment may not be feasible and immediate transport to an approved disposal site will be required.

3.2.6.2 Disposal of Contaminated Materials

Actual disposal techniques for contaminated materials are the same as those for any hazardous substance - incineration, landfilling and/or treatment. The problem centers around the assignment of responsibility for disposal. The responsibility must be determined and agreed on by all involved parties before the fieldwork starts.

If testing conducted on a waste that was generated onsite (RCRA extraction, organic screening, inorganic and organic analysis, etc.) shows that the waste is nonhazardous, the material can be handled as a non-RCRA waste and disposed of onsite at the direction of EPA. For hazardous waste materials, onsite disposal should not be practiced. The material should be properly packaged and disposed of in a RCRA-approved off site facility. The same procedure applies to residuals of samples (see Section 5 for a discussion).

A majority of the waste material generated during onsite activities is hazardous. Either it is a health hazard, or the waste material when tested, fails the RCRA extraction tests. In these instances, EPA has provided guidance for the disposal of these materials. The guidance, in the form of a memorandum dated 13 December 1964 from Russel H. Wyer of EPA Headquarters, provides the general procedure for disposing of RCRA waste material from hazardous waste facilities. Site specific disposal options are developed by consulting with the EPA regions through the EPA RPM and by specifying disposal actions in the work plan.

3.2.6.3 Waste Storage and Management

Wastes generated through investigative activities (e.g., drilling) are governed by RCRA requirements with regard to packaging, labeling, transporting, storing, and record keeping. These requirements are stated in 40 CFR 262 entitled “Standard Applicable to Generators of Hazardous Wastes.” However, some state laws have primacy over RCRA requirements. To determine this, the appropriate state agency must be contacted. A list of the state environmental agencies has been attached for this use and appears as Exhibit 3-1.

Wastes that are accumulated through onsite activities are to be stored in a secure location that is under the control of the operator. Therefore, to meet this requirement, it is common practice for the waste-staging area to be located onsite. Wastes generated from offsite activities, such as wells, are addressed in standard 40 CFR 262.34(c), This standard states the generator “may accumulate as much as 55 gallons of hazardous waste or 1 quart of acutely hazardous waste...in containers at or near any point of generation where wastes initially accumulate, which is under the control of the operator of the process generating the waste . ...” Offsite wells are typically areas that cannot be considered to be under the operator’s control. Therefore, the operator must place the wastes in containers and then label, manifest, and transport these wastes to the onsite staging area.

Exhibit 3-1
LISTING OF STATE ENVIRONMENTAL AGENCIES

ALABAMA
Department of Environmental
Management
State Capital
Montgomery, AL 36130
205/271 -7700

ALASKA
Department of Environmental
Conservation
3220 Hospital Dr.
Pouch O
Juneau, AK 99811
907/465-2600

ARIZONA
Division of Environmental
Health Services
Department of Health Servs.
1740 W. Adams St.
Phoenix, AZ 85007
602/255-1 130

ARKANSAS
Department of Pollution
Control and Ecology
8001 National Dr.
Little Rock, AR 72209
501 /562-7444

CALIFORNIA
Resources Agency
1311 Resources Building
1416 9th St.
Sacramento, CA 95814
91 6/445-5656

COLORADO
Department of Natural
Resources
718 State Centennial Bldg.
1313 Sherman St.
Denver, CO 80203
303/666-331 1

CONNECTICUT
Department of Environmental
Protection
117 State office Bldg.
165 Capitol Ave.
Hartford, CT 06106
203/566-21 10

DELAWARE
Division of Environmental
Control
Department of Natural
Resources and
Environmental Control
R and R Complex
89 Kings Highway
P.O. Box 1401
Dover, DE 19903
302/736-4764

DISTRICT OF COLUMBIA
Environmental Control
Division
Housing and Environmental
Regulation Administration
Department of Consumer and
Regulatory Affairs
505 North Potomac Building
614 H St., NW
Washington, DC 20001
202/767-7370

FLORIDA
Department of Environmental
Regulation
Twin Towers Building
2600 Blair Stone Rd.
Tallahassee, FL 32301
904/488-4805

GEORGIA
Environmental Protection
Division
Department of Natural
Resources
825 Trinity-Washington Bldg.
270 Washington St., SW
Atlanta, GA 30334
4041656-4713

HAWAII
Office of Environmental
Quality Control
550 Haiekauwila St.
Hone:..u, HI 96813
808/548-691 5

IDAHO
Division of Environment
Department of Health
and Welfare
Towers Bldg.
450 W. State St.
Boise, ID 83720
208/3344059

ILLINOIS
Environmental Protection
Agency
220 Churchill Rd.
Springfield, IL 62706
21 7/782-3397

INDIANA
Environmental Management
Board
State Board of Health
Health Bldg.
1330 W. Michigan St.
Indianapolis, IN 46206
31 7/633-8404

IOWA
Department of Water, Air,
and Waste Management
Henry A. Wallace Bldg.
900 E. Grand Ave.
Des Moines, IA 50319
5151281-8854

KANSAS
Division of Environment
Department of Health and
Environment
Bldg. 740, Forbes Field
Topeka, KS 66620
913/862-9360, Ext. 283

KENTUCKY
Department of Environment
Natural Resources and
Environmental Protection
Cabinet
Ash Bldg., 18 Reilly Rd.
Frankfort, KY 40601
502/564-2150

Exhibit 3-1
(continued)

LOUISIANA
Department of Environmental Quality
700 State Land and Natural Resources Bldg.
625 N. 4th St.
P.O. Box 44068
Baton Rouge, LA 70804
504/342-1 265

MAINE
Department of Environmental Protection
Ray Bldg., AMHI Complex
Hospital St.
Mail to: State House, Station 17
Augusta, ME 04333
207/289-281 1

MARYLAND
Maryland Environmental Service
Department of Natural Resources
60 West St.
Annapolis, MD 21401
301 /269-3351

MASSACHUSETTS
Executive Office of Environmental Affairs
Leverett Saltonstall State
Office Bldg.
100 Cambridge St.
Boston, MA 02202
61 7/727-9800

MICHIGAN
Department of Natural Resources
Stevens T. Mason Bldg.
7th Floor
P.O. Box 30028
Lansing, MI 48909
51 7/373-2329

MINNESOTA
Environmental Quality Board
100 Capital Square Bldg.
550 Cedar St.
St. Paul, MN 55101
61 2/296-2603

MISSISSIPPI
Bureau of Pollution Control
Department of Natural Resources
Southport Mall
Hwy. 80-W at Ellis Ave.
P.O. Box 10385
Jackson, MS 39209
601/961-5171

MISSOURI
Division of Environmental Quality
Department of Natural Resources
1915 Southridge Dr.
P.O. Box 1366
Jefferson City, MO 65102
314/751-3241

MONTANA
Environmental Sciences Division
Department of Health and Environmental Sciences
W. F. Cogswell Bldg.
Lockey St.
Helena, MT 59620
406/444-3948

NEBRASKA
Department of Environmental Control
State Office Bldg.
301 Centennial Mall, S.
P.O. Box 94877
Lincoln, NE 685094877
402/471 -2188

NEVADA
Division of Environmental Protection
Department of Conservation and Natural Resources
221 Nye Bldg.
201 S. Fall St.
Capitol Complex
Carson City, NV 89710
702/8854670

NEW HAMPSHIRE
Environmental Protection Division
Office of the Attorney General
State House Annex
25 Capital St.
Concord, NH 03301
603/271 -3679

NEW JERSEY
Department of Environmental Protection
John Fitch Plz.
P.O. Box 1390
Trenton, NJ 08625
609/292-2885

NEW MEXICO
Environmental Improvement Division
Health and Environment Department
Crown State Office Bldg.
725 St. Michael's Dr.
P.O. Box 968
Santa Fe, NM 87504-0968
503/984-0020, Ext. 200

NEW YORK
Department of Environmental Conservation
50 Wolf Rd.
Albany, NY 12233-0001
51 8/457-3446

Exhibit 3-1
(continued)

NORTH CAROLINA
Division of Environmental
Management
Department of Natural
Resources and Community
Development
Archdale Bldg.
512 N. Salisbury St.
P.O. B0X 27687
Raleigh, NC 27611
91 9/733-7015

NORTH DAKOTA
Environmental Health Section
Department of Health
102 Missouri Office Bldg.
1200 Missouri Ave.
Bismarck, ND 58501
701/224-2374

OHIO
Ohio Environmental Protection
Agency
Seneca Towers
361 E. Broad St.
P.O. Box 1049
Columbus, OH 43216
614/466-8318

OKLAHOMA
Department of Pollution
Control
1000 N.E. 10th St.
P.O. Box 53504
Oklahoma City, OK 73152
405/271 -4677

OREGON
Department of Environmental
Quality
Yeon Bldg.
522 S.W. 5th Ave.
P.O. Box 1760
Portland, OR 97207
503/229-5696

PENNSYLVANIA
Department of Environmental
Resources
Fulton Bank Bldg., 9th Fl.
200 N. 3rd St.
P.O. Box 2063
Harrisburg, PA 17105
71 7/787-2814

RHODE ISLAND
Department of Environmental
Management
83 Park St.
Providence, RI 02903
401/277-2771

SOUTH CAROLINA
Division of Environmental
Quality Control
Department of Health and
Environmental Control
415 J. Marion Sims Bldg.
2600 Bull St.
Columbus, SC 29201
803/758-5450

SOUTH DAKOTA
Department of Water and
Natural Resources
Joe Foss Bldg.
523 E. Capital Ave.
Pierre, SD 57501
605/773-3151

TENNESSEE
Bureau of Environment
Department of Health and
Environment
TERRA Bldg.
150 9th Ave., N.
Nashville, TN 37203
615/741 -3667

TEXAS
Environmental Protection
Division
Office of the Attorney
General
Executive Office Bldg.
411 W. 13th St.
P.O. B0X 12548, Capital Sta.
Austin, TX 78711
512/475-1 101

UTAH
Division of Environmental
Health
Department of Health
Social Services Bldg.
150 W. North Temple St.
P.O. B0X 2500
Salt Lake City, UT 84110-2500
801/533-6121

VERMONT
Agency of Environmental
Conservation
Heritage II Complex
79 River St.
Montpelier, VT 05602
802/828-31 39

VIRGINIA
Council on the Environment
903 Ninth St. Office Bldg.
9th and Grace Sts.
Richmond, VA 23219
804/7864500

WASHINGTON
Washington Department of
Ecology
St. Martin's College
Mail Stop PV-11
Olympia, WA 98504
206/4596168

WEST VIRGINIA
Department of Natural
Resources
669 State Office Bldg. 3
1800 Washington St., E.
Charleston, VW 25305
3041348-2754

WISCONSIN
Department of Natural
Resources
General Executive Facility II
101 S. Webster St.
P.O. B0X 7921
Madison, WI 53707
608/266-21 21

Exhibit 3-1
(continued)

WYOMING
Department of Environmental Quality
Herschler Bldg., 4th FL.
122 W. 25th St.
Cheyenne, W 82002
307/777-7938

AMERICAN SAMOA
Environmental Quality Commission
Office of the Governor
Pago Pago, AS 96799
Country Code 684/63341 16 and 633-4398

GUAM
Guam Environmental Protection Agency
P.O. Box 2950
Agana, GU 96910
Country Code 671/646-8863 8864, and 8865

PUERTO RICO
Environmental Quality Board
204 Del Parque St.
P.O. Box 11488
Santurce, PR 00910
809/725-8898 and 723-1617

VIRGIN ISLANDS
Division of Natural Resources Management
Department of Conservation and Cultural Affairs
P.O. Box 4340
Charlotte Amalie,
St. Thomas, VI 00801
809/774-3320

The maximum duration for storing wastes onsite is 90 days without a permit or without having interim status, provided that the stored wastes meet the RCRA requirements for containing and labeling. Storage duration beyond 90 days alters the status of the controller from a generator of hazardous waste to an operator of a storage facility. Such a change in status, subjects the operator to compliance with RCRA requirements stated in 40 CFR Parts 264 and 265. A final concern is that, during dismantling, the storage area will need to be sampled (e.g., soil sampling) to determine that no releases of hazardous substances occurred during storage.

Questions on the interpretation of the requirements for storing and handling hazardous substances can be directed to the RCRA Hotline (1/800/424-9346).

Provided below is an outline of the suggested procedures for disposal of investigation-derived wastes.

• 1. Determine whether or not investigation derived wastes will be generated during the project. If yes, obtain RCRA EPA Notification of Hazardous Waste Activity Form (Form No. 8700-12). If no, note the decision in the work plan.

• 2. Obtain a RCRA generator provisional number from the EPA Remedial Project Manager (RPM).

• 3. Fill out the provisional number questionnaire and submit it to the EPA RPM.

• 4. Contact waste transporters and disposers to request bids for their services; obtain necessary documentation required by a company for those services. (All companies require the filing of some type of waste data sheet.) A bid will not be awarded until a waste characterization, including data, is provided to the transporter/ disposer. These forms can be found in the *Hazardous Waste Services Directing Transportation Disposal Sites, Laboratories, and Consultants* published by J.J. Keller Associates (414/722-2848).

• 5. Obtain necessary state/ federal shipping and disposal manifest forms. (A manifest is required from the state where the waste originated.)

• 6. Conduct field activities.

• 7. Sample and characterize waste. This step includes all RCRA parameters plus special analyses such as TCDD.

• 8. Receive analysis from laboratory.

• 9. Complete waste data sheets, and submit them to potential transporters and disposal facilities.

• 10. Receive bids for transportation and disposal activities.

• 11. Prepare EPA Form 8700-12, including waste characterization data for sign off by designated EPA official. (Note: Materials generated are considered to be EPA wastes, and an EPA employee must sign off on all paperwork.)

• 12. Prepare state and federal shipping and disposal manifest forms for signature by EPA personnel.

• 13. Award subcontract for waste transportation and disposal,

3.2.7 Region-Specific Variances

No region-specific variances have been identified; however, all future determined variances will be incorporated within subsequent revisions of this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPMs for full details on current regional practices and requirements.

3.2.8 Information Sources

Resource Conservation and Recovery Act of 1976.

3.3 ORGANIZATION OF THE FIELD TEAM

3.3.1 Scope and Purpose

The objective of this subsection is to provide the roles and responsibilities of field team members who conduct remedial response activities at hazardous waste sites.

3.3.2 Definitions

None.

3.3.3 Applicability

The primary function of the field investigation team is to gather information according to the approved work plan. These guidelines describe the components and duties of team members, and suggest the numbers of members that are necessary for the field team to safely meet the stated goals of the investigation. These guidelines are applicable to field work involving hazardous waste disposal sites.

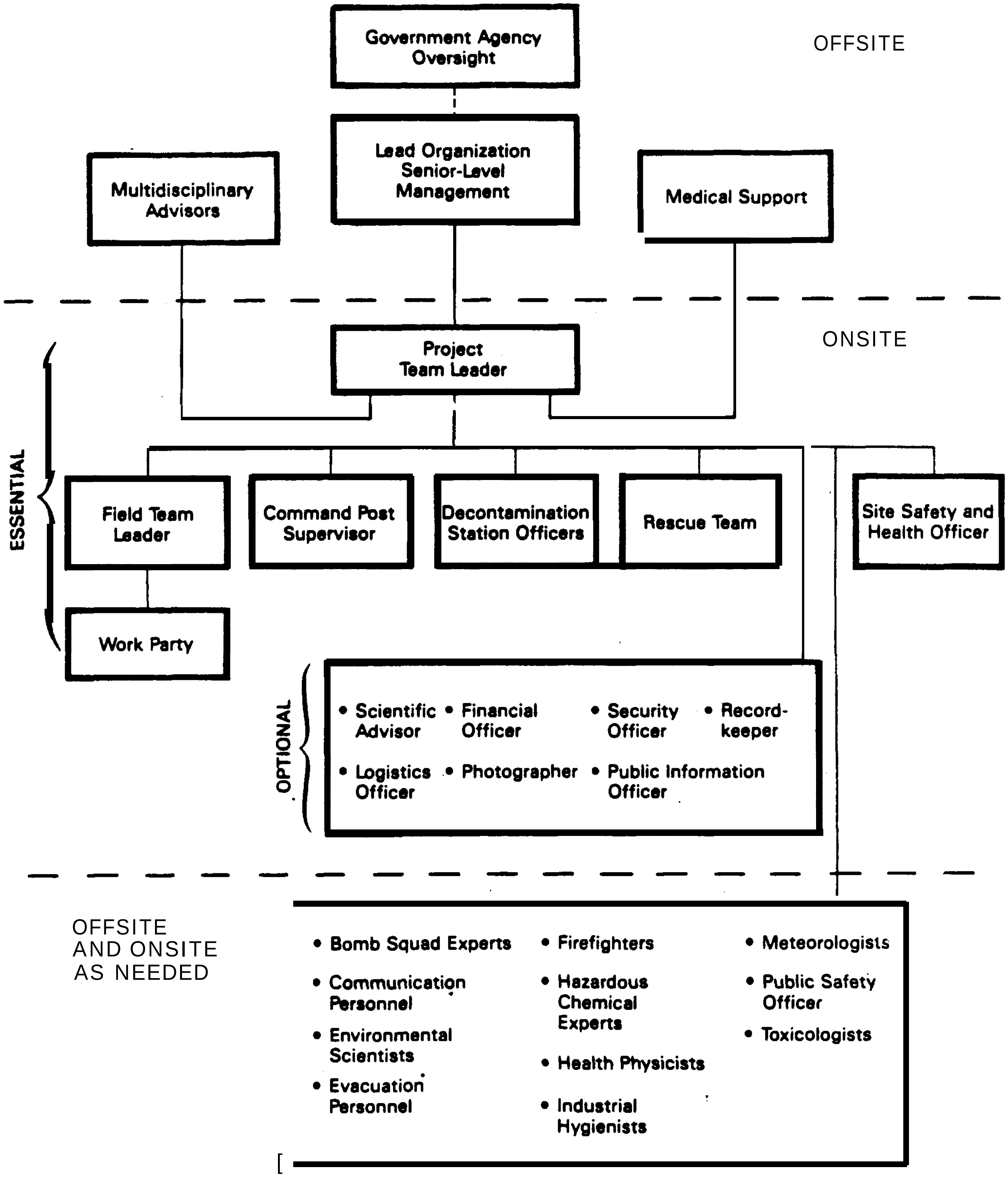
3.3.4 Responsibilities

The NIOSH/0SHA / USCG/ EPA ***Occupational Safety and Heath Guidance Manual for Hazardous Waste Site Activities*** presents a generalized approach to personnel organization for remedial response activities (see Exhibit 3-2 taken from that publication) and provides an excellent summary of the responsibilities of each of the named positions.

Typically, at least eight roles maybe required for a field investigation team: SM, field team leader, site safety officer, personnel decontamination station operator / equipment specialist, communications supervisor, initial entry patty, work party, and emergency response team.

The number of roles needed at each site is dictated by the potential hazards and the specific needs of the site. Dual role assignments may be acceptable when hazardous substances and physical conditions at a site are well documented and the nature of the work is limited.

Exhibit 3-2
GENERALIZED APPROACH TO PERSONNEL ORGANIZATION FOR SITE INVESTIGATION AND RESPONSE



3.3.4.1 Site Manager

The SM is responsible for the following:

- All the team does or falls to do
- Preparing and organizing project work
- Selecting team personnel and briefing them on specific assignments
- Coordinating with the EPA RPM, who Is responsible for obtaining the owner's permission to enter the site
- Coordinating with the field team leader to complete the work plan
- Completing final reports and preparing the evidentiary file
- Establishing safety and equipment requirements that are to be met, and monitoring compliance with those requirements
- Coordinating with the lead agency
- Assisting in quality assurance efforts

Some of these responsibilities may be delegated to the field team leader and the site safety coordinator.

3.3.4.2 Field Team Leader

The field team leader is responsible for the overall operation and safety of the field team. As mentioned earlier, this role can be filled by the SM or the designated representative. The field team leader may join the work party in the exclusion zone. The field team leader is responsible for the following:

- Execution of the site work plan
- Safety procedure compliance through coodination with the site safety officer
- Field operations management Including coordination with laboratories and subcontractors
- Community relations, typically through state and federal liaison officials
- Site control
- Compliance of field documentation and sampling methods with evidence collection procedures

3.3.4.3 Site Safety Officer

The site safety officer is responsible for safety procedures and operations at the site. The site safety officer is responsible to whoever is responsible for safety in the organization rather than to the field team leader or SM. This reporting system provides for two separate lines of authority, thereby allowing decisions based on safety to be represented on an equal basis with decisions based on the pressures for accomplishing the investigation according to schedule.

The site safety officer either remains on the clean side of the exclusion area while monitoring the work . party and site activities or may accompany the downrange team to supervise hazardous work. The site safety officer is also responsible for the following:

- Determining of the level of personal protection required
- Updating equipment or procedures based on new information gathered during the site inspection
- Changing the levels of protection based on site observations (Subsection 3.3.4)
- Monitoring compliance with the safety requirements
- Stopping work as required to protect personal worker safety or where noncompliance with safety requirements is found
- Determining and posting emergency telephone numbers (including poison control centers) and routes to capable medical facilities arranging for emergency transportation to medical facilities
- In conjunction with the SM, notifying local public emergency officers (i.e., police and fire department) of the nature of the team's operations and coordinating the team's contingency plan with that of the local authorities
- Informing personnel other than team members who want access to the potential hazards of the site
- Entering the exclusion area in emergencies when at least one other member of the field team is available to stay behind and notify emergency services (or after the emergency services have been notified)
- Examining work party members for symptoms of exposure or stress
- Determining that each team member has been given the proper medical clearance by a qualified medical consultant; monitoring team members to determine compliance with the applicable physical requirements as stipulated in the health and safety program
- Maintaining communications and line-of sight contact with the work party
- Providing emergency medical care and first aid as necessary at the site

3.3.4.4 Personnel Decontamination Station Operator / Equipment Specialist

The personnel decontamination station (PDS) operator / equipment specialist functions in two roles that do not require concurrent attention. The equipment specialist role requires the following:

- Determining that equipment is properly maintained and operational
- inspecting equipment before and after use
- Obtaining the required equipment before arriving at work site
- Decontaminating personnel, samples, and equipment that return from the exclusion area

The role of PDS operator/ equipment specialist includes the following responsibilities:

- Designing and setting up the PDS
- Preparing the necessary decontamination solutions so that chemical contamination is not transported into the clean area by equipment, samples, protective clothing, or personnel
- Managing the mechanics of removing contaminanted clothing from the work party
- Property disposing of discarded contaminated clothing and decontamination solutions

3.3.4.5 Communications Supervisor

The communications supervisor functions as the clearinghouse for communications. This person does not enter the exclusion area to assist the work party. Should an emergency arise, the communications supervisor notifies emergency support personnel by phone, radio, or some other communication device to respond to the situation. Depending on the team size and the nature of the emergency, the communications supervisor may be needed to assist the site safety officer in effecting a rescue. Usually, the communications supervisor assists the PDS operator / equipment specialist in operating the PDS during an emergency and the site safety officer in taking emergency medical measures. The field team leader may assume the position of communications supervisor.

The communications supervisor is also responsible for the following:

- Maintaining a log of communications and site activities, such as duration of work periods with respirators or movement of personnel and equipment, onto and off the site
- Assisting the site safety officer in sustaining communication and line-of-sight contact with the work party
- Maintaining good community relations in the absence of the field team leader, usually by referring questions to the appropriate head agency liaison officer
- Assisting the site safety officer and PDS operator/equipment specialist as required

The communications supervisor may also be responsible for logging and packaging for transport, the samples taken by the work party. This person also maintains a weather watch, and provides security for the emergency response vehicle and other equipment.

3.3.4.6 Initial Entry Party

The initial entry patty enters the site first, employing “specialized instrumentation to characterize site hazards. To become familiar with the conditions and dangers associated with the site, the field team leader should usually be a part of the initial entry party. The major purpose of this team is to measure existing hazards and to survey the site to ascertain if the level of personal protection determined from preliminary assessment, site inspection, or site screening study must be adjusted.

The initial entry party can consist of as few as two people (using the “buddy system”), if a nonsparking cart or other device is used to transport all the instrumentation. Three or four people are able to do the job more efficiently.

3.3.4.7 Work Party

The work-party performs the onsite tasks necessary to fulfill the objectives of the investigation (e.g., obtaining samples or determining locations for monitoring wells). No team member should enter or exit the exclusion area alone. The work party consists of a minimum of two individuals, and any work party should follow the buddy system. Aside from the safety considerations, it is much easier for two persons dressed in protective clothing to perform such tasks as notetaking, photographing and sampling.

The number of individuals In the work party varies. Often, several teams may be working simultaneously at several different sampling efforts. In cases where a number of activities are taking place simultaneously or where activities are widely separated, the site safety officer maybe supplemented with several assistants assigned to each of the smaller work teams. Depending on the nature of the hazards onsite, the work team safety officer may perform concurrent duties" (photography, air monitoring, headspace analysis, sample logging) that would not Interfere with the primary duty of maintaining safety.

In cases of multiple or widely separated work teams, a means of communication among the teams, the site safety officer, and the field team leader is vital.

3.3.4.8 Emergency Response Team

Some means of providing emergency assistance to workers In the exclusion zone must be established for every site. Most often, the site safety officer has that responsibility. Extensive assignments requiring long hours and large work parties may necessitate the use of a standby emergency response team. Members of the emergency response team are “half-dressed” in the appropriate protective gear so that they can quickly enter the exclusion area in an emergency. This team is particularity valuable at sites where protective equipment produces stress and heat loads on the work party and where the rotation of workers provides a rested group of workers able to respond to the emergency without increasing the team size.

3.3.5 Records

Records normally kept for field activities are identified in other sections of this manual. For details, see the following sections:

Section 4	Sample Control, Including Chain of Custody
Section 5	Laboratory Interface
Section 17	Document Control

3.3.6 Procedures

The different guidelines that exist for organizing field operations are based generally on the size of the field team used.

Team size depends on site organization, levels of protection, work objectives, and site hazards. Team members can always be added according to the roles required.

3.3.6.1 Two-Person Team

The two-person team is the minimum for a hazardous-substance site investigation, and the team's capabilities are very limited. Such a team should never enter an uncharacterized hazardous-substance site. The two-person team is best suited for offsite surveys and inspections or for obtaining environmental (nonhazardous, offsite) samples. Verifying accuracy of aerial photographs by ground surveys, inspecting files, or interviewing can all be accomplished by the two-person team. The two-person team can also conduct RCRA inspections at facilities that have an OSHA-approved safety program.

3.3.6.2 Three-Person Team

The three-person team Is recommended for sites requiring Level C (air purifying respirators) protection and, in some cases, at sites requiring Level B (supplied-air respirator) protection. (Levels of protection are discussed in the NIOSH / OSHA / USCG / EPA guidance manual and are set forth in the OSHA 29 CFR 1910.120 regulations.) This team is composed of a field team leader; an individual fulfilling the combined functions of PDS operator/ equipment specialist, site safety officer, and communications supervisor; and another individual (buddy) to enter the site with the field team leader.

The three-person team is used where extensive PDS procedures are not required and where the likelihood of needing emergency rescue is low. This field team is best used where the primary objective is to map, photograph or inventory.

Considerable care and thought are necessary before a three-person team is employed on a site, because each individual has numerous responsibilities. In the event of an accident, the third member does not enter the site to offer emergency assistance until outside assistance has been summoned; even then, entry should be made only when absolutely necessary.

3.3.6.3 Four-Person Team

Most short-term Level B operations can be conducted with a four-person team. These operations would include work on active sites where facility personnel are present or on inactive sites with potentially IDLH (Immediately Dangerous to Life and Health) atmospheres. The objective of a four-person team at a site requiring Level B protection might include limited sampling of ponds, soils, or open containers and inspections at sites known for poor housekeeping (i.e., sites witha history of spills, leaks, or other accidents).

The team consists of the standard two-person work party, a combination site safety officer and PDS operator / equipment specialist, and a communications supervisor who may assist in the PDS operation. Because life-threatening hazards are assumed or known to be present at a Level B site, it is essential that all personnel be fully acquainted with their duties. During an emergency, the communications supervisor stays in the support area to maintain communication while the site safety officer / PDS operator / equipment specialist enters the exclusion area to aid the work party. Once the work patty is in the contamination reduction area, the command post supervisor can offer assistance on the PDS or provide fresh equipment from the support area. During the work In the exclusion area, team members may rotate individual assignments.

3.3.6.4 Five-Person Team

The five-person team is the typical minimum size for most Level A and Level B operations or for operations when known percutaneous hazards exist or when there is an absence of historical information. The site hazards that necessitate Level A protection, combined with the limitations and stresses placed on personnel by wearing Level A protection, require a full-time PDS operator/ equipment specialist who can also serve In emergency response. In the event of a serious emergency such as a fire, explosion, or acutely toxic release, both the site safety officer and the PDS operator/ equipment specialist may need to enter the exclusion area dressed In Level A gear. The communications supervisor remains In the support ares to direct outside help to the site and then to assume the functions of PDS operator / equipment specialist.

3.3.6.5 Teams of Six or More

Certain hazardous-substance site activities may require operations that necessitate larger or alternating work parties and additional support personnel in the contamination reduction area. A seven-person team, for example, employs the basic structure of the five-person team plus an additional work party for alternating work loads. The eight-person team includes an additional PDS operator/equipment specialist to assist in the continuous decontamination tasks that are involved with alternating work parties and to decontaminate and pack samples as they are received.

it is not unusual to employ teams of 12 where such tasks as drum opening, may require three work parties working concurrently. This operation may involve teams to move the drums, open the drums, and sample and reseal them under rigorous safety procedures. Larger teams can be designed with additional work parties and support personnel, to safely gather the site data, and ensure communication and site control.

On some sites, many Individuals will be required for concurrent operations, such as building demolition or wastes excavation, that will also entail the use of mobile heavy equipment. it is not feasible to provide a “buddy" to the operators of such equipment. Rather, a number of site safety observers (two usually will suffice) may be established at vantage points (rented scaffolding located onsite Is ideal), to observe the equipment operators and the ground-based workers simultaneously. By means of radios or visual and audible signals, the site safety observers can assist In “directing traffic,” a particularly Important safety procedure where the protective gear interferes with hearing and vision.

3.3.7 Region-Specific Variances

in Region Vi, the site safety officer for the Field investigation Team (FIT) cannot downgrade the level of protection without consulting the FIT regional safety coordinator. No other region-specific variances have been identified. All subsequent variances will be incorporated within Revision 01 of this compendium. Because information on variances may become dated rapidly, users should contact the regional EPA RPMs for full details on current regional practices and requirements. Regional variations of team organizations should be established by coordinating the work plan with the EPA RPM.

3.3.8 Information Sources

Office of Safety and Health Administration, 29 CFR 1910.120. “interim Final Rule for Hazardous Waste Operations and Emergency Response.” 19 December 1986.

U.S. Environmental Protection Agency. *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities.* Developed by NIOSH / OSHA / USCG / EPA October 1985.

U.S. Environmental Protection Agency. “Standard Operating Safety Guides.” Memorandum from William Hedeman, Jr. 19 November 1984

3.4 DECONTAMINATION

3.4.1 Scope and Purpose

Personnel conducting activities that involve hazardous substances may have their personal protective gear contaminated by those substances through the course of the work effort. In addition, equipment may become contaminated. Since such contamination is not always easily discernible, it Is necessary to assume that all personnel and equipment working in the area (where the presence of such substances is known or suspected) have been contaminated. Effective decontamination procedures are implemented to minimize the potential for cross contamination (the transfer of contaminants, usually from one sample to another, by improperly decontaminated sampling equipment, containers, or devices such as drill rigs); offsite contaminant migration (the transfer of contaminants to areas outside the exclusion zone, usually by improperly decontaminated equipment); or personnel exposure from improperly decontaminated protective gear.

The subsections below present a general discussion of decontamination issues. Detailed guidance on methods, techniques, procedures, equipment, and solutions exist in the documents shown in Subsection 3.4.7. The SM and site safety officer should study and reference these documents when preparing the decontamination procedures.

3.4.2 Definitions

Decontamination

The process of neutralization, washing, rinsing, and removing exposed outer surfaces of equipment and personal protective clothing to minimize the potential for contamination migration.

Cross Contamination

The transfer of contaminants from their known or suspected location into a noncontaminated area; a term usually applied to sampling activities.

3.4.3 Applicability

The procedures in this subsection apply to activities where the potential exists for exposures of personnel and equipment to hazardous substances.

3.4.4 Responsibilities

The SM is responsible for determining the type of decontamination facility to be used onsite, the solutions to be employed, and the methodologies to be used in determining the effectiveness of the decontamination approach. The SM Is assisted by the field team leader and site safety officer. Onsite, the field team leader is responsible for implementing the decontamination plan by providing materials and staff members. The site safety officer oversees the decontamination process and provides verification of the effectiveness of the procedures. The decontamination plan should be presented or referenced in the work plan and Quality Assurance Project Plan (QAPjP).

3.4.5 Records

The QAPjP and work plan document the decontamination approach. The use of equipment cleaning blanks, decontamination rinse blanks, and other quality control procedures serves to document the effectiveness of the cleaning before and the decontamination after working onsite. The site safety officer typically furnishes documentation of equipment decontamination for those items leaving the site (see Exhibit 3-3). Such documentation is typically required by EPA for government-owned equipment. In some Instances, such as decontaminating a drill rig normally used by a subcontractor for water well Installation, the SM may need to arrange for laboratory testing of wipe samples before documenting the “cleanliness” of a piece of equipment.

3.4.6 Procedures

Numerous procedures are used in decontaminating people and things. The most effective procedure is contamination avoidance, that is, the use of procedures or materials to minimize or eliminate the potential for contact with contaminants. Personal protection gear and standard operating procedures are used to protect workers; other techniques Include encasing instruments and equipment in disposable outer wrappings (plastic sheeting), using disposable sampling devices, or Isolating the contaminants.

Decontaminating procedures include flushing with water or other advents; using pressure or steam jets; heating, flaming, or baking items scraping, rubbing, or grinding away or, most simply, disposing of the item after determining that the cost In time and staff necessary for decontamination is not acceptable, or that decontamination would not be effective. Several documents offer detailed guidance on procedures (see below).

3.4.7 Information Sources

Chapter 10, Decontamination, of the *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities* developed by NIOSH / OSHA / USCG / EPA. October 1985.

U.S. Environmental Protection Agency. “Decontamination Techniques for Mobile Response Equint Used at Waste Sites (State-of-the-Art Survey).” EPA/600/52-85/105. January 1986.

U.S. Environmental Protection Agency. *Guide for Decontaminating Buildings, Strnctures, and Equipment at Superfund Sites. EPA/800/2 85/028.* March 1985.

U.S. Environmental Protection Agency. *Field Standard Operating Procedures #7 Decontamination of Response Personnel.* January 1985.

U.S. Environmental Protection Agency. “Standard Operating Safety Guides.” November 1984.

Exhibit 3-3

DOCUMENTATION OF EQUIPMENT DECONTAMINATION

Contract No: ____________________
Work Assignment: ____________________
Project No: ____________________
Site Name/Location: ____________________

Site Manager: ____________________
Firm: ____________________
Phone No: ____________________

The following items of (government-owned) (corporate-owned) (rental) equipment have been decontaminated following the procedures detailed in the Site Safety Plan dated ________, (as modified on ________). Additional information on the procedures used is contained in (list site logs, work plans, photographs, etc. ____________________).

Equipment Nomenclature	Manufacturer's or EPA Serial Number	Dates of Use	Date of Decon.

SIGNED:

____________________ DATE: ____________________
Site Safety Coordinator

____________________ DATE: ____________________
Site Manager/Field Team Leader

NOTE: Attach tags to the decontaminated EPA-owned equipment showing the date of decontamination, the SSC's initials, and the work assignment/project number(s).

3.5 GENERAL HEALTH AND SAFETY CONSIDERATIONS

3.5.1 Scope and Purpose

Field activities at hazardous waste sites are conducted according to detailed health and safety procedures. These procedures are developed in accordance with the implementing regulations for Public Law 91-596, the Occupational Health and Safety Act of 1970, contained in 29 CFR Part II (29 CFR 1910.120, 1910.126, 1910.134, 1910.141, 1910.165, and 1910.1200, among others). Following standardized health and safety procedures will reduce the possibility of accidents or excess exposures of onsite workers to hazardous materials while allowing field activities to be carried out in a uniform manner. The purpose of this subsection is to out line several standard health and safety field procedures that are normally used in the conduct of remedial response activities. Site specific health and safety requirements are detailed in health and safety plans developed for each onsite visit. The general procedures to meet health and safety requirements are described below.

3.5.2 Definitions

None.

3.5.3 Applicability

This procedure is applicable to onsite activities that are carded out at hazardous waste sites by field personnel.

3.5.4 Responsibilities

The Site Managers are ultimately responsible for the health and safety of workers onsite. They are assisted by the site safety officer.

The site safety officer is responsible for developing safe work procedures for onsite and offsite assessment and for monitoring compliance with those procedures. The site safety officer obtains and implements the site safety plan.

The field team leader is responsible for the overall operation of the field team. The field team leader works with the site safety officer to conduct operations in compliance with the site safety plan.

Field team members are responsible for conducting tasks in accordance with the site safety plan developed for the activity. Field team members are also responsible for reporting to the field team leader any information that may have an impact on the health and safety of the operation.

3.5.5 Records

The measurements and observations mentioned in this subsection are documented in the project logbook. A site safety plan must be prepared for each field activity and must be available for review by onsite personnel.

3.5.6 Procedures

3.5.6.1 Site Safety Plan

A site safety plan (SSP) must be prepared by a qualified safety person for each field investigation activity. Review and approval by a different, equally qualified, safety staff member is typically required. For remedial action at hazardous waste sites, safety plans can be developed simultaneously with general operation plans and implemented when remedial actions begin. Emergency response situations may require verbal safety instructions and the use of standard operating safety procedures, until specific safety protocols can be written. For any remedial response activities, the SSP must include health and safety considerations for all activities required at the scene. The SSP must be reviewed and updated whenever additional site data are received, onsite personnel change, the level of protection used onsite is upgraded or downgraded, or site operations differ from those covered by the existing plan.

The field team members shall be thoroughly trained in the use of safety plans. The plan will be prepared under the direction of the site safety officer by persons knowledgeable with the site conditions and safety requirements. The SM and a designated health and safety staff member must approve the plan.

Minimum Requirements Paragraph (i) of 29 CFR 1910.120 requires employees to develop a site safety and health plan that, as a minimum, addresses the following:

- Evaluate the risks associated with the site and with each operation conducted. A scope of work will be included that summarizes the tasks required to perform each operation safely.

- Identify key personnel and alternates responsible for both site safety and remedial response operations.

- Address the levels of protective equipment to be worn by personnel during each site activity. Also, include a decision logic for upgrading or downgrading the level of protection.

- Designate work areas (exclusion zone, contamination reduction zone, and support zone), boundaries, size of zones, distance between zones, and access control points into each zone.

- Establish decontamination procedures for personnel and equipment.

- Determine the number of personnel and equipment needed in the work zones during initial entries and subsequent operations.

- Establish site emergency procedures (e.g., escape routes; signals for evacuating work patties; internal, external, and emergency communications; and procedures for fire and explosions). Emergency phone numbers (fire department, police department, hospital, ambulance, poison control center, and medical consultant) must appear on an emergency reference page.

- Implement a program and make arrangements with the nearest medical facility (and medical life squad unit) for emergency medical care of routine injuries and toxicological problems. A map showing *the* route from the site to the medical facility must be included in the plan.

- Document individual training requirements for the available use of protective gear and field instruments and for the performance of particular tasks.

- Identify known or suspected contaminants onsite, location and concentration of contaminants, hazards associated with each contaminant (including toxicity and health effects), and action levels that would require upgrading the level of personal protective equipment.

- Describe the procedures and equipment required to monitor the work area for potentially hazardous materials. Detail the necessary records associated with the monitoring program.
- Consider weather and other conditions that may affect the health and safety of personnel during site operations.
- Implement control procedures to prevent access to the site by unauthorized personnel.
- Describe medical surveillance requirements for each operation.
- Provide background Information to familarize the field team with the site history, current status, physical features, disposal practices, past monitoring data, and community/worker health complaint

3.5.6.2 General Safety Practices

Personnel Precautions: The fallowing are standard personnel safety precautions

- Eating, drinking, chewing gum or tobacco, smoking, or any practice that increases the probability of hand-to-mouth transfer and ingestion of material, is prohibited in any area designated as contaminated.
- Hands and face must be thoroughly washed upon leaving the work area and before eating, drinking, or any other activities.
- Whenever decontamination procedures for outer garments are in effect, the entire body shall be thoroughly washed as soon as possible after the protective garment is removed.
- No excessive facial hair, which interferes with a satisfactory fit of the mask-to-face seal, is allowed on personnel required to wear respiratory protective equipment.
- Contact with contaminated surfaces or with surfaces suspected of being contaminated shall be avoided. Whenever possible, a person shall not walk through puddles, mud, and other discolored surface kneel on ground; or lean, sit, or place equipment on drums, containers, vehicles, or the ground.
- Medicine and alcohol can potentate the effects from exposure to toxic chemicals. Prescribed drugs shall not be taken by personnel on response operations, if there is likelihood of such potentiation.
- Personnel and equipment In the contaminated area shall be kept to a minimum, consistent with effective site operations.
- Work areas for various operational activities must be established.
- Procedures for leaving a contaminated area must be planned and implemented before personnel go to the site. Work areas and decontamination procedures must be established on the basis of prevailing site conditions
- Contact lenses shall not be worn by Individuals required to wear respiratory protection or required to enter a potentially contaminated area.

Weather: Adverse weather conditions are important considerations in planning and conducting site operations. Hot or cold weather can cause physical discomfort, loss of efficiency, and Personnal Injury. Of particular importance Is heat stress resulting when protective clothing decreases natural body ventilation. One or more of the following can be used to reduce heat stress:

- Provide plenty of liquids. To replace body fluids (water and electrolytes) lost because of sweating, use a 0.1 percent saltwater solution, more heavily salted foods, or commercial mixes. Current research indicates commercial mixes high in electrolytes and low in salt are preferable.
- Provide coding devices to aid natural body ventilation. These devices, however, add weight and their use must be balanced against worker efficiency.
- Install mobile showers or hose-down facilities to reduce body temperature and to cool protective clothing.
- In extremely hot weather, conduct operations in the early morning or the evening.
- Provide adequate shelter to protect personnel against heat (or cold, rain, snow, etc.), which can decrease physical efficiency and increase the probability of accidents.
- In hot weather, rotate shifts of workers as required to manage heat stress; reduce the length of the work period and Increase the length of the rest period.
- Maintain good hygienic standards; frequent change of clothing; and daily showering. Clothing should be permitted to dry during rest periods. Persons who notice skin problems should immediately consult medical personnel.

Heat Stress Monitoring: For monitoring the body's recuperative ability after exposure to excess heat, several techniques are available as a screening mechanism. Monitoring of personnel who wear impervious clothing typically commences when the ambient temperature is 70°F or above, When temperatures exceed 85°F, workers are monitored for heat stress after every work period, usually 2 hours. The following are two monitoring schemes:

- 1. Heart rate (HR) is measured by the radial pulse for 30 seconds as early as possible in the resting period. The HR at the beginning of the rest period should not exceed 110 beats/minute. If the HR Is higher, the next work period is shortened by 10 minutes (or 33 percent), while the length of the rest period stays the same. If the pulse rate is 100 beats/minute at the beginning of the next rest period, the following work cycle is shortened by 33 percent.
- 2. Body temperature is measured orally with a clinical thermometer as early as possible in the resting period. Oral temperature (OT) at the beginning of the rest period should not exceed 99°F. If it does, the next work period is shortened by 10 minutes (or 33 percent), while the length of the rest period stays the same. However, if the OT exceeds 99.7°F at the beginning of the next period, the following work cycle is further shortened by 33 percent. OT is measured again at the end of the rest period to make sure that it has dropped below 99°F. (Since a mercury thermometer requires as long as 5 minutes to register the correct body temperature, the use of digital thermometers should be considered.)

Effects Of Heat Stress: If the body's physilogical processes fail to maintain a normal body ' temperature because of excessive heat, a number of physical reactions can occur ranging in degree from mild (such as fatigue, irritability, anxiety, or a decrease in concentration, dexterity, or movement) to fatal. First aid books should be consulted for specific symptoms and treatment.

Effects of Cold Exposure: Persons working outdoors in temperatures at or below freezing may be frostbitten. Exposure to extreme cold for a short time may cause severe injury to the surface of the body or result in profound generalized coding, causing death. Areas of the body that have a high surface-area-to-volume ratio, such as fingers, toes, and ears, are the most susceptible.

Two factors influence the development of a cold injury ambient temperature and the velocity of the wind. Wind chill is used to describe the chilling effect of moving air in combination with low temperature. For instance, 10^0F with a wind of 15 mph is equivalent in chilling effect to still air at -18^0F. Charts depicting the wind-chill factor are readily available.

As a general rule, the greatest incremental increase in wind chill occurs when a wind of 5 mph increases to 10 mph. Additionally, water conducts heat 240 times faster than air. Thus, the body cools suddenly when chemical-protective equipment is removed if the clothing underneath is soaked with perspiration.

Local injury resulting from cold is included in the generic term frostbite. There are several degrees of damage.

Systemic hypothermia is caused by exposure to freezing or rapidly dropping temperature. Its symptoms are usually exhibited in five stages: (1) shivering; (2) apathy, listlessness, sleepiness, and (sometimes) rapid coding of the body to less than 95^0F; (3) unconsciousness, glassy stare, slow pulse, and slow respiratory rate; (4) freezing of the extremities; and, finally (5) death.

First aid books should be consulted for symptoms and specific treatments for cold injury

3.5.6.3 Site Survey and Reconnaissance

Before the team enters the site, as much information as possible should be collected concerning the types of hazards, degree of hazards, and risks that may exist. Using available information (shipping manifests, transportation placards, existing records, container labels, etc.) or off site studies, the team will assess the hazards and identify the initial safety requirements.

The team(s) initially entering the site must accomplish one or more of the follwing objectives:

- Characterize the hazards that exist, or potentially exist, affecting the public health, the environment, and the response personnel.
- Verify existing information and/or obtain data about the incident.
- Evaluate the need for prompt mitigative actions.
- Collect supplemental information to determine the safety requirements for personnel who initially and subsequently enter the site.

Preliminary Onsite Evaluation: The initial onsite survey Is to determine, on a preliminary basis, hazardous or potentially hazardous conditions. The main effort Is to rapidly Identify the immediate hazards that may affect the public, the response personnel, and the environment. Of major concern are the real potential dangers – fire, explosion, oxygen deficient atmospheres, radiation, airborne contaminants, or containerized or pooled hazardous substances-that could affect workers during subsequent operations.

Visual Observations: While at the site, the initial entry team should make visual observations that would help in evaluating site hazards. Some examples are dead fish or other animals; land features; wind direction; labels on containers indicating explosive, flammable, toxic, or corrosive materials; conditions conducive to splash or contact with unconfined liquids, sludges, or solids; and other general conditions.

Direct-Reading Instruments: A variety of toxic air pollutants Including organic and inorganic vapors, gases, or particulate can be produced at abandoned waste sites by fires at chemical manufacturing, storage, reprocessing, or formulating facilities or by the inadvertent mixing of chemicals during bulking operations. Direct-reading field instruments will not detect or measure all of these substances. Thus, lack of response should not be interpreted as the complete absence of airborne toxic substances. Verification of zero results can be done only by collecting air samples and analyzing them in a laboratory.

Priority for Initial Entry Monitoring: Of immediate concern to initial entry personnel are atmospheric conditions that could affect the immediate safety of these personnel (see Exhibit 3-4). These conditions are airborne toxic substances, combustible gases or vapors, lack of oxygen, and, to a lesser extent, ionizing radiation. Priorities for monitoring these potential hazards should be established after a careful evacuation of conditions.

When the type(s) of material(s) involved in the investigation is identified and its release into the environment suspected or known, the material's chemical or physical properties and the prevailing weather conditions may help determine the order of monitoring. An unknown substance(s) or situation(s) presents a more difficult monitoring problem.

In general, when poorly ventilated spaces (buildings, ships' holds, boxcars, or bulk tanks) are entered, combustible vapors or gases and oxygen-deficient atmospheres shall be monitored first by team members wearing (as a minimum) supplied-air respirators and a high degree of dermal protection. Measurement of toxic gases or vapors and radiation, unless known not to be present, should be the next priority.

For open, well-ventilated areas, combustion gases and oxygen deficiency are lesser hazards and require lower priority. However, areas of lower elevation at the site (such as ditches and gullies) and downwind areas may have combustible gas mixtures, in addition to toxic vapors or gases, and may lack sufficient oxygen to sustain life. Entry teams should approach and monitor whenever possible from the upwind side of an area.

Periodic Monitoring: The monitoring surveys made during initial entry to the site are for a preliminary evaluation of atmosphere hazards. In some situations, the information obtained may be sufficient to preclude additional monitoring. A chlorine tank determined to be releasing no chlorine, Is one such example. Materials detected during the initial site. survey may indicate the need for a more comprehensive evaluation of hazards and analyses for specific components. A program must be established for monitoring, sampling, and evaluating hazards for the duration of site operations. Since site activities and weather conditions change, a continuous program to monitor atmospheric changes must be implemented using a combination of stationary sampling equipment, personnel monitoring devices, and periodic area monitoring with direct reading instruments.

Exhibit 3-4
ATMOSPHERIC HAZARD GUIDELINES

Monitoring Equipment	Hazard	Ambient Level	Action
Combustible Gas Indicator	Explosive atmosphere	LT[a] 10% LEL[b]	Continue investigation.
		10-20%	Continue onsite monitoring with extreme caution as higher levels are encountered.
		GT[c] 20% LEL	Explosion hazard; withdraw from area immediately.
Oxygen Concentration Meter	Oxygen	LT 19.5%	Monitor, wearing self-contained breathing apparatus (SCBA). NOTE: Combustible gas readings are not valid in atmospheres with LT 19.5% oxygen.
		19.5-25%	Continue investigation with caution. SCBA not needed, based on oxygen content only.
		GT 25.0%	Discontinue inspection; potential fire hazard. Consult specialist.
Radiation Survey	Radiation	LT 1 mR/hr	Continue investigation. If radiation is detected above background levels, this signifies the presence of possible radiation sources; at this level, more thorough monitoring is advisable. Consult a health physicist.
	Radiation	GT 10 mR/hr	Potential radiation hazard; evacuate site. Continue monitoring only upon the advise of a health physicist.
Thermoluminescent Detector (TLD) Badge	Radiation		All employees shall wear a TLD badge when working on hazardous waste sites and during any response operation. Badges will be analyzed quarterly to determine compliance with federal standards.
Colorimetric Tubes	Organic and inorganic vapors/gases	Depends on species	Consult standard reference manuals for air concentration/toxicity data.
Photoionization Detectors	Total organic vapors/gases and limited inorganic species	Above background	Consult EPA standard operating procedures.
Flame-ionization Detectors	Total organic vapors/gases	Above background	Consult EPA standard operating procedures.
	Specific organic vapor/gases	Depends on species	Consult standard reference manuals for air concentrations/toxicity data.

---

[a] LT means less than.

[b] LEL is defined as lower explosive limit.

[c] GT means greater than.

Peripheral Monitoring: Whenever possible, atmospheric hazards in the areas adjacent to the onsite zone are monitored with direct-reading instruments, and air samples should be taken before the initial entry for onsite monitoring. The lack of readings on instruments away from the site does not indicate a lack of hazards onsite. Offsite readings are only another piece of information to assist in the preliminary evaluation.

Monitoring Instruments: It is imperative that personnel using monitoring instruments be thoroughly familiar with their use, limitations, and operating characteristics. All instruments have inherent constraints in their ability to detect and/or quantify the hazards for which they were designed. Unless trained personnel use instruments and assess data readout, air hazards can be misinterpreted. In addition, only intrinsically safe instruments shall be used until the absence of combustible gases or vapors can be confirmed.

Ambient Atmospheric Concentrations: Any indication of atmospheric hazards (toxic substances, combustible gases, lack of oxygen, radiation, and other specific materials) should be viewed as a sign to proceed with care and deliberation. Readings indicating nonexplosive atmospheres, low concentrations of toxic substances, or other conditions may increase or decrease suddenly, changing the associated risks.

3.5.7 Information Sources

U.S. Environmental Protection Agency. “Standard Operating Safety Guides.” Memorandum from William Hedeman, Jr. 19 November 1984.

U.S. Environmental Protection Agency. *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities.* Developed by NIOSH / OSHA / USCG / EPA. October 1985.

Occupational Safety and Health Administration. “Interim Final Rule for Hazardous Operations and Emergency Response.” 29 CFR 1910.120. 19 December 1986.

SECTION 4

SAMPLE CONTROL, INCLUDING CHAIN OF CUSTODY

4.1 SCOPE AND PURPOSE

This section describes procedures for sample identification and chain of custody. The purpose of these procedures is to maintain the quality of samples during collection, transportation, and storage for analysis. Sample control and chain-of-custody procedures specific to the Contract Laboratory Program (CLP) are presented In the *User's Guide to the Contract Laboratory Program.*

4.2 DEFINITIONS

Sample

Physical evidence collected for environmental measuring and monitoring. Evidence includes remote-sensing imagery and photographs.

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

4.3 APPLICABILITY

When environmental measuring or monitoring data are collected for the Environmental Protection Agency (EPA), workers should refer to the procedures in this section.

4.4 RESPONSIBILITIES

The SM or designee Is responsible for monitoring compliance with these procedures. In general, it is desirable to appoint one person to be responsible for implementing sample control procedures (i.e., field operations leader). However, each sampler is responsible for the activities described in Subsections 4.5 and 4.6.

4.5 RECORDS

The following records are kept:

- Sample Identification tags (varies with the EPA region; see Subsection 4.7 and Exhibit 5-7)
- Sample traffic reports (e.g., Special Analytical Services (SAS); see Exhibits 5-2,5-3, and 5-9)
- Chain-of-custody (COC) forms and records (see Exhibits 5-4 5-5, and 5-6)
- Receipt-for-samples forms (varies among EPA regions; see Subsection 4.7 and Exhibit 4-3)

- Field investigation Team (FIT) receipt (for sample forms and field notebooks not serially numbered by the U.S. EPA)
- Field notebooks
- Airbills or bills of lading
- Dioxin analysis forma (as applicable)
- Photographic logs

Subsection 4.6 describes procedures for these records; Subsection 5.1.6 shows completed exhibits of the first three Items.

4.6 PROCEDURES

Sample identification documents must be prepared to maintain sample identification and chain of custody. The following are sample identification documents:

- Sample identification tags
- Sample traffic Reports
- Chain-of-custody records
- Receipt-for-samples forms
- custody seals
- Field notebooks

These documents are usually numbered (serialized) by EPA Some varieties of custody seals, field notebooks, or photographic logs may not be senrialized.

The following additional forms are used for samples shipped to CLP laboratories:

- Organic traffic reports
- Inorganic traffic reports
- High-hazard traffic reports
- SAS request forms
- Dioxin shipment records (as applicable)

Completed examples of these forms are in Subsection 5.1.6 of this compendium.

The organization's document control officer (designated on exhibits In this subsection as the Regional Document Control Officer or RDCO) or another designated person maintains a supply of the documents listed above, including field note books. The document control officer is responsible for the Inventory of serialized documents and the assignment of these documents to specific projects. Unused field documents are usually returned to the document control officer at the end of the field sampling went. The document control officer notes the return of these documents in the serialized document logbook. In some EPA regions, unused field documents are retained by the sampler to whom they were originally assigned for use on future projects. The sampler maintains a personal logbook in which Is recorded the final disposition of all relevant field information. Unused, returned documents may be checked out to another project by the RDCO, as needed. A cross reference of serialized field documents is usually maintained for each project in the project files. A sample cross-reference matrix is shown In Exhibit 4-1.

The document control officer orders sample identification tags, receipt-for samples forms, custody seals, and chain-of-custody records from the EPA regional offices. Traffic reports and SAS request forms are obtained through the Sample Management Office (SMO) representative.

Exhibit 4-2 shows how the sample control documents can be integrated Into the document control procedures used in an EPA project. The procedures for using each document are discussed below. Subsection 4.7 discusses regional variations; however, because procedures change and vary from region to region, the EPA Regional sample coordinating Center (RSCC) should be contacted during the planning of field activities to obtain the most current procedures. Appendix A of the *User's Guide to the CLP* contains a directory of RSCC contacts and telephone numbers.

4.6.1 Sample Identification Tags

Sample identification tags (see Exhibit 5-7) are distributed as needed to field workers by the SM (or designated representative). Procedures vary among EPA regions. Generally, the EPA serial numbers are recorded in the project files, the field notebook, and the document control officer's serialized document logbook. Individuals are accountable for each tag assigned to them. A tag is considered to be in an individual's possession until it has been filled out, attached to a sample, and transferred to another individual along with the corresponding chain-of custody record. Sample identification tags are not to be discarded. If tags are lost, voided, or damaged, the facts are noted in the appropriate field notebook, and the SM Is notified.

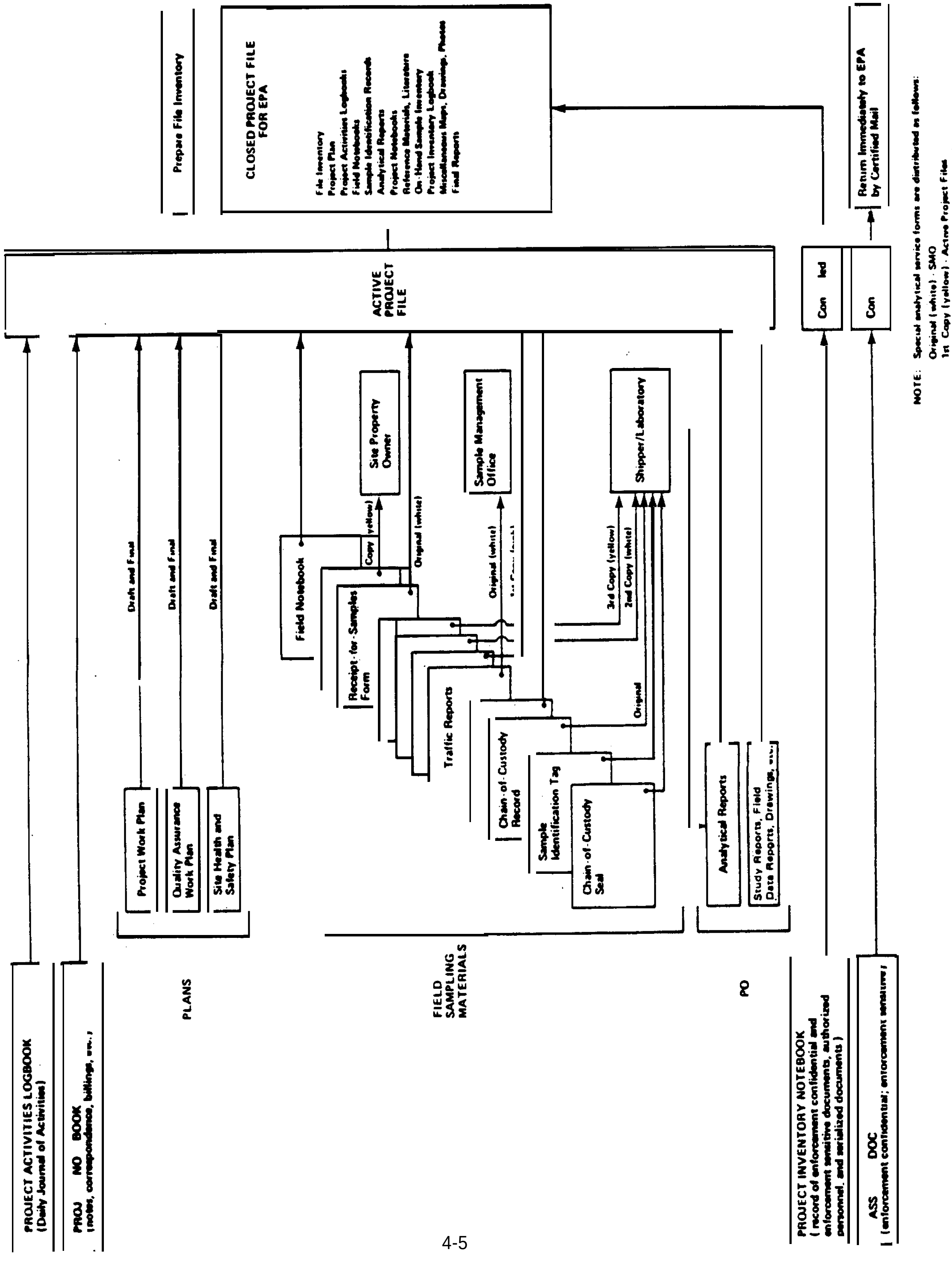
Upon the completion of the field activities, unused sample identification tags are returned to the document control officer, who checks them against the list of assigned serial numbers. Tags attached to those samples that are spilt with the owner, operator, agent-in-charge, or a government agency are accounted for by recording the serialized tag numbers on the receipt-for-samples form (Exhibit 4-3). Alternatively, the split samples are not tagged but are accounted for on a chain-of-custody form.

Samples are transferred from the sample location to a laboratory or another location for analysis. Before transfer, however, a sample is often separated into fractions, depending on the analysis to be performed. Each portion is preserved in accordance with prescribed procedures (see User's Guide to the CLP and Section 6 of this compendium) and Is identified with a separate sample identification tag, which should indicate in the "Remarks" section that the sample is a split sample.

Exhibit 4-1
CROSS REFERENCE MATRIX FOR SERIALIZED DOCUMENTS

Sample Station	Sample Indentification Tag Number	Type of Analysis	Organic Traffic Report Number	Inorganic Traffic Report Number	High-Hazard Traffic Report Number	Dioxin Forms	Chain-of-Custody Record Number	Receipt-for-Samples Form Number	Airbill Number	Date Shipped

Exhibit 4-2
DOCUMENT CONTROL PROCEDURES



NOTE: Special analytical service forms are distributed as follows:
Original (white) - SMO
1st Copy (yellow) - Active Project Files
2nd & 3rd Copies (pink & gold) - Shipper/Laboratory

The following information is recorded on the tag:

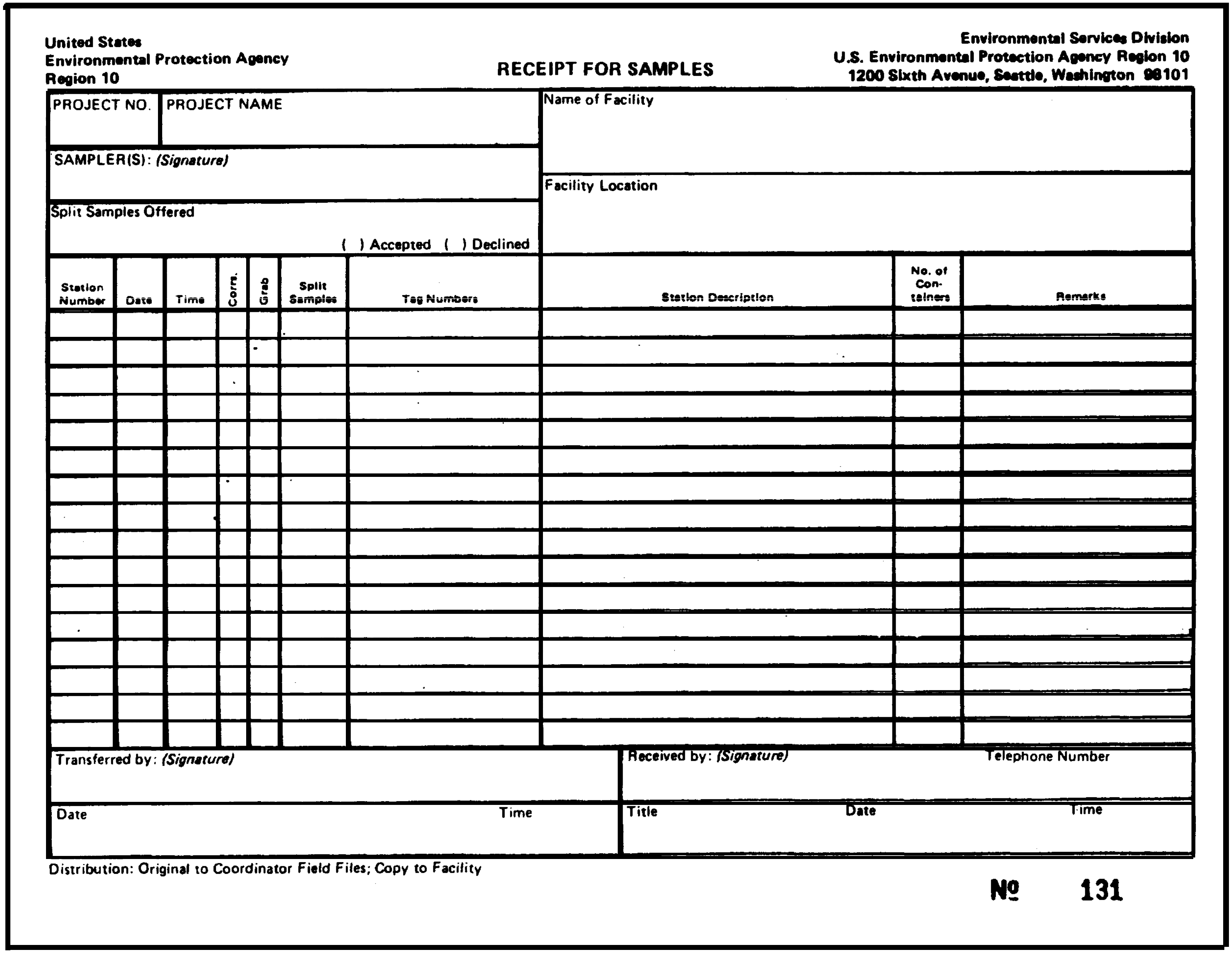
- CLP Case/ SAS Number(s): The unique number(s) assigned by SMO to identify the sampling event (entered under "Remarks" heading)
- CLP Sample Number The unique sample identification number (from the TR, DSR, or PL) used to document that sample (entered under "Remarks" heading)
- Project Code: An assigned contractor project number
- Station Number A unique identifier assigned to a sampling point by the sampling team leader and listed in the sampling plan
- Date: A six-digit number indicating the year, month, and day of collection
- Time: A four-digit number Indicating the local standard time of collection using the 24-hour clock notation (for example, 1345 for 1:45 p.m.)
- Station Location: The sampling station description as specified in the sampling plan
- Samplers: Each sampler's name and signature
- Preservative: Whether a preservative is used and the type of preservative
- Analysis The type of analysis requested
- Tag Number A unique serial number, stamped on each tag
- Batch Number The sample container cleaning batch number, recorded in the "Remarks" section
- Remarks: The sampler's record of pertinent information, such as batch number, split samples, and special procedures
- Laboratory Sample Number Reserved for laboratory use

The tag used for water, soil, sediment, and biotic samples contains an appropriate place for identifying the sample as a grab or a composite, the type of sample collected, and the preservative used, if any. The tag used for air samples requires the sampler to designate the sequence number and identify the sample type. Sample identification tags are attached to, or folded around each sample, and are taped in place.

After collection, separation, identification and preservation, a traffic report is completed and the sample is handled using chain-of-custody procedures discussed in the following sections. If the sample Is to be split, aliquots are placed into similar sample containers. Depending on the EPA region, sample identification tags are completed and attached to each split and marked with the tag numbers of the other portions and with the word "split." Blank or duplicate samples are labeled in the same manner as "normal" samples. Information on blanks or duplicate samples is recorded in the field notebook. Some EPA regions require that laboratories be informed of the number of blanks and duplicates that are shipped, but not the identity of the quality assurance samples.

The printed and numbered adhesive sample labels affixed to the traffic reports are secured to sample containers by the sampler. Forms are filled out with waterproof ink, if weather permits. If a pen will not function because of inclement conditions, an indelible pencil maybe used. If a pencil is used, a note ex-

Exhibit 4-3
TYPICAL RECEIPT-FOR-SAMPLES FORM



United States
Environmental Protection Agency
Region 10

RECEIPT FOR SAMPLES

Environmental Services Division
U.S. Environmental Protection Agency Region 10
1200 Sixth Avenue, Seattle, Washington 98101

PROJECT NO.

PROJECT NAME

Name of Facility

SAMPLER(S): *(Signature)*

Facility Location

Split Samples Offered

( ) Accepted ( ) Declined

Station Number	Date	Time	Corr.	Grab	Split Samples	Tag Numbers	Station Description	No. of Containers	Remarks

Transferred by: *(Signature)*

Received by: *(Signature)*

Telephone Number

Date

Time

Title

Date

Time

Distribution: Original to Coordinator Field Files; Copy to Facility

№ 131

plaining the conditions must be included in the field notebook. When necessary, the label is protected from water and solvents with clear tape.

The original Is sent to the SMO. The first copy is retained for the project file. The second and third copies are sent with the shipment to the laboratory. Complete instructions for the use of traffic reports are given in the *User's Guide to the CLP.*

4.6.2 Sample Traffic Report (TR)

The sample documentation system for the CLP sample preparation program is based on the use of the sample traffic report (TR), a four-part carbonless form printed with a unique sample identification number. One TR and its printed identification number is assigned by the sampler to each sample collected. The three types of TRs currently in use include organic, Inorganic dioxin, and high-concentration TRs. (See Subsection 5.1.6 for examples of completed TRs.)

To provide a permanent record for each sample collected, the sampler completes the appropriate TR, recording the case number, site name or code and location, analysis laboratory, sampling office, dates of sample collection and shipment, and sample concentration and matrix. Numbers of sample containers and volumes are entered by the sampler, beside the analytical parameter(s) requested for particular sample portions.

4.6.3 Chain-of-Custody Forms and Records

Because samples collected during an investigation could be used as evidence in litigation, possession of the samples must be traceable from the time each is collected until it is introduced as evidence in legal proceedings. To document sample possession, chain-of-custody procedures are followed.

4.6.3.1 Definition of Custody

A sample is under custody if one or more of the fallowing criteria are met:

- The sample Is in the sampler's possession.
- It is in the sampler's view after being in possession.
- It was in the sampler's possession and then was locked up to prevent tampering.
- It is in a designated secure area.

4.6.3.2 Field Custody Procedures

Only enough of the sample should be collected to provide a good representation of the medium being sampled. To the extent possible, the quantity and types of samples and the sample locations are determined before the actual fieldwork. As few people as possible should handle the samples.

Field samplers are personally responsible for the care and custody of the samples collected by their teams until the samples are transferred or dispatched properly, A person is usually designated to receive he samples from the field samplers after decontamination; this person maintains custody until the samples are dispatched.

The SM determines whether proper custody procedures were followed during the fieldwork and decides if additional samples are required.

4.6.3.3 Transfer of Custody and Shipment

Samples are accompanied by a chain-of-custody (COC) form or record (Exhibits 5-4 and 5-5). When transferring samples, the individuals relinquishing and receiving them should sign, date and note the time on the form. This form documents sample custody transfer from the sampler, often through another person, to the analyst, who is in a mobile or contract laboratory.

Samples are packaged properly for shipment and dispatched to the appropriate laboratory for analysis, with a separate COC record accompanying each shipment. Shipping containers are padlocked or sealed with custody seals for shipment to the laboratory. The method of shipment, courier name(s), and other pertinent information such as the laboratory name should be entered in the “Remarks” section of the COC record.

When samples are split with an owner, operator, or government agency, the event is noted in the “Remarks” section of the COC record. The note indicates with whom the samples are being spilt. The person relinquishing the samples to the facility or agency requests the signature of the receiving party on a receipt-for-samples form (Exhibit 4-3) (described in the following subsection), thereby acknowledging receipt of the samples. If a representative is unavailable or refuses to sign, this situation is noted in the “Remarks” section of the COC record. When appropriate, for example, when an owner’s representative is unavailable, the COC record and receipt-for-samples form should contain a statement that the samples were deilivered to the designated location at the designated time. A witness to the attempted delivery should be obtained. The samples shall be secured if no one is present to receive them.

All shipments are accompanied by a COC record identifying their contents. The original form accompanies the shipment; the copies are retained by the sampler and returned to the sampling coordinator.

If nonhazardous samples are sent by mail, the package is registered, and a return receipt is requested. Note: Hazardous materials shall not be sent by mail. If samples are sent by common carrier, a bill of lading is used. Air freight shipments are sent prepaid. Freight bills, postal service receipts, and bills of lading should be retained as part of the permanent documentation for the COC records.

4.6.3.4 Laboratory Custody Procedures

Laboratory personnel are responsible for the care and custody of samples from the time they are received until the samples are exhausted or returned to the laboratory sample custodian for ultimate disposal. Laboratory-specific variations exist however, a generally accepted laboratory chain-of-custody procedure is presented below. Any laboratory used for the analysis of samples taken in the course of EPA remedial response must have an adequate chain-of-custody procedure. This procedure is required as an exhibit in the Quailty Assurance Project Plan (QAPjP) if the laboratory is not in the CLP.

A designated custodian of laboratory samples accepts custody of the shipped samples and verifies that the information on the sample identification tags matches that on the COC records. Pertinent information on shipment, pickup, courier, and condition of samples is entered in the “Remarks” section. The custodian then enters the sample identification tag data into a bound logbook, which is arranged by project code and station number.

The laboratory custodian uses the sample identification tag number or assigns a unique laboratory number to each sample; the custodian transfers the samples to the proper analyst or stores them in the appropriate secure area. A limited number of named individuals are allowed access to the sample storage area. The appropriate analysts are responsible for the samples until they are returned to the custodian.

When sample analyses and necessary quality assurance (QA) checks have been completed, the unused portion of the sample and the sample containers must be disposed of properly (see Subsection 5.2.6.4). Ail identifying tags, data sheets, and laboratory records, are retained as part of the permanent documentation.

4.6.4 Receipt-for-Samples Form

Section 3007(a)(2) of the RCRA states “if the officer, employee, or representative obtains any samples, prior to leaving the premises he shall give to the owner, operator, or agent-in-charge, a receipt describing the samples obtained and, if requested, a portion of each such sample equal in volume or weight to the Portion retained.” Section 104 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), contains identical requirements.

completing a receipt-for-samples form complies with these requirements; such forms should be used whenever splits are offered or provided to the site owner, operator, or agent-in-charge. The particular form used may vary between EPA regions; an example is shown in Exhibit 4-3. This form is completed and a copy given to the owner, operator, or agent-in-charge even if the offer for split samples is declined. The original is given to the SM and is retained in the project files. in addition, the contractor must provide analytical results from the Samples collected to the owner, operator, or agent in charge, as mandated in SARA.

4.6.5 Custody Seals

When samples are shipped to the laboratory, they must be placed in padlocked containers or containers sealed with custody seals; a completed example is shown in Exhibit 5-6. Some custody seals are serially numbered. These numbers must appear in the cross-reference matrix (Exhibit 4-1) of the field document and on the COC report. Other types of custody seals include unnumbered seals and evidence tape.

When samples are shipped, two or more seals are to be placed on each shipping container (such as a cooler), with at least one at the front and one at the back, located in a manner that would indicate if the container were opened in transit. Wide, clear tape should be placed over the seals to ensure that seals are not accidentally broken during shipment. Nylon packing tape may be used providing that it does not completely cover the custody seal. completely covering the seal with this type of tape may allow the label to be peeled off. Alternatively, evidence tape maybe substituted for custody seals.

If samples are subject to interim storage before shipment, custody seals or evidence tape may be placed over the lid of the jar or across the opening of the storage box. Custody during shipping would be the same as described above. Evidence tape may also be used to seal the plastic bags or metal cans that are used to contain samples in the coder or shipping container. Sealing individual sample containers assures that sample integrity will not be compromised if the outer container seals are accidentally broken.

4.6.6 Field Notebooks

A bound field notebook must be maintained by the sampling team leader to provide daily records of significant events, observations, and measurements during field investigations. All entries are to be signed and dated. All members of the field investigation team are to use this notebook, which is to be kept as a permanent record. Observations or measurements that are taken in an area where contamination of the field notebooks may occur may be recorded in a separate bound and numbered logbook before being transferred to the project notebook. The original records are retained, and the delayed entry is noted as such.

‘Field notebooks are intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during projects and to refresh the memory of the field personnel if called upon to give testimony during legal proceedings. In a legal proceeding, notes, if referred to, are subject to cross-examination and are admissible as evidence. The field notebook entries should be factual, detailed, and objective.

4.6.7 Corrections to Documentation

Unless restricted by weather conditions, ail original data recorded in field notebooks and on sample identification tags, chain-of-custody records, and receipt-for-samples forms are written in waterproof ink. These accountable serialized documents are <u>not</u> to be destroyed or thrown away, even if they are illegible or contain inaccuracies that require a replacement document.

If an error is made on an accountable document assigned to one person, that individual may make corrections simply by crossing out the error and entering the correct information. The erroneous information should not be obliterated. Any error discovered on an accountable document should be corrected by the person who made the entry. All corrections must be initialed and dated.

For all photographs taken, a photographic log is kept; the log records date, time, subject, frame and roll number, and photographer. For “instant photos,” the date, time, subject, and photographer are recorded directly on the developed picture. The serial number of the camera and lens are recorded in the project notebook. The photographer should review the photographs or slides when they return from developing and compare them to the log, to assure that the log and photographs match. It can be particularly useful to photograph the labeled sample jars before packing them into shipping containers. A clear photograph of the sample jar, showing the label, any evidence tape sealing the jar, and the color and amount of sample, can be most useful in reconciling any later discrepancies.

4.7 REGION-SPECIFIC VARIANCES

Region-specific variances are common; the SM should contact the EPA RPM or the RSCC before any sampling campaign to ascertain the latest procedures. Future changes in variances will be incorporated in subsequent revisions to this compendium.

4.7.1 Region I

Region I uses a standard contractor serialized chain-of-custody form and an unnumbered chain-of-custody seal, which are placed on the outside of the shipping cooler. Numbered sample bottle labels are used for REM site work and numbered tags for FIT site work.

4.72 Region II

Region II uses an unnumbered chain-of-custody form and numbered sample bottle labels for ail site work. Custody seals are placed on the outside of the shipping coder.

4.7.3 Region Ill

Region Ill uses a serialized chain-of-custody form and numbered sampling tags. Chain-of-custody seals used by Region Ill are unnumbered and placed on the outside of the shipping coder.

4.7.4 Region IV

Region IV has a detailed procedural discussion In the *Engineering Support Branch Standards Operating Procedures and Quality Assurance Manual,* U.S. EPA Region IV, Environmental Services Division, 1 April 1986.

4.7.5 Region V

Region V uses a serialized chain-of-custody seal. Region V seals are color coded; orange is used for REM and FIT work Seals are placed on the outside of the shipping coder only if the samples are sent the same day as collected; otherwise, seals are placed across sample jar lids. FIT does not note whether or not samples were split on the chain-of-custody record. FIT includes the corresponding Traffic Report number under the remarks section of the tag. The bottle lot numbers or “batch numbers” are not recorded here. but on the “Chain-of Custody form.”

4.7.6 Region VI

Region Vi does not use a serialized number control system on custody seals.

4.7.7 Region VII

Region VII personnel provide onsite sample control. Samples are logged into a computer by regional personnel. Although contractor personnel do not seal and log samples, chain of custody is fallowed as described above.

4.7.8 Region Viii

Region Viii does not use a serialized number control system on custody seek.

4.7.9 Region IX

Region IX does not use a serialized number control system on chain-of-custody seals.

4.7.10 Region X

Region X does not use a serially numbered custody seal. Seals are signed, and the sample ID number is written on the seal.

4.8 INFORMATION SOURCES

Superfumd Amendments and Reauthorization Act (SARA). Section 104(m), "information Gathering Access Authorities."

U.S. Environmental Protection Agency. *NEIC Policies and Procedures. EPA-3W9-78-OW* -R. May 1978. (Revised February 1983.)

U.S. Environmental Protection Agency. REM IV *Zone Management Plan. Contract* No. 68-01-7251, CH2M HILL and U.S. EPA

U.S. Environmental Protection Agency. *Use's Guide to the Contract Laboratory Program. Office of* Emergency and Remedial Response. December 1986.

U.S. Environmental Protection Agency. *Zone II REM/FIT Quality Assurance Manual. Contract No. 88-*014692, CH2M HILL and Hazardous Site Control Division.

SECTION 5

LABORATORY INTERFACE

5.1 NATIONAL CONTRACT LABORATORY PROGRAM

Note: This section Is organized by contract and noncontract laboratory programs to provide a clearer differentiation between programs.

5.1.1 Scope and Purpose

This subsection summarizes how to schedule analyses through the NationaL Contract Laboratory Program (CLP), the types of services provided by the CLP, the papeerwork involved in submitting samples to a CLP laboratory, and how to contact a CLP laboratory regarding final disposition of analytical data. A detailed discussion of the entire CLP, including the CLP tracking system, can be found in the *User's Guide to the CLP.*

5.1.2 Definitions and Abbreviations

National Contract Laboratory Program (CLP)
(See *User's Guide to the CLP.)*

Regional Sample Control Center (RSCC)
(See *User's Guide to the UP.)*

Sample Management Office (SMO)
(See *User's Guiide to the (CLP)*

Site Manager (SM)
The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

5.1.3 Applicability

This subsection is applicable to samples collected during Superfund projects. Only EPA may grant exceptions to the required use of CLP. The use of CLP is a requirement only when justified by the choice of data quality objectives (DQO). There will be many opportunities to use mobile laboratories, screening protocols, subcontracted private laboratories or EPA regional laboratories,

5.1.4 Responsibilities

Detailed responsibilities are described in Subsection 5.1.6 on procedures. General responsibilities are given to the following:

- Site Managers for planning the sampling dates and analytical requirements
- EPA Remedial Project Managers (RPMs) for communicating the sampling or analytical schedule to the RSCC
- RSCC for deciding sample priorities within their region and for telling SMO their analytical needs on a monthly, as well as a weekly, basis
- SMO for scheduling sample analysis, communicating the laboratory information back to the RSCC, and contacting the laboratories concerning late or missing data
- Sampling personnel for completing the required paperwork and for contacting SMO and RSCC with shipping information

5.1.5 Records

The following sample documentation is required (examples are given in Subsection 5.1.6):

- Organic traffic report
- inorganic traffic report
- High-concentration traffic report
- CLP dioxin shipment record
- Special analytical service packing list
- Sample tag and label
- custody Seal
- Chain-of-custody (COC) form

Note: All of the above are not required for each sample collected. The reader should refer to subsection 5.1.6 for specific requirements.

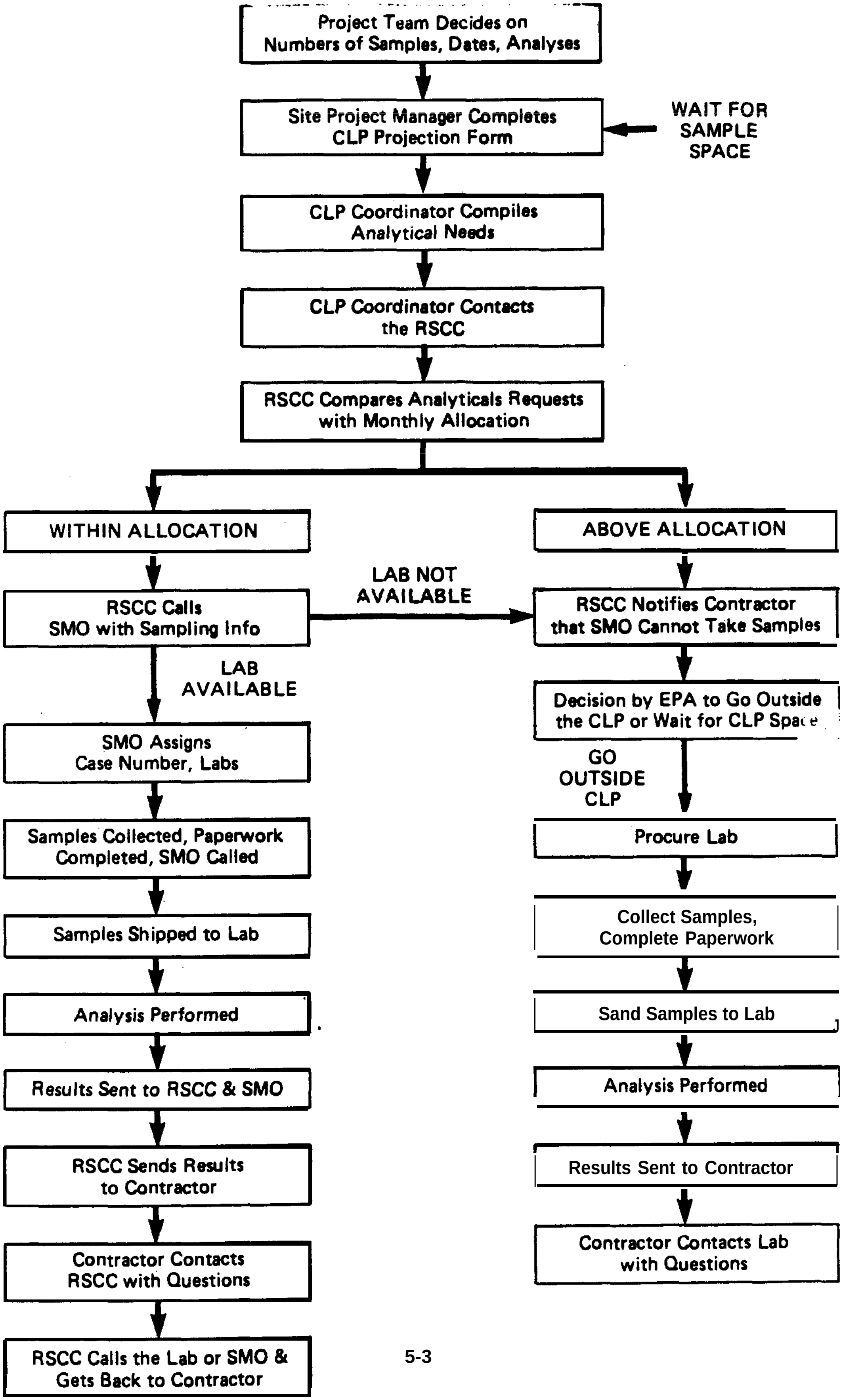
5.1.6 Procedure

The procedures in this subsection are presented in the chronological order used during a routine sampling episode; they are applicable to routine, as well as special, analytical services. Exhibit 5-1 summarizes the process from start to finish. These procedures are generic with an approach to regional differences discussed in Subsection 5.1.7. (See also Subsection 6.1.6.1.)

5.1.6.1 Activities Before Sampling

1. The project team decides what sampling is to occur at the site and the analyses to be performed, based on available data. The CLP provides a choice of two analytical services: routine and special. Routine analytical services include analysis of a soil or water sample at low-to-

Exhibit 5-1
ROUTINE SAMPLING PROCESS



medium concentration levels (<15 per cent of any single compound) for the Target Compound List (TCL) organics and/or inorganic with a 30-day to 45-day turnaround requirement. The TCL includes organic compounds, trace elements and cyanide. Special analytical services Include any analysis that is not routine, such as analysis for non-TCL compounds; different turnaround times; high concentration soils, water, drums, etc.; or different sample media (e.g., fish, air, etc.).

2. The SM completes a CLP monthly projection form that details the sampling anticipated for the present month as well as the following 2 months. This form is submitted to the contractor's CLP coordinator, who compiles the analytical needs.

3. The contractor's CLP coordinator contacts the EPA RPM with the information. The RPM contacts the authorized requesters (AR) at the appropriate RSCC and gives them the appropriate information. The AR calls the SMO with the necessary information.

The SMO requires the following information from an AR to Initiate a RAS request:

- Name of RSCC authorized requester
- Name(s), association, and telephone number(s) of sampling personnel
- Name, city, and state of the site to be sampled
- Superfund site/ spill ID (2-digit alpha-numeric code)
- Dioxin tier assignment, where applicable
- Number and matrix of samples to be collected
- Type of analyses required
    - Organics Full (VOA, BNA, and pesticides / PCB) or VOA and/or BNA and/or pesticides / PCB
      Inorganic: Metals and/or cyanide
      Dioxin: 2,3,7,8-TCDD
- Scheduled sample collection and shipment dates
- Nature of sampling event (i.e., investigation, monitoring, enforcement, remedial, drilling project, CERCLA Cooperative Agreements)
- Suspected hazards associated with the sample and/or site
- Other pertinent information that may affect sample scheduling or shipment (i.e., anticipated delays because of site access, weather conditions, sampling equipment)
- Name(s) of regional or contractor contacts for immediate problem resolution

This information is submitted to the RSCC as early as possible before the anticipated sampling date. A minimum of 2 weeks lead time is strongly suggested for RAS requests. Changes in the sample schedule are relayed to the RSCC as soon as they become known. It should be recognized that changes in the sampling schedule may delay laboratory assignments, especially If they are frequent or "last minute." This reporting sometimes necessitates daily contact with the RSCC.

RSCC telephone numbers are found in the *User's Guide to the CLP,* Appendix A.

4. Special Analytical Service (SAS) is handled slightly differently. Because these services are individually procured on a competitive basis, a minimum lead time of 2 weeks Is required to process a completely defined SAS request. More lead time is strongly recommended whenever possible. Certain types of SAS requests require a longer lead time, as follows: A minimum lead time of 2 to 3 weeks is required for SAS requests that involve distribution of protocols. A minimum lead time of 4 or more weeks is recommended for large-scale, analytically complex, and/or non-Superfund SAS requests. Award of non-Superfund SAS subcontracts may be made only after the appropriate funding process is complete.

SMO requires the following information from an AR to initiate an SAS request:

- Name of RSCC authorized requestor
- Name(s), association, and telephone number(s) of sampling personnel
- Name, city and state of the site to be sampled
- Superfund site / spill ID (2-digft alpha-numeric code)
- Number and matrix of samples to be collected
- Specific analyses required and appropriate protocols and QA/QC
- Required detection limits
- Matrix spike and duplicate frequency
- Data turnaround and data format
- Justification for fast turnaround request, if appropriate
- Scheduled sample collection and shipment dates
- Nature of sampling event (i.e., Investigation, monitoring, enforcement, remedial, drilling project, CERCLA Cooperative Agreements)
- Suspected hazards associated with the samples and/or site
- Other pertinent information that may affect sample scheduling or shipment (i.e., anticipated delays because of site access, weather condition, sampling equipment)
- Name(s) of regional or contractor contacts for immediate problem resolution

5. The RSCC contacts SMO to schedule analysis at least 1 week before start of sampling for Routine Analytical Analysis (RAS) only for SAS, additional time is needed. SMO assigns a case number, an SAS number (i applicable) and laboratories; this information is communicated to the RSCC.

6. The RSCC contacts the RPM or the SM regarding the case number, SAS number, and laboratory information no later than noon on the Wednesday of the week before sample shipment. The RSCC also provides traffic reports, custody seals, SAS packing lists, chain-of+custody forms, sample tags, and CLP dioxin shipment record forms, as appropriate for EPA/CLP sampling events.

8.1.6.2. Sampling Activities

1. During the sampling process, sampling personnel maintain dose contact with SMO and RSCC, relaying sampling information, shipping information, problems encountered during sampling, and any changes from the originally scheduled sampling program. Shipping information is called into SMO before 5:00 p.m. Eastern Standard Time (EST) on the day of shipment or by 8:00 a.m. EST the next day. Friday shipments are called in to SMO before 3:00 p.m. EST to confirm Saturday delivery.

2. samplers should provide SMO with the following information during the call:

- sampler name and phone number
- Case number and/or SAS number of the project
- Site name /code
- Batch numbers (dioxin only)
- Exact number(s), matrixes and concentration(s) of samples shipped
- Laboratory(ies) that samples were shipped to
- Carrier name and airbill number(s) for the shipment
- Method of shipment (e.g., overnight, May)
- Date of shipment
- Suspected hazards associated with the samples or site
- Any Irregularities or anticipated problems with the samples, including special handling instructions, or deviations from established sampling procedures
- Status of the sampling project (e.g., final shipment update of future shipping schedule)

3. samplers must complete the required SMO / CLP paperwork before sample shipment. Examples of properly completed forms are given in Exhibits 5-2 through 5-10. (Also see Section 4 for information regarding sample control and chain-of-custody reports.)

4. The designated copies& the completed paperwork are sent to the laboratory or SMO, as appropriate. All paperwork must be submitted within the same week of the sampling event.

Exhibit 5-2
TYPICAL ORGANICS TRAFFIC FORM

U.S. ENVIRONMENTAL PROTECTION AGENCY HWI Sample Management Office

[illegible]

ORGANICS TRAFFIC REPORT

Sample Number
AH 719

① **Case Number:**
9999

Sample Site Name/Code:
CHEMICAL SOUP/
$750.75

② **SAMPLE CONCENTRATION**
(Check One)
X **Low Concentration**
___ **Medium Concentration**

③ **SAMPLE MATRIX**
(Check One)
X **Water**
___ **Soil/Sediment**

④ **Ship To:**
QZR LAB
321 ROAD STREET
SOMETOWN, STATE 12345

Attn: SAMPLER COORDINATOR

Transfer
Ship To:

⑤ **Regional Office:** NUS REM
Sampling Personnel:
SAMPLER
(Name)
412/788-1080
(Phone)
Sampling Date:
1/15/85
(Begin) (End)

⑥ **For each sample collected specify numb of containers used and mark volume level on each bottle.**

	Number of Containers	Approxima Total Volur
Water (Extractable)	2	1 gal
Water (VOA)	2	80 ml
Soil/Sediment (Extractable)		
Soil/Sediment (VOA)		
Other		

AH 719	- Water (Extractable)
AH 719	- Water (Extractable)
AH 719	- Water (Extractable)
AH 719	- Water (Extractable)
AH 719	- Water (VOA)
AH 719	- Water (VOA)
AH 719	- Soil/Sediment (Extractable)
AH 719	- Soil/Sediment (Extractable)
AH 719	- Soil/Sediment (VOA)
AH 719	- Soil/Sediment (VOA)

⑦ **Shipping Information**
FEDERAL EXPRESS
Name of Carrier
1/15/85
Date Shipped:
350262356
Airbill Number:

⑧ **Sample Description**

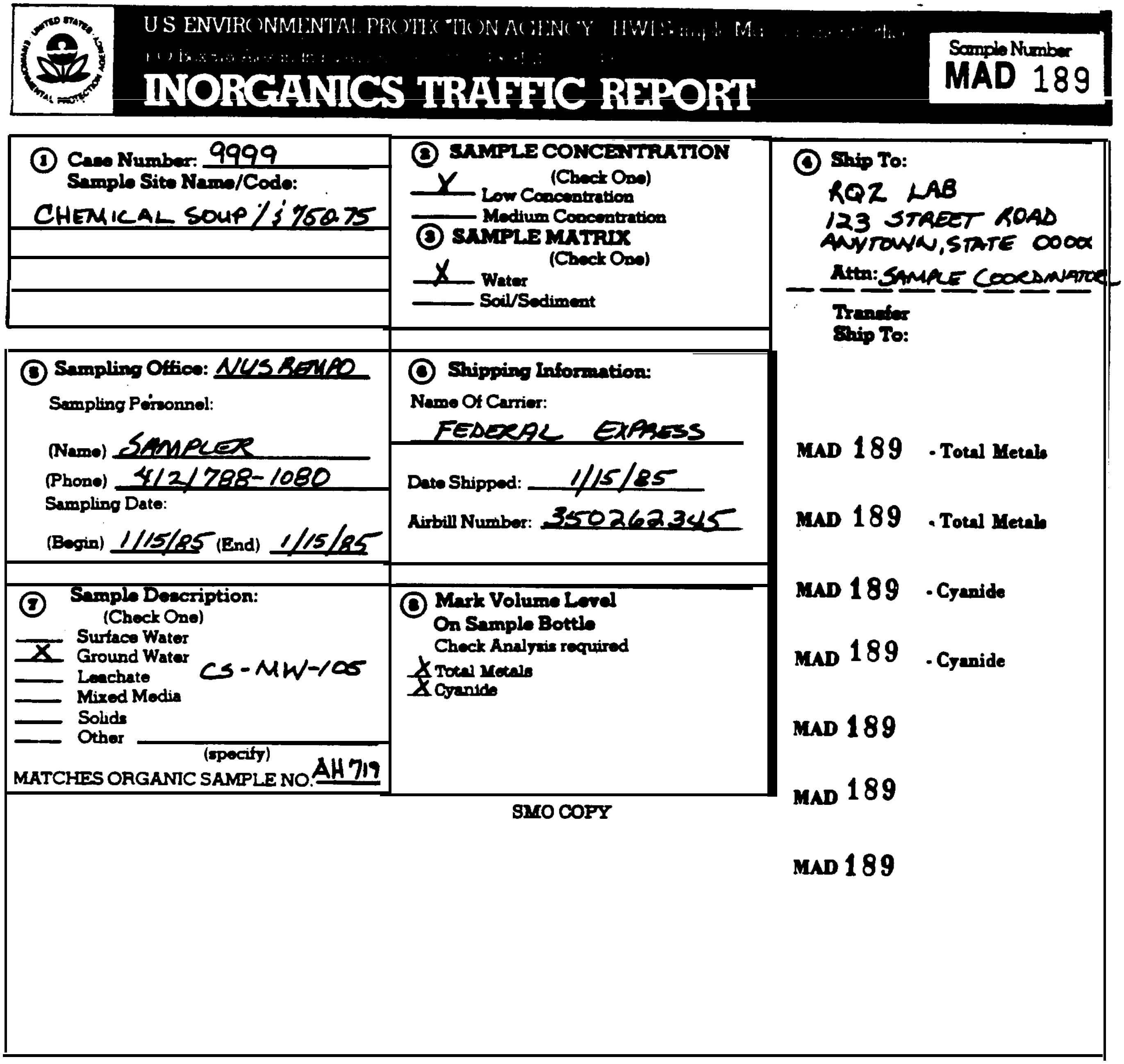
___ Surface Water	___ Mixed Media
___ Ground Water	___ Solids
___ Leachate	___ Other (specify) ________

⑨ **Sampl**
CS-MW-105
MATCHES ITR # MAD 189

⑩ **Special Handling Instructions:**
(e.g., safety precautions, hazardous nature)

SMO COPY

Exhibit 5-3
TYPICAL INORGANICS TRAFFIC FORM



U S ENVIRONMENTAL PROTECTION AGENCY HWI Sample Ma [illegible]

[illegible]

INORGANICS TRAFFIC REPORT

Sample Number
MAD 189

① **Case Number:** 9999
Sample Site Name/Code:
CHEMICAL SOUP / $750a75

② **SAMPLE CONCENTRATION**
(Check One)
X Low Concentration
___ Medium Concentration

③ **SAMPLE MATRIX**
(Check One)
X Water
___ Soil/Sediment

④ **Ship To:**
RQZ LAB
123 STREET ROAD
ANYTOWN, STATE 0000
Attn: SAMPLE COORDINATOR
Transfer
Ship To:

⑤ **Sampling Office:** NUS REMPO
Sampling Personnel:
(Name) SAMPLER
(Phone) 412/788-1080
Sampling Date:
(Begin) 1/15/85 (End) 1/15/85

⑥ **Shipping Information:**
Name Of Carrier:
FEDERAL EXPRESS
Date Shipped: 1/15/85
Airbill Number: 350262345

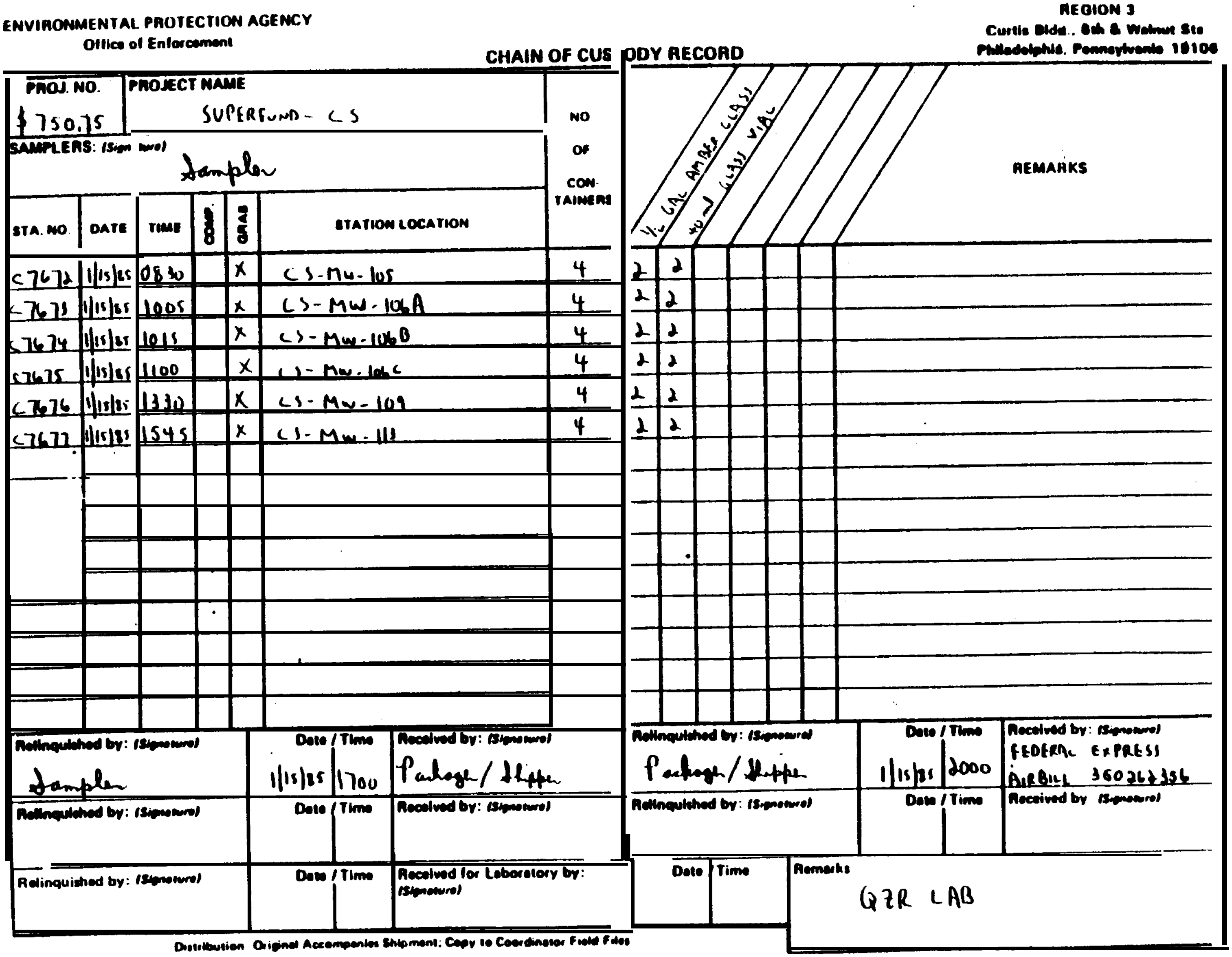
⑦ **Sample Description:**
(Check One)
___ Surface Water
X Ground Water CS-MW-105
___ Leachate
___ Mixed Media
___ Solids
___ Other ________
(specify)
MATCHES ORGANIC SAMPLE NO. AH 719

⑧ **Mark Volume Level On Sample Bottle**
Check Analysis required
X Total Metals
X Cyanide

MAD 189 - Total Metals
MAD 189 - Total Metals
MAD 189 - Cyanide
MAD 189 - Cyanide
MAD 189
MAD 189
MAD 189

SMO COPY

Exhibit 5-4
TYPICAL CHAIN-OF-CUSTODY FORM
(REGION III EXAMPLE)



ENVIRONMENTAL PROTECTION AGENCY
Office of Enforcement

REGION 3
Curtis Bldg., 6th & Walnut Sts
Philadelphia, Pennsylvania 19106

CHAIN OF CUSTODY RECORD

PROJ. NO. $750.75

PROJECT NAME SUPERFUND - CS

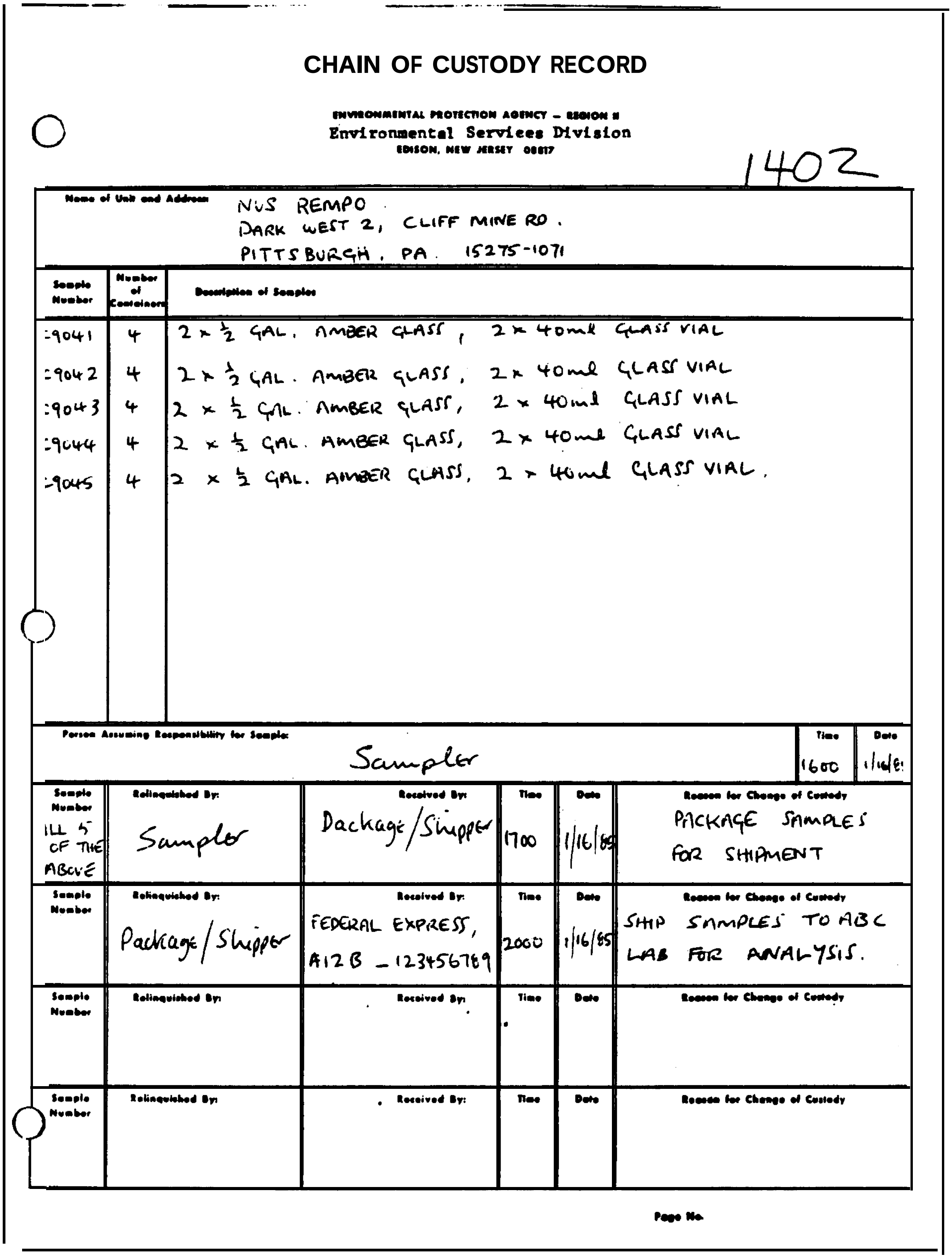
SAMPLERS: (Signature) Sampler

STA. NO.	DATE	TIME	COMP	GRAB	STATION LOCATION	NO OF CONTAINERS	½ GAL AMBER GLASS	40 ml GLASS VIAL						REMARKS
C7672	1/15/85	0830		X	CS-MW-105	4	2	2						
C7673	1/15/85	1005		X	CS-MW-106A	4	2	2						
C7674	1/15/85	1015		X	CS-MW-106B	4	2	2						
C7675	1/15/85	1100		X	CS-MW-106C	4	2	2						
C7676	1/15/85	1330		X	CS-MW-109	4	2	2						
C7677	1/15/85	1545		X	CS-MW-113	4	2	2						

Relinquished by: (Signature) Sampler	Date / Time 1/15/85 1700	Received by: (Signature) Package/Shipper	Relinquished by: (Signature) Package/Shipper	Date / Time 1/15/85 2000	Received by: (Signature) FEDERAL EXPRESS AIRBILL 360262356
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by (Signature)
Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	Remarks QZR LAB	

Distribution: Original Accompanies Shipment; Copy to Coordinator Field Files

Exhibit 5-5
CHAIN-OF-CUSTODY RECORD USED BY REGION II IN LIEU OF CHAIN-OF-CUSTODY FORM



CHAIN OF CUSTODY RECORD

ENVIRONMENTAL PROTECTION AGENCY – REGION II
Environmental Services Division
EDISON, NEW JERSEY 08817

1402

Name of Unit and Address:
NUS REMPO
PARK WEST 2, CLIFF MINE RD.
PITTSBURGH, PA. 15275-1071

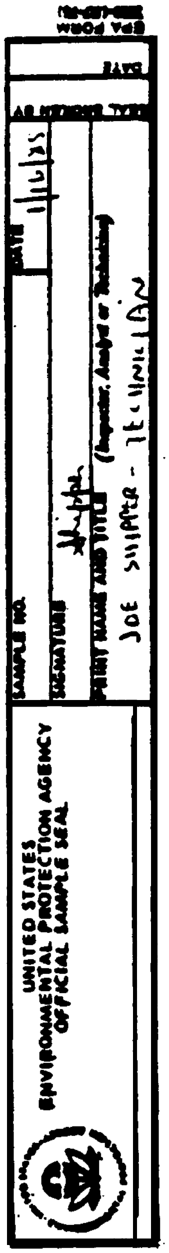
Sample Number	Number of Containers	Description of Samples
9041	4	2 × ½ GAL. AMBER GLASS, 2 × 40ml GLASS VIAL
9042	4	2 × ½ GAL. AMBER GLASS, 2 × 40ml GLASS VIAL
9043	4	2 × ½ GAL. AMBER GLASS, 2 × 40ml GLASS VIAL
9044	4	2 × ½ GAL. AMBER GLASS, 2 × 40ml GLASS VIAL
9045	4	2 × ½ GAL. AMBER GLASS, 2 × 40ml GLASS VIAL.

Person Assuming Responsibility for Sample:	Time	Date
Sampler	1600	1/16/8

Sample Number	Relinquished By:	Received By:	Time	Date	Reason for Change of Custody
ILL 5 OF THE ABOVE	Sampler	Dackage/Shipper	1700	1/16/85	PACKAGE SAMPLES FOR SHIPMENT
	Package/Shipper	FEDERAL EXPRESS, A12B – 123456789	2000	1/16/85	SHIP SAMPLES TO ABC LAB FOR ANALYSIS.

Page No.

Exhibit 5-6
TYPICAL CUSTODY SEALS



UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
OFFICIAL SAMPLE SEAL

SAMPLE NO.

DATE 1/16/85

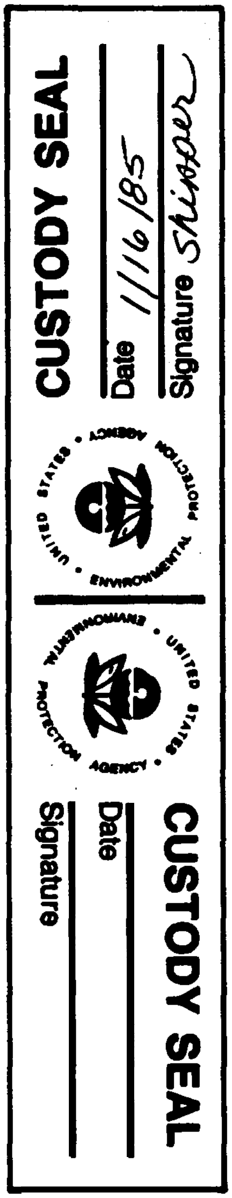
SIGNATURE

PRINT NAME AND TITLE (Inspector, Analyst or Technician)
JOE SHIPPER - TECHNICIAN

[illegible]

DATE

EPA FORM
[illegible]



CUSTODY SEAL

Date 1/16/85

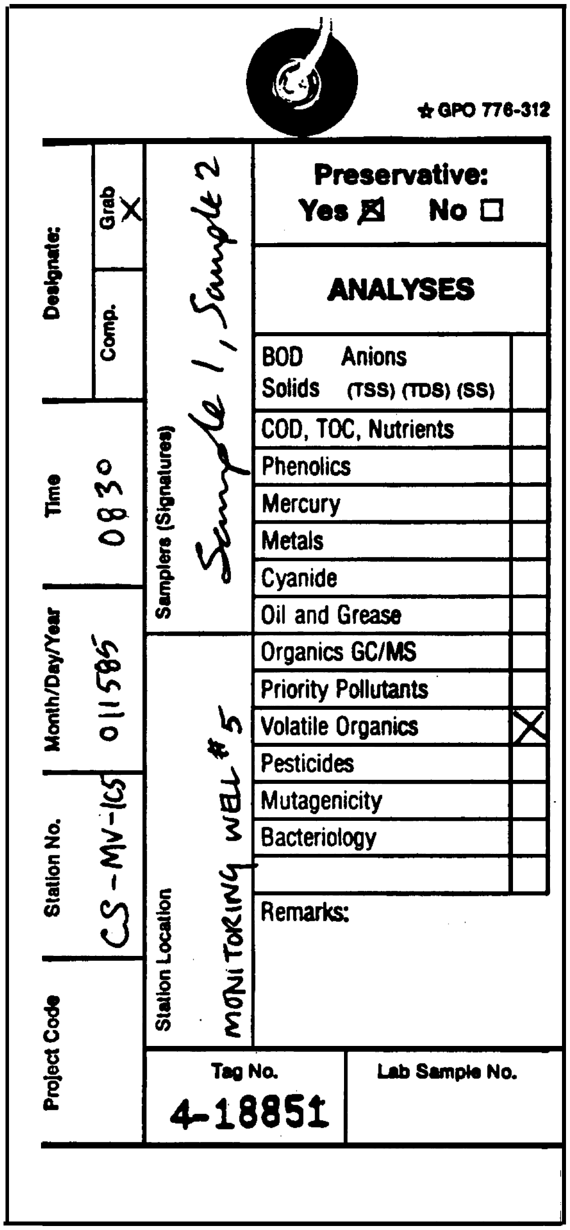
Signature Shipper

CUSTODY SEAL

Date

Signature

Exhibit 5-7
TYPICAL SAMPLE IDENTIFICATION TAGS



★ GPO 776-312

Designate: Grab X Comp.

Time: 0830

Month/Day/Year: 011585

Station No.: CS-MV-105

Project Code:

Samplers (Signatures): Sample 1, Sample 2

Station Location: MONITORING WELL #5

Preservative: Yes ☒ No ☐

ANALYSES

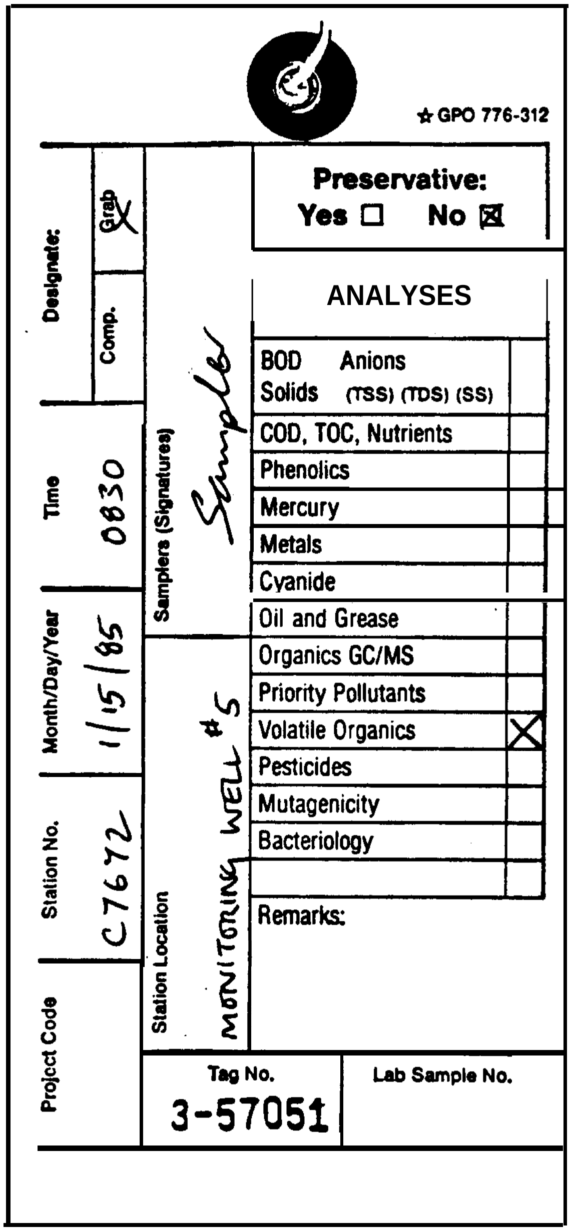
BOD Anions Solids (TSS) (TDS) (SS)	
COD, TOC, Nutrients	
Phenolics	
Mercury	
Metals	
Cyanide	
Oil and Grease	
Organics GC/MS	
Priority Pollutants	
Volatile Organics	X
Pesticides	
Mutagenicity	
Bacteriology	

Remarks:

Tag No. 4-18851

Lab Sample No.

Region IV Sample Tag



★ GPO 776-312

Designate: Grab X Comp.

Time: 0830

Month/Day/Year: 1/15/85

Station No.: C7672

Project Code:

Samplers (Signatures): Sample

Station Location: MONITORING WELL #5

Preservative: Yes ☐ No ☒

ANALYSES

BOD Anions Solids (TSS) (TDS) (SS)	
COD, TOC, Nutrients	
Phenolics	
Mercury	
Metals	
Cyanide	
Oil and Grease	
Organics GC/MS	
Priority Pollutants	
Volatile Organics	X
Pesticides	
Mutagenicity	
Bacteriology	

Remarks:

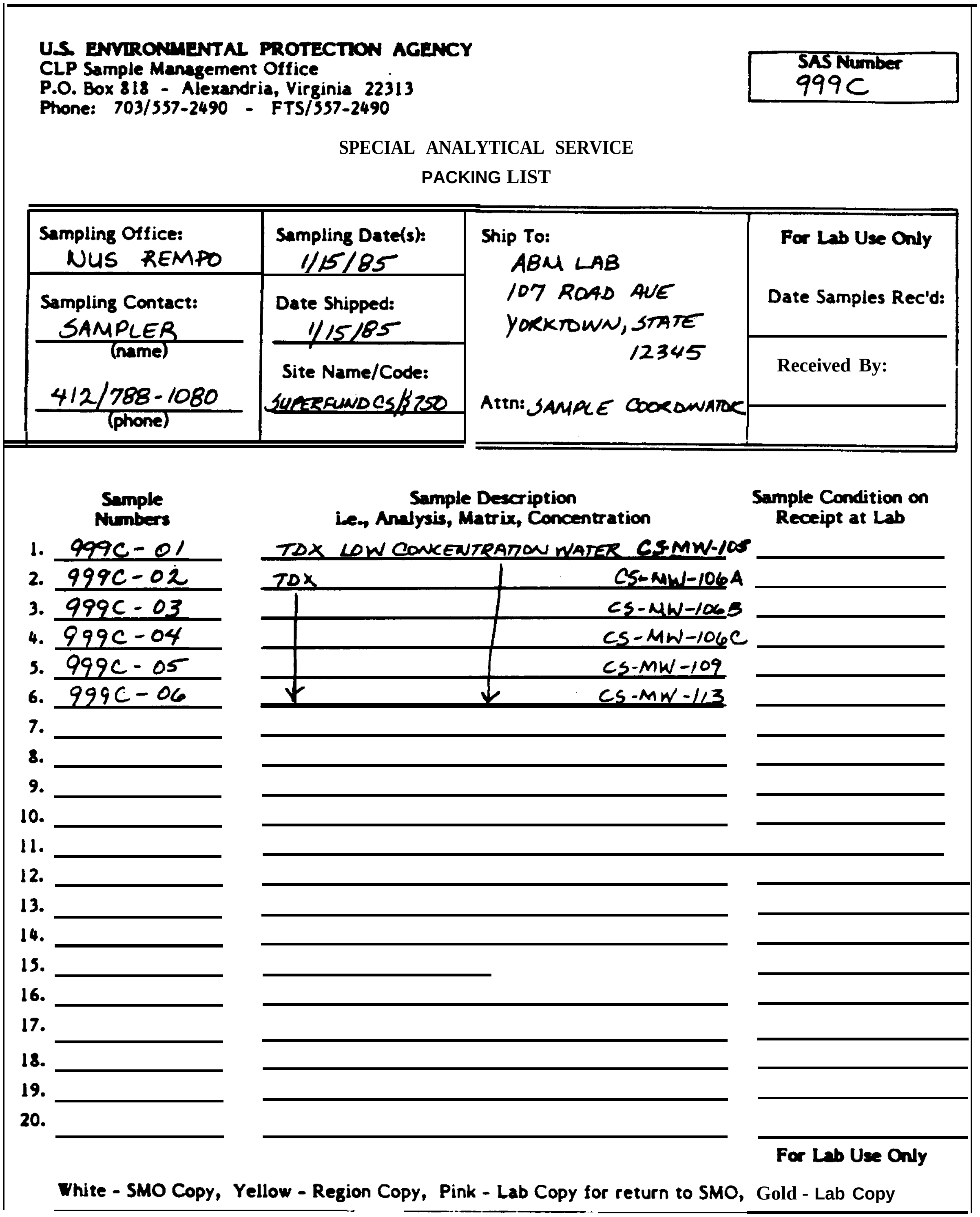
Tag No. 3-57051

Lab Sample No.

Region III Sample Tag

Note: The obverse side of the sample tag bears an EPA logo and the appropriate regional address.

Exhibit 5-8
SPECIAL ANALYTICAL SERVICES PACKING LIST



U.S. ENVIRONMENTAL PROTECTION AGENCY
CLP Sample Management Office
P.O. Box 818 - Alexandria, Virginia 22313
Phone: 703/557-2490 - FTS/557-2490

SAS Number 999C

SPECIAL ANALYTICAL SERVICE
PACKING LIST

Sampling Office: NUS REMPO

Sampling Date(s): 1/15/85

Ship To:
ABM LAB
107 ROAD AVE
YORKTOWN, STATE
12345

Attn: SAMPLE COORDINATOR

For Lab Use Only

Date Samples Rec'd:

Received By:

Sampling Contact: SAMPLER
(name)
412/788-1080
(phone)

Date Shipped: 1/15/85

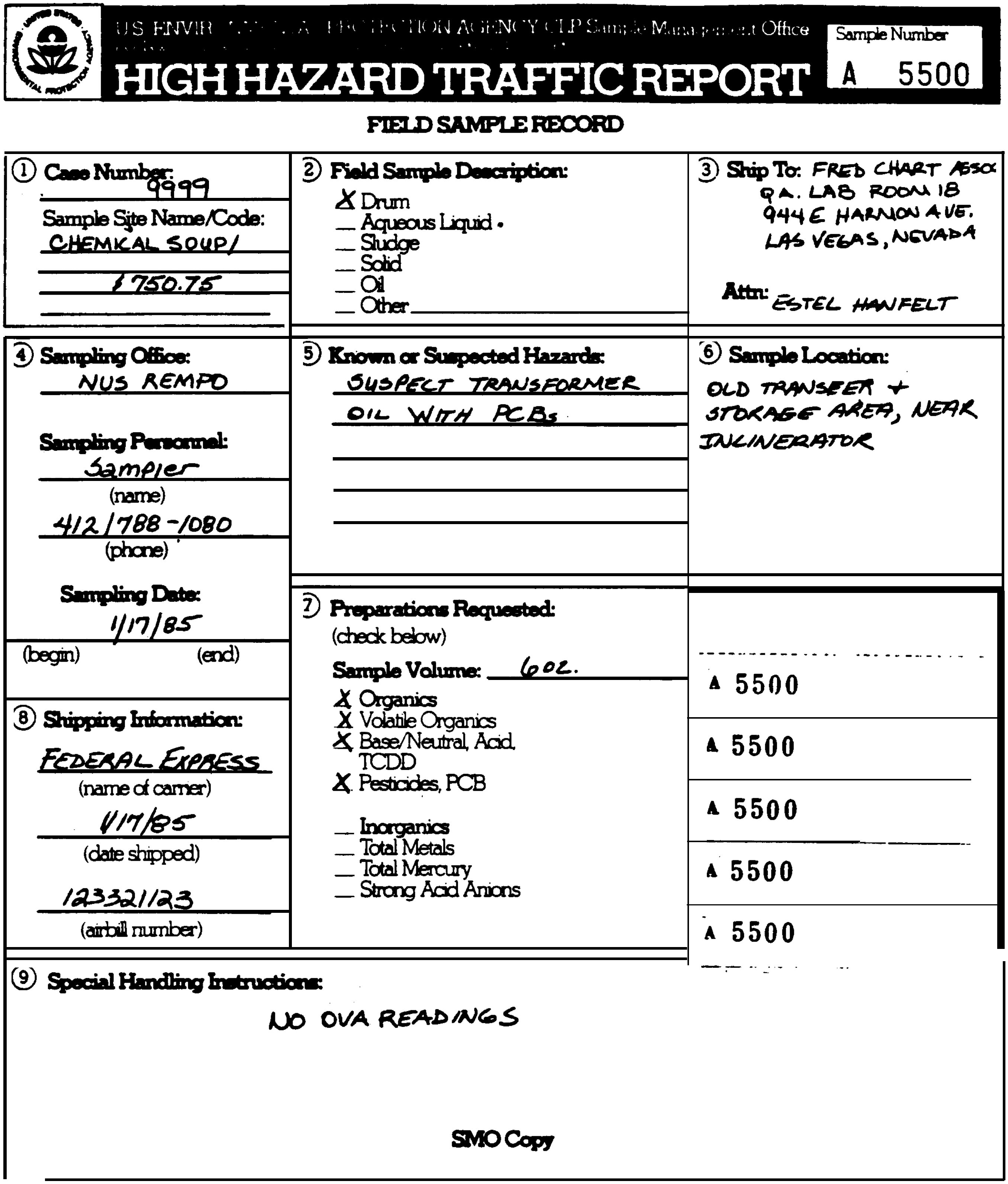
Site Name/Code: SUPERFUND CS/B750

	Sample Numbers	Sample Description i.e., Analysis, Matrix, Concentration	Sample Condition on Receipt at Lab
1.	999C-01	TDX LOW CONCENTRATION WATER CS-MW-105	
2.	999C-02	TDX CS-MW-106A	
3.	999C-03	CS-MW-106B	
4.	999C-04	CS-MW-106C	
5.	999C-05	CS-MW-109	
6.	999C-06	CS-MW-113	
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.			
20.			

For Lab Use Only

White - SMO Copy, Yellow - Region Copy, Pink - Lab Copy for return to SMO, Gold - Lab Copy

Exhibit 5-9
HIGH-HAZARD TRAFFIC REPORT



U.S. ENVIRONMENTAL PROTECTION AGENCY CLP Sample Management Office

HIGH HAZARD TRAFFIC REPORT

Sample Number
A 5500

FIELD SAMPLE RECORD

① **Case Number:** 9999

Sample Site Name/Code: CHEMKAL SOUP/
$750.75

② **Field Sample Description:**

X Drum
___ Aqueous Liquid
___ Sludge
___ Solid
___ Oil
___ Other

③ **Ship To:** FRED CHART ASSOC
QA. LAB ROOM 18
944 E HARMON AVE.
LAS VEGAS, NEVADA

Attn: ESTEL HANFELT

④ **Sampling Office:** NUS REMPO

Sampling Personnel: Sampler
(name)
412/788-1080
(phone)

Sampling Date: 1/17/85
(begin) (end)

⑤ **Known or Suspected Hazards:**
SUSPECT TRANSFORMER
OIL WITH PCBs

⑥ **Sample Location:**
OLD TRANSFER +
STORAGE AREA, NEAR
INCINERATOR

⑦ **Preparations Requested:**
(check below)

Sample Volume: 6 oz.

X Organics
X Volatile Organics
X Base/Neutral, Acid, TCDD
X Pesticides, PCB

___ **Inorganics**
___ Total Metals
___ Total Mercury
___ Strong Acid Anions

A 5500
A 5500
A 5500
A 5500
A 5500

⑧ **Shipping Information:**
FEDERAL EXPRESS
(name of carrier)
1/17/85
(date shipped)
123321123
(airbill number)

⑨ **Special Handling Instructions:**
NO OVA READINGS

SMO Copy

Exhibit 5-10
CLP DIOXIN SHIPMENT RECORD

USEPA Contract Laboratory Program
Sample Management Office
P.O. Box 818 Alexandria, Virginia 22313
FTS 8-557-2490 703/557-2490

CASE NO:	**BATCH NO:**

CLP DIOXIN SHIPMENT RECORD

Site Name: NAME
City & State: City Name, MO
EPA Site No: MOD 123456789
Latitude: 7 digit number
Longitude: 8 digit number
Tier: [✓ 1] 2 3 4 5 6 7 (circle one)

Sampling Office: Region VII
City & State: Kansas City, KS
Sampling Contact: NAME (name)
Sampling Date: 6-12-84
Data Turnaround: 15-Day ____ 30-Day ✓

Ship To: LAB NAME
Attention:
Date Shipped: 6-12-84

	MATRIX		DESCRIPTION						ADD'L ANALYSIS
SAMPLE NUMBERS	SOIL/ SEDIMENT	OTHER: SOLVENT	FIELD SAMPLE	SAMPLE TO DUPLICATE	SAMPLE TO SPIKE	BLANK	EQUIPMENT RINSATE	OTHER: (SAS ONLY)	SPECIFY: (SAS ONLY)
DG 000101	✓		✓						
DG 000102	✓		✓						
DG 000103	✓				✓				
DG 000104	✓		✓						
DG 000105	✓		✓						
DG 000106	✓		✓						
DG 000107		✓					✓		
DG 000108	✓		✓						
DG 000109	✓		✓						
DG 000110	✓		✓						
DG 000111	✓		✓						
DG 000112	✓		✓						
DG 000113	✓		✓						
DG 000114	✓		✓						
DG 000115	✓		✓						
DG 000116	✓		✓						
DG 000117	✓		✓						
DG 000118	✓			✓					
DG 000119	✓		✓						
DG 000120	✓		✓						
DG 000121	✓		✓						
DG 000122	✓		✓						
DG 000123	✓		✓						
DG 000124.	✓		✓						

WHITE—SMO Copy **YELLOW**—Region Copy **PINK**—Lab Copy for Return to SMO **GOLD**—Lab Copy

5.1.6.3 Postsampling Activities

1. When the laboratory finishes the analysts, a copy of the results is forwarded to SMO and another copy to the RSCC. The RSCC forwards a copy of the results to the RPM and the contractor. If the results do not arrive at the contractor's office within the contractually required time frame, the contractor's CLP coordinator initiates a call to the RSCC regarding the status and expected completion data of the analysis

2. Once the data are received, questions may arise regarding their Interpretation. The SM will contact the EPA RPM or RSCC, who contacts SMO or the laboratory to resolve questions about the data.

3. SMO routinely performs Contract compliance Screening (CCS) on all RAS data, modified CCS can be performed on a case-by-case basis for mixed RAS-plus-SAS or all -SAS data. This review determines completeness of data deliverables and compliance with contract specification by the laboratory,

4. Data review services are provided by SMO upon request of the Regional Deputy Project Officer. Data review can be used by the SM to determine the usability and limitations of data, to maximize usable data and to provide standardized data quality assessment. Review cannot be initiated until all (CLP deliverables have been received from the laboratory,

contractually, the required time span is for analyses to be conducted by the laboratory. Review and validation for compliance with quality assurance / quality control (QA/QC) requirements consume additional time. The SM should plan accordingly.

5.1.7 Region-Specific Variances

Each EPA region has developed variations in laboratory interface procedures, including the records procedures for sampling and postsampling activities and the Individual forms used for the Individual tasks. Information on variations provided here may become dated rapidly. Thus, it Is Imperative that the user contact the individual EPA RPM or RSCC to get full details on current regional practices and requirements. Future changes in variances will be Incorporated In subsequent revisions to this compendium.

The regional variances presented in this subsection-as examples only-are given In chronological order to allow for comparison with the general procedure outlined In Subsection 5.1.6.

5.1.7.1 Activities Prior to Sampling

1. In Region 1, the Site Managers must submit an analytical request for each individual sampling event at least 1 week prior to its occurrence. The request is submitted to the EPA RPM, who forwards the request to the EPA RSCC personnel. This request confirms the previously scheduled sampling.

2. Regions i and will provide a supply of organic and inorganic traffic reports that are used as needed and that are replaced periodically. Region II supplies traffic reports on a trip-by+trip basis. Regions iii and N provide a supply of organic and inorganic traffic reports to major contractors. These reports are used as needed and are replaced periodically as the supply diminishes. Ail other contractors within Regions III and IV will receive traffic reports on a trip-by-trip basis, as needed.

3. In Region V, the RSCC ranks by priority the monthly sampling requests and indicates that sampling can occur. The contractor is responsible for scheduling the analysis through SMO.

4. in Region IX the Site Managers communicate directly with the RSCC, providing them with the monthly CLP projections.

5.1.7.2 Sampling Activities

1. Regions I,III, V, VI, and VIII use sample tags supplied by the region. Region II does not supply sample tags, which necessitates the use of contractor sample labels. Region IX supplies sample labels; no tags are used. Dedicated major Region IV contractors use sample tags supplied by the region. All other Region IV contractors must supply their own tags according to the region's specifications.

2. The Region IV sample tag is filled out differently from the Region III sample tag. Exhibit 5-7 gives an example of completed tags from Regions III and IV.

3. The Region II chain-of-custody (COC) form is entirely different from the COC form used by the other regions. The Region I, III, IV, V, VIII, and IX COC forms are almost identical. Exhibits 5-4 and 5-5 show two types of forma.

4. Region IV requires that custody seals be put on each bottle, unless one can ensure custody, as in hand delivery situations. Regions I, II, III, and VI require custody seals on the outer shipping container only. Region IX requires custody seals on both the sample bottles and the outer shipping container. Regions V and VIII require custody seals on the outer shipping container, with an option to put seals on each sample container.

5. Region IV places the traffic report label on the sample tag and the sample bottle, whereas Regions I, II, III, V, VI, VIII, and IX place the label directly on the bottle.

6. When the regional supply of COC forms or sample tags is not available, the contractor may supply COC forms and sample labels. These contractor supplied materials must satisfy all regional requirements for these forms.

7. Sampling personnel in Region IX contact the RSCC rather than SMO with shipping information.

8. The Region V procedures manual is being updated and will be available in June 1987; examples of completed paperwork are shown in that manual.

5.1.7.3 Postsampling Activities

1. Regions II, VI, and IX conduct the validation of the laboratory data, whereas data from sampling conducted in Regions I and Viii are validated by the contractor. Both the contractor and the EPA validate the data generated in Regions III, IV, and V.

2. The contractor-CLP coordinators provide the RSCCs in Regions ii and Vi with blank sample numbers, duplicate sample numbers, and other pertinent sampling information needed by the data validators. This same information is provided by the SM in Region IX.

5.1.8 Information Sources

U.S. Environmental Protection Agency. *User's Guide to the Laboratory Program.* Office of Emergency and Remedial Response. December 1986.

CH2M HILL *REM/FIT Documentation Protocol for* Region *V. May* 1984.

U.S. Environmental Protection Agency. *Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual* Region IV, Environmental Services Division. 1 April 1986.

5.2 NONCONTRACT LABORATORY PROGRAM

5.2.1 Scope and Purpose

There is no formal noncontract laboratory program (non-CLP) run parallel to the Contract laboratory Program. A noncontract laboratory is procured by a method other than going through the SMO.

This subsection discusses how to contact a non-CLP laboratory, the paperwork involved when submitting samples to such a laboratory, and the resolution of questions once the analyses have been completed.

5.2.2 Definitions

Noncontract Laboratory

A laboratory that works directly for a contractor rather than SMO.

5.2.3 Applicability

The procedures in this subsection apply to two situations (1) the CLP does not have the capacity to accept a sample, or (2) the EPA grants an exemption to the CLP usage requirement. The use of CLP is not a requirement unless justified by the choice of DQO. There will be opportunities to use mobile laboratories, field screening protocols, subcontracted private laboratories, or EPA regional laboratories.

5.2.4 Responsibilities

Responsibilities are discussed in Subsection 5.2.6 on procedures. General responsibilities areas follows:

- Site Managers plan the sampling dates and analytical requirements; the EPA RPM approves.
- The project chemist and chemistry section manager prepare the invitation for bids and evaluate and choose qualified laboratories to receive the invitation. The SM and EPA RPM select the laboratory.
- sampling personnel complete the required paperwork and contact the laboratory with shipping information.

5.2.5 Records

The following sample documentation is required (examples are given in Subsection 5.1.6):

- Sample tag or label
- custody seal
- Chain-of-custody (COC) form

A sample tag or label is required for each bottle of sample collected, while each shipment requires custody seals and COC forms.

5.2.6 Procedures

The procedures in this subsection are presented in the chronological order used during a routine sampling episode; they are applicable to any type of analysis. Exhibit 5-1 summarizes the process from start to finish.

5.2.6.1 Activities Before Sampling

The first four activities conducted for a non-CLP laboratory before sampling are identical to steps 1 through 4 in Subsection 5.1.6.1. These steps continua as follows:

5. Each RSCC is given a monthly allocation of sample slots from SMO, for which the RSCCs may submit samples for analysis. Sometimes a region has more samples for analysis than slots, in which case some sampling must be postponed or canceled. The RSCC notifies the contractor when such a situation arises. Likewise, there are times when SMO cannot find a laboratory to perform the requested analysis. This is especially true for SAS work. The RSCC once again notifies the contractor of the unavailability of a laboratory.

6. The SM evaluates the advantages between waiting until CLP space becomes available and sending the samples outside the CLP system and advises the EPA RPM. The EPA RPM is responsible for deciding which laboratory to use. The EPA regional laboratory may be available to analyze the samples, in which case the EPA laboratory is treated as a CLP laboratory and the procedures in Section 5.1 are followed. if the decision is to go outside CLP, the RSCC and its QA coordinator can be very helpful in choosing a properly qualified laboratory.

As an alternate to steps 1 through 6, the project team and EPA RPM may determine that CLP-level data are not necessary for all analyses. in situations that involve taking a large number of samples, possibly taking a number of “clean” samples, or gathering information that will clearly never be used in an enforcement action, the appropriate analytical procedures maybe furnished either by field instrumentation, by mobile laboratories, by a temporary laboratory set up near the site, or by contracting the work to a local laboratory. (CLP laboratories may also be used if they have non-CLP capacity available.) Procurement of these analytical services follows the steps discussed below.

7. A laboratory is procured using a standard bidding process. The laboratories chosen to receive the invitation for bids (IFB) are usually approved by the EPA regional QA representative, as well as other qualified EPA personnel. The analytical protocol is specified in the bid package and conforms closely to CLP or other EPA-approved methods. CLP methods are preferred because of the QA requirements. Typically, IFBs are sent to at least three laboratories. The SM selects the laboratory with technical assistance from the EPA RSCC, if available. The EPA Headquarters Project Officer and/or Contracting Officer must approve the subcontract before work begins.

On state lead sites, the prime contractor subcontracts with the laboratory and separate IFBs are not sent. Several remedial engineering management (REM) contractors have the availability to use team member laboratories that have established costs for several analyses. These laboratories may also respond to SAS requests in the form of subcontract bids.

The analytical procedures, and the QA/QC and sample control procedures used by the non-CLP laboratory are included as part of the Quality Assurance Project Plan (QAPjP). Depending on the type of analysis to be performed (e.g., field screening using portable instruments), QA/QC procedures may be greatly simplified when compared to CLP requirements. Data validation will be less time consuming also. Specific procedures for local, temporary, or mobile laboratories vary widely the SM must carefully review these procedures before contracting any work.

5.2.6.2 Sampling

1. During sample collection, the samplers complete the required paperwork before the sample shipment. Examples of properly completed forms are given in Exhibits 5-7 through 5-7. it should be noted that whenever a noncontract laboratory is used, the contractor sample number should be substituted for the traffic report number, since no traffic report forms are used.

2. The samplers call the laboratory when samples are shipped” or if shipment is delayed for any reason. This ceil allows for immediate notification when samples do not arrive on time, and it facilitates sample tracking. For mobile laboratories, care must be exercised to prevent “flooding” the sample preparation or analytical capabilities of the laboratory. Daily meetings with the mobile laboratory are sometimes needed.

3. The designated copy of the COC form is sent to the laboratory with the samples. Standard EPA and DOT shipping procedures are followed.

5.2.6,3 Postsampling

1. When the laboratory finishes the analyses, a copy of the results is forwarded to the contractor. The project chemist contacts the laboratory if results do not arrive on time. Unlike at CLP laboratories, verbal reporting of unvalidated results can be obtained from contractor chosen or mobile laboratories. While the SM must be judicious in the use of these results, the rapid turnaround allows the SM to adjust the sampling plan and to more intelligently use CLP resources for full analyses.

2. Once the data are received, questions may arise regarding their interpretation. The project chemist is the primary laboratory contact to resolve such questions.

5.2.6.4 Residual Samples and Analytical Wastes

At EPA's direction, duplicate samples are often collected and stored for later use. These archived samples, the residuals of samples sent out for analyses, and some of the wastes generated during analyses are regulated by various federal regulatory programs. CLP laboratories will assume responsibility for sample residuals at the laboratories. However, the SM must make arrangements for the proper disposal of archived or residual samples at non-CLP laboratories.

5.2.6.4.1 Regulatory Framework

Each major federal program has elements that are expected to apply to sample and laboratory operations. These elements are cited and discussed briefly in this subsection.

RCRA The Resource Conservation and Recovery Act (RCRA) regulations apply only to those wastes designated as hazardous under 40 CFR 261.3. If a sample is not a solid waste as defined In 40 CFR 261.2 or if the sample is a solid waste but not designated as hazardous in 40 CFR 261.3, that sample is not regulated under RCRA.

Even hazardous waste samples as defined in 40 CFR 261.3 are <u>exempt from RCRA</u> regulation if the terms of paragraph 40 CFR 261.4(d) are met. Section 40 CFR 261.4(d) is presented in its entirety below.

<u>40 CFR 261.4(d) Samples</u>

(1) Except as provided in paragraph (d)(2) of this section, a sample of solid waste or a sample of water, soil, or air, which is collected for the sole purpose of testing to determine its characteristics or composition, is not subject to any requirements of this part, or Parts 262 through 267, or Part 270, or Part 124 of this chapter, or to the notification requirements of Section 3010 of RCRA, when:

(261.4(d) introductory paragraph amended by 46 FR 30115, June 30, 1963)

(i) The sample is being transported to a laboratory for the purpose of testing; or

(ii) The sample Is being transported back to the sample collector after testing; or

(iii) The sample is being stored by the sample collector before transport to a laboratory for testing; or

(iv) The sample is" being stored in a laboratory before testing; or

(v) The sample is being stored In a laboratory after testing but before It is returned to the sample collectoor; or

(vi) The sample is being stored temporarily in the laboratory after testing for a specific purpose (for example, until conclusion of a court case or enforcement action where further testing of the sample maybe necessary).

(2) To qualify for the exemption In paragraph (d)(1)(i) and (ii) of this section, a sample collector shipping samples to a laboratory, and a laboratory returning samples to a sample collector must;

(i) Comply with DOT, U.S. Postal Service (USPS), or any other applicable shipping requirements; or

(ii) Comply with the following requirements If the sample collector determines that DOT, USPS, or other shipping requirements do not apply to the shipment of the sample

(A) Assure that the following information accompanies the sample

(1) The sample collector's name, mailing address, and telephone number

(2) The laboratory's name, mailing address, and telephone number

(3) The quantity of the sample;

(4) The date of shipment; and

(5) A description of the sample.

(B) Package the sample so that it does not leak, spill, or vaporize from its packaging.

(3) This exemption does not apply if the laboratory determines that the waste Is hazardous but the laboratory is no longer meeting any of the conditions stated in paragraph (d)(1) of this section.

A section of the RCRA regulations recognizes that analytical laboratory operations could generate wastewater which Is mixed with small amounts of listed toxic hazardous wastes. This section [40 CFR 261.3(a)(2)(iv)(E)] excludes such wastewater from the RCRA hazardous waste regulations if the wastewater discharge is subject to regulation under either Section 402 or Section 307(b) of the Clean Water Act (CWA) and If the calculated annualized average wastewater flow from the laboratory constitutes 1 percent or less of the flow Into the headworks of the treatment facility. (This calculation does not apply to septic systems or any treatment system not regulated by Section 402 or 307(b) of the CWA.)

CWA The clean Water Act (CWA) regulates wastewater discharges to publicly owned treatment works (POTWs) under Section 307(b) and wastewater discharges to surface waters under Section 402. Therefore, If a laboratory discharges into a POTW system or a privately run wastewater treatment plant that discharges treated effluent under an NPDES permit, that laboratory Is Indirectly regulated under the CWA. As noted above, RCRA conditionally excludes laboratory wastewater from regulation when this indirect CWA authority exists. Laboratory managers should know, however, that industrial wastewater discharges Into POTWs are usually monitored and regulated by local authorities, such as sewer districts. Even though no pretreatment standards currently exist on a national basis for analytical laboratories, the general industrial effluent requirements for a particular POTW system might apply to the laboratory's effluent. Compliance with the locally established requirements Is necessary to satisfy the RCRA exclusion.

CERCLA The comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) is designed to provide a framework for both planned and emergency responses to releases of hazardous substances into the environment. Laboratory analytical samples are often associated with defining and responding to situations that fall under CERCLA authority. However, CERCLA, SARA, and the National Contingency Plan (NCP) (40 CFR Part 300) are not explicit on the issue of how hazardous substance samples are to be managed. The NCP will be revised In July 1967 and may address the issue more fully.

AS stated earlier, samples of hazardous waste (as defined by 40 CFR 261.3) are managed In accordance with 40 CFR 261.3 and 261.4. No such standards, exclusions, or limitations exist for hazardous substance samples. However, management of hazardous substance samples as if they were hazardous waste may be appropriate based on Section 104(c)(3)(B) of CERCLA, which requires that any offsite treatment, storage, or disposal of hazardous substances be conducted in compliance with Subtitle C of the Solid Waste Disposal Act.

5.2.6.4.2 Procedures

Hazardous waste samples must be handled in conformance with 40 CFR 261.4(d) to be excluded from RCRA regulation regarding administrative requirements for transport, storage, treatment, and disposal. Similarly, samples of solid waste that might be hazardous (i.e., for which the hazard determination has not yet been made) and samples of hazardous substances as defined by CERCLA may be handled in conformance with 40 CFR 261.4(d).

Conformance with 40 CFR 261.4(d) requires that these hazardous samples be returned to their generator for proper management after the analysis. This return should be specified as an agreed-upon last task in analytical contracts for hazardous samples if the SM wishes to avoid the effort entailed In treating the material as other than a sample. Without the RCRA sample exclusion, samples would require manifesting for shipment to the laboratory the receiving facility would need to be a RCRA Treatment, Storage, and Disposal Facility (TSDF); and offsite ultimate disposal would require yet another manifest. The American Chemical Society has prepared a booklet titled “RCRA and Laboratories” that details these requirements.

Some samples received by laboratories are clearly not hazardous by RCRA or CERCLA definitions other samples are determined by analysis to be nonhazardous. These samples are not required to be managed In accordance with the RCRA exclusion paragraph. However, before any nonhazardous samples are disposed of as part of laboratory solid refuse or wastewater, the state and local solid waste codes and industrial wastewater discharge codes should be examined to assure that their terms are being met. (Many sewer districts, for example, require that total oil and grease loading not exceed a noted maximum at the facility outfall. This might restrict the disposal of large nonhazardous oily samples from disposal through the sewers.) Even for these nonhazardous samples, it might be necessary to have contract conditions or additional fees to cover the disposal of samples.

To meet the requirements, laboratory and storehouse managers should develop a specific Instruction list noting logging, disposition, and contractual standards for each type of sample and analytical waste. These specific Instructions could differ appreciably from one laboratory to another because of local codes and the nature and size of the sanitary sewer system compared to laboratory contribution. The SM should have a clear understanding of the residual sample deposition before shipping samples to a laboratory or warehouse.

5.2.6.4.3 Analytical Wastes

During chemical analysis, various extracts, components, and mixtures are derived from samples to determine their character and composition. Typically, these analytically derived substances are small in volume, but are not totally used up In the actual analysis. The leftover substances then become what is referred to as analytically derived waste.

In some cases, analytical wastes are not hazardous wastes (as defined In RCRA) or hazardous sub stances (as defined in CERCLA). As such, these wastes are disposed of in accordance with state and local solid waste and industrial waste water discharge requirements. Typically, these wastes can be disposed of in the wastewater discharged from the laboratory to the sanitary sewer.

In some cases, however, analytical wastes might have been derived from listed hazardous wastes, or the chemicals used to obtain the derivative, could cause the waste to be classified as hazardous. in either case, RCRA regulations provide for such waste to be disposed of with laboratory wastewater if certain conditions are met. Wastes that are considered hazardous only because of a characteristic (ignitability, corrosivity, reactivity, or EP toxicity-see 40 CFR 261, Subpart C) are no longer hazardous once they are mixed to eliminate the characteristic. Mixing small volumes of analytical waste with the sanitary sewer flow would cause the waste to become so diluted that itl no longer exhibits hazardous characteristics.

When analytically derived wastes are produced in such volume or concentration that the conditions specified in the RCRA regulations or the discharge limits for the sanitary sewer cannot be met by disposing of these wastes with laboratory wastewater, other arrangements with need to be made.

5.2.7 Ragion-Specific Variances

The regional variances associated with the non-CLP are the same as for the CLP and can be found in Subsection 5.1.7.

5.2.8 Information Sources

American Chemical Society, Task Force on RCRA "RCRA and Laboratories." Department of Government Relations and Science Policy, 1155 16th Street, NW, Washington, DC 20036. September 1986.

CH2M HILL REM/FIT Documentation *Protocol for Region V.* May 1964.

U.S. Environmental Protection Agency. *Engineering Support Branch Standard Operating Procedures and* Quality Assumnce *Manual* Region IV, Environmental Services Division. 1 April 1966.

U.S. Environmental Protection Agency. *User's Guide to the Contract Laboratory Program. Office* of Emergency and Remedial Response. December 1966.

SECTION 6

SAMPLE CONTAINERS, PRESERVATION AND SHIPPING

Note: This section Is presented by topic for greater clarity.

6.1 SAMPLE CONTAINERS AND PRESERVATION

6.1.1 Scope and Purpose

This subsection describes the sample containers and the preservatives used for environmental and hazardous samples collected at waste sites. The procedures described meet Contract Laboratory Program (CLP) requirements and analytical procedures. Periodic updates and changes are detailed in amendments to the User's *Guide to the CLP.* To obtain further Information or copies of the *User's Guide to the CLP,* contact the Sample Management Office (SMO) at 703/557-2490 or FTS 557-2490.

6.1.2 Definitions

Low-Concentration Sample
The contaminant of highest concentration is present at less than 10 parts per million (ppm). Examples Include background environmental samples.

Medium-Concentration Sample
The contaminant of highest concentration is present at a level greater than 10 ppm and less than 15 percent (150,000 ppm). Examples Include material onsite that is obviously weathered.

High-Concentration Sample
At least one contaminant is present at a level greater than 15 percent. Samples from drums and tanks are assumed to be high concentration unless information indicates otherwise.

Routine Analytical Services (RAS)
Analysis of a soil or water sample on a 30- to 45-day turnaround time for a list of 126 organics, 23 metals, and cyanide.

Site Manager (SM)
The Individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

6.1.3 Applicability

The procedures described In Section 6 apply to samples collected for routine, as well as for special analytical services. They are to be fallowed when the samples are being sent to either a CLP laboratory or a noncontract laboratory.

6.1.4 Responsibilities

Responsibilities are described in Subsection 6.1.6. General responsibilities are assigned as follows:

- The SM (and project team) will determine the number and type of samples to be collected and the analyses to be performed; the EPA RPM approves work plan.
- Equipment manager will obtain the proper grades and types of preservatives and bottles.
- Sampling personnel will collect a representative sample and, if necessary, will add the proper sample preservatives (as defined herein) once the samples have been collected.

6.1.5 Records

The preservatives used for each bottle are recorded on the sample tag or label. Tags and labels are discussed in Subsection 6.2.6; examples of completed tags are shown in Subsection 5.1.6. Shipping records are maintained as part of the chain-of-custody documentation. (See Section 4 of this compendium.)

6.1.6 Procedures

The procedures in this subsection are presented In the chronological order of a typical sampling episode. Exhibit 6-1 summarizes the sampling process. Procedures presented here are generic; an approach to regional differences Is presented in Subsection 6.1.7.

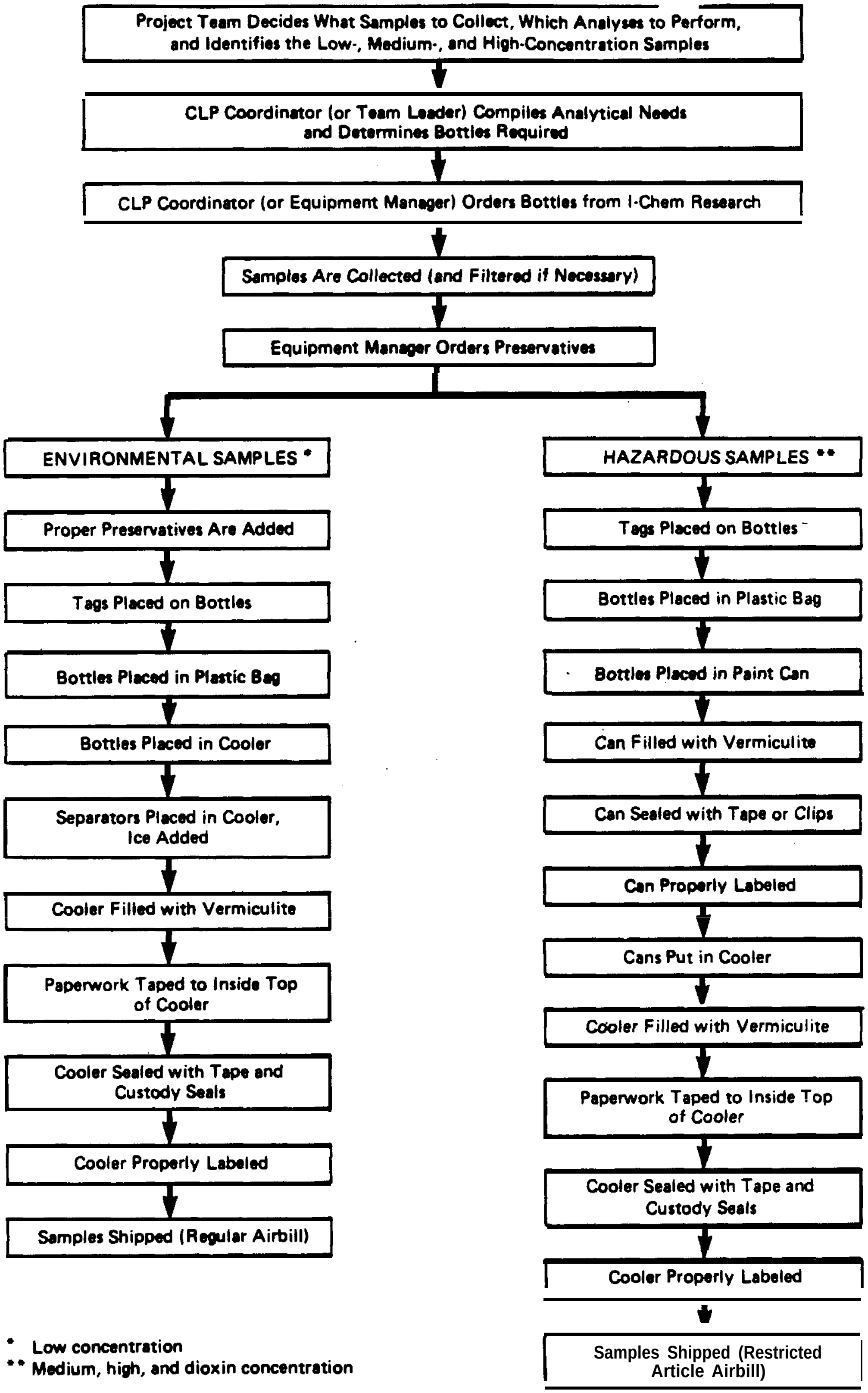
6.1.6.1 Activities Before Sampling

1. In addition to the activities detailed in Subsection 5.1.6.1 for resewing laboratory space, the SM (or designee) obtains sample bottles by contacting an EPA authorized requester at the Regional Sample Control Center (RSCC) who orders the necessary bottles. (Currently, I-Chem Research In California (415/762-905), runs the official bottle repository for the Superfund program.) Exhibit 6-2 lists the types of bottles available from the repository and summarizes the bottle requirements for each class of sample (as presented in the *User's Guide to the CLP,* December 1966).

2. At the same time, the SM (or designee) must order the chemicals necessary to preserve the samples once they are collected. The chemicals that may be used include the following:

    - Nitric acid, American Chemical Society (ACS) grade, 16N
    - Sodium hydroxide, ACS grade, pellets
    - Sulfuric acid, ACS grade, 37N
    - Hydrochloric acid, ACS grade, 12N
    - Sodium thiosulfate, ACS grade, crystalline
    - Mercuric chloride, ACS grade, powder

Exhibit 6-1
TYPICAL SAMPLING PROCEDURES



* Low concentration

** Medium, high, and dioxin concentration

Exhibit 6-2
SAMPLE BOTTLES AVAILABLE FROM THE REPOSITORY

Container Type	Description	No. Per Carton	Used for RAS Sample Type*
A	80-oz amber glass bottle with Teflon-lined black phenolic cap	6	Extractable organics--Low-concentration water samples
B	40-ml glass vial with Teflon-lined silicon septum and black phenolic cap	72	Volatile organics--Low-and medium-concentration water samples
C	1-liter high-density polyethylene bottle with white poly cap	42	Metals, cyanide--Low-concentration water samples
D	120-ml wide-mouth glass vial with white poly cap	72	Volatile organics--Low-and medium-concentration soil samples
E	16-oz wide-mouth glass jar with Teflon-lined black phenolic cap	48	Metals, cyanide--Medium-concentration water samples
F	8-oz wide-mouth glass jar with Teflon-lined black phenolic cap	96	Extractable organics Low- and medium- concentration soil samples and Metals, cyanide-Low- and medium-concentration soil samples and Dioxin-Soil samples and Organics and inorganics--High-concentration liquid and solid samples

Exhibit 6-2
(continued)

Container Type	Description	No. Per Carton	Used for RAS Sample Type*
G	4-oz wide-mouth glass jar with Teflon-lined black phenolic cap	120	Extractable organics--Low- and medium-concentration soil samples and Metals, cyanide--Low- and medium-concentration soil samples and Dioxin--soil samples and Organic and Inorgank-High concentration liquid and solid samples
H	1-liter amber glass bottle with Teflon-lined black phenolic cap	24	Extractable organics--Low-concentration water samples
J	32-pz wide-mouth glass jar with Teflon-lined black phenolic cap	36	Extractable organics--Medium-concentration water samples
K	4-liter amber glass bottle with Teflon-lined black phenolic cap	4	Extractable organics--Low-concentration water samples

---

* This column specifies the only type(s) of samples that should be collected in each container.

6.1.6.2 Sampling Activities

1. The samplers collect representative aliquots of each medium and place them in the appropriate sample jars as described in Exhibit 6-2.

2. The samplers preserve the low-concentration water samples as follows:

- Nitric acid (HNO_3) is added to the TCL metals bottle until the pH is less than 2 (2 ml of 1 + 1 is usually sufficient).

Note: Analysis for dissolved metals requires filtration of the sample before preservation; however, the preservation method is the same for both dissolved and total metals.

For the cyanide aliquot, the following guidelines should be fallowed:

- Test a drop of sample with potassium iodide-starch test paper (K1-starch paper); a blue color indicates the presence of oxidizing agents and the need for treatment. Add ascorbic add, a few crystals at a time, until a drop of sample produces no color on the indicator paper. Then add an additional 0.6g of ascorbic add for each liter of sample volume.
- Test a drop of sample on lead acetate paper previously moistened with acetic acid buffer solution. Darkening of the paper indicates the presence of S^{2-}. If S^{2-} is present, add powdered cadmium carbonate until a drop of the treated solution does not darken the lead acetate test paper and then filter the solution before raising the pH for stabilization.
- Preserve samples with 2 ml of 10 N sodium hydroxide per liter of sample ($pH \geq 12$).
- Store the samples so that their temperature is maintained at 4°C until the time of analysis.
- Samples to be analyzed for TCL organics are packed in ice and shipped to the laboratory with ice in the coder.

The following RAS samples do not require preservatives

- Soil or sediment samples
- Medium or high-concentration water samples

Exhibit 6-3 lists the preservatives used for frequently requested special analytical services.

3. The samples are shipped to the laboratory for analysis.

Exhibit 6-3
SAMPLE PRESERVATION REQUIREMENTS

Analysis	Preservation
Acidity	Cool, 4°C
Alkalinity	Cool, 4°C
Bicarbonate	Cool, 4°C
Carbonate	Cool, 4°C
Chloride	None
Chemical Oxygen Demand (COD)	H_2SO_4 to pH < 2, Cool, 4°C
EP toxicity	None
Nitrogen	
Ammonia	H_2SO_4 to pH < 2, Cool, 4°C
Kjeldahl, total	H_2SO_4 to pH < 2, Cool, 4°C
Nitrate	H_2SO_4 to pH < 2, Cool, 4°C
Nitrite	Cool, 4°C
Oil and grease	H_2SO_4 to pH < 2, Cool, 4°C
Sulfate	Cool, 4°C
Solids	
Total dissolved	Cool, 4°C
Total suspended	Cool, 4°C
Total Organic Carbon (TOC)	H_2SO_4 or HCl to pH < 2, Cool, 4°C
Total Organic Halogen (TOH or TOX)	Several crystals of sodium thiosulfate if chlorine is present, cool, 4°C

Refer to RCRA Ground-Water Monitoring Technical Enforcement Guidance Document (TEGD) and SW-846 for additional information on sample preservation, recommended containers, maximum holding times, and volume requirements. EPA's Characterization of Hazardous Waste Sites, Vols. 1 and 2, and Soil Sampling QA User's Guide contain information regarding holding time criteria for soil or sediment.

6.1.7 Region-Specific Variances

The regional variances listed In this subsection are In chronological order to allow for easy comparison with the generic procedure described In Subsection 6.1.6. Because this information may become dated rapidly, the user should contact the EPA RPM or RSCC to get full details on current regional practices or requirements before planning sampling activities. Future changes in variances will be Incorporated in subsequent revisions to this compendium.

6.1.7.1 Presampling Activities

Regional variances during the presampling phase will be discussed in Revision 01.

6.1.7.2 Sampling Activitiee

1. Region IV requires that samples collected for volatile analysis be preserved with hydrochloric acid. Four drops of concentrated HCI are added to each VOA vial before the vial is filled with the sample.

2. Region V preserves the metals sample with 5 ml of nitric acid. in addition, Region V uses a 10 normal sodium hydroxide solution rather than sodium hydroxide pellets.

6.1.8 Information Sources

U.S. Environmental Protection Agency. The *User's Guide to the Contract Laboratory Program.* Office of Emergency and Remedial Response. December 1986.

Federal Register. Vol. 49, No. 209, p. 43260. 28 October 1984.

U.S. Environmental Protection Agency. *Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual* Region IV, Environmental Services Division. 1 April 1986.

CH2M HILL REM/FITDocumentation Protocol for *Region* V. May 1964.

6.2 PACKAGING, LABELING AND SHIPPING

6.2.1 Scope and Purpose

This subsection describes the packaging, labeling and shipping used for environmental and hazardous samples collected at a waste site.

6.2.2 Definitions

The definitions are the same as those in Subsection *6.1.2.*

6.2.3 Applicability

The procedures described in this subsection apply to samples collected at a waste site. They must be followed whether shipping to a CLP laboratory or a noncontract laboratory.

The shipment of hazardous materials is governed by the Transportation Safety Act of 1974. Following Isa list of references that detail the regulations

- Title 49 CFR
  - Parts 100-177- Shipper Requirements and Hazardous Material Table
  - Parts 178-199- Packaging Specifications
  - Section 262.20-Hazardous Waste Manifest
- International Civil Aviation Regulations (ICAO)
  - Technical Instructions for the Safe Transport of Dangerous Goods by Air (lists mandatory international and optional domestic regulations)
- International Air Transport Association (IATA)
  - Dangerous Goods Regulations (This tariff incorporates 49 CFR, ICAO, and additional IATA regulations. Most international and domestic airlines belong to IATA and require conformance to all applicable regulations.)
- Tariff BOE-6000-D (reprint of 49 CFR with updates)

6.2.4 Responsibilities

Detailed responsibilities are described in the procedures subsection. General responsibilities are assigned as follows:

- Site Managers will state, to the best of their knowledge, whether samples planned for collection are environmental or hazardous samples.
- Equipment manager will procure shipping supplies (metal cans, shipping labels, vermiculite, etc.) using RSCC whenever needed.
- Sampling personnel will properly label and package the samples.

6.2.5 Records

The user should refer to Section 4 for discussion of the records associated with sample collection and chain-of-custody forms.

The following records are associated with the labeling and shipping process:

- Sample tag or label
- Traffic report label

- Custody seal
- Chain-of-custody (COC) form
- Bill of lading (airbill or similar document)

Examples of the first four documents are given in Subsections 4.6 and 5.1.6; an example of an airbill is given in Subsection 6.2.

6.2.6 Procedures

The procedures described In this subsection are carried out aft&the sample preservation described in Subsection 6.1.6.2. They are generic in nature; an approach to regional differences Is presented in Subsection 6.2.7.

6.2.6.1 Environmental Samples

Low-concentration samples are defined as environmental samples and should be packaged for shipment as follows:

1. A sample tag is attached to the sample bottle. Examples of properly completed sample tags are given in Exhibit 5-7.

2. All bottles, except the volatile organic analysts (VOA) vials, are taped dosed with electrical tape (or other tape as appropriate). Evidence tape maybe used for additional sample security.

3. Each sample bottle is placed in a separate plastic bag, which Is then sealed. As much air as possible is squeezed from the bag before sealing. Bags may be sealed with evidence tape for additional security.

4. A picnic coder (such as a Coleman or other sturdy coder) Is typically used as a shipping container. In preparation for shipping samples, the drain plug is taped shut from the inside and outside, and a large plastic bag Is used as a liner for the coder. Approximately 1 inch of packing material, such as asbestos-free vermiculite, perlite, or styrofoam beads, is placed in the bottom of the liner. Other commercially available shipping containers may be used. However, the use of such containers (cardboard or fiber boxes complete with separators and preservatives) should be specified in the sampling plan and approved by the EPA RSCC if CLP Is used.

5. The bottles are placed in the lined picnic coder. Cardboard separators maybe placed between the bottles at the discretion of the shipper.

6. Water samples for low or medium-level organics analysis and low-level Inorganic analysis <u>must</u> be shipped coded to 4°C with ice. <u>No ice</u> is to be used In shipping Inorganic low-level soil samples or medium/high-level water samples, or organic high-level water or soil samples, or dioxin samples. Ice Is not required in shipping soil samples, but may be utilized at the option of the sampler. All cyanide samples, however, must be shipped coded to 4°C.

7. The lined cooler is filled with packing material (such as asbestos-free vermiculite, perlite, or styrofoam beads), and the large inner (garbage bag) liner is taped shut. Sufficient packing material should be used to prevent sample containers from making contact during shipment. Again, evidence tape maybe used.

8. The paperwork going to the laboratory is placed inside a plastic bag. The bag is sealed and taped to the inside of the coder lid. A copy of the COC form should be included In the paperwork sent to the laboratory. Exhibit 5-4 gives an example of a properly completed COC form. The last block on the COC form should indicate the overnight carrier and airbill number. The airbill must be filled out before the samples are handed over to the carrier. The laboratory should be notified if another sample is being sent to another laboratory for dioxin analysis, or if the shipper suspects that the sample contains any other substance for which the laboratory personnel should take safety precautions.

9. The coder is closed and padlocked or taped shut with strapping tape (filament-type).

10. At least two signed custody seals are placed on the coder, one on the front and one on the back. Additional seals may be used if the sampler or shipper thinks more seals are necessary. Exhibit 5-6 gives an example of the two types of custody seals available.

11. The cooler is handed over to the overnight carrier, typically Federal Express. A standard airbill is necessary for shipping environmental samples. Exhibit 6-4 shows an example of the standard Federal Express airbill.

6.2.6.2 Hazardous Samples

Medium- and high-concentration samples are defined as hazardous and must be packaged as follows:

1. A sample tag is attached to the sample bottle. Examples of properly completed sample tags are shown in Exhibit 5-7.

2. All bottles, except the VOA vials, are taped closed with electrical tape (or other tape as appropriate). Evidence tape maybe used for additional security.

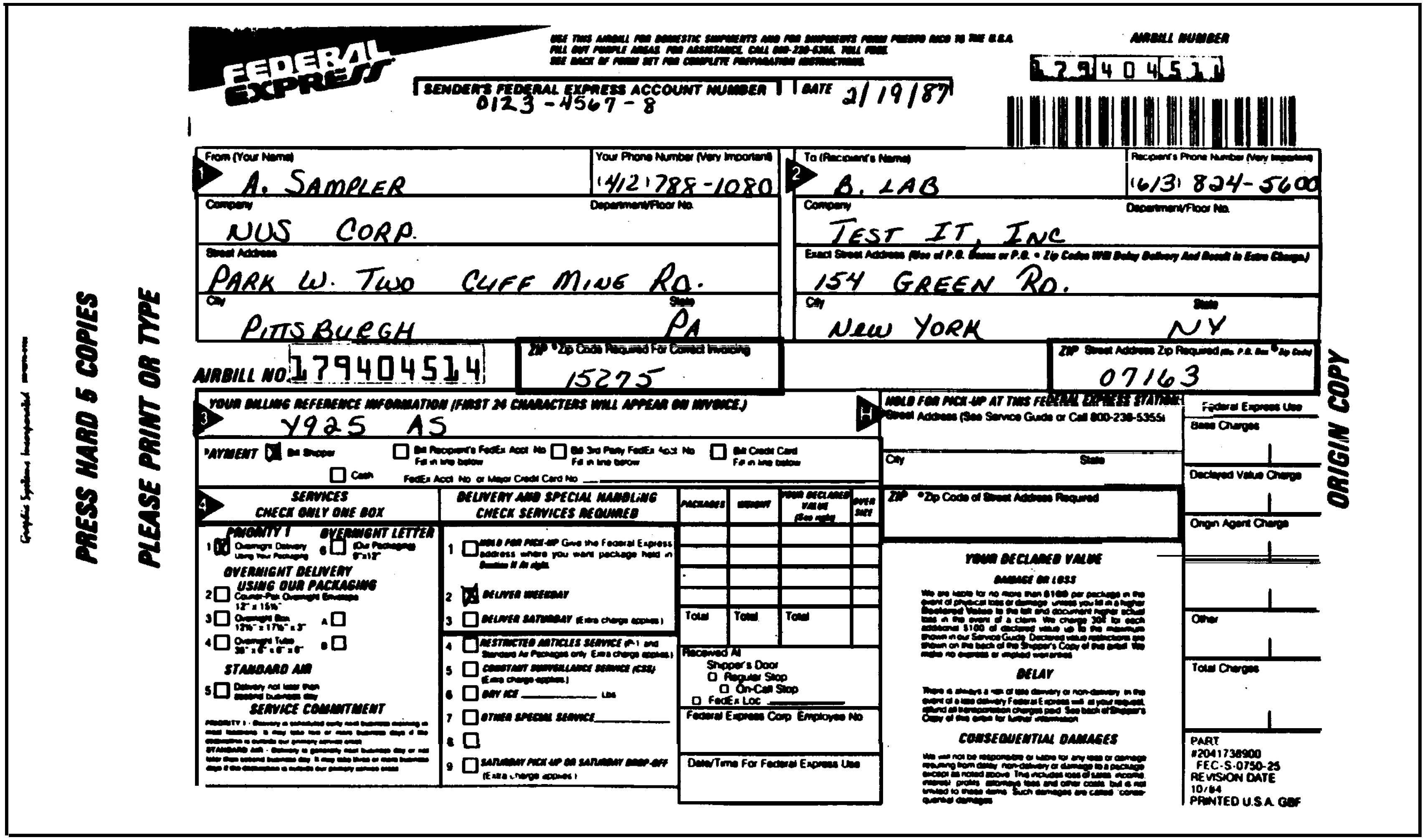
3. Each sample bottle is placed In a plastic bag, and the bag is sealed. For medium-concentration water samples, each VOA vial is wrapped in a paper towel, and the two vials are placed in one bag. As much air as possible is squeezed from the bags before sealing. Evidence tape may be used to seal the bags for additional security.

4. Each bottle is placed in a separate paint can, the paint can is filled with vermiculite, and the lid is fixed to the can. The lid must be sealed with metal clips or with filament or evidence tape; if clips are used, the manufacturer typically recommends six clips.

5. Arrows are placed on the can to indicate which end is up.

6. The outside of each can must contain the proper DOT shipping name and identification number for the sample. The information may be placed on stickers or printed legibly. A liquid sample of an uncertain nature is shipped as a flammable liquid with the shipping name “FLAMMABLE LIQUID, N. O. S.” and the Identification number “UN1993.” A solid sample of uncertain nature is shipped as a flammable solid with the shipping name “FLAMMABLE SOLID, N. O. S.”

Exhibit 6-4
STANDARD FEDERAL EXPRESS AIRBILL



USE THIS AIRBILL FOR DOMESTIC SHIPMENTS AND FOR SHIPMENTS FROM PUERTO RICO TO THE U.S.A.
FILL OUT PURPLE AREAS. FOR ASSISTANCE, CALL 800-238-5355, TOLL FREE.
SEE BACK OF FORM SET FOR COMPLETE PREPARATION INSTRUCTIONS.

AIRBILL NUMBER 179404511

SENDER'S FEDERAL EXPRESS ACCOUNT NUMBER: 0123-4567-8
DATE: 2/19/87

1 From (Your Name): A. SAMPLER
Your Phone Number (Very Important): (412) 788-1080
Company: NUS CORP.
Department/Floor No.:
Street Address: PARK W. TWO CLIFF MINE RD.
City: PITTSBURGH
State: PA
ZIP *Zip Code Required For Correct Invoicing: 15275

2 To (Recipient's Name): B. LAB
Recipient's Phone Number (Very Important): (613) 824-5600
Company: TEST IT, INC
Department/Floor No.:
Exact Street Address (Use of P.O. Boxes or P.O. • Zip Codes Will Delay Delivery And Result in Extra Charge.): 154 GREEN RD.
City: NEW YORK
State: NY
ZIP Street Address Zip Required (Not P.O. Box • Zip Code): 07163

AIRBILL NO. 179404514

3 YOUR BILLING REFERENCE INFORMATION (FIRST 24 CHARACTERS WILL APPEAR ON INVOICE.): Y925 AS

PAYMENT ☒ Bill Shipper ☐ Bill Recipient's FedEx Acct No Fill in line below ☐ Bill 3rd Party FedEx Acct No Fill in line below ☐ Bill Credit Card Fill in line below
☐ Cash
FedEx Acct No or Major Credit Card No ____

4 SERVICES
CHECK ONLY ONE BOX

PRIORITY 1
1 ☒ Overnight Delivery Using Your Packaging
OVERNIGHT LETTER
6 ☐ (Our Packaging 9"x12")

OVERNIGHT DELIVERY USING OUR PACKAGING
2 ☐ Courier-Pak Overnight Envelope 12" x 15½"
3 ☐ Overnight Box 12¾" x 17½" x 3" A ☐
4 ☐ Overnight Tube 38" x 6" x 6" x 6" B ☐

STANDARD AIR
5 ☐ Delivery not later than second business day

SERVICE COMMITMENT

DELIVERY AND SPECIAL HANDLING
CHECK SERVICES REQUIRED

1 ☐ HOLD FOR PICK-UP Give the Federal Express address where you want package held in Section H At right.
2 ☒ DELIVER WEEKDAY
3 ☐ DELIVER SATURDAY (Extra charge applies)
4 ☐ RESTRICTED ARTICLES SERVICE (P-1 and Standard Air Packages only. Extra charge applies)
5 ☐ CONSTANT SURVEILLANCE SERVICE (CSS) (Extra charge applies)
6 ☐ DRY ICE ____ Lbs
7 ☐ OTHER SPECIAL SERVICE ____
8 ☐
9 ☐ SATURDAY PICK-UP OR SATURDAY DROP-OFF (Extra charge applies)

PACKAGES	WEIGHT	YOUR DECLARED VALUE (See right)	OVER SIZE
Total	Total	Total	

Received At
Shipper's Door
☐ Regular Stop
☐ On-Call Stop
☐ FedEx Loc ____
Federal Express Corp. Employee No
Date/Time For Federal Express Use

H HOLD FOR PICK-UP AT THIS FEDERAL EXPRESS STATION
Street Address (See Service Guide or Call 800-238-5355)
City
State
ZIP *Zip Code of Street Address Required

YOUR DECLARED VALUE

DAMAGE OR LOSS

We are liable for no more than $100 per package in the event of physical loss or damage unless you fill in a higher Declared Value to the left and document higher actual loss in the event of a claim. We charge 30¢ for each additional $100 of declared value up to the maximum shown in our Service Guide. Declared value restrictions are shown on the back of the Shipper's Copy of this airbill. We make no express or implied warranties.

DELAY

There is always a risk of late delivery or non-delivery. In the event of a late delivery Federal Express will, at your request, refund all transportation charges paid. See back of Shipper's Copy of this airbill for further information.

CONSEQUENTIAL DAMAGES

We will not be responsible or liable for any loss or damage resulting from delay, non-delivery or damage to a package except as noted above. This includes loss of sales, income, interest, profits, attorney's fees and other costs, but is not limited to these items. Such damages are called "consequential damages."

Federal Express Use
Base Charges
Declared Value Charge
Origin Agent Charge
Other
Total Charges

PART
#2041738900
FEC-S-0750-25
REVISION DATE
10/84
PRINTED U.S.A. GBF

ORIGIN COPY

PLEASE PRINT OR TYPE

PRESS HARD 5 COPIES

Graphic Systems Incorporated

and the identificatlon number “UN1325.” If the nature of the sample is known, 49 CFR-171-177 is consulted to determine the proper labeling and packaging requirements.

7. The cans are placed upright in a cooler that has had Its drain plug taped shut inside and out, and the coder has been lined with a garbage bag. Vermiculite Is placed on the bottom. Two sizes of paint cans are used: half-gallon and gallon. The haff-gallon paint cans can be stored on top of each other; however, the gallon cans are too high to stack. The coder Is filled with vermiculite, and the liner is taped shut.

8. The papeerwork going to the laboratory is placed inside a plastic bag and taped to the inside of the coder lid. A copy of the COC form, an example of which is shown in Exhibit 5-4, should be Included in the paperwork sent to the laboratory. The sampler keeps one copy of the COC form. The laboratory should be notified if a parallel sample is being sent to another laboratory for dioxin analysis, or if the sample Is suspected of containing any substance for which laboratory personnel should take safety precautions.

9. The coder is dosed and sealed with strapping tape. At least two custody seals are placed on the outside of the coder (one on the front and one on the back). More custody seals may be used at the discretion of the sampler.

10. The fallowing markings are placed on the top of the cooler:

- Proper shipping name (49 CFR 172.301)
- DOT Identification number (49 CFR 172.301)
- Shipper’s or consignee’s name and address (49 CFR-172.306)
- "This End Up" legibly written if shipment contains liquid hazardous materials (49 CFR 172.312)

Other commercially available shipping containers may be used. The SM should ascertain that the containers are appropriate to the type of sample being shipped. The SM should clearly specify the type of shipping container to be used In the QAPjP.

11. The fallowing labels are required on top of the coder (49 CFR 172.406e):

- Appropriate hazard class label (placed next to the proper shipping name)
- “Cargo Aircraft Only (if applicable as identified In 49 CFR 172.101)

12. An arrow symbol(s) Indicating "This Way Up” should be placed on the cooler in addition to the markings and labels described above.

13. Restricted-article airbills are used for shipment. Exhibit 6-5 shows an example of a restricted article Federal Express airbill. The “Shipper certification for Restricted Articles” section is filled out as fallows for a flammable solid or a flammable liquid:

. Number of packages or number of coders

- Proper shipping name: if Iknown, use

  Flammable solid, N.O.S., or
  Flammable liquid, N.O.S.

- Classification; If Unknown, use

  - Flammable solid or
  - Flammable liquid

- Identification number if unknown, use

  UN1325 (for flammable solids) or
  UN1993 (for flammable liquids)

- Net quantity per package or amount of substance in each cooler

- Radioactive materials section (Leave blank.)

- Passenger of cargo aircraft (Cross if the nonapplicable. Up to 25 pounds of flammable solid per coder can reshipped on a passenger or cargo aircraft. Up to 1 quart of flammable liquid per coder can be shipped on a passenger aircraft, up to 10 gallons of flammable liquid per coder can be shipped on a cargo aircraft)

- Name and title of shipper (printed)

- An emergency telephone number at which the shipper can be reached within the fallowing 24 to 48 hours

- Shipper's signature

Note: The penalties for Improper shipment of hazardous materials are severe; a fine of $25,000 and 5 years imprisonment can be imposed for each violation. The SM or designee is urged to take adequate precautions.

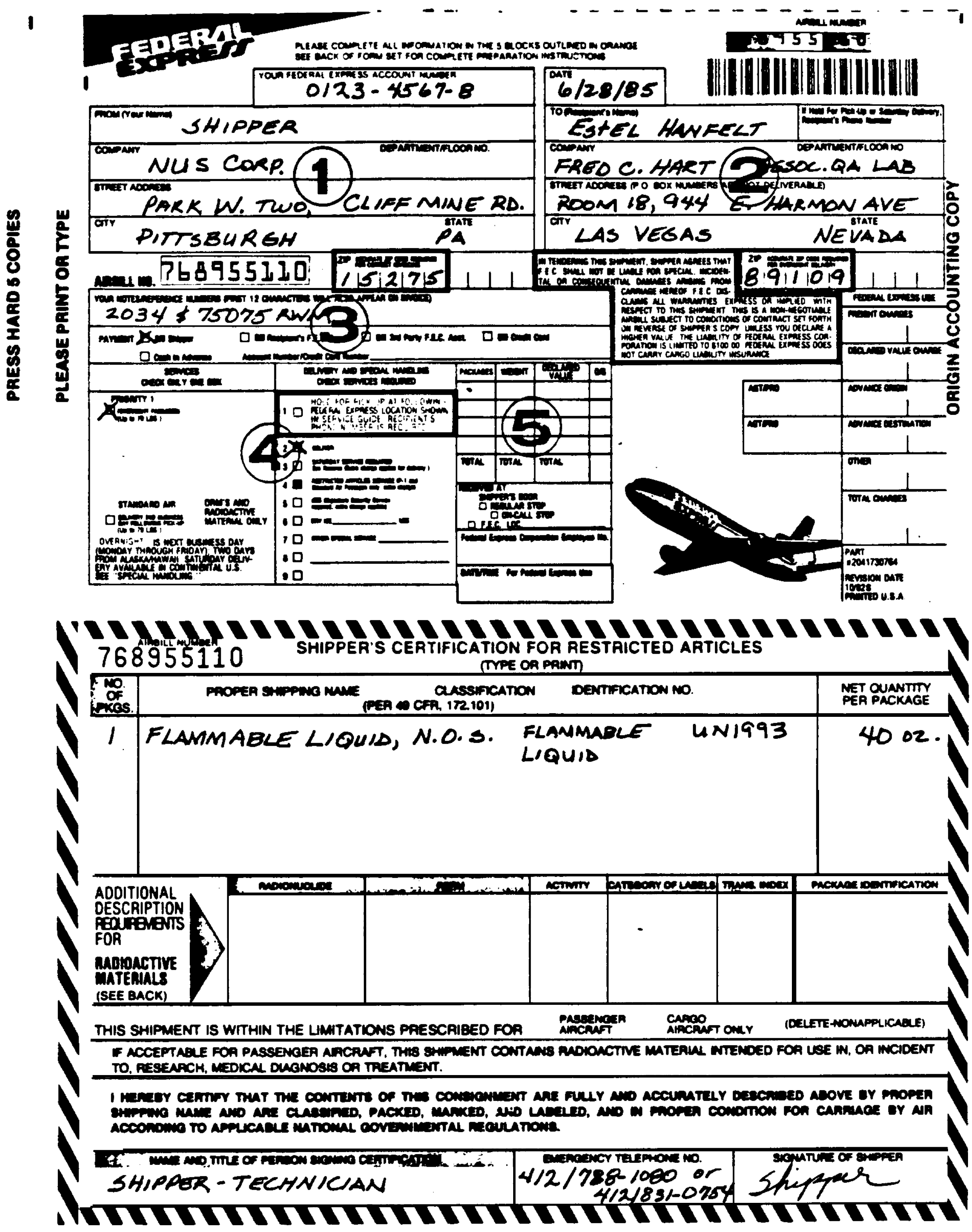
6.2.7 Regional Variances

There are no known regional variances.for the shipment of hazardous samples. However, regional variances for the shipment of environmental samples (low concentration) are common. Information in a compendium on such variances can become dated rapidly. Thus, users are urged to contact the EPA RPM or the RSCC for the latest regional variances.

1. Region 1 Includes the five-digit laboratory number of each sample in the "Remarks" section of the chain-of-custody form to act as a cross check on sample Identification.

2. Separators must be placed between the bottoles of samples shipped from a Region IV site. ESD also tapes the VOA vials and uses blue Ice.

Exhibit 6-5
RESTRICTED ARTICLE FEDERAL EXPRESS AIRBILL



PRESS HARD 5 COPIES

PLEASE PRINT OR TYPE

FEDERAL EXPRESS

PLEASE COMPLETE ALL INFORMATION IN THE 5 BLOCKS OUTLINED IN ORANGE
SEE BACK OF FORM SET FOR COMPLETE PREPARATION INSTRUCTIONS

AIRBILL NUMBER

YOUR FEDERAL EXPRESS ACCOUNT NUMBER: 0123-4567-8

DATE: 6/28/85

FROM (Your Name): SHIPPER

COMPANY: NUS CORP. ①

DEPARTMENT/FLOOR NO.:

STREET ADDRESS: PARK W. TWO, CLIFF MINE RD.

CITY: PITTSBURGH

STATE: PA

ZIP: 15275

AIRBILL NO. 768955110

TO (Recipient's Name): ESTEL HANFELT

COMPANY: FRED C. HART ② ASSOC. QA LAB

DEPARTMENT/FLOOR NO

STREET ADDRESS (P O BOX NUMBERS ARE NOT DELIVERABLE): ROOM 18, 944 E. HARMON AVE

CITY: LAS VEGAS

STATE: NEVADA

ZIP: 89109

YOUR NOTES/REFERENCE NUMBERS (FIRST 12 CHARACTERS WILL ALSO APPEAR ON INVOICE): 2034 $ 75075 RW ③

PAYMENT ☒ Bill Shipper ☐ Bill Recipient's F.E.C. Acct. ☐ Bill 3rd Party F.E.C. Acct. ☐ Bill Credit Card

☐ Cash in Advance Account Number/Credit Card Number

IN TENDERING THIS SHIPMENT, SHIPPER AGREES THAT F.E.C. SHALL NOT BE LIABLE FOR SPECIAL, INCIDENTAL OR CONSEQUENTIAL DAMAGES ARISING FROM CARRIAGE HEREOF. F.E.C. DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, WITH RESPECT TO THIS SHIPMENT. THIS IS A NON-NEGOTIABLE AIRBILL SUBJECT TO CONDITIONS OF CONTRACT SET FORTH ON REVERSE OF SHIPPER'S COPY. UNLESS YOU DECLARE A HIGHER VALUE, THE LIABILITY OF FEDERAL EXPRESS CORPORATION IS LIMITED TO $100.00. FEDERAL EXPRESS DOES NOT CARRY CARGO LIABILITY INSURANCE.

SERVICES
CHECK ONLY ONE BOX

PRIORITY 1
☒ (Up to 70 LBS.)

STANDARD AIR
☐ (Up to 70 LBS.)

DRM'S AND RADIOACTIVE MATERIAL ONLY

OVERNIGHT IS NEXT BUSINESS DAY (MONDAY THROUGH FRIDAY). TWO DAYS FROM ALASKA/HAWAII. SATURDAY DELIVERY AVAILABLE IN CONTINENTAL U.S. SEE "SPECIAL HANDLING."

DELIVERY AND SPECIAL HANDLING
CHECK SERVICES REQUIRED ④

1 ☐ HOLD FOR PICK-UP AT FOLLOWING FEDERAL EXPRESS LOCATION SHOWN IN SERVICE GUIDE. RECIPIENT'S PHONE NUMBER IS REQUIRED.
2 ☒
3 ☐ SATURDAY SERVICE REQUIRED
4 ■ RESTRICTED ARTICLES SERVICE
5 ☐
6 ☐
7 ☐
8 ☐
9 ☐

PACKAGES	WEIGHT	DECLARED VALUE	
	⑤		
TOTAL	TOTAL	TOTAL	

RECEIVED AT
SHIPPER'S DOOR
☐ REGULAR STOP
☐ ON-CALL STOP
☐ F.E.C. LOC.

Federal Express Corporation Employee No.

DATE/TIME For Federal Express Use

ACT/PRO

ACT/PRO

FEDERAL EXPRESS USE

FREIGHT CHARGES

DECLARED VALUE CHARGE

ADVANCE ORIGIN

ADVANCE DESTINATION

OTHER

TOTAL CHARGES

PART #2041730764
REVISION DATE 10/828
PRINTED U.S.A.

ORIGIN ACCOUNTING COPY

AIRBILL NUMBER 768955110

SHIPPER'S CERTIFICATION FOR RESTRICTED ARTICLES
(TYPE OR PRINT)

NO. OF PKGS.	PROPER SHIPPING NAME	CLASSIFICATION (PER 49 CFR, 172.101)	IDENTIFICATION NO.	NET QUANTITY PER PACKAGE
1	FLAMMABLE LIQUID, N.O.S.	FLAMMABLE LIQUID	UN1993	40 oz.

ADDITIONAL DESCRIPTION REQUIREMENTS FOR RADIOACTIVE MATERIALS (SEE BACK)

RADIONUCLIDE	FORM	ACTIVITY	CATEGORY OF LABELS	TRANS. INDEX	PACKAGE IDENTIFICATION

THIS SHIPMENT IS WITHIN THE LIMITATIONS PRESCRIBED FOR PASSENGER AIRCRAFT CARGO AIRCRAFT ONLY (DELETE-NONAPPLICABLE)

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS OR TREATMENT.

I HEREBY CERTIFY THAT THE CONTENTS OF THIS CONSIGNMENT ARE FULLY AND ACCURATELY DESCRIBED ABOVE BY PROPER SHIPPING NAME AND ARE CLASSIFIED, PACKED, MARKED, AND LABELED, AND IN PROPER CONDITION FOR CARRIAGE BY AIR ACCORDING TO APPLICABLE NATIONAL GOVERNMENTAL REGULATIONS.

NAME AND TITLE OF PERSON SIGNING CERTIFICATION	EMERGENCY TELEPHONE NO.	SIGNATURE OF SHIPPER
SHIPPER - TECHNICIAN	412/788-1080 or 412/831-0764	Shipper

3. Region V tapes the VOA vials and does not line the cooler with a plastic bag. Region V FIT indicates the OTR / ITR number, bottle lot numbers, sample concentrations and matrix in the right-hand portion of the "Remarks" section of the chain-of-custody form. The custody seal numbers, airbill number, and "samples shipped via Federal Express" are Included In the lower right-hand section.

4. Region VI does not tape sample bottles, put sample bottles in plastic bags, or line coolers with plastic. Glass bottles are wrapped with "bubble wrap" instead of cardboard separators. In addition, the traffic report stickers are placed at the liquid level on the sample bottlee to allow the laboratories to check for leakage.

5. Region VII does not put the sample In a plaetic hag.

Because information on variances can become dated rapidly, the user should contact the EPA RPM or RSCC for currant regional practices and requirements. Future changes and additional regional variances will be Incorporated In Revision 01 of this document.

6.2.8 Information Sources

CH2M HILL. *REM/FIT Documentation Protocol for Region V.* May 1984.

Code of Federal Regulations, Title 49, Parts 171 to 177, Transportation.

U.S. Environmental Protection Agency. *Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual.* Region IV, Environmental Services Division. 1 April 1986.

U.S. Environmental Protection Agency. *The User's Guide to the Contract Laboratory Program.* Office of Emergency and Remedial Response. December 1986.

SECTION 7

FIELD METHODS FOR RAPID SCREENING FOR HAZARDOUS MATERIAL

7.1 SCOPE AND PURPOSE

Section 7 provides an overview of current techniques used by some contractors to rapidly screen the hazardous waste material at waste sites. The section also describes the functions and capabilities of available analytical Instrumentation and suggests some analytical protocols for mobile laboratories. The purpose of this section Is not to provide standard operating procedures for rapid screening for hazardous material onsite or to establish performance criteria for direct-reading Instruments or mobile laboratories. The purpose is to provide a narrative description of some approaches and techniques that have been used on certain projects. in Fail 1987, the Contract laboratory Program (CLP) will publish a “Field Screening Methods Catalog” that will contain detailed discussions of field analytical methods. The CLP catalog will provide a consolidated reference for use by EPA, contractors, state and local agencies, and Potentiality Responsible Parties (PRPs) who will be conducting field analysis. When this compendium is updated, it will reflect the information contained in the CLP catalog. The updated compendium will also contain any additional methods that were found useful by contractors but were not included in the catalog.

7.2 DEFINITIONS

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor’s employee (see Subsection 1.1).

7.3 APPLICABILITY

Field analysis involves the use of portable or transportable instruments that are based at or near a sampling site. Field analysis should not be confused with the process of obtaining total organic readings using portable meters.

Field analysis can provide data from the analysis of air, soil, and water samples for many Target Compound List (TCL) organic compounds, including volatiles, base neutral acid (BNA) extractable organics, and pesticides / PCBs. inorganic analysis can also be conducted using portable atomic adsorption (AA) or other instruments.

The ability to assess data quality for field activities depends on the QA/QC steps taken in the process (e.g., documentation of blank injections, calibration standard runs, runs of qualitative standards between samples, etc.).

Field analytical techniques are used whenever the data quality objectives specify Level I and II analytical support as adequate.

The objective of Level I analysis is to generate data that are generally used in refining sampling plans and estimating the extent of contamination at the site. This type of support provides real-time data for health and safety purposes. Additional data that can effectively be obtained by Level 1 analyses include pH, conductivity, temperature, salinity, and disolved oxygen for water (see Sections 8 and 10), as well as some measurement of contamination using various kits (see Subsection 7.6).

Level I analyses are generally effective for total vapor readings using portable photoionization or flame ionization meters that respond to a variety of volatile inorganic and organic compounds (see Section 15).

Level I analysis provides data for onsite, real-time total vapor measurement, evaluation of existing conditions, refinement of sampling location and health and safety evaluations. Data generated from Level I support are generally considered qualitative in nature, although limited quantitative data can also be generated. Data generated from this type of analysis provide the fallowing:

- Identification of soil, water, air and waste locations that have a high likelihood of showing contamination through subsequent analysis
- Real-time data to be used for health and safety consideration during site reconnaissance and subsequent intrusive activities
- Quantitative data if a contaminant is known and the instrument is calibrated to that substance

The procedures discussed in this section have been used for several purposes including screening the site to determine the level of safety required for personnel working at the site; screening samples to determine which compounds, or groups of compounds, should be specified for further analysis, usually under the Contract Laboratory Program (CLP); and screening for characterizing material for removal and in refining the sampling plan to more precisely determine the number and type of samples to be taken. By using field screening, changes in sampling can occur while the field team is mobilized, rather than waiting for several months for data to return from CLP analysis. Field screening techniques, such as the removal of drums, lagoons, pits, ponds, and other waste sources, allows testing for compatibility and disposal category classification (Exhibit 7-1) before disposal.

Note: Because of the many safety factors to be considered when undertaking such screening, the SM should consult documents such as “Drum Handling Practices at Hazardous Waste Sites,” EPA/600/2-86/013, January 1986.

7.4 RESPONSIBILITIES

Field screening generally consists of two phases:

- A field survey using instruments such as OVA meters or HNU detectors to analyze the ambient conditions onsite or to conduct limited analyses of samples (Level I on Data Quality Objectives rating; see Section 15)
- Mobile laboratory analyses to provide better qualitative and quantitative data upon which decisions can be made about site safety, CLP use and the sampling campaign (Level II “on Data Quality Objectives rating)

The SM is responsible for defining the screening program and obtaining the proper equipment. The equipment manager and the mobile laboratory director are responsible for keeping the equipment in good

Exhibit 7-1
POTENTIAL ANALYTICAL REQUIREMENTS FOR DISPOSAL

1. Flammability
2. pH
3. specific gravity
4. PCB analysis
5. Thermal content (BTU/lb)
6. Physical state at 7°F
7. Phases (layering in liquids)
8. Solids (%)
9. Hydrocarbon composition
10. Pesticide analysis
11. Sulfur content
12. Phenols
13. Oil and grease (%)
14. Water (%)
15. Viscosity
16. Organochlorine percentage
17. Metals analysis

    a. Liquids for soluble metals
    b. Solids extracted according to the EPA Toxicant Extraction Procedure (24 hr), which shows leachable metals
    c. Both liquid and solids checked for concentrations of the following metals:

        - Arsenic
        - Barium
        - Cadmium
        - Chromium
        - copper
        - Lead
        - Mercury
        - Nickel
        - Selenium
        - Silver
        - Zinc

18. Content checked for both free and total cyanide
19. Solids checked for solubility in water, sulfuric acid, and,dimethyl sulfoxide

---

Reprinted from Muller, Broad, and Leo, 1982. Exhibit originally printed in the Proceedings of the National Conference on Management of Uncontrolled Hazardous Waste Sites, 1982. Available from Hazardous Materials Control Research Institute, 9300 Columbia Blvd., Silver Spring, Maryland 20910.

working order. The field Investigator(s) and the mobile laboratory analyst(s) are responsible for checking the equipment in the field and for verifying calibration and proper operation at the site.

7.5 RECORDS

Reporting is essential to thoroughly document technical methods and results. For screening of samples and field surveys, activity logs may be kept to record and document the results. Bound field notebooks with numbered pages should be used as the permanent record of results. Records should include field calibration procedures and duplicate readings. The equipment manager and the field analyst should keep records of equipment maintenance and field laboratory calibration and should make these records part of the permanent project file. The reader should refer also to Sections 4, 5, 6, and 17 of this compendium.

With a few exceptions, such as the mass-produced TAGA 6000E Mobile MS/MS System, mobile laboratories are each crafted differently. Accordingly, each mobile laboratory develops discrete standard operating and documentation procedures that are specific to the instrumentation, power and water supply, configuration, transportation arrangements, and housekeeping requirements for that laboratory. These specific procedures should be appended to the QAPjP and rigorously followed. The laboratory notebooks should document any deviations from the procedures or development of modifications to the procedures for site-specific needs.

Results from field screening are recorded In field or laboratory notebooks for the permanent record; tear sheets or carbonless forms are generally used to record results for the Site Manager's use before a report is written. (See Exhibit 7A-1 and 7A-3 for mobile laboratory reporting procedures.)

7.6 PROCEDURES

7.6.1 Inorganic Compounds

Exhibit 7-2 presents a list of typical Inorganic compounds that a laboratory program might analyze for during a hazardous waste site investigation.

Several approaches are used to determine inorganic compounds. These approaches Include the use of various field test kits as well as traditional and state-of-the-art instrumentation. Examples of field test kits include the Hach Hazardous Materials Detection Laboratory, the Hach COD kit, the Scintrex Atomic Absorption Spectrometer, indicator papers, portable wet chemistry test sets, and packaged test kits such as those produced by Chemetrics. Each of these kits includes a detailed set of instructions on use of the instruments and chemicals and on interpretation of results. A general discussion of the capabilities of some kits is presented below.

The kits offered by Hach and LaMotte Chemical Include reagents to produce a calorimetric reaction with subsequent relative quantitative determination using a spectrophotometer, which Is also in the kit. The Chemetrics test kits use self-filling ampoules that serve as disposable test cells. These ampoules contain a measured amount of reagent sealed under vacuum. These are calorimetric tests, and results are obtained through comparison with a color chart or through the use of a spectrophotometer or calorimeter. The Hach Hazardous Materials Laboratory (which is also usable for a limited number of organic compounds) is only class selective (e.g., heavy metals as a group) and Is subject to interferences. The Hach kits and other calorimetric methods are best used in a survey mode analogous to that of the Organic Vapor Meters, because positive results would not be conclusive without supporting data.

Exhibit 7-2
LISTING OF TYPICAL INORGANICS

Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Cyanide
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Potassium
Selenium
Silver
Sodium
Thallium
Vanadium
Zinc

The Scintrex Atomic Absorption Spectrometer Is somewhat comparable to usual laboratory capabilities. The Inclusion of Zeemann Effect background correction compensates for the lower optical performance, and the use of a tungsten furnace compares to the traditional laboratory instrument. The operator of the Atomic Absorption unit In the field must be well versed in sample preparation and sample handling techniques to avoid Interference and contamination problems. The mobile Atomic Absorption unit appears to be well suited for overall field application from the standpoint of both mobility and analytical performance.

Although the process is expensive, inorganic analyses that use state-of-the art laboratory instruments such as an Inductively Coupled Plama (ICP) Spectrometer can be performed in a field screening mode. A protocol for Inorganic analysis in mobile and fixed-base laboratories by ICP, flame, flameless, and cold-vapor atomic absorption techniques is attached as Exhibit 7A-3 in Appendix 7A. Heavy metals in solid samples can be analyzed by X-ray diffraction. An operating procedure for the Columbia Scientific X-Met 840 Analyzer Is attached as Exhibit 7A-4 in Appendix 7A.

7.6.2 Organic Compounds

Exhibit 7-3 shows a typical list of organic compounds that the CLP analyzes for. Equipment for field analysis and screening of organic compounds falls into three broad categories:

- Portable, total organic vapor monitors
- Portable, selective organic instruments
- Mobile, selective organic instruments

7.6.2.1 Portable, Total Organic Vapor Monitors

Equipment In this category includes the HNU Model 101, the AID Models 710/712 and 580, and the Foxboro OVA 108/128. These instruments are essentially gas chromatographic detectors that continuously sample the ambient atmosphere. With the exception of two instruments, they respond to all organic vapors and are nonselective. The exceptions are the HNU Modal 101 and the AID Model 580; both use a Photo Ionization Detector (PID). The PID does not respond to methane (or any other organic molecule with an Ionization potential greater than the energy of the ionizing lamp). This selective response Is advantageous, since methane is a common organic decomposition product and does not necessarily indicate the presence of toxic materials.

This type of equipment is already commonly used for health and safety as well as sample screening. Zero instrument response is a definitive result; it indicates an undetectable amount of organic vapors (toxic or otherwise) within the range of the instrument's ionzing lamp. However, a positive instrument response is not conclusive evidence of the presence of toxic materials, since the detector responds to both toxic and nontoxic organics. In addition to the selective response limitation, the organic vapor meters accept only vapor state samples. This equipment not only limits the sample type but also restricts the range of measurable compounds to the relatively high volatility materials.

Section 15 provides procedures for use of the equipment described above.

7.6.2.2 Portable, Selective Organic instruments

These types of instruments include the Photovac 10A1O, the AID Model 511, and the Foxboro OVA Century. While these Instruments are portable, they are not as simple to use and transport as the total organic vapor instruments. If samples other than ambient air are to be analyzed, it would be more convenient to perform the analyses In a van, trailer, or building. The Instruments listed above are isothermal gas chromatography (GC). The Foxboro is designed to operate at either O°C or 40°C, while the Photovac operates at ambient temperature. Thus, neither instrument is applicable for analysis of relatively nonvolatile compounds such as napthalene, phenol, or PCBs. The AID, while an Isothermal GC, will maintain 200°C for 8 hours on battery power if preheated on AC power. This elevated temperature capability makes the AID suitable for analyzing PCBs and other semi-volatiles. The AID can be used by injecting a liquid sample, a process that is the most common method of sample introduction for semi-volatile organics analysis. The Photovac, the AID, and the Foxboro do not offer temperature programming or capillary column capability, both of which considerably enhance the selectivity of GCS.

This type of instrument is capable of identifying and quantitating organic compounds in relatively noncomplex samples. The presence of large numbers of compounds in a sample can severely restrict the selectivity of this Instrument. An example of a situation in which adequate selectivity would not be available is the analysis of phenanthrene or anthracene in the presence of oil. The large number of hydrocarbon compounds In the oil would obscure and Interfere with the phenanthrene or anthracene.

One type of detector that Is available for this type of equipment and that offers special selectivity is the electron capture detector (ECD), which exhibits high sensitivity for halogenated molecules. Thus, it is possible to analyze for chlorinated compounds such as PCBs in the presence of unhalogenated hydrocarbon compounds such as oils. Other compounds, such as phthalates, also cause a response with this detector, so Interferences must always be considered. While this selectivity is advantageous when the compounds of Interest are halogenated, this detector Is not very useful for compounds such as benzene. This situation illustrates the type of considerations that should be used in selecting equipment appropriate for a given site.

7.6.2.3 Mobile, Selective Organic instruments

This type of Instrument ranges from GCs such as the Shimadzu Mini 2, the Hewlett-Packard 5890, the HNU Model 301, and the Unacon 810 through the Mass Spectrometric GC detectors to the tandem Mass Spectrometer / Mass Spectrometer (MS/MS) TAGA 3000 and 8000. These instruments require at least 120 volts of AC power, either from regular utility supplies or from generators. The GCs are amenable to

Exhibit 7-3
ORGANIC COMPOUNDS

Volatile Fraction

Chloromethane
Bromomethane
Vinyl chloride
Chloroethane
Methylene chloride
Acetone
Carbon disulfide
1, 1-Dichloroethene
1, 1-Dichloroethane
Trans-1,2-dichloroethene
Chloroform
1, 2-Dichloroethane
2-Butanone (methyl ethyl ketone)
1, 1, 1-Trichloroethane
Carbon tetrachloride
Vinyl acetate
Bromodichloromethane
1, 1, 2, 2-Tetrachloroethane
1, 2-Dichloropropane
Trans-1, 3-dichloropropene
Trichloroethene
Dibromochloromethane
1, 1, 2-Trichloroethane
Benzene
Cis-1, 3-dichloropropene
2-Chloroethylvinylether
Bromoform
2-Hexanone (methly butyl ketone)
4-methyl-2-pentanone (methyl isobutyl ketone)
Tetrachloroethene
Toluene
Chlorobenzene
Ethylbenzene
Styrene
Total xylenes

Semi-Volatile Compounds

Phenol
Bis(2-chloroethyl) ether
2-Chlorophenol
1, 3-Dichlorobenzene
1, 4-Dichlorobenzene
Benzyl alcohol
1, 2-Dichlorobenzene
2-Methylphenol
Bis (2-chloroisopropyl) ether
4-Methylphenol
N-nitroso-di-n-propylamine
Hexachloroethane
Nitrobenzene
Isophorone
2-Nitrophenol
2, 4-Dimethylphenol
Benzcic acid
Bis (2-chloroethoxy) methane
2, 4-Dichlorophenol
1, 2, 4-Trichlorobenzene
Naphthalene
Acenaphthene
2, 4-Dinitrophenol
4-Nitrophenol
Dibenzofuran
2, 4-Dinitrotoluene
2, 6-Dinitrotoluene
Diethylphthalate
4-Chlorophenyl-phenylether
Fluorene
4-Nitroaniline
4, 6-Dinitro-2-methylphenol
N-Nitrosodiphenylamine
4-Bromophenyl-phenylether
Hexachlorobenzene
Pentachlorophenol
Phenanthrene
Anthracene
Di-n-butylphthalate
Fluoranthene
Pyrene
Butylbenzylphthalate
3, 3'-Dichlorobenzidine

Exhibit 7-3
(continued)

Semi-Volatile Compounds (continued)

4-Chloroaniline
Hexachlorobutadiene
4-Chloro-3-methylphenol
2-Methylnapthalene
Hexachlorobyclopentadiene
2, 4, 6-Trichlorophenol
2, 4, 5-Trichlorophenol
2-Chloronapthalene
2-Nitroaniline
Dimethyl phthalate
Acenaphthylene
3-Nitroaniline

Benzo (a) anthracene
Bis (2-ethylhexyl) phthalate
Chrysene
Di-n-octyl phthalate
Benzo (b) fluoranthene
Benzo (k) fluoranthene
Benzo (a) pyrene
Ideno (1, 2, 3-cd) pyrene
Dibenzo (a, h) anthracene
Benzo (g, h, i) perylene

Pesticides

Alpha-BHC
Beta-BHC
Delta-BHC
Gamma-BHC (lindane)
Heptachlor
Aldrin
Heptachlor epoxide
Endosulfan 1
Dieldrin
4,4'- DDE
Endrin
Endosulfan II
4, 4'-DDD
Endosulfan sulfate
4, 4'-DDT
Methoxychlor
Endrin ketone
Chlordane
Toxaphene

PCBs

Aroclor-1016
Aroclor-1221
Aroclor-1232
Arochlor-1242
Arochlor-1248
Aroclor-1254
Aroclor-1260

transportation and setup facilities that are available onsite. The Mass Spectrometric detectors should be installed in dedicated mobile vans or trailers for transportation and operation, and the TAGA Is transported and operated in a custom motor home with an integral generator.

Although the mobile GCs are more restricted than the portable GCs in the locations where they can be used, they offer significantly more potential selectivity. The ability to use capillary columns and to employ temperature programming greatly increases the resolution of chromatographic separations and enhances the selectivity of the analysis. Exhibit 7A-1 of Appendix 7A contains mobile laboratory protocols for organic analyses based on GC techniques.

The Unacon is a special device for sample preparation, which, in addition to purging and trapping aqueous samples, also facilitates the analyses of gases, soils, and sediments by gas chromatography. Solid sample materials (such as soil or dry sediment) can be loaded into a Unacon sample tube and heated to thermally desorb organics for GC analysis. The Unacon also provides for purge and trap and for direct solvent injection of liquid samples.

If a GC is Interfaced to a Mass Spectrometric Detector, such as the Hewlett-Packard 5970 B or the Finnigan Ion Trap Detector (ITD), the resulting system will approach the selectivity of laboratory equipment. These mass-selective detectors are designed to operate with capillary column GCs and to include microcomputer-based data systems. While these data systems are compact *and* inexpensive, they *can* be fried for high capacity storage that provides the capability to search mass spectral databases, such as the EPA/NIH Spectrum Library. The combination of a GC and a Mass Spectrometric Detector installed In a van offers the potential for a highly selective mobile-analysis capability.

The TAGA MS/MS unit has been used in field situations for which it provided a great deal of selectivity, although at a relatively high cost. When the situation warrants, the TAGA unit can provide exceptional specificity and sensitivity for the analysis of problem compounds such as 2,3,7,8-tetra-chlorodibenzo-p-dioxin (TCDD). The TAGA does not use a GC for initial separation of individual compounds. As the name implies, two mass spectrometers In tandem provide both compound separation and Identification information within the same unit.

Effective use of these analytical instruments requires a high level of expertise and experience on the part of the analyst.

7.6.3 Class A Poisons

7.6.3.1 General

Class A poisons are defined as being extremely dangerous poisonous gases or liquids of which an extremely small amount of gas or vapor of the liquid mixed with air Is dangerous to life.

Exhibit 7-4 lists 25 compounds that fall into this category. Sixteen of these compounds are listed by the Department of Transportation (DOT) as Class A poisons, and these compounds were selected for screening at waste sites in an EPA report entitled *Available Field Method for Rapid Screening of Hazardous Waste Materials at Waste Sites,* Interim Report, Class A Poisons, December 1982. Determining the presence of Class A poisons is of interest to the SM because of the extremely strict requirements placed on the shipping of Class A poisons by DOT. The fallowing paragraphs summarize the methods evaluated by EPA for screening Class A poisons.

Exhibit 7-4
CLASS A POISONS

Arsine
Bromoacetone
Carbonyl flouride
Chloropicrin
Cyanogen
Cyanogen chloride
Dichlorodiethyl sulfide
Ethyl bromoacetate
Ethyldichloroarsine
Germane
Hydrocyanic acid
Methyldichloroarsine
Nitric oxide
Nitrogen dioxide
Nitrogen tetroxide
Nitrogen trioxide
Phosgene
Diphosgene
Phosphine
Phenylcarbylamine chloride
Trichloroacetyl chloride
Tetrachlorodinitroethane
Allyl isothiocyanate
Dichloro-(2-chlorovinyl) arsine*
Hydrogen selenide

---

* Lewisite blistering agent (mustard gas)

7.6.3.2 Screening Methods for Class A Poisons

The current state of the art for existing methods of general detection does not provide for the specific field screening of Class A poisons. It appears that a more promising approach is the specific detection method for each of the Class A poisons of interest. A convenient method for the field screening of specific volatile substances is the use of gas detection tubes. These tubes contain a granulated solid support, such as silica gel, with an adsorbed reagent that changes color in the presence of the species the reagent is designed to detect. A known quantity of sample gas is drawn through the detection tube, and the length of the resulting discoloration is read against a precalibrated scale to give the concentration of the species of interest. Interferences are common and can give erroneous results. The following summary of the literature describes the more promising systems for detection against reagents that might be used with the gas detection tube concept. Gas detection tubes for several of the Class A poisons are already commercially available. Colorimetric-indicating gas detection tubes are most useful in situations in which the contaminant is known or suspected; the tubes can reduce the possibility of interferences that produce erroneous results.

The EPA survey showed that 16 reagent detection systems lend themselves to field screening for hydrocyanic acid. Of the methods that were considered, four employed photometric analysis, while the other procedures used adsorption of hydrocyanic acid and/or the detector reagent on some type of solid support, such as silica gel, filter paper, or activated charcoal. Considering all factors, the commercially available Draeger detector tube for hydrocyanic acid appeared to offer the greatest potential for incorporation into field methodology. This tube has a detection range of 2.3 to 34 mg/m^3; acid gases such as hydrogen sulfide, hydrogen chloride, sulfur dioxide, and ammonia are retained in the precleanse layer.

Ten reagent systems were reported for the detection of arsine. Three methods involve photometric analysis; one is a titration procedure; the other six use adsorption on a solid support, as described above. The most promising of these methods for field screening appears to be the Draeger arsine detector tube, which has a detection range of 0.16 to 195 mg/m^3. Phosphine and antimony hydride are listed as positive interferences. It should be noted that phosphine is also classified as a Class A poison.

A total of 16 reagent detection systems were reported for the screening of ethyl and/or methyldichloroarsine. Two of these methods used a precipitate in the reagent solution as a positive result. Twelve methods used reagent-treated filter paper, while one used a coloration change made by marks of a treated crayon. The method that appears to be the most suitable for incorporation into a field test kit used a detector tube containing silica gel that has been impregnated with a mixture of zinc sulfate and molybdic acid. This tube offers direct and sensitive detection for alkyldichloroarsine. The detection limit of the reagent is given as 2.5 ug; other closely related organo-arsenic halides and hydrogen sulfide are given as positive interferences.

Eleven reagent detector systems could be used for field screening of mustard gas. There are two types of chemical warfare blistering agents: H (and its distillates HD and HT) and Lewisite. Ail are known by the general term "mustard gas." The most attractive of these methods for H compounds appears to be silica gel impregnated with auric chloride. According to the literature, a characteristic reddish-brown color appears in the presence of mustard gas.

Eleven potential field screening methods were found for the detection of dichloro-(2-chlorovinyl) arsine. The most promising of these methods appears to be that which uses Michler's thioketone (4,4'-bis (dimethylamino) thiobenzo phenone) as the reagent adsorbed on silica gel. This reagent system is currently used by the U.S. Army in its M256 gas detector kit for the detection of Lewisite.

Seven methods were identified that could be used for the field detection of cyanogen chloride. Two methods required photometric analysis, while one involved titration. The other four approaches used reagents adsorbed on some type of solid support. The most promising approach appears to be the use of the cyanogen chloride detector tube made by Draeger. This tube has a detection range of 0.64 to 12.8 mg/m^3. Cyanogen bromide is listed as a positive interference.

Nitric oxide and nitrogen dioxide can be detected by using the Draeger nitrous fumes detector tube. A total of 15 reagent systems were examined for the detection of nitric oxide and/or nitrogen dioxide. The Draeger tube method appears to be the most advantageous approach since both gases can be detected simultaneously and since the method is commercially available.

Eleven methods appeared suitable for adaptation to field screening for phosphine. One method involved titration; two used photometric analysis the remaining eight methods used liquid reagents adsorbed on solid supports. The most promising method appears to be the use of the Draeger phosphine detector tube, which has a detection range of 0.14 to 5.68 mg/m^3 Antimony hydride and arsine, a Class A poison, are given as positive interferences.

Only four reagent detection methods were found for the field screening of bromoacetone. The best approach for the detection of this compound appears to be a two-step method. Sodium nitroprusside is used as a detecting reagent for methyl ketones in the first step. An orange coloration of the sodium nitroprusside indicates the presence of this class of compounds. The second step is the detection of bromine using fuchsin-sulfurous acid test paper. A positive response is indicated when a violet color appears. When both of these tests are positive, bromoacetone is assumed to be present.

Sixteen reagent systems were examined for the detection of phosgene. Three methods require photometric analysis; one involves titration; the remaining approaches use a reagent on solid support. The best method appears to be the Draeger phosgene detector tube, which has a detection range of 0.17 to 6.2 mg/m^3. Carbonyl bromide and acetyl chloride are listed as positive interferences. Literature dealing with the detection of diphosgene stated that to use the Draeger tubes, the gas must be heated 300°C to 350°C to decompose it to phosgene, which is then detected by the above methods. Further testing will determine the necessity for this heat treatment.

One method was found for the specific detection of cyanogen. The reagents used for this test are 8-quinolinol and potassium cyanide, which turns red In the presence of this species. In addition, cyanogen may be converted to hydrogen cyanide or cyanogen chloride and can be detected as these substances.

Five detection means were reported for germanium. Two of these methods involved titrimetric analysis. Currently, the most promising approach for field detection appears to be the use of the reagent, hydroxyphenyl fluorene, which turns an orange color in the presence of germanium.

Only one method was reported for the detection of phenylcarbylamine chloride. This method uses Sudan red, ground chalk, and iron (III) chloride, which turns from red to green in the presence of phenyl-carbylamine-chloride. Sudan red is listed as a carcinogen.

The EPA report recommended that the above methods be evaluated in a laboratory as a means of screening for the Class A poison for which each system is designed.

7.7 REGION-SPECIFIC VARIANCES

Because field screening techniques are not completely standardized, the SM must prepare a detailed explanation of the methods to be used and the associated QA/QC procedures. This Information is included in the QAPjP for review and approval by EPA.

7.8 INFORMATION SOURCES

CDM Federal Programs corporation. *REM II Team Operating Procedures for X-Ray Fluorescemce Analyzer.* April 1987.

Equipment Available for Sample Screening and Onsite Mea.surements. Technical Directive Document No. HQ-8311 -04, Contract No. 88-01-8899. 30 May 1984.

NUS Corporation, Superfund Division. *Operating Guidelines Manual Rapid Field Screening of Hazardous Substances.* Procedure 4.35 (Draft 1).

REM?FIT Mobil Lab QA Procedure Development. Technical Directive Document No. HQ-8505-04. 30 June 1985.

Roffman, H.K, and M.D. Neptune. *Field Screening of Samples From Hazardous Wastes.* Proceedings, institute of Environmental Sciences. April 1985.

U.S. Environmental Protection Agency. *Available Field Methods for Rapid Screening of Hazardous Wrote Materials at Wrote Sites.* Interim Report, Class A Poisons, EPA Report No. 8001X-82-014. December 1982.

U.S. Environmental Protection Agency. *Drum Handling Practices at Hazardous Waste Sites,* EPA Report No. EPA/800/2-88-013. Cincinnati, Ohio: HWERL August 1988.

APPENDIX 7A

PROTOCOLS, REPORTING, AND DELIVERABLES

The following sections discuss methodologies that have been used in screening samples on hazardous waste sites. The Site Manager (SM) should realize that these methodologies may not be suitable for all sites and may require extensive modification to meet the validation requirement of a specific region. Also, the methodologies used must be related to the data quality objectives of the project.

Exhibit 7A-1 presents protocols that have been used for analyses, reporting and deliverables for the mobile laboratory analysis of organic compounds for screening. Exhibit 7A-2 lists the estimated limits of detection for organics on the target compounds list. Exhibit 7A-3 presents the protocols to be followed for the mobile laboratory screening of inorganic trace elements and cyanide. Exhibit 7A-4 describes the operating procedure for XRF analysis of soils and tailings with the Columbia X-Met 640 Analyzer.

HOLDING TIMES BEFORE ANALYSIS

Samples should be analyzed as soon as possible after sampling. One advantage to field analysis is rapid turn around, generally 24 hours, for most analyses. If samples are not analyzed immediately, the following holding times are suggested. Volatile organic analyses (VOAs) should be held no more than 7 days from sampling until analysis for water samples and no more than 10 days for soil or sediment samples. Base neutral acids (BNAs) and pesticides should be held no more than 5 days until extraction for water samples and no more than 10 days for soil or sediment samples. Samples must be refrigerated before analysis.

inorganic samples should be preserved in the field according to EPA protocols found in the *User's Guide to the CLP*. The holding time for cyanides shall not exceed 24 hours.

Exhibit 7A-1
MOBILE LABORATORY PROTOCOLS FOR ORGANIC ANALYSES

I. VOLATILE ORGANIC COMPOUNDS

A. Instrumentation for Water and Soil Sample Analyses

1. Tekmar purge and trap or equivalent
2. Temperature-programmed gas chromatography equipped with flame-ionization detector
3. GC column
    a. 60/60 Carbopack B/l percent SP-1000 6 ft x 44mm I.D. glass-packed column

B. Water Sample Analysis

1. Adapted from Method 5030, SW-646, purge and trap
2. Calibration standard solution
    a. Spike an aliquot of commercial (Supelco) standard mixture into 20 ml of reagent water and purge.
3. Analysis

Exhibit 7A-1
(continued)

- a. Use calibration standard through purge and trap system.
  - 1) Once per site before sample analyses
  - 2) After every 20 sample analyses
- b. Purge organic-free water blank (5 ml). solution analysis
  - 1) After every calibration standard solution analysis.
  - 2) After every 10 sample analyses
- c. Perform corrective maintenance when calibration standard responses decrease by 20 percent of the initial calibration standard run; clean the injection port and the purge and trap appara

C. Soil /Sediment Sample Analysis

1. Adapted from Method 5030, SW-846, methanol extraction
2. Calibration standard solution preparation
   - a. Spike aliquot of commercial (Supelco) standard mixture into 20 ml of reagent water and purge.
3. Extraction
   - a. Place 1 g soil sample/10 methanol in a 40-ml glass Teflon-capped vial.
   - b. Shake for 2 minutes.
   - c. Allow solids to settle.
4. Analysis
   - a. Use 400 μl extract injected/20 ml organic-free water (equivalent to 1 ppm limit of detection).
5. Quality control
   - a. Use calibration standard through purge and trap system.
     - 1) Once per site before sample extract analyses
     - 2) After every 20 sample extract analyses
   - b. Purge organic-free water blank (20 ml organic-free water containing the 400 μl methanol used for extraction).
     - 1) After every calibration standard analysis
     - 2) After every 10 sample extract analyses
     - 3) After any sample extracts that exceed 100 ppm
   - c. Perform corrective maintenance when calibration standard responses decrease by 20 percent of the initial calibration standard run; clean the injection port and the purge and trap apparatus.

II. SEMI-VOLATILE ORGANIC COMPOUNDS

A. Instrumentation for Water and Soil Sample Analyses

1. Base / neutral and acid extractable organic
   - a. Temperature-programmed gas chromatography equipped with a flame-ionization detector
2. Pesticides / PCBs
   - a. Isothermal gas chromatograph equipped with an electron capture detector
3. GC column
   - a. Base / neutral and acid extractable organics

Exhibit 7A-1
(continued)

1) Fused silica capillary column DB-5 or equivalent 30 mm x 0.32 mm, 1 micron film thickness

b. Pesticides / PCBs

1) 3 percent OV-1 on 80/100 Supelcoport 6 ft x 4 mm I.D. or equivalent

B. Water Sample Analysis

1. Pesticides / PCBs
   - a. Extraction
     - 1) Use 15 ml water sample/1.5 ml hexane in 20 ml disposable culture tube with cap (Teflon or aluminum foil liner).
     - 2) Shake for 2 minutes.
   - b. Analysis
     - 1) Inject 5 µl extract.
     - 2) Use detection limits 0.5 (for compounds such as lindane) to 20 ppb (for compounds such as Aroclor PCBs).
   - c. Calibration standard solution
     - 1) Pesticide mixture: lindane, 0.005 ng/µl; aldrin, 0.01 ng/µl; p-p'-DDT, 0.025 ng/µl
     - 2) PCBs: Aroclor 1254, 0.15 ng/µl
   - d. Quality control
     - 1) Inject calibration standard solution
       - a) Once per site before sample analysis
       - b) After every 20 sample extracts
     - 2) Inject solvent blank.
       - a) After each calibration standard solution analysis
       - b) After every 10 sample extract analyses.
     - 3) Spike (field) sample.
       - a) Spike water with spiking solution of lindane, 0.5 µl; aldrin,1.0 µg/l; p-p'-DDT, 2.5 µg/l
     - 4) Perform corrective maintenance when calibration response decreases 20 percent from initial calibration; clean injection port and front of GC column.
2. Base / neutral and acid extractable organic compounds
   - a. Extraction
     - 1) Adjust 100 ml sample to pH 2 or less, in a 125 ml separatory funnel.
     - 2) Extract with 10 ml methylene chloride.
     - 3) Shake for 2 minutes with proper venting and appropriate safety measures.
   - b. Analysis
     - 1) Inject 2 µl of extract
     - 2) Note that limits of detection vary depending on recovery and sensitivity of compound, 100 ppb-1 ppm.
   - c. Calibration standard solution
     - 1) Commercial (Supelco) solution containing the compounds of interest at appropriate concentrations
   - d. Quality control
     - 1) Inject calibration standard solution.
       - a) Once per site before sample analysis
       - b) Every 20 sample analyses
     - 2) Use spiked (field) sample to check extraction recovery.
       - a) Spiking solution of phenol, phenanthrene, 4-6-dinitro-2 methyl-phenol, hexachlorobenzene, and di-n-octyl-phthalate

Exhibit 7A-1
(continued)

b) Spike water sample at 1,000 µg/l

c) Spiked sample to check extraction recovery

   (1) Every 20 sample extract analyses

   (2) At least once per site

   (3) Solvent blank

      (a) After each calibration standard analysis

      (b) After every 10 sample analyses

   (4) Conduct corrective maintenance when calibration response decreases 20 percent from initial calibration; clean injection port and front of GC column.

C. Soil / Sediment Sample Analysis

1. Pesticides / PCBs
   - a. Extraction
     - 1) Place 1 g soil sample in glass scintillation vial of at least 20 ml volume with screw caps (Teflon or aluminum foil liner).
     - 2) Add 2 g anhydrous sodium sulfate.
     - 3) Mix well with spatula to free-flowing powder.
     - 4) Add 10 ml hexane.
     - 5) Shake for 2 minutes.
     - 6) Allow solids to settle.
   - b. Analysis
     - 1) 5 µl extract injected
     - 2) Limits of detection 0.05 ppm for compounds such as lindane to 2 ppm for compounds such as Aroclor PCBs
   - c. Calibration standard solution
     - 1) Pesticide solution of lindane, 0.005 ng/µl; aldrin, 0.01 ng/ml; and p-p'-DDT, 0.025 ng/µl
     - 2) PCBs--Aroclor 1254, 0.15 ng/µl
   - d. Quality control
     - 1) Calibration standard injected (both pesticides and PCBs)
       - a) Once per site before sample analysis
       - b) After every 10 sample analyses
     - 2) Spiked (field) sample
       - a) Spiking solution--concentration in soil will be lindane, 50 ng/g; aldrin, 100 ng/g; and p-p'-DDT, 250 ng/g
       - b) Spiked sample every 20 samples
       - c) Once per site, minimum
     - 3) Solvent blank injection
       - a) After each calibration standard solution injection
       - b) After every 10 samples extract
       - c) After any samples that exceed 20 ppm
     - 4) Conduct corrective maintenance when calibration response decreases by 20 percent of initial calibration; clean injection port and front of GC column
2. Base / neutral and acid extractable compounds
   - a. Extraction
     - 1) Place 1 g soil sample in glass scintillation vial of at least 20 ml volume with screw cap (Teflon or aluminum foil liner).
     - 2) Add 2 g anhydrous sodium sulfate.

Exhibit 7A-1
(continued)

3) Mix well with spatula to a free-flowing powder.
4) Add 10 ml methylene chloride.
5) Shake for 2 minutes.

6) Allow solids to settle.

b. Analysis
  1) 2 μl extract injected
  2) Detection limits vary, 10 ppm-100 ppm

c. Calibration standard solution - commercial (Supelco) solution containing the compounds of interest at appropriate concentrations

d. Quality control
  1) Calibration standard injected
    a) Once per site prior to sample extract analysis
    b) After every 10 sample extract analyses
  2) Spiked (field) samples
    a) Spiking solution – concentration in soil will be 100 μg/g for each of the following compounds: phenol, phenanthrene, 4-6-dinitro-2-methyl phenol, hexachlorobenzene, and di-n-octylphthalate
    b) Spiked sample every 20 samples
    c) Spiked sample once per site, minimum
  3) Solvent blank injection
    a) After each calibration standard injection
    b) After every 10 sample extract analyses
    c) After any sample extracts that exceed 10,000 ppm
  4) Conduct corrective maintenance when calibration response decreases by 20 percent from initial calibration; clean injection port and front of GC column

III. DELIVERABLES AND REPORTING - MOBILE LABORATORY ORGANICS ANALYSES

A. For each sample analyzed, a summary sheet containing the following information shall be provided:

1. Site name
2. Sample number
3. Date received
4. Date analyzed
5. Analyst
6. Number of peaks recorded on chromatogram (**Note:** For each sample chromatogram, peaks recorded will be numbered sequentially (#1, #2, #3, etc.) directly on the chromatogram)
7. Retention time of each peak
8. Relative concentration of each peak - compare sample chromatogram to calibration standard chromatogram; determine the closest eluting standard; and assume a response factor of 1.0. Other response factors may be assumed if indicated.

B. Copies of all analysts' logbooks, calibration logs, daily activity logs, and all chromatograms for calibration runs, blank injections, and samples will be received within 14 days of the receipt of the last sample from a particular site.

Exhibit 7A-2
TARGET COMPOUND LIST (TCL) ESTIMATED DETECTION LIMITS

	Volatiles[a,b]	CAS Number	Estimated Detection Limits*, **	
			Water µg/1	Soil/Sediment µg/kg
1.	Chloromethane	74-87-3	10	10
2.	Bromomethane	74-83-9	10	10
3.	Vinyl chloride	75-01-4	10	10
4.	Chlorethane	75-00-3	10	10
5.	Methylene chloride	75-09-2	5	5
6.	Acetone	67-64-1	10	10
7.	Carbon disulfide	75-15-0	5	5
8.	1, 1-Dichloroethene	75-35-4	5	5
9.	1, 1-Dichloroethane	75-35-3	5	5
10.	Trans-1, 2-dichloroethene	156-60-5	5	5
11.	Chloroform	67-66-3	5	5
12.	1,2-Dichloroethane	107-06-2	5	5
13.	2-Butanone	78-93-3	10	10
14.	1,1,1-Trichloroethane	71-55-6	5	5
15.	Carbon tetrachloride	56-23-5	5	5
16.	Vinyl acetate	108-05-4	10	10
17.	Bromodichloromethane	75-27-4	5	5
18.	1,1,2,2-Tetrachloroethane	79-34-5	5	5
19.	1,2-Dichloropropane	78-87-5	5	5
20.	Trans-1,2-dichloropropene	10061-02-6	5	5
21.	Trichloroethene	79-01-6	5	5
22.	Dibromochloromethane	124-48-1	5	5
23.	1,1,2-Trichloroethane	79-00-5	5	5
24.	Benzene	71-43-2	5	5
25.	Cis-1,3-dichloropropene	10061-01-5	5	5
26.	2-Chloroethyl vinyl ether	110-75-8	10	10
27.	Bromoform	75-25-2	5	5
28.	2-Hexanone	591-78-6	10	10
29.	4-Methyl-2-pentanone	108-10-1	10	10
30.	Tetrachloroethene	127-18-4	5	5
31.	Toluene	108-88-3	5	5
32.	Chlorobenzene	108-90-7	5	5
33.	Ethyl benzene	100-41-4	5	5
34.	Styrene	100-42-5	5	5
35.	Total Xylenes	100-42-5	5	5

Exhibit 7A-2
(continued)

	Semi- Volatiles[a], [b]	CAS Number	Estimated Detection Limits*, **	
			Water µg/1	Soil/Sediment µg/kg
36.	N-nitrosodimethylamine	62-75-9	10	330
37.	Phenol	108-95-2	10	330
38.	Aniline	62-63-3	10	330
39.	Bis (2-chloroethyl) ether	11144-4	10	330
40.	2-Chlorophenol	95-57-8	10	330
41.	1, 3-Dichlorobenzene	541-73-1	10	330
42.	1,4-Dichlorobenzene	106-46-7	10	330
43.	Benzyl alcohol	100-51-6	10	330
44.	1,2-Dichlorobenzene	95-50-1	10	330
45.	2-Methylphenol	95-48-7	10	330
46.	Bis (2-chloroisopropyl) ether	39638-32-9	10	330
47.	4-Methylphenol	106-44-5	10	330
48.	N-nitroso-dipropylamine	621-64-7	10	330
49.	Hexachloroethane	67-72-1	10	330
50.	Nitrobenzene	98-95-3	10	330
51.	Isophorone	78-59-1	10	330
52.	2-Nitrophenol	88-75-5	10	330
53.	2,4-Dimethylphenol	105-67-9	10	330
54.	Benzoic acid	65-85-0	50	1600
55.	Bis (2-chloroethoxy) methane	111-91-1	10	330
56.	2,4-Dichlorophenol	120-83-2	10	330
57.	1,2,4-Trichlorobenzene	120-82-1	10	330
58.	Naphthalene	91-20-3	10	330
59.	4-Chloroaniline	10647-8	10	330
60.	Hexachlorobutadiene	8748-3	10	330
61.	4-Chloro-3-methylphenol (para-chloro-meta-cresol)	59-50-7	10	330
62.	2-Methylnaphthalene	91-57-6	10	330
63.	Hexachlorocyclopentadiene	77-474	10	330
64.	2,4,6-Trichlorophenol	88-06-2	10	330
65.	2,4,5-Trichlorophenol	95-954	50	1600
66.	2-Chloronaphthalene	91-58-7	10	330
67.	2-Nitroaniline	88-74-4	50	1600
68.	Dimethyl phthalate	131-11-3	10	330
69.	Acenaphthylene	208-96-8	10	330
70.	3-Nitroaniline	99-09-2	50	1600
71.	Acenaphthene	83-32-9	10	330
72.	2,4-Dinitrophenol	51-28-5	50	1600
73.	4-Nitrophenol	100-02-7	50	1600
74.	Dibenzofuran	132-64-9	10	330
75.	2,4-Dinitrotoluene	121-14-2	10	330

Exhibit 7A-2
(continued)

			Estimated Detection Limits*, **	
	Semi-Volatiles^{c,d}	CAS Number	Water µg/1	Soil/Sediment µg/kg
76.	2,6-Dinitrotoluene	606-20-2	10	330
77.	Diethylphthalate	84-66-2	10	330
78.	4-Chlorophenyl phenyl ether	7005-2-3	10	330
79.	Fluorene	86-73-7	10	330
80.	4-Nitroaniline	100-01-6	50	1600
81.	4,6-Dinitro-2-methylphenol	534-52-1	50	1600
82.	N-Nitrosodiphenylamine	86-30-6	10	330
83.	4-Bromophenyl phenyl ether	101-55-3	10	330
64.	Hexachlorobenzene	116-74-1	10	330
65.	Pentachlorophenol	87-66-5	50	1600
86.	Phenanthrene	85-01-8	10	330
87.	Anthracene	120-12-7	10	330
88.	Di-n-butylphthalate	84-74-2	10	330
89.	Fluroanthene	206-44-0	10	330
90.	Benzidine	92-87-5	50	1600
91.	Pyrene	129-00-0	10	330
92.	Butyl benzyl phthalate	85-68-7	10	330
93.	3, 3'-Dichlorobenzidine	91-94-1	20	660
94.	Benzo (a) anthracene	56-55-3	10	330
95.	Bis (2-ethylhexyl) phthalate	117-81-7	10	330
96.	Chrysene	218-01-9	10	330
97.	Di-n-octyl phthalate	117-844	10	330
98.	Benzo (b) fluoranthene	205-99-2	10	330
99.	Benzo (k) fluroanthene	2074)6-9	10	330
100.	Benzo (a) pyrene	50-32-8	10	330
	Pesticides^{e,f}			
101.	Ideno (1, 2, 3-cd) pyrene	193-39-5	10	330
102.	Dibenz (a, h) anthracene	53-70-3	10	330
103.	Benzo (g,h,i) perylene	191-24-2	10	330
104.	Alpha-BHC	319-84-6	0.05	2.0
105.	Beta-BHC	319-85-7	0.05	2.0
106.	Delta-BHC	319-86-8	0.05	2.0
107.	Gamma-BHC (lindane)	58-89-9	0.05	2.0
108.	Heptachlor	76-44-8	0.05	2.0
109.	Aldrin	309-00-2	0.05	2.0
110.	Heptachlor epoxide	1024-57-3	0.05	2.0

Exhibit 7A-2
(continued)

			Estimated Detection Limits*, **	
	Pesticides[e],[f]	CAS Number	Water µg/1	Soil/Sediment µg/kg
111.	Endosulfan I	959-98-8	0.05	2.0
112.	Dieldrin	60-57-1	0.10	4.0
113.	4,4' -DDE	72-55-9	0.10	4.0
114.	Endrin	72-20-8	0.10	4.0
115.	Endosulfan II	33213-65-9	0.10	4.0
116.	4,4' -DDD	72-54-8	0.10	20.0
117.	Endrin aldehyde	7421-934	0.10	20.0
118.	Endosulfan sulfate	103147-8	0.10	40.0
119.	4,4' -DDT	50-29-3	0.10	20.0
120.	Endrin ketone	53494-70-5	0.10	20.0
121.	Methoxychlor	72-43-5	0.5	20.0
122.	Chlordane	57-74-9	0.5	20.0
123.	Toxaphene	8001-35-2	1.0	20.0
124.	AROCLOR-1016	12674-11-2	0.5	40.0
125.	AROCLOR-1221	11104-28-2	0.5	40.0
126.	AROCLOR-1232	11141-16-5	0.5	
127.	AROCLOR-1242	53469-21-9	0.5	
128.	AROCLOR-1248	12672-29-6	0.5	
129.	AROCLOR-1254	11097-69-1	1.0	
130.	AROCLOR-1260	11096-82-5	1.0	

---

[a] Medium Water Contract Required Detection Limits (CRDL) for Volatile Target Compound List (TCL) Compounds are 100 times the individual Low Water CRCL.

[b] Medium Soil/Sediment CRDL for Volatile TCL Componds are 100 times the individual Low Soil/Sediment CRDL.

[c] Medium Water CRDL for Semi-Volatile TCL Compounds are 100 times the individual Low Water CRDL.

[d] Medium Soil/Sediment CRDL for Semi-Volatile TCL Compounds are 60 times the individual low Soil/Sediment CRDL.

[e] Medium Water CRDL for Pesticide TCL Compounds are 100 times the individual Low Water CRDL.

[f] Medium Soil/Sediment CRDL for Pesticide TCL compounds are 60 times the individual Low Soil/Sediment CRDL.

* Detection limits listed for soil/sediment are based on wet weight. The detection limits calculated by the laboratory for soil/sediment, calculated on dry weight basis as required by the contract, will be higher.

** Specific detection limits are highly matrix dependent. The detection limits listed herein are provided. for guidance and may not always be achievable.

Exhibit 7A -3
INORGANIC ANALYSIS PROTOCOLS

PROTOCOLS FOR INORGANICS ANALYSIS – MOBILE LABORATORY AND FIXED-BASE LABORATORY

Metals: Approved EPA method for ICP, flame, flameless, or cold vapor atomic adsorption are used, provided that the required detection limits listed herein can be achieved. These methods are detailed in the CLP's *Scope of Work for Inorganic Analysis, Multi-Media, Multi-Concentration,* SOW No. 785, July 1985 (a new version is expected soon). However, perform digestion using a technique appropriate for the elements of concern. Perform analyses for the following elements:

aluminum
antimony
arsenic
barium
beryllium
cadmium
calcium
chromium
cobalt
copper
cyanide
iron
lead
magnesium
manganese
mercury
nickel
potassium
el m
silver
sodium
thallium
vanadium
zinc

Cyanide: Use approved EPA method that meets the detection limits required herein, as specified in CLP SOW No. 785

DETECTION LIMITS

For inorganic analyses, use the required detection limits for soils. Limits should be no higher than 100 times the required limits for waters, which are listed below. (However, it is understood that occasional interferences may prevent these limits from being achieved in every case. Provide documentation stating the reason(s) if these limits are not achieved.)

Element / Compound and Required Detection Limit in µg/l

aluminum	200	cobalt	50	nickel	40
antimony	60	copper	25	potassium	5,000
arsenic	10	cyanide	10	selenium	5
barium	200	iron	100	silver	10
beryllium	5	lead	5	sodium	5,000
cadmium	5	magnesium	5,000	thallium	10
calcium	5,000	manganese	15	vanadium	50
chromium	10	mercury	0.2	zinc	20

Exhibit 7A-3
(continued)

GENERAL QUALITY CONTROL

- Perform one matrix spike and matrix spike duplicate on all fractions for each matrix (water or soil). Spike with as many compounds as are currently in a stock mix, and report all levels found.
- Perform one laboratory (method) blank on all fractions for each matrix (water or soil).
- Homogenize solids carefully.

METALS ANALYSIS QUALITY CONTROL

- Whenever spike recoveries indicate that sample results for a particular metal may not be accurate, perform a standard addition on all samples (from one site) of the same matrix if the samples have positive results for this element. Use the control limits for spike recoveries as action levels for standard additions that must not exceed 60 to 140 percent. Report standard addition corrected results with a footnote that indicates this fact.
- Before running any samples and thereafter at least once per shift, run an instrument blank followed by calibration for all metals.
- Run a calibration check standard after every 10 samples are run on an instrument. Recalibrate, if necessary, based upon control limits that must not exceed 80 to 120 percent. If ICP is used, run a QC standard at least twice per shift to check interelement interference correction. Interferent concentrations should be approximately 100 to 1,000 times higher than analyte concentrations.
- When results for calibration check standards or ICAP interference check standards fall outside of control limits (which must not exceed 60 to 140 percent), reanalyze all preceding samples (since the last check analysis) having positive results for the affected parameters. Reanalysis should occur after the problem has been corrected.

DELIVERABLES

- For each sample analyzed, provide a summary sheet containing the following information:
    - Site name
    - Sample number
    - Date received
    - Date analyzed
    - Analyst
- Report results for all samples, spikes, instrument, and method blanks. For each sample, list all compounds for which analyses were per formed with either the amount detected or the approximate detection limit next to each compound. Report results in mg/l or mg/kg. Do not perform subtraction of method or calibration blank values from sample results. Report quantitations to two significant figures.
- Report all matrix spike recoveries including amount added and recovered. If zero recoveries, check for a problem, and document the explanation in the results. Calculate and report the relative percentage of difference (difference divided by mean) for all matrix spike and matrix spike duplicate recoveries.
- Report the sample preparation weight / volume, the final analysis volume, and the injection volume for each sample and for each analytical fraction.
- Provide calibration check data for each sample run series. Report the true and measured concentrations of each analyte in the calibration checks.
- If ICP is used, provide results for all applicable interference check samples including true and measured concentrations of each analyte in the check sample.

Exhibit 7A-3
(continued)

- Report the type of analytical method used for each parameter analyzed, since different interferences occur with ICAP, Flame AA, and furnace methods.
- For each ICAP parameter, report the wavelength for measurement, together with a list of all known interfering elements and their approximate correction factors.

Receipt of results: Complete results and documentation (analysts' logbooks, calibration logs, daily activity logs, and all machine-generated documentation) must be received within 14 days of sample receipt for mobile laboratory analyses.

Verbal results for sample analyses will be provided upon request immediately following analysis; verbal results are simply an indication of the presence or absence of contaminants in samples.

Periodic analyses on EPA quality assurance check samples will be performed as established by data quality objectives and the QAPjP; results for these analyses will be reported in the same manner as any samples.

Exhibit 7A-4
OPERATING PROCEDURE FOR SRF ANALYSIS OF SOILS / TAILINGS WITH COLUMBIA SCIENTIFIC X-MET 840 ANALYZER

This procedure describes the use of the X-MET 840 X-ray fluorescence analyzer for analysis of heavy metals in solid samples.

1.0 EQUIPMENT

1. X-MET 840 XRF analyzer electronic unit.
2. HEPS sample probe, either Cm-244 or Am-241 radioisotope source, or both.
3. Distribution box (optional) for analysis requiring both probes.
4. Pure element standards, one for each element present within the samples to be analyzed.
5. Sample calibration standards.
6. Sample cups, polyethelene film, and scissors (included in unit storage box).
7. Automatic pulverizer, or mortar and pestle, for grinding samples to a powder.
8. Oven and aluminum pans for drying samples.
9. Acid-rinsed silica sand for cleaning grinding equipment.
10. Plastic sampling spoons.
11. Plastic vials (50 dram).

2.0 SAMPLE PREPARATION

This procedure describes the method of preparing both samples and calibration standards for analysis with the X-MET 840.

2.1 Drying

In order to avoid analytical errors due to moisture content (a matrix effect) of all samples must be dried in the same manner.

2.1.1 Spread sample evenly in the aluminum pan. It is important that the sample in the pan be as homogeneous as possible and that all large chunks be broken up.

2.1.2 Place pan with sample in an oven and dry at 300°F for approximately 20 min., or until moisture is removed. Alternatively, samples may be dried in direct sunlight.

Exhibit 7A-4
(continued)

2.2 Subsampling

It is recommended that the entire sample be ground to avoid sampling error due to nonhomogeneity. However, if this is not possible, sampling error may be minimized by selection of a representative portion of the sample in the pan. With the use of a plastic spoon, remove one or more pie-shaped sections and place into the grinding apparatus.

2.3 Grinding

It is important that all samples be ground in the same manner. Analytical error due to differences in particle size can be substantial.

2.3.1 Samples should be ground with a portable hammer mill or, alternately, a mortar and pestle, until of equal consistency.

2.3.2 The grinding equipment must be cleaned (decontaminated) by grinding with silica sand. Liquid solvents should not be used.

2.4 Use of sample cups

2.4.1 Turn cup over and cover bottom with polyethelene film. Snap ring over film and onto bottom of cup. Cut cup free of film with scissors.

2.4.2 Trim excess film from edges of cup and check for holes or wrinkles. If the film is not completely smooth, or wrinkles cannot be removed, repeat the procedure.

2.4.3 Place sample in cup using a plastic spoon. Cups should be at least 3/4 filled with sample. Pack sample into cup until bottom (at film surface) is as smooth as possible. Brush away loose powder from outside edges of cup with a small brush to avoid contamination of the probe.

2.5 Note: Analysis with the X-MET requires only about 5 grams of sample. However, a minimum of approximately 40 grams is required for complete metals analysis by AAS or ICP techniques. Therefore, a minimum of 45 grams should be ground: 40 grams for verification and/or referee analyses and 5 grams retained for X-MET analyses. This is not critical if the entire sample is ground.

2.6 Ground powders should be stored in labeled plastic vials (50 dram).

3.0 PREPARATION FOR OPERATION

This procedure must be followed prior to both calibration (Section 4.0) and/or measurement (Section 5.0).

3.1 Power Supply

Connect the X-MET electronic unit to a suitable power source, either A.C. power, charged battery pack, or 12 volt battery. (**Note:** the unit will operate for approximately 8 hours on a fully charged battery pack).

3.2 Probe Connection

Connect probe cable to PROBE connector on bottom left of front panel. If more than one probe is to be used, they must be connected via the distribution box. (**Note:** Never connect / disconnect probe while the electronic unit is ON; this may damage the probe).

3.3 Switch ON

Turn the unit on by pressing the ON button. The display should then read: SELF TEST COMPLETED followed by the"" prompt and "_"cursor" indicator. The "" prompt indicates the ready (quiescent) state. (**Note:** Before switching the instrument OFF it should be returned to the quiescent state).

3.4 Electrical and Thermal Stabilization

Allow the unit to stabilize for approximately 30 min., prior to any measurements. Stabilization time is required to allow the X-MET to adjust to its surroundings. At least 1 min., of stabilization time should be allowed for each 1 deg F temperature change. (**Note:** When using 2 or 3 probes via the distribution box, electrical stabilization occurs simultaneously for all probes).

Exhibit 7A-4
(continued)

3.5 Gain Control

Each probe should be allowed at least 5 min., for gain control operation. Gain control takes place automatically when the unit is in the quiescent state ("" prompt) and the probe shutter is closed (lid open and green light on).

3.5.1 If the display reads: UNINITIALIZED PROBE, then no initial value have been entered for gain control and an instrument calibration must be performed before proceeding further.

3.5.2 Gain control parameters may be checked and/or changed via the maintenance set of programs () refer to Section 9.0).

3.5.3 The unit should be left ON between measurements with probe shutter closed for continuous gain control operation.

3.5.4 When more than one probe is being used, each must be allowed separate gain control operation.

3.6 Update Normalization Factors

Due to continual decay of the radioactive source in the probe, it may be necessary to check and/or update the pure element normalization factors. This is not usually necessary unless a significant amount of time has elapsed between successive uses of the instrument.

3.6.1 Select approximately the same time as in the previous normalization. Key in the NOR command. The display should read: NORMALIZING SAMPLE? Enter the element symbol for which normalization is desired. The display should now reads: MEASURE. Place the corresponding pure element standard in position in the probe, open the shutter (close the lid) and measure (press START button).

3.6.2 If the relative deviations between old and new normalization factors are less than about 3%, or if the new measurements are statistically equal to each other, measurements can begin; otherwise, a new instrument calibration is required before proceeding.

4.0 CALIBRATION

The calibration procedure programs the X-MET 840 for the desired application. The elements to be analyzed are defined by setting up element channels (or windows) using the pure element standards. Concentrations of elements are established by measuring known calibration standards and calculating calibration coefficients using multiparameter regression analysis. There are eight separate calibration memories or "models". In each model, 1 to 10 element channels can be set up.

Figure 1 shows a diagram summarizing the main steps in the calibration procedure. Because of the complexities involved, only a brief description of the process is given here (refer to the operating manual for a more detailed discussion).

4.1 Instrument Calibration

Instrument calibration encompasses gain control initialization and stabilization, choice of elements, and pure element measurements. The choice of elements to measure depends on knowledge of their concentrations in the samples to be analyzed and their suspected degree of spectral interference. Once the appropriate pure elements have been selected, follow Sections 2.0 (Preparation for Operation) and 5.0 (Measurement). Pure element calibration is initiated through the PUR or CPU commands.

4.2 Sample Calibration

Sample calibration includes measurement of calibration standards (CAL command), input of calibration standard concentrations (ASY command), and calculation of calibration coefficients (MOD command). Calibration coefficients may also be calculated externally and entered via the PAR command. Follow Sections 2.0 (Preparation of Operation) and 5.0 (Measurement).

Exhibit 7A-4
(continued)

4.3 Number of Calibration Standards

The number of calibration standards depends on two factors: number of elements to be analyzed and number of interfering elements. Spectral overlap between elements is automatically corrected for through measurement of the appropriate pure element standards and selection of channel limits. Correction of matrix effects due to absorption or enhancement of fluorescent x-rays requires statistical evaluation. If a one-to-one correlation between element concentration and x-ray intensity (linear regression) is determined, the number of necessary calibration standards may be small. Matrix effects due to the presence of interfering elements, on the other hand, may require the use of multiple regression analysis, and the number of calibration standards necessary may increase (refer to Table 1).

5.0 MEASUREMENT

This section describes the measurement of either standards (calibration or pure element) or samples.

5.1 Select the appropriate model by pressing the MODEL function key, typing in the desired model (1-8), and pressing the CONT/YES editing key.

5.2 Select the appropriate measurement time by pressing the MTIME function key, typing in the desired time in seconds, and pressing the CONT/YES editing key. (**Note:** Measurement times may range between 1 and 32,767 seconds and it is not necessary that sample measurement times be the same as calibration measurement times.)

5.3 Place sample to be measured in the sample holder in the appropriate probe. Close the lid (green light should go out) and press START button. The screen should now indicate the remaining measurement time. At the end of measurement, an audible signal (three short tones) is given and the results displayed. Raise the probe lid and remove the sample.

5.4 If the sample is to be run again with another probe connected via the distribution box, turn the probe indicator switch to that probe and repeat steps 5.1 through 5.3.

5.5 To re-display the results of the previous run, press the RECALC button. If calculations are desired for the previous run under a different model, first change to the desired model (see Section 5.1) and then press RECALC.

TABLE 1
RECOMMENDED MINIMUM NUMBER OF CALIBRATION SAMPLES VERSUS NUMBER OF ELEMENTS TO BE ANALYZED AND NUMBER OF INTERFERING ELEMENT (INTENSITIES)

	Number of Elements					
Intensities	1	2	3	4	5	6
1	5	5	10	15	30	30
2	5	5	10	15	30	30
3	5	10	10	15	30	30
4	5	15	15	15	30	30
5	5	30	30	30	30	30
6	5	30	30	30	30	30

Exhibit 7A-4
(continued)

Figure 1 – Summary of calibration procedure

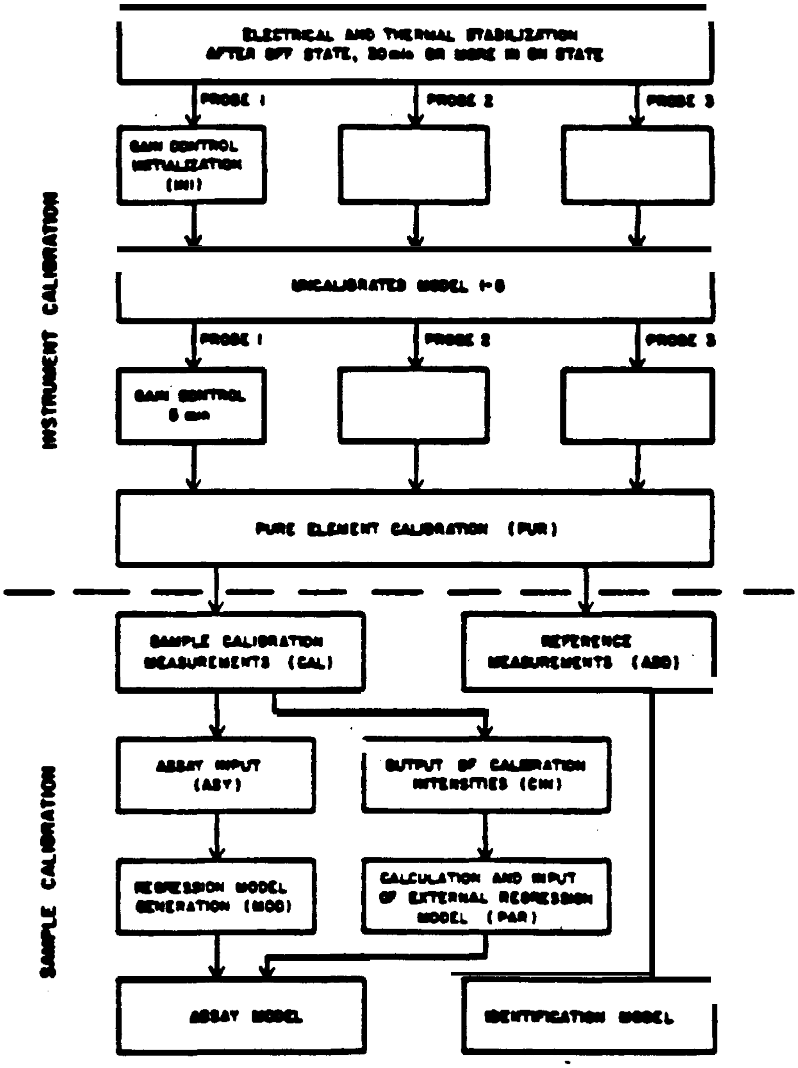


Exhibit 7A-4
(continued)

6.0 QA/QC

6.1 Quality Control

Throughout the analysis, midpoint standards should be re-checked after an average of approximately five sample runs. Analyses are generally considered to be out of control when values obtained for the check standards are outside ±3 standard deviations of their "true" value. The instrument is then recalibrated and the previous samples rerun.

6.2 Instrumental Precision and Detection Limit

The standard deviation of counting statistics (STD command) can be considered a very close approximation of instrumental precision. True instrumental precision is obtained by repetitive measurements of a sample. As a general rule, the detection limit may be established as three times the instrumental precision. (**Note:** Instrumental precision can be increased and thus detection limit lowered by increasing the number of calibration standards and/or the measurement time).

6.3 Sample Splits

Sampling error can be determined by running sample duplicates, or splits. Both field duplicates and splits from the sample pan (if applicable) should be run an average of one every 20 samples. To test for grinding error due to powder non-homogeneity, powder splits should also be run at the rate of one per 20 samples.

7.0 FUNCTION KEYS

Key	**Description**
START	Start measurement
MODEL	Select Model
MTIME	Select measurement time
RECALC	Recalculated assay in selected model
ON	Switch on
OFF	Switch off

8.0 EDITING KEYS

Key	**Description**
"<"	Delete keyboard entry
" "	Scroll backwards
SHIFT	Shift to upper case (if in lower case) or to lower case (if in upper case)
CONT/YES	Accept, continue or scroll forwards
END/NO	Reject, terminate or agree to negative question

9.0 COMMANDS

Key	**Description**
ADD	Add reference samples to identification library
ASY	Enter assays of calibration samples
CAL	Measure calibration samples
CIN	Output calibration sample intensities
CMS	Measure repeatedly (continuously)
CPU	Transfer or continue instrument calibration
DEL	Delete model
DTM	Display time and date
EMP	Enter maintenance programs (with PRM)
INI	Initialize gain control
INT	Output net count rates of channels
LIM	Examine and edit channel limits
	Output normalization factors
LOC	Lock the keyboard
MOD	Regression modeling

Exhibit 7A-4
(continued)

NOR	Normalization
PAR	Enter and edit calibration coefficients
PUL	Output gross count rates of element channels
PUR	Instrument ("Pure Element") calibration
PRM	Instrument Calibration Parameters (with EMP)
REF	Referencee sample examination and editing
SPE	Output spectra
SPL	Plot spectra
STD	Output standard deviation (counting statistics)
STM	Set time and date
TCR	Output total count rate
UNL	Unlock keyboard

10. REFERENCES

Columbia Scientific Industries Corp. 1985. Operating Instructions X-Met 840 Portable XRF Analyzer.

SECTION 8

EARTH SCIENCES

Note: Because the scope of this section Is large, the section is organized by topics; the most pertinent topics, In order, areas follows:

Appendixes 8.4A to 8.4E contain detailed discussion of the theory of geophysical Instruments.

Each of the topics is organized into subsections on applications and limitations. These subsections follow the general compendium format.

8.1 GEOLOGIC DRILLING

8.1.1 Scope and Purpose

This subsection provides general guidance for the planning, method selection, and implementation of geologic drilling and subsurface soil sampling for field Investigations of hazardous waste sites.

8.1.2 Definitions

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

Soils

"The collection of natural bodies on the earth's surface, in places modified or even made by man of earthy materials, containing living matter and supporting or capable of supporting plants out-of-doors. The lower limit is normally the lower limit of biological activity, which generally coincides with the common rooting of native perennial plants" (Glossary of *Geology*, 1972, p. 671). Typically, soils at a hazardous waste site are defined as the weathered material located above bedrock; thus, soil sampling can occur to depths of many feet.

8.1.3 Applicability

Although this subsection focuses on drilling for sarmpling purposes, it is important to recognize that borings are also required for in situ testing of subsurface materials and groundwater, and to allow installation of monitoring devices including wells.

Selection of the most appropriate method or combination of methods must be dictated by the special considerations imposed by multipurpose borings. For example, although the best apparent method for well installation at a particular site may be direct air rotary with driven casing, most air rotary equipment allows sampling only by cuttings. if, in this case, soil sampling is required, pilot (or separate) borings done with equipment capable of providing adequate undisturbed samples maybe necessary. In addition, if drilling is to be conducted in an area of perched or multiple aquifer systems, auger techniques should not be used because of the possibility of cross contamination; borings must be advanced using multiple casing techniques that allow isolation of each aquifer encountered.

Examples of such optimization of techniques are too numerous to be thoroughly covered in this section, but the general applicability of various methods Is discussed. Routine soil drilling and sampling techniques are discussed. Specialized techniques that may be applicable only under unusual conditions are not presented.

The planning, selection, and Implementation of any drilling program requires careful consideration by qualified, experienced personnel. At a minimum, the following general steps are required:

- Review of existing site, area, and regional subsurface, geologic, and hydrogeologic Information including physical and chemical characteristics
- Development of a site-specific health and safety program
- Definition of the purpose of the drilling and sampling, selection of drilling methods and general site layout, and preparation and execution of the drilling contract
- Field implementation and decontamination including continuous Inspection by qualified, experienced personnel
- Reporting

Selection and implementation of soil drilling and sampling methods also require that specific considerations be given to the following Issues, which are common to all drilling at or near hazardous waste sites:

- Prevention of contaminant spread
- Maintenance of sample integrity
- Minimization of disruption of existing conditions
- Minimization of long-term impacts

8.1.4 Responsibilities

The SM is responsible for determining that the soil drilling and sampling techniques being used are appropriate to the site conditions and drilling objectives. . ,

8.1.5 Records and inspection

All drilling and sampling activities should be continuously inspected by qualified, experienced personnel. Continuous inspection is essential to assure that the intent of the drilling program is being followed and to provide knowledgeable direction to the field crews when conditions dictate variance from the original plan.

Inspection personnel should prepare daily reports that include the following:

- Activity logs or field notebooks
- Boring logs
- Sample documentation

Reporting Is essential to adequately document the unusual site conditions, the drilling and sampling quantities, and the personnel onsite for project control and to thoroughly document technical methods and results.

8.1.6 Procedures

The following methods should be considered for application at various sites. Exhibit 8.1-1 presents a summary of advantages, disadvantages, and depth limitations of various drilling techniques.

8.1.6.1 Drilling Procedures

8.1.6.1.1 Hand Augers

Description: The most commonly used manually operated augers include the Iwan, ship, closed-spiral, and open-spiral augers. In operation, a hand auger is attached to the bottom of a length of pipe that has a crossarm at the top. The hole Is drilled by turning this crossarm at the same time the operator presses the auger into the ground.

As the auger is advanced and becomes filled with soil, it is taken from the hole, and the soil Is removed. Additional lengths of pipe are added as required. The Iwan, a post-hole type of auger, generally retains sample material better than the other hand-operated augers. Hand augers of the type mentioned are shown in Exhibit 8.1-2.

Application: In general, hand-operated augers are useful for sampling all types of soils except cohesionless materials below the water table and hard or cemented soils. The ship auger, with a helical flight on a solid stem, is best suited for use in cohesive materials. Spiral augers were developed for use in those cases in which helical and screw augers do not work well. The dosed-spiral auger Is used in dry day and gravelly soils. The open-spiral auger is most useful In loosely consolidated deposits.

The Iwan auger is available in diameters ranging from 3 to 9 inches. The other types of augers are available in diameters ranging from approximately 2 to 3.5 inches.

Auger borings are used primarily in cases In which there Is no need for undisturbed samples and in which the drilling will be done in soils where the borehole will stay open without casing or drilling mud, generally above the ground water table. The high mobility of the equipment makes the hand auger ideally suited for sites with impaired access.

Exhibit 8.1-1
DRILLING PROCEDURES SUMMARY

Drilling Technique	Depth Limitation (ft)	Advantages	Disadvantages
Hand Auger	30	Mobility	Not useful in unconsolidated material below water table. Not useful in cemented material. Limited application in gravelly material. Mixed samples.
Power-Assisted Hand Auger	80	Same as above.	Same as above.
Power Auger Hollow-Stem	300 ±	Ease of soil sampling. No fluids required.	Not good in caving formations or those containing boulders. Not useful when undisturbed soil samples are required.
Solid-Stem	100		
Bucket and Disk		Holes up to 3 ft + in diameter. Shallow holes above water table.	
Cable Tool	1,000 +	Low drilling fluid requirements. Good definition of water-bearing zones. Good in caving, high-gravel content material. Good formation in samples.	Slow. Not good for small-diameter wells. Must drive casing following bit.
Mud Rotary	5,000 +	Good cutting samples. Can leave hole open during drilling Rapid drilling.	Mud may plug permeable zones. Not effective in boulder-rich sediments. Not acceptable to EPA control of drilling fluids. Lost circulation.
Air Rotary	5,000 +	Fast in consolidated formations. No drilling liquids introduced into well.	Small cuttings. May be "watered out" in high-water zones. Containment of drilling return difficult.
Reserve Air-and-Mud or Water Rotary		Minimizes wellbore disturbance. Better cuttings removal	Same limitations as mud rotary. Best for holes > 12 inches.
Drive-and Wash			Limited to unconsolidated material. Slow. Large fluid volumes.

Limitations: Borings drilled with augers have the disadvantage that the samples are mixed and that, in general, it is difficult if not impossible to locate precisely the changes in soil strata. Augering does not case off the upper portion of the hole. if the walls collapse or slough, representative samples may be difficult to obtain.

The exact depth to which any hole can be carried is a function of the types of soil in the profile, the type of auger being used, the amount of power available to turn the auger, and the location of the groundwater table. Gravel larger than 2 cm impairs the use of hand augers. Hand augers are typically used for shallow (2 to 8 feet) depths but may reach a maximum depth of 30 feet In unsaturated, unconsolidated material. These augers typically are not used for boring more than a few feet below the water table. Power assists have been added to hand auger systems to increase depth capability without substantially decreasing mobility.

8.1.6.1.2 Powered Augers

Description: A powered auger is motordriven and is advanced by a helical worm with sections that can be screwed together. Three types of powered augers (which are discussed later) are hollow-stem, solid-stem, and bucket augers. The augers themselves are available in sizes ranging from 2 to 48 inches in diameter. The auger can be either hand held or rig mounted (Exhibit 8.1-3). The rig is self-sufficient and generally does not require additional lifting devices, although a simple hoist and tripod is useful In holes more than 10 feet deep.

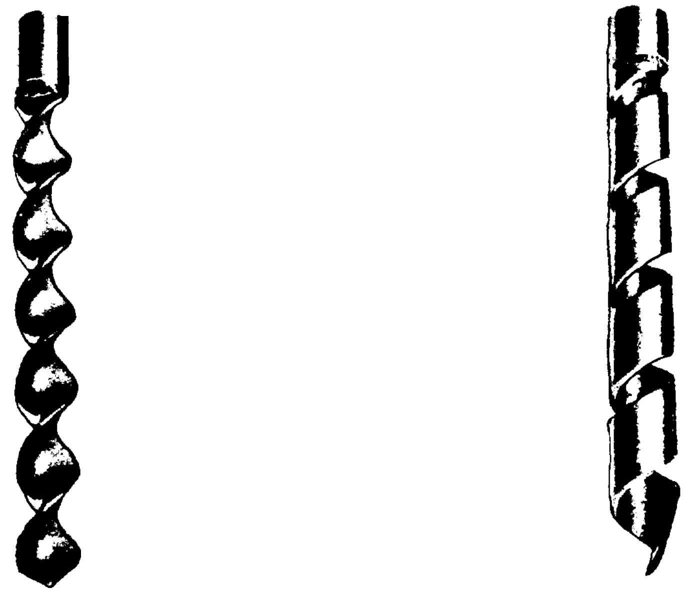
Auger flights are available in several types depending on their intended use. These consist of single-flight earth augers, double-flight earth-rock augers, double-flight rock augers, and high-spiral augers (Exhibit 8.1-4). In operation, these augers are attached to a drilling rod, which is rotated and pressed downward to achieve penetration. The rod with the auger is advanced for the distance of the flight or until the flight has become filled with soil. The rod is then raised until the auger is clear of the hole, and the soil is thrown free from the cutter head. The hole is drilled by repeating this process until the required depth is reached. Two or four people can operate a powered auger.

Application: The maximum depth of penetration that can be achieved with powered augers is limited by the geologic material, the depth to water, and the length of the Kelly rod that can be accommodated by the drilling rig used. in general, the depth is limited to between 100 and 200 feet. The advantage of auger boring over wash boring, percussion, and rotary drilling is that the cuttings brought to the surface (although disturbed) are generally suitable for positive identification of the soil material but not for precise soil content. Using powered augers also makes it easier to determine the groundwater level. Casing is not generally needed, except when drilling through noncohesive sand and gravel and sometimes when drilling below the water table. Drilling practice has shown that, where applicabie, powered auger drilling is preferable to many other methods because the work progresses fast in drilling holes not deeper than 100 feet (when undisturbed samples are not required).

8.1.6.1.3 Hollow-stem Augers (Helical Augers)

Description: Hollow-stem augers (Exhibit 8.1-5) are a type of powered auger used primarily to advance the borehole when soil sampling is required. The hollow-stem auger consists of (1) a section of seamless steel tube with a spiral flight to which are attached a finger-type cutter head at the bottom and an adapter cap at the top, and (2) a center drill stem composed of drill rods to which are attached a center plug with a drag bit at the bottom and an adapter at the top. The adapters at the top of the drill stem and auger flight are designed to allow the auger to advance with the plug in place. As the hole is drilled, additional lengths of hollow-stem flights and center stem are added. The center stem and plug may be removed at any time during the drilling to permit disturbed, undisturbed, or core sampling below the bottom of the cutter head by using the hollow-stem flights as casing. This process also permits the use of augering in loose deposits below the water table. Where this technique is used in unconsolidated material

Exhibit 8.1-2
HAND AUGERS: (a) SHIP AUGER; (b) CLOSED-SPIRAL AUGER; (c) OPEN SPIRAL AUGER; (d) IWAN AUGER

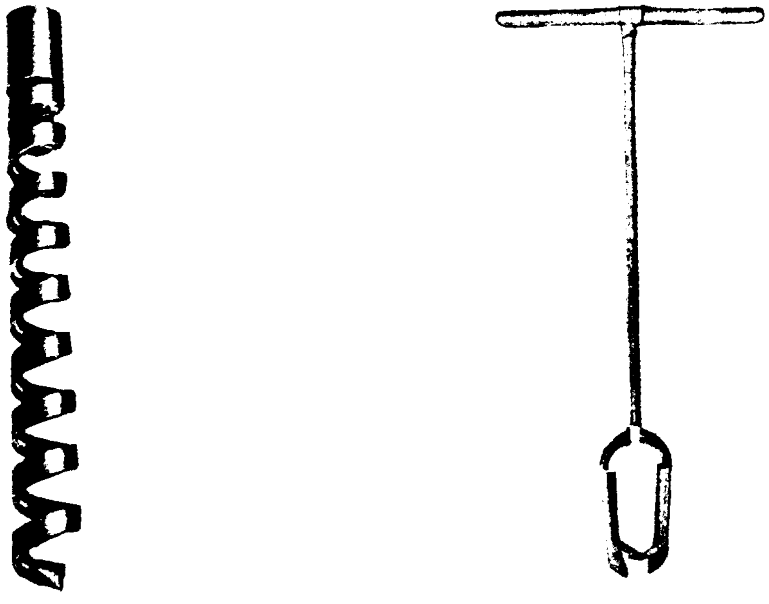


(a)

Ship Auger

(b)

Closed-Spiral Auger



(c)

Open-Spiral Auger

(d)

Iwan Auger

below the water table, fluids of known chemical quality maybe used to control groundwater inflow. Undisturbed samples taken in this manner maybe more useful than those taken from a cased hole, since the disturbance caused by advancing the auger is much less than that caused by driving the casing. Augers of this type are available with hollow stems having inside diameters from 2-3/4 to 6 inches.

Application: The use of hollow-stem augers is advantageous, because drilling fluids that need to be controlled and limited when advancing a borehole are used only under special circumstances. The augers also allow direct access for soil sampling through the hollow inner part of the auger stem.

The depths to which hollow-stem augers can bore are limited by the geologic formation and depth to groundwater. Hollow-stem augers are used primarily in formations that do not cave or have large boulders.

Upon reaching the desired depth, a small-diameter casing and screen can be set inside the hollow stem to produce a monitoring well. The augers are removed by section while the well screen and risers are held in place. Typically, one 5-foot section of auger is removed at a time. In incompetent formations, the borehole surrounding the screen may be allowed to cave around the screen, or a clean sand or gravel pack may be installed as the augers are withdrawn. Once the screen is properly covered (usually to 2 feet above the top of the screen), a clay (bentonite) seal is installed. As a final step, grout or other impermeable material is tremied in place on top of the clay seal to ground level as the remaining auger sections are removed. Careful installation of clay and/or grout seals is essential, especially in areas where multiple aquifers are encountered.

Allowing the formation to collapse around the well may damage the screen and/or risers. Depending on formation material, sand or gravel pack may provide a better peforming well. Gravel packing may require a slightly larger hollow-stem auger but maybe worth the effort.

8.1.6.1.4 Solid--stern Augers

Description: Solid-stem augers (Exhibit 8.1$ area type of powered auger that is advanced into the ground by the rotation and downward pressure of a rotary drill rig. These augers have interchangeable heads or bits for use in various types of soil.

As the solid-stem auger is advanced into the ground, new auger sections are added. Auger borings may be advanced to a depth of about 100 feet, depending on the soil conditions encountered. Casing may be used to prevent caving in of unstable soil, especially below the water table, when the auger is removed for sampling or placement of a monitoring well.

The soil displaced by the auger is transported to the surface by the auger blade. This soil shows the general type of material through which the auger is passing, but definite determinations cannot be made about the depth from which the soil was excavated or about the soil structure.

Solid-stem augers are most efficient in advancing a boring in moist, cohesionless soils with some apparent cohesion and in medium-soft to stiff cohesive soils. These augers are not well suited for use in very hard or cemented soils, very soft soils, or saturated cohesionless soils.

Application: Borings advanced with solid-stem augers are not useful when it is necessary to obtain undisturbed samples of soil material or to determine the location of soil contacts. Under ceterain conditions, solid-stem auger borings are useful in providing holes for monitoring well installation. It should be noted that it is almost impossible to drill through a contaminated soil zone with a solid- stem continuous-flight auger without downward transport of contaminants.

Exhibit 8.1-3
RIG-MOUNTED POWERED AUGER

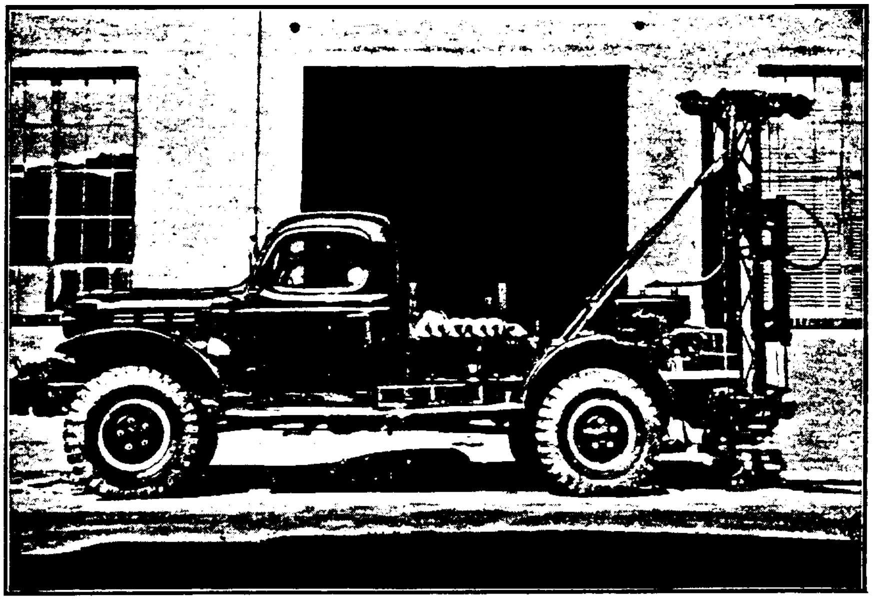
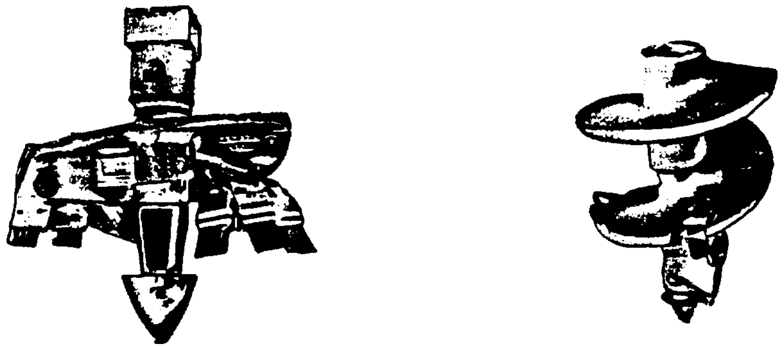


Exhibit 8.1-4

AUGERS: (a) SINGLE-FLIGHT EARTH AUGER; (b) DOUBLE-FLIGHT EARTH-ROCK AUGER; (C) DOUBLE-FLIGHT ROCK AUGER; (d) HIGH-SPIRAL AUGER.

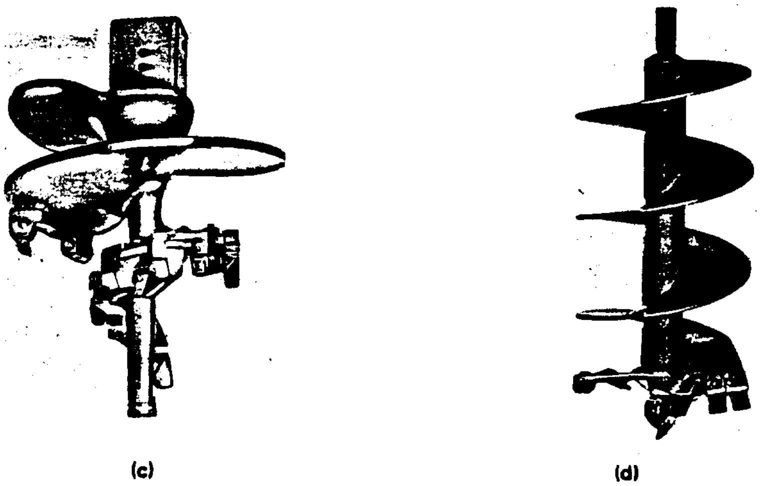


(a)

Single-Flight Earth Auger

(b)

Double-Flight Earth-Rock Auger



(c)

Double-Flight Rock Auger

(d)

High-Spiral Auger

Exhibit 8.1-5
KECK-SCREENED, HOLLOW-STEM, CONTINUOUS-FLIGHT AUGER

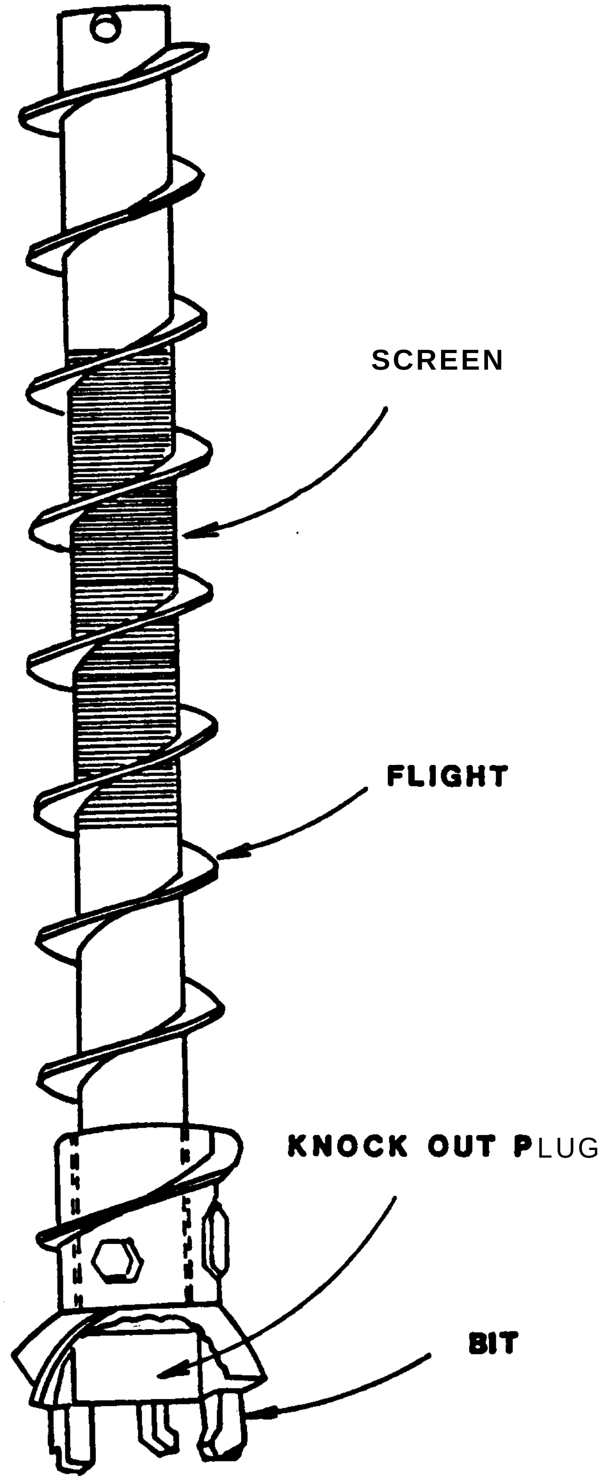
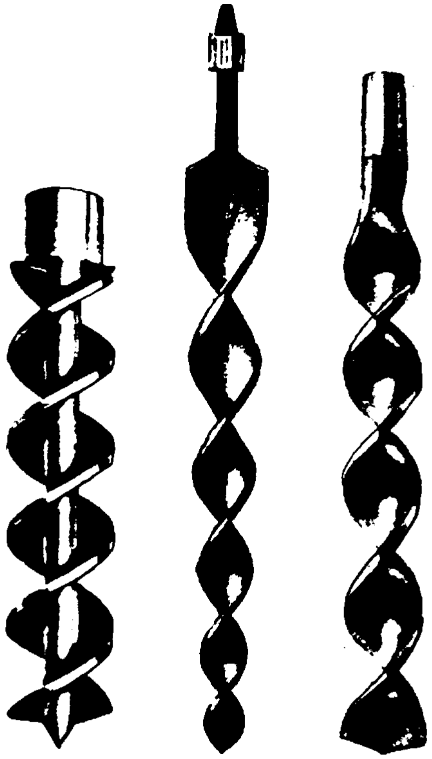
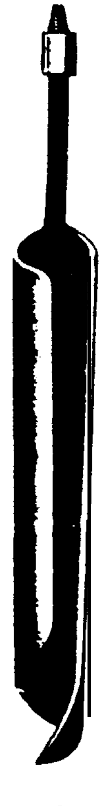


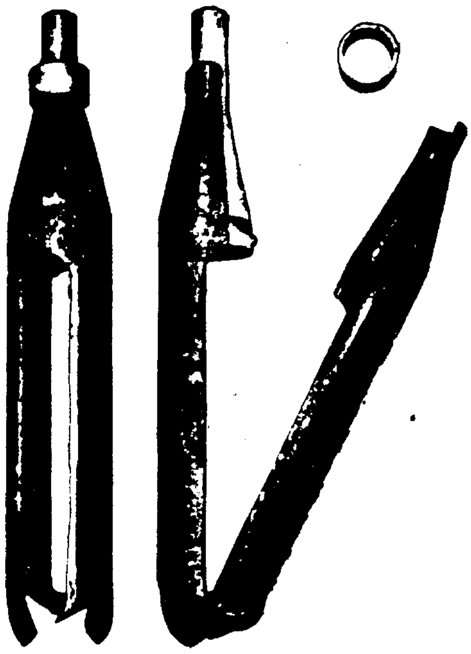
Exhibit 8.1-6
SOLID-STEM AUGERS



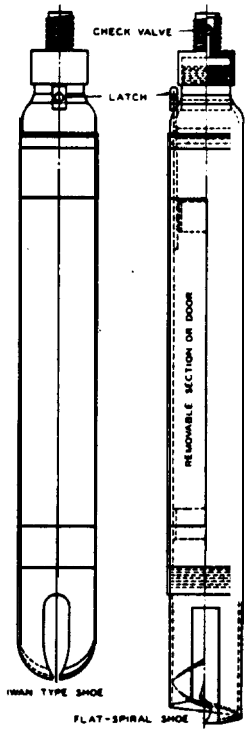
Large Helical or Worm-Type Augers



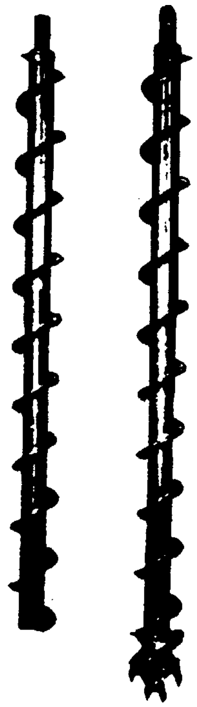
Spoon Auger



Vicksburg Hinged Augers



Sprague & Henwood Barrel Augers



Buda Continuous Helical Augers

8.1.6.1.5 Bucket Augers and Disk Augers

Description: The bucket auger is a type of powered auger that consists of a cylindrical bucket 10 inches to 72 inches in diameter with teeth arranged at the bottom. The bucket is fastened to the end of a Kelly bar that is rotated and pushed downward. The bucket is then filled, brought to the surface, and emptied by tipping it over. Bucket holes more than 3 feet in diameter may be drilled using a special attachment. These wide holes permit visual inspection and direct sampling by a person lowered into the hole. Disk augers are similar to helical augers but are larger and are used to make larger holes. Helical and disk augers are shown in Exhibit 8.1-7. Large-diameter casing can be used to keep holes open in noncohesive material.

Application: These methods of augering are used if the boreholes are relatively shallow and above the water table. The methods are very rapid if boulders are not encountered.

8.1.6.1.6 Cable Tools

Description: A cable tool rig uses a heavy, solid-steel, chisel-type drill bit suspended on a steel cable that, when raised and dropped, chisels or pounds a hole through the soil and rock. Cable tool drilling is also commonly referred to as percussion drilling or churn drilling. Required equipment includes a drilling rig, a drill stem, percussion bits, and a bailer. Casing is needed when advancing a hole through soft, caving materials. Cable tool drilling equipment is shown in Exhibit 8.1-8.

Application: Cable tool rigs can operate satisfactorily in all formations, but they are best suited for large, caving, gravel-type formations with cobbles or boulders or for formations with large cavities above the water table. The use of cable tool rigs for small diameter (2-inch) wells is not recommended.

Information regarding water-bearing zones can be easily obtained during cable tool drilling. Relative permeabilities and some water quality data can be obtained from different zones penetrated if a skilled operator is available. Formation samples can be excellent when a skilled driller uses a sand pump bailer.

In hazardous waste applications, contaminated materials can be closely controlled through periodic bailing and through containment of suspended cuttings. Some water is required to replace water removed by bailing in unsaturated zones, but the water requirements for this method of drilling are generally low.

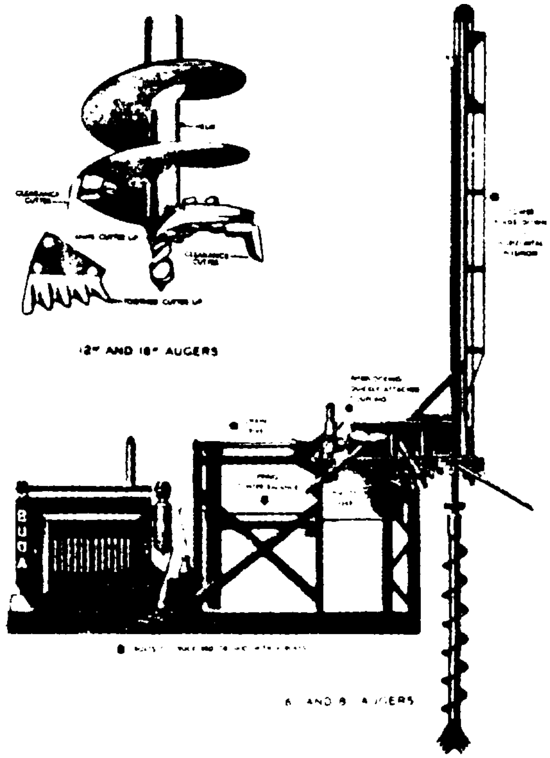
Limitations: Cable tool drilling is slow compared with rotary drilling. The necessity of driving the casing along with drilling in unconsolidated formations requires that the casing be pulled back to expose selected water-bearing zones. This process complicates the well completion process and often increases cost. Relatively large-diameter (at least 4 inches) casing is required, which increases the costs when compared with rotary-drillied wells with plastic casing. The casing, which has a sharp, hardened casing shoe on the bottom, must be driven into the hole. The shoe cuts a slightly larger hole than does the drill bit, and it can not be relied onto form a seal when overlying water-bearing zones are encountered.

With some types of cable tool drilling equipment, it maybe difficult to reach some sites that are steep or marshy.

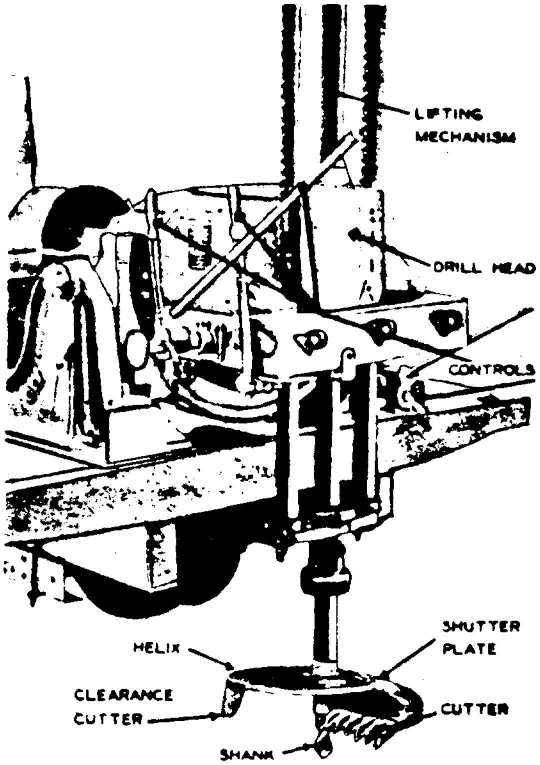
8.1.6.1.7 Mud and Water Rotary Drilling

Description: In rotary drilling, the borehole is advanced by rapid rotation of the drilling bit, which cuts, chips, and grinds the material at the bottom of the hole into small particles. The cuttings are removed by pumping water or drilling fluid from a sump down through the drill rods and bit and up the annulus between the borehole wall and the drill rods. This water flows first into a settling pit and ultimately back to the

Exhibit 8.1-7
HELICAL AND DISK AUGERS

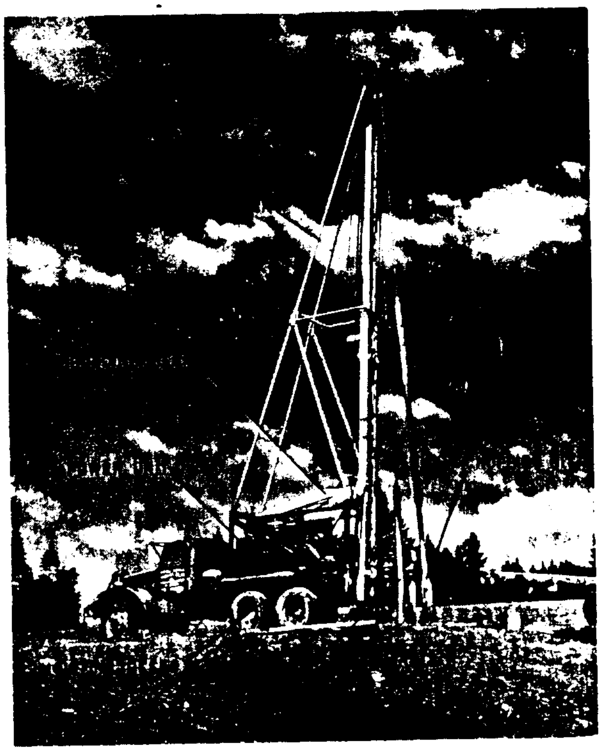


Buda Earth Drill with Continuous Helical Augers



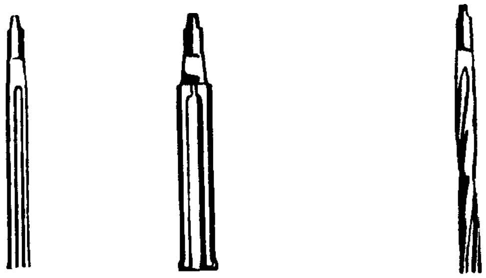
Buda Earth Drill with Disk Auger

Exhibit 8.1-8
CABLE TOOL (PERCUSSION) DRILLING EQUIPMENT



Drilling Rig

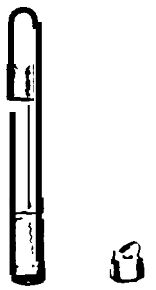
Drill Stem



Regular Mother Hubbard Twisted Mother Hubbard

Chopping Bits

Drill Jar

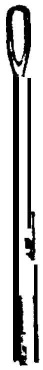


Bailer Valve

Flat Valve Bailer

Bailer Valve

Dart Valve Bailer



Rod Plunger Type
Sand Pump
with Regular Bottom

main pit for recirculation. Water alone may be used when the depth is small and the soil is stable. Drilling mud is sometimes preferred, since the required flow is smaller and the mud serves to stabilize the hole; however, the mud may clog permeable soil units. A sample should be collected of any material Introduced into the well (water, drilling mud, additives, etc.). The sample should be retained for future analysis if any question of contamination arises. A section of casing is used to start the hole, but the remaining part of exploratory boreholes advanced by rotary drilling is usually uncased except In soft soils.

When rotary drilling is used for exploratory borings, Items such as motors, rotary driving mechanisms, winches, and pumps, are generally assembled as a unit, with a folding mast mounted on a truck or tractor. The unit also may be mounted on intermediate skids so that it can be placed on a raft or moved Into places inaccessible to motor vehicles. A diagrammatic sketch of such a drilling rig Is shown in Exhibit 8.1-9. Skid mounted drilling machines can also be used for rotary drilling.

Many types of rotary drilling bits are used, depending on the character of the material to be penetrated. Fishtail bits and two-bladed bits are used In relatively soft soils and three-to four-bladed bits In firmer soils and soft rock. The cutting edges are surfaced with tungsten carbide alloys or are formed by special hard-metal inserts. The bits used in rock have several rollers with hard-surfaced teeth. The two-cone bits are used in soft or broken formations, but the tri-cone and roller bits provide smoother operation are are more efficient in harder rocks. The number of rollers and the number and shape of the teeth are varied in accordance with the character of the rock. Relatively few and large teeth are used in soft rock, and the teeth are intermitting so that the bit will be self-cleaning. The teeth in all bits are flushed by drilling fluid flowing out of vents in the base of the bit.

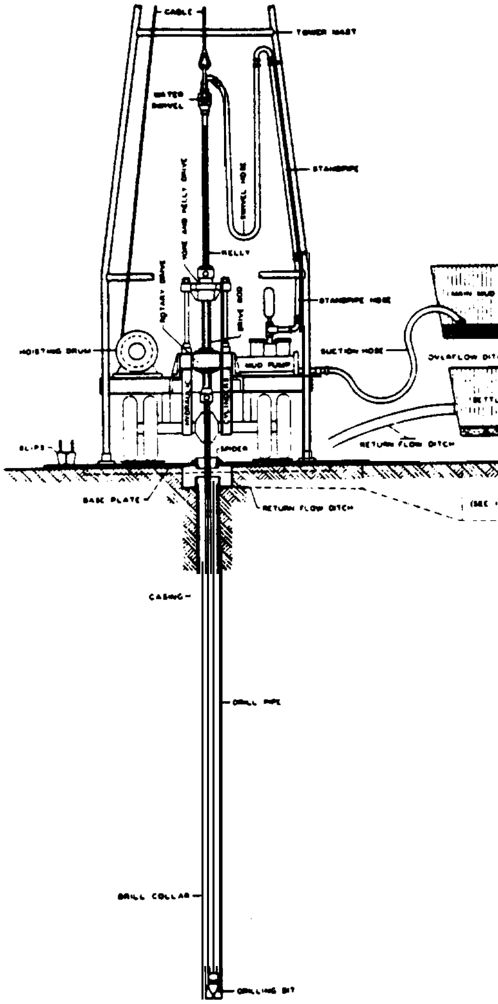
Boreholes produced by rotary drilling may be cased to provide stability. The drill rod and bit can be removed from the borehole, and a sampler can be lowered through the casing to remove soil from the bottom of the boring.

Uncased boreholes are often filled with water to stabilize the hole and to remove material ground up by the boring tools. Water will exert a stabilizing effect on the parts of the hole that extend below groundwater level; however, above the water table, the water may result In a loss of soil strength and a collapse of the hole. Water alone generally prevent neither caving of borings in soft or cohesionless soils nor a gradual squeezing-in of a borehole In plastic soils. Uncased boreholes filled with water are generally used in rock and are often used In stiff, cohesive soils.

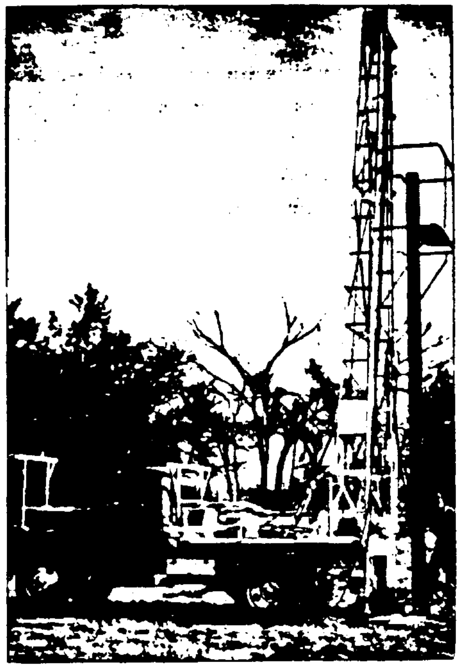
An uncased borehole can often be stabilized by filling it with a properly proportioned drilling fluid or “mud,” which, when circulated, also serves to remove ground-up material from the bottom of the hole. A satisfactory drilling fluid can occasionally be obtained by mixing locally available fat clays with water, but it is usually advantageous and often necessary to add commercially prepared drilling mud addatives. When suitable native clays are not available, the drilling fluid is prepared with commercial products alone. These mud-forming products consist of highly colloidal, gel-forming, thixotropic clays – primarily bentonite – with various chemicals added to control dispersion, thixotropy, viscosity, and gel strength. A sample of the drilling fluid should be analyzed to eliminate the possibility of introducing contamination into the borehole.

The stabilizing effect of the drilling fluid is caused in part by its higher specific gravity (in comparison with water alone) and in part by the formation of a relatively impervious lining or “mudcake” on the side walls of the borehole. This lining prevents sloughing of cohesionless soils and decreases the rate of swelling of cohesive materials. The drilling fluid also facilitates removal of cuttings from the hole. The required velocities and volume of circulation are smaller than for water alone, and the problem of uncontrolled erosion at the bottom of the hole is decreased. Furthermore, the drilling fluid is thixotropic; that is, it stiffens and forms a gel when agitation is stopped, and it can be liquified again by resuming the agitation. Drilling mud is, therefore, better able than water to keep the cuttings in suspension during the time required for withdrawal and reinsertion of boring and sampling teds. It also reduces abrasion and retards corrosion of these teds.

Exhibit 8.1-9
MUD AND WATER ROTARY DRILLING



Rotary Drilling



Truck-Mounted Rotary Drilling Rig

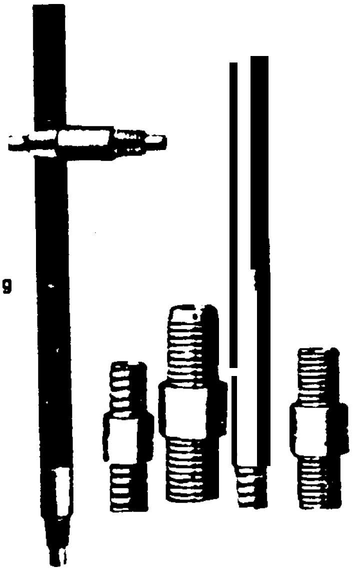
Water Swivel

Hoisting Plug

Two-Blade Bit Three-Blade Bit Four-Blade Bit

BLADED BITS

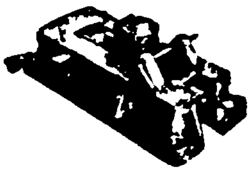
Fishtail Bit



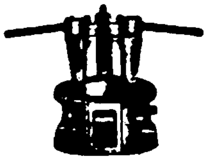
Drill Rods and Couplings

Two-Cone Bit Tri-Cone Bit Roller Bit

ROCK BITS



Safety Clamp



Spider and Slips

Application: Rotary drilling is best suited for borings with a diameter of not less than 4 Inches; a diameter of 6 to 8 Inches is generally preferred when the method is used for exploratory boring. In most soils and rocks, the rate of progress is greater than that of other methods. However, rotary drilling Is not well suited for use in deposits containing very coarse gravel, numerous stones and boulders, or chert nodules; in badly fissured or cavernous rock; or in very porous deposits with a strong groundwater flow, since an excessive amount of drilling fluid may be lost by seepage in such formations. Judicious selection of drilling mud additives and lost circulation material can ameliorate fluid loss problems. This method has a rapid drilling rate and generally can avoid placement of a casing by creating a mud lining on the wall of the well.

Major disadvantages of rotary drilling are as follows: (1) If not properly used, drilling fluids may introduce potential contaminants into the borehole; (2) a large amount of water needs to be controlled after use; and (3) the problem of lost circulation exists in highly permeable or cavernous geologic formations. The “filter cake” produced when drilling mud is used may reduce the permeability In water-bearing zones. Proper completion and well development can significantly lessen the adverse effect of filter cake and mud invasion into a formation.

When using the rotary drilling method for the Installation of monitoring wells, care must be exercised to prevent recirculation of potentially contaminated drilling fluids Into uncontaminated formations. In addition, during well development, drilling fluids must be thoroughly flushed from the borehole and the invaded zone to ascertain that samples collected are representative of true formation fluids.

8.106.1.8 Air Rotary Method

Description: Air rotary rigs operate in the same manner as mud rotary drills, except the air Is circulated down the drill pipe and returns with the cuttings up the annulus. Air rotary rigs are available throughout much of the United States and are well suited for many drilling applications. A variation of the air rotary method Is the air hammer method, which uses a pneumatic or percussion hammer that pulverizes rock and uses air to return cuttings to the surface.

Air rotary rigs operate best In hard rock formations. Formation water is blown out of the hole along with the cuttings, so it Is possible to determine when the first water-bearing zone is encountered, After filtering water blown from the hale, collection and field analysis may provide preliminary information regarding changes In water quality for some parameters. Where significant water Inflow Is encountered, foaming agents may be added to enhance the ability of the air stream to remove cuttings from the wellbore. Formation sampling ranges from excellent in hard, dry formations to nonexistent when circulation is lost In cavernous limestones and other formations with cavities.

Casing is required to keep the borehole open when drilling in soft, caving formations below the water table. When more than one water-bearing zone is encountered and where the hydrostatic pressures are different, flow between zones will occur between the time the drilling is done and the time the hole can be properly cased and one zone grouted off. Multiple casing strings can be used to rectify this problem, if necessary. Synthetic drilling aids are not usually used in air rotary drilling. If the air is filtered to capture compressor lubricants, contamination can be minimized more effectively than with other methods. In badly contaminated subsurface situations, air rotary drilling must be used carefully to minimize the exposure of drilling personnel to potentially hazardous materials.

Application: Air rotary methods are conducive to drilling in hard rock and other consolidated formations where a mud or water lining is unnecessary to support the walls against caving. An important advantage of using the air rotary method is that contamination of the water zone is not a factor since no drilling fluid Is used.

8.1.6.1.9 Reverse Air-and-Mud or Water Rotary

Description: The difference between the straight rotary drilling method and the reverse rotary circulation method lies in the circulation of the drilling fluid used to remove the cuttings and in the equipment used. in the reverse rotary method, as the rods are rotated the drilling fluid is introduced under gravity into the annular space between the drill rods and the walls of the hole. The fluid, along with cuttings from the bottom of the hole, returns to the surface through hollow drill rods. The return flow is accomplished by (1) application of a head at the top of the annulus relative to the discharge end of the drill rods, (2) application of suction on the drill rods, and (3) introduction into the drill rods of a supply of air that mixes with the slurry and causes it to be removed by air lift.

Application: This method has two advantages. It minimizes disturbance to the walls of the hole because of the higher head in the hide and more outward seepage pressure on the hole walls. It also provides more rapid and efficient removal of cuttings from the hole, since the area of the drill rods is smaller than that of the annulus, thereby giving higher upward veloity. Reverse rotary drilling is best suited to holes 12 inches and larger in diameter, but it has the same limitations as the mud and water rotary system.

8.1.6.1.10 Drive and Wash

Description: The drive-and-wash method is simliar to cable tool drilling and is often used in EPA Region i states. in this method of drilling, the casing is driven by a weight or hammer into the unconsolidated material. Soil entering the casing is washed out by circulating drilling fluid (water), and the casing is advanced again. A water rotary wash may also be used to clean the inside of the casing.

Application: Drive and wash is limited to unconsolidated materials. The casing also acts as a temporary seal to prevent cross-contamination of aquifers. Although faster than cable tool drilling, drive and wash is not a very rapid method. if the wash water is not recycled, large quantities of fluids may require collection and disposal.

8.1.6.2 Sampling Techniques

The purpose of soil sampling is to obtain a portion of soil (disturbed or undisturbed) that is representative” of the horizon sampled for chemical analysis, geotechnical analysis, and geomorphological classification. The volume of each sample is about 1 pint. samples are usually taken at intervals approved by the geologist or field engineer and at each change in formation or material type. Where sampling difficulties are encountered or a larger volume of material is needed, a larger diameter split-spoon sampler, a Shelby tube, a pitcher-type sampler, or a piston-type sampler might be required. Continuous coring may be desirable when it is necessary to establish the presence and distribution of permeable layers and to establish stratigraphic control.

in areas where contamination is possible, soil samples are usually screened for contamination by the use of various monitoring instruments (see Section 15). Any positive readings or visual evidence of contamination will necessitate treating the sample as a hazardous material and using appropriate packaging, labeling, and shipping techniques, as well as personal protection for the drillers and samplers. This level of protection should be determined before the start of drilling.

Standard penetration tests should be conducted in accordance with American Society for Testing and Materials (ASTM) D1586, with the interval tested varying from continuous sampling to 5-foot intervals. Where rock samples are required, N-series split inner tube core barrels are usually used. Air is the preferred drilling fluid. Techniques for obtaining and handling disturbed or undisturbed samples are described In this subsection.

8.1.6.2.1 Split-Spoon Samplers

The split-spoon sampler is a thick-walled, steel tube that is split lengthwise. A cutting shoe is attached to the lower end; the upper end contains a check valve and Is connected to the drill rods. When a boring is advanced to the point that a sample Is to be taken, drill tools are removed and the sampler is lowered into the hole on the bottom of the drill rods.

The sampler Is driven 18 Inches Into the ground in accordance with a standard penetration test (ASTM D1586). The effort taken to drive the sampler the last 12 inches is recorded at 6-inch intervals, and the sampler is removed from the boring. The density of the sampled material is obtained by counting the blows per foot as the split-spoon sampler is driven by a 140-lb hammer falling 30 inches.

The standard-size split-spoon sampler has an inside diameter (ID) of 1.38 to 1.5 Inches. When soil samples are taken for chemical analysis, it may be desirable to use a 2 or 2.5 ID sampler, which provides a larger volume of material but can not be used to calculate aquifer properties by using the stated ASTM test method,

Samples to be chemically analyzed are placed In the appropriately sized decontaminated jar and labeled with EPA serialized sample tags. Samples are kept out of direct sun light and stored at about 4C until they are shipped to the laboratory. The split-spoon sampler is decontaminated between samples. In some Instances, separate, previously decontaminated split-spoon samplers may be required for each sample taken.

When taking samples for Geotechnical analyses, the disturbed soil samples removed from the sampler are placed in a sealable glass jar and labeled to Indicate the project name and number, boring number, date, depths at top and bottom of sample Interval, recovery, number of sample, number of blows for each 6 inches (15 centimeters) of penetration, date of sampling, and any other information required by the field engineer or geologist. This Information is placed on a gummed printed label that can be affixed to the jar. In addition, the jar lid Is marked with the project number, boring number, number of sample, and depths at the top and bottom of the sample Interval.

Jar samples are placed In containers, such as cardboard boxes, with dividers to prevent movement of the jars. To aid in retrieving samples, only one boring Is generally placed In a box. The boxes are labeled on the top and four sides to show the project number and name, the identification of samples contained in the box, and the depth from which the samples were taken.

Samples are taken In 6-inch increments and are placed In jars or, where lenses or layers are evident, the material types should be separated Into different jars. All samples recovered, except for slough or cuttings, should be saved until analysis is completed. They should then be properly disposed of. Section 5 of this compendium describes disposal of samples. Each 6-inch increment of a sample should be assigned a letter suffix, beginning with “A at the bottom of the sample. If only 6 inches of a sample are recovered, this would be given the suffix “A.”

If the jar samples are to be temporarily stored onsite; they should be protected from weather, especially heat and freezing temperatures. Evidence tape or custody seals should be placed across the jar lids. For commercial shipment, the boxes are marked “KEEP FROM HEAT AND FREEZING" and are labeled with the appropriate Department of Transportation (DOT) labels. The reader should refer to Section 5 of this compendium.

8.1.6.2.2 Thin-Walled Tube Samplers

Thin-walled Samplers, such as a Shelby tube, are used to take relatively undisturbed samples of soil from borings. The samplers are constructed of cold drawn steel tubing about 1 mm thick (for tubes 2 inches in diameter) or 3 mm thick (for tubes 5 inches in diameter). The lower end is bent to form a tapered cutting edge. The upper end is fastened to a check valve to help hold the sample in the tube when the tube is being withdrawn from the ground. Thin-walled tube samples are obtained by any one of several methods including pushed-tube, Pitcher sampler, Denisen sampler, and piston sampler methods. Choosing the most appropriate method requires that field personnel use their own judgment. Since the purpose of thin-walled tube sampling is to obtain the highest quality undisturbed samples possible, special care should be taken in ail sampling, handling, packaging, and shipping of these samples.

In obtaining pushed-tube samples, the tube is advanced by hydraulically pushing in one continuous movement with the drill rig. The maximum hydraulic pressure is recorded. At the end of the designated push interval and before lifting the sample, the tube is twisted to break the bottom of the sample.

Upon recovery of a thin-walled tube, the actual length of sample is measured and recorded (excluding slough or cuttings). At least 1/2 inch of soil is cleaned from each end of the tube, and the ends of the soil sample are squared off. Usually the top of the sample will contain cuttings or slough. These must be removed before sealing. The soil that has been cleaned from the tube can be used for a visual classification of the sample. The resulting space at each end of the tube is filled with melted sealing material, such as approved wax, or with expandable packers. Previously decontaminated Teflon or stainless steel plugs are also used. After this Initial seailng, a dry filler such as cuttings, sand, or paper can be placed in the remaining void areas, and seailng is again conducted. This filler prevents the sample from breaking the initial end seals during handling and shipment. The ends of the tube are then closed with tight-fitting metal or plastic caps, and the seam between the cap and tube is wrapped with tape. Finally, the ends are dipped in hot wax, completely covering the tape to ensure sealing.

The sample container and the top cap are labeled by writing on them with an indelible marker or by affixing a label. If possible, all labeling should be located in the top 1 foot of the tube. The information on the tube includes the project number, project name, date of sampling, boring number, sample number, zone of sampling, and any other information the field engineer or geologist feels is pertinent. In addition, the tube is marked TOP and BOTTOM so that the orientation of the soil sample is known.

As much as possible, the tubes should be carried by hand to the soils laboratory in an upright vertical position to maintain the in situ orientation and to minimize sample dis-aggregation. If the tubes are being transposed by air plane, they should be carried, if possible, on the plane and not checked as baggage. (NOTE: Soil samples that yield positive readings during screening with an HNU or organic vapor analyzer (OVA), that show visual evidence of contamination, or that can reasonably be assumed to be contaminated should never be carried on a passenger aircraft. The reader should refer to Section 5 of this compendium for the proper packaging, labeling, and shipping of hazardous samples.) If the tubes are to be transported by truck or automobile, they should be carefully padded and wedged in place to prevent movement and minimize vibration. if tubes must be shipped as freight, they should be packed in secure wooden boxes with dividers built in to prevent movement of the tubes, or the boxes should be tightly filled with packing material such as wood chips to prevent movement. The boxes should be marked “FRAGILE’ and “KEEP FROM HEAT AND FREEZING” and labeled according to the type of hazard presented by the assumed contamination. Ail packaging of tubes should be supervised by the field engineer or geologist.

Finally, if field engineers or geologists think the tubes have been disturbed in shipment, they should notify the Project Manager and soils laboratory coordinator in writing.

In addition to Geotechnical testing, such as permeability testing, thin-walled samples maybe extruded in the laboratory and used for chemical analysis.

8.1.6.2.3 Cutting or Wash Samples

Occasionally, cutting or wash samples might be required as the boring is advanced. Cutting or wash samples should be handled and packaged as outlined for split-spoon samples. An estimate of the depth (or range of depth) from which the sample was obtained should be recorded on the log sheet. "Samples are usually taken every 5 feet. Samples should be labeled In the manner outlined for jar samples.

8.1.6.3 Decontamination and Waste Handling

Waste handling and decontamination of equipment should be coordinated with the SM or designated field person before entering the site. Removing any possible sources of offsite contamination from the drilling equipment before beginning work will minimize the offsite transportation of waste upon completion of work and will minimize cross contamination while working onsite.

Between samples, the sampling equipment shall be decontaminated as approved by the SM or designated personnel. The decontamination procedure generally involves the following:

- Brush off visible mud or dirt; scrub and wash with clean water. Organic-free water, distilled water, or tap water may be used; the tap water source must be noncontaminated. (Note: Sample cleaning blanks will be submitted for analysis to assure adequacy of decontamination.)
- Scrub and wash with trisodium phosphate.
- Scrub and wash with methanol or acetone.
- Rinse with clean water, preferably de-ionized or distilled water. (See remarks above about clean water.)

Between boreholes, all casing, rods, samplers, and other equipment used in the boreholes must be decontaminated as approved by the SM. The cleaning process generally consists of steam cleaning or hosing the drilling equipment with a high-pressure hot water rinse. After cleaning, the drilling equipment must be placed on a clean surface on the driller's truck bed or wrapped In clean polyethylene sheeting.

Upon completion of drilling activities, all equipment including the drill rig and all casing, rods, tools, and miscellaneous equipment must be decontaminated before leaving the site, as approved by the SM. The drill rig and equipment are usually cleaned with a steam cleaner or mobile high-pressure hot water washer. Wipe tests may be used to determine the extent of remaining contamination, if any this testing is particularly relevant when a commercial well driller has been used as a contractor.

Solid waste from the drilling should be placed in barrels following completion of each borehole or disposed of onsite with approval of the SM and EPA. Barrels containing solid wastes will be marked so the contents can be identified and stored in a secure area onsite (shed or fenced area), at the direction of the SM.

Fluids that are produced during drilling or well development or that are potentially contaminated during equipment decontamination will have to be contained onsite and analyzed for contamination. If shown to be uncontaminated, these fluids may be disposed of by an EPA- and SM-approved site-specific method. Contaminated fluids will be handled according to procedures specified in the site-specific Quality Assurance Project Plan (QAPjP). This consideration will be of particular importance at well locations adjacent to surface waters. To prevent a runoff, a fluid discharge containment trench may be excavated so that all fluids from drilling, well development, and decontamination can be diverted to the trench. one trench may be large enough to contain all fluids produced at a given borehole location. The trench is usually lined. Consideration must be given to proper security (fencing or lights) around a trench when personnel are absent from the site. Air emissions from the fluids in a trench should be monitored.

Closure of the trench or removal of the trench contents or other contained fluids must be planned before initiating any drilling. Trench contents may be allowed to drain into the soil; may be solidified by backfilling; or may be drained, pumped, or sucked dry, followed by removal of the liner and proper disposal. Samples may be taken from the trench fluids to determine the proper disposal methods. In some cases, the SM or designated personnel may direct that all fluids be contained in a mobile tank or drums for subsequent discharge at a location removed from surface waters. This location will be determined by the SM and is usually less than 1 mile from a given well. Care must be taken in transporting such potentially contaminated material on public roads to the collection point.

8.1.7 Region-Specific Variances

In general, site-specific conditions and the purpose of the project should be the main criteria for selection of drilling and sampling methods. However, regional variations from the methods recommended above might be necessary because of local availability of certain types of equipment. However, because information on variances can become dated rapidly, the user should contact the EPA RPM for current regional practices and requirements. Future changes will be incorporated In Revision 01 of this compendium.

8.1.7.1 Region I

The hydrogeologists in Region 1 of EPA do not permit the use of mud rotary drilling techniques to drill a boring for an unconsolidated zone monitoring well.' Region requires the performance of continuous split-spoon sampling during all drilling operations. Also, Region requires permeability testing at regular 5-foot intervals during drilling operations.

8.1.7.2 Region IV

Region IV EPA personnel recommend the use of pesticide-grade isopropyl alcohol as a cleaning solvent in place of acetone or methanol.

8.1.7.3 Region IX

Region IX EPA personnel do not permit the use of hand augers in sampling for TCDD.

8.1.8 Information Sources

Ackel, W.L. *Basic Procedures for Soil Sampling and Core Drilling.* Scranton, Pennsylvania: Ackel Drill Co., Inc. 1976.

Barcelona, M.J., J.P. Gibb, J.A. Helfrid, and E.E. Garske. *Practical Guide for Groudwater Sampling.* SWS Contract Report *324.* Champaign, Ilinois: Illinois State Water Survey. 1985.

Barcelona, M. J., J.P. Gibb, and R.A. Miller. A *Guide to the Selection of MatetiaLs for Monitoring Well Construction and Groundwater Sampling.* ISWS Contract Report 327. Champaign, Ilinois: Illinois State Water Survey. 1983.

Hvorslev, M.J. *Substance Exploration and Sampling of Soils for Civil Engineering Purposes.* Vicksburg, Mississippi: Waterways Experiment Station. 1949. Reprinted by ASCE Engineering Foundation. 1985.

Johnson Division, UOP, inc. *Ground Waterand Wells.* St. Paul, Minnesota. 1980.

National Water Well Association. *Water We/l Specifications.* Berkeley, California: Premier Press. 1981.

Sowers, G.F. *Introductory Mechanics and Foundatiions: Geotechnical Engineering.* New York: Macmillan Publishing Co. 1979.

Winterkorn, H. F., and H.Y. Fang. *Foundation EngineeringHandbook* Van Nostrand Reinhold Company. 1975.

8.2 TEST PITS AND EXCAVATIONS

8.2.1 Scope and Purpose

The scope and purpose of this subsection Is to provide reference material for conducting test pit and trench excavations at hazardous waste sites. These reference materials provide general guidelines; consequently, project-specific plans take precedence.

8.2.2 Definitions

Site Manager

> The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

Trenches or Test Pit

> Open shallow excavations, typically longitudinal (if a trench) or rectangular (if a pit), to determine the shallow subsurface conditions for engineering, gedogical, and soil chemistry exploration and/or sampling purposes. These pits are excavated manually or by a machine, such as a backhoe, clamshell, trencher excavator, or bulldozer.

8.2.3 Applicability

This subsection presents routine test pit or trench excavation techniques. Specialized techniques that are applicable only under certain conditions are not presented.

During the excavation of trenches or pits at hazardous waste sites, several health and safety concerns arise and control the method of excavation. All excavations that are deeper than 4 feet must be stabilized (before entry into the excavation) by bracing the pit sides using wooden or steel support structures. Personnel entering the excavation may be exposed to toxic or explosive gases and oxygen-deficient environments. in these cases, substantial air monitoring is required before entry, and appropriate respiratory gear and protective clothing is mandatory. There must be at least two persons present at the immediate site before entry by one of the investigators. The reader should refer to OSHA regulations 29 CFR 1926, 29 CFR 1910.120, and 29 CFR 1910.134.

Machine-dug excavations are generally not practical where a depth of more than about 15 feet is , desired. These excavations are also usually limited to a few feet below the water table. in some cases, a pumping system may be required to control water leveis within the pits, providing that pumped water can be adequately stored or disposed. if data on soils at depths greater than 15 feet are required, the data are usually obtained through test borings instead of test pits.

in addition, hazardous wastes maybe brought to the surface by excavation equipment. This material, whether removed from the site or returned to the subsurface, must be properly handled.

8.2.4 Responsibilities

The SM or field team leader Is responsible for developing the test pit program and instituting the program, Including sample acquisition. A minimum two-person crew, In addition to the excavating equipment operator, Is recommended for test pit work at a hazardous waste site. Larger crews maybe required if unusually hazardous conditions may be encountered or the scope of work requires additional staffing. One person onsite must function as the health and safety officer to monitor compliance with health and safety requirements. Other duties that may be required Include sampling operations, both chemical and/or Geotechnical, and soil or rock descriptions. The personnel onsite may divide the required duties according to their capabilities. Where physical or Geotechnical soil descriptions are required, a geologist should be included In the crew.

8.2.5 Records

Test pit logs should contain a sketch of pit conditions. In addition, at least one photograph with a scale for comparison should be taken of each pit. Included in the photograph should be a card showing the test pit number and site name. Test pit locations should be documented by typing in the location of two or more nearby permanent landmarks (trees, house, fence, etc.) and should be located on a site map. Surveying may also be required, depending on the requirements of each project. Other data to be recorded in the field logbook include the fallowing:

- Name and location of job
- Date of excavation
- Approximate surface elevation
- Total depth of excavation
- Dimensions of pit
- Method of sample acquisition
- Type and size of samples
- Soil and rock descriptions
- Photographs
- Groundwater levels
- Organic gas or methane levels
- Other pertinent Information, such as waste material encountered

8.2.6 Guidelines

8.2.6.1 Teat Pit and Trench Construction

These guidelines describe the methods for excavating and logging test pits and trenches to determine subsurface soil and rook conditions.

Test pits and trenches may be excavated by hand or by power equipment to permit detailed explanation and clear under standing of the nature and contamination of the In situ materials. The size of the excavation will depend primarily on the following:

- The purpose and extent of the exploration
- The space required for efficient excavation
- The chemicals of concern
- The economics and efficiency of available equipment

Test pits normally have a cross section that is 4 to 10 feet square; test trenches are usually 3 to 6 feet wide and may be extended for any length required to reveal conditions along a specific line. The following table, which is based on equipment efficiencies, can give a rough guide for design consideration:

Equipment	Typical Widths, in Feet
Trenching machine	2
Backhoe	2 - 6
Track dozer	10
Track loader	10
Excavator	10
Scraper	20

Fifteen feet Is considered to be the economical vertioal limit of excavation. However, larger and deeper excavations have been used when special problems justified the expense.

The construction of test pits and trenches should be planned and designed in advance as much as possible. However, field conditions may necessitate revisions to the initial plans. The field supervisor should determine the exact depth and construction. The test pits and trenches should be excavated In compliance with applicable safety regulations as specified by the health and safety officer.

If the depth exceeds 4 feet and people will be entering the pit or trench, Occupational Safety and Health Administration (OSHA) requirements must be met: Walls must be braced with wooden or steel braces, ladders must be in the hole at all times, and a temporary guardrail must be placed along the surface of the hole before entry. It is advisable to stay out of test pits as much as possible if possible, the required data or samples should be gathered without entering the pit. Samples of leachate, groundwater, or sidewall soils can be taken with telescoping poles, etc.

Stabilization of the sides of test pits and trenches, when required, generally is achieved by sloping the walls at a sufficiently flat angle or by using sheeting. Benching or terracing can be used for deeper holes.

Shallow excavations are generally stabilized by sheeting. Test pits excavated Into fill are generally much more unstable than pits dug into natural in-place soil.

Sufficient space should be maintained between trenches or pits, to place soil that will be stockpiled for cover, as well as to allow access and free movement by haul vehicles and operating equipment. Excavated soil should be stock piled to one side, in one location, preferably downwind, away from the edge of the pit to reduce pressure on the pit walls.

Dewatering may be required to assure the stability of the side walls, to prevent the bottom of the pit from heaving, and to keep excavation dry. This Is an important consideration for excavations in cohesionless material below the groundwater table. Liquids removed as a result of dewatering operations must be handled as potentially contaminated materials. Procedures for the collection and disposal of such materials are discussed in the site-specific QAPjP.

The overland flow of water from excavated saturated soils and the erosion or sedimentation of the stockpiled soil should be controlled. A temporary detention basin' and a drainage system should be planned to prevent the contaminated wastes from spreading.

8.2.6.2 Sampling Techniques

Sampling from test pits can be performed by “disturbed” and “undisturbed” methods. Sampling should begin from within the pit or trench only after proper safety precautions have been initiated.

All samples collected should be identified on the test pit logs and In the field notebook. Information such as sample number, depth, type, volume, and method of collection is required. Preservation, packing, and shipping methods are specified elsewhere in this compendium (Sections 4,5, and 6).

Equipment: The fallowing is a list of equipment that maybe needed for taking samples from test pits and trenches

- Backhoe or other excavating machinery
- Shovels, picks, or scoops
- Sample containers (5-gal bucket with locking lid for large samples and 250-mL glass bottles for chemical analysis samples)

Disturbed samples: Disturbed samples are those that have been collected In a manner in which the In-situ physical structure and fabric of the soil have been disrupted. Disturbed sampling techniques typically include sampling from the walls or floors of the test pit by means of scraping or digging with a trowel, rockpick, or shovel. Large disturbed samples can be taken directty from the backhoe bucket during excavation; however, car. must be taken to assure that the sample is actually from the unit desired and does not Include slough or scraped material from the sides of the trench.

Undisturbed samples: “Relatively undisturbed” samples can be obtained from test pits. Typically, an undisturbed sample is collected by isolating by hand a large cube of soil at the base or side of the test pit. This sample can be cut using knives, shovels, and the like. Care Is taken to keep disturbances to a minimum. After the block of soil is removed, it is placed in an airtight, padded container for shipment to the lab. The overexcavated sample Is “trimmed” at the laboratory to the size required for the designated test. In some instances (e.g., in soft cohesive soil), it may be possible to get an undisturbed sample by pushing a Shelby tube sampling device into an undisturbed portion of the test pit and by using a backhoe.

Waste samples: Trenching and test pitting are excellent methods of obtaining waste samples from dumps and landfills. While borings may be useful at greater depths, drilling through a landfill or dump creates unusual hazards, such as hitting pockets of explosive gases; rupturing intact, buried containers; or potentially contaminating the transfer by penetrating confining layers beneath a landfill. Additionally, the samples gathered by drilling are not representative of the heterogeneous conditions found in a landfill. Trenching and test pitting allow **a** larger, more representative area to be observed, permit selection of specific samples from the pile of spoiled or stockpiled material (biased grab sampling), and, with reasonable precautions, allow the retrieval of intact, buried containers.

8.2.6.3 Backfilling of Trenches and Test Pits

Before backfilling, the onsite crew should photograph all significant features exposed by the test pit and trench and should include in the photograph a scale to show dimensions. Photographs of test pits should be marked to include site number, test pit number, depth, description of feature, and date of photograph. In addition, a geologic description of each photograph should be entered in the book. All photographs should be indexed and maintained for future reference.

After inspection, backfill material should be returned to the pit under the direction of the field supervisor.

If **a low** permeability layer is penetrated (resulting in groundwater flow from an upper contaminated flow zone into a lower uncontaminated flow zone), backfill material must represent original conditions or be impermeable. Backfill could consist of a soil-bentonite mix prepared In a proportion specified by the field supervisor (representing a permeability equal to or less than original conditions). Backfill should be covered by “clean” soil and graded to the original land contour. Revegetation of the disturbed area may also be required.

8.2.6.4 Decontamination

For decontamination procedures, the reader should refer to Subsection 8.1.6.3.

8.2.7 Region-Specific Variances

Site-specific conditions and project objectives dictate the methods of test pit or trench excavation and sampling. No region-specific variances from the methods described above are known. Decontamination procedures for sampling equipment vary with region. Most regions permit methane **or** acetone for **a** decontamination solution; however, some allow only isopropyl alcohol. Because Information on variances can become dated rapidly, the user should contact the EPA RPM for current regional practices and requirements. Future changes and additional regional variances will be incorporated in Revision 01 of this compendium.

8.2.8 Information Sources

NUS Corporation. ***NUS Operating Guidelines Manual.*** Superfund Division, Sections 4.13 and 4.38.

U.S. Department of Interior. ***The Earth Manual*** 2nd ed. U.S. Government Printing Office: Washington, D.C. 1980. 810 pp.

8.3 GEOLOGICAL RECONNAISSANCE AND GEOLOGICAL LOGGING

8.3.1 Scope and Purpose

This subsection describes geological reconnaissance studies and geological logging activities for field investigations of hazardous waste sites.

Geological reconnaissance studies require considerable professional judgment. Successful completion relies more on professional experience and insight than on acknowledged standards or procedures. Because there are no industy standards, this subsection describes basic methods, procedures, and activities to be accomplished or considered for a geological reconnaissance. Each site will require a special approach that will depend on the local geology, the amount of available data, the project schedule, and the judgment of the project geologist.

Geological logging of soil or rock materials derived from subsurface investigations is a more objective activity, and several industry standards exist for the physical description of earth materials. These standards will be described below.

8.3.2 Definitions

Geological Reconnaissance Studies

> The American Geological institute (AGI) defines a geological reconnaissance as “a general, exploratory examination or survey of the main features (or certain specific features) of a region, usually conducted as a preliminary to a more detailed survey.”
>
> The geological reconnaissance, therefore, provides the basis for more detailed investigations by identifying the major geological or physical features at and near the hazardous waste site. Geological reconnaissance studies are conducted early in project site investigations as part of the site characterization process.

Geological and Geophysical Logging

> Geological and geophysical logging is a detailed, systematic, and sequential record of the progress of drilling a well or borehole, or of excavating pits and trenches.
>
> The record of geological logging is kept on printed log forms and may include notes on the following:

- Soil and rock classifications and descriptions
- Outcrop descriptions
- Depths and thicknesses of the earth materials penetrated
- Groundwater conditions
- Origin and geologic structure(s)

- Drilling progress
- Borehole geophysical logging
- Sampling
- Type of equipment used
- Unusual or significant conditions
- Date of drilling, location of borehole, and so forth

Materials encountered are classified and described by obtaining samples or cuttings and by applying the standards described below.

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

8.3.3 Applicability

8.3.3.1 Geological Reconnaissance

Geological reconnaissance studies are applicable to most investigations of hazardous waste sites and are dependent on the existing database for the site. Sites having little existing information concerning site setting and relevant geologic features may require more detailed work than sites with a considerable database.

8.3.3.2 Geological Logging

Geological logging of subsurface explorations is always necessary to record events and conditions encountered in the field. Maintenance of acceptable log forms and adherence to established, or mandated procedures for material description, are critical to technically sound and defensible field investigations.

8.3.4 Responsibilities

The SM is ultimately responsible for determining that proper logging and geologic reconnaissance techniques are applied to the project. Because of the variability of geologic conditions from on-site to another and the judgment required by such studies, an experienced project geologist with local knowledge should work with the SM to plan, implement, and evaluate the reconnaissance.

8.3.5 Procedures

8.3.5.1 Geological Reconnaissance

8.3.5.1.1 General

Experienced personnel should plan and implement a cost-effective and technically sound reconnaissance study. The scope of the study will depend on anticipated problems and conditions at the site, coupled with professional judgment. The scope will vary depending on the following:

- Amount of available reference material and base maps
- Site accessibility
- Size of site and type of facility (landfill, tanks, industrial, other)
- Geologic setting of the site
- Site topography or geomorphology
- Anticipated subsurface and groundwater conditions
- Anticipated extent and type of contamination
- Level of personal protection required during the conduct of the reconnaissance
- Overall goal of the site investigation activities

8.3.5.1.2 Methods

Hunt (1984) describes the basic steps of a geological reconnaissance as fallows:

- Research of reference materials and collection of available data
- Terrain analysis based on topographic maps and remote sensing imagery
- Preparation of a preliminary geological map Including (where appropriate) saprolite mapping, outcrop mapping with strike and measurements of structural features, and locating of springs and seeps
- Site reconnaissance to confirm and amplify the geological map, fallowed by preparation of the final version of the map
- Preparation of a subsurface exploration program based on anticipated conditions and data gaps

The proportion of field work to office work will vary from site to site.

References and data gathered to initiate the work may include any or all of the fallowing historical or recent materials geological maps and texts; SON surveys; hydrogeologic reports and well logs; topographic maps, air photos, and remote sensing imagery climatic data; Geotechnical engineering reports for the area; and site-related data and reports.

Exhibit 8.3-1
SOIL BORING LOG

PROJECT NUMBER	BORING NUMBER SHEET OF

SOIL BORING LOG

PROJECT ______ LOCATION ______

ELEVATION ______ DRILLING CONTRACTOR ______

DRILLING METHOD AND EQUIPMENT ______

WATER LEVEL AND DATE ______ START ______ FINISH ______ LOGGER ______

ELEVATION	DEPTH BELOW SURFACE	SAMPLE			STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	SYMBOLIC LOG	COMMENTS
		INTERVAL	TYPE AND NUMBER	RECOVERY	6"-6"-6" (N)	NAME, GRADATION OR PLASTICITY, PARTICLE SIZE DISTRIBUTION, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY, USCS GROUP SYMBOL		DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS AND INSTRUMENTATION

REV 11/82 FORM D15

In addition to the items listed above, all pertinent observations about drilling rate, equipment operation, or unusual conditions should be noted. Such information might include the following:

- Size of casing used and method of installation
- Rig reactions such as chatter, rod drops, and bouncing
- Drilling rate changes
- Depth and percentage of fluid losses
- Changes in fluid color or consistency
- Material changes
- Zones of caving or heaving

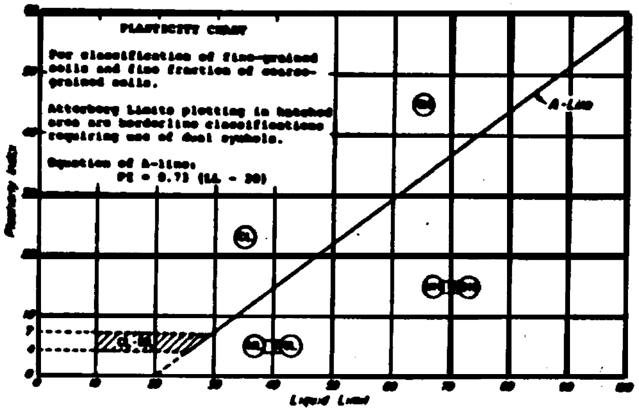
8.3.5.2.3 Soil Description

Description of soils (well logging) should be done in accordance with the Unified Soil Classification System (USCS) as described in ASTM D2487-69 (1975): Test Method for Classification of Soils for Engineering Purposes (see Exhibit 8.3-2). The approach and format should generally conform to ASTM D2488-69(1975): Recommended Practice of Description of Soils (Visual-Manuai Procedure). Alternatively, the Burmeister system of soil description may be used, although the use of this system seems to be concentrated in the Northeast. The complete title of the Burmeister system can be found in the references. Because the Burmeister system relies heavily on handling the soil, it should not be used In areas of significant soil contamination.

The soil description should be concise and should stress major constituents and characteristics. Soil descriptions should be given in a consistent order and format. The following order is as given in ASTM D2488:

- 1. Soil Name: The basic name of the predominant constituent and a single-word modifier indicating the major subordinate constituent.
- 2. Gradation or Plasticity For granular soil (sands or gravels) that should be described as well- graded, poorly graded, uniform, or gap-graded, depending on the gradation of the minus 3-inch fraction. Cohesive soil (silts or clays) should be described as nonplastic, slightly plastic, moderately plastic, or highly plastic, depending on the results of the manual evacuation for plasticity as described in ASTM 02488.
- 3. Particle Size Distribution: An estimate of the percentage and grain-size range of each of the soil's subordinate constituents with emphasis on clay-particle constituents. This description may also include a description of angularity. This parameter is critical for assessing hydrogeology of the site and should be carefully and fully documented.
- 4. Color: The basic color of the soil. (Refer to Munsell color charts.)
- 5. Moisture Content: The amount of soil moisture, described as dry, moist, or wet.
- 6. Relative Density or Consistency An estimate of density of a granular soil or consistency of a cohesive soil, usually based on standard penetration test results (see Exhibit 8.3-3).

Exhibit 8.3-2
UNIFIED SOIL CLASSIFICATION

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES	CLASSIFICATION CRITERIA		
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve[a]	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines Less than 5% Pass No. 200 sieve GW, GP, SW, SP More than 12% Pass No. 200 sieve GM, GC, SM, SC 5% to 12% Pass No. 200 sieve Borderline Classification requiring use of dual symbols	$C_u = D_{60}/D_{10}$ Greater than 4 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW	
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-clay mixtures		Atterberg limits plot above "A" line and plasticity index greater than 7	
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines		$C_u = D_{60}/D_{10}$ Greater than 6 $C_z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3	
			SP	Poorly graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW	
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures		Atterberg limits plot below "A" line or plasticity index less than 4	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits plot above "A" line and plasticity index greater than 7	
FINE-GRAINED SOILS 50% or more passes No. 200 sieve[a]	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands			
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts			
			CH	Inorganic clays of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity			
Highly Organic Soils			PT	Peat, muck and other highly organic soils	Visual-Manual Identification, See ASTM Designation D 2488		

PLASTICITY CHART

For classification of fine-grained soils and fine fraction of coarse-grained soils.

Atterberg Limits plotting in hatched area are borderline classifications requiring use of dual symbols.

Equation of A-line:
PI = 0.73 (LL - 20)

[a] Based on the material passing the 3-in. (75-mm) sieve.

SOURCE: ASTM D 2487

Exhibit 8.3-3
RELATIVE DENSITY OF NONCOHESIVE SOIL

Blows/Ft	Relative Density	Field Test
0-4	very loose	Easily penetrated with 1/2-inch steel rod pushed by hand
5-10	Loose	Easily penetrated with 1/2-inch steel rod pushed by hand
11-30	Medium	Easily penetrated with 1/2-inch steel rod driven with 5-lb hammer
31-50	Dense	Penetrated afoot with 1/2-inch steel rod driven with 5-lb hammer
>50	Very dense	Penetrated only a few inches with 1/2-inch steel rod driven with 5-lb hammer

CONSISTENCY OF COHESIVE SOIL

Blows/Ft	Consistency	Pocket Penetrometer (TSF*)	Torvane (TSF)	Field Test
<2	Very soft	<0.25	<0.12	Easily penetrated several Inches by fist
2-4	soft	0.25-0.5	0.12-0.25	Easily penetrated several inches by thumb
5-8	Firm	0.50-1.0	0.25-0.5	Can be penetrated several inches by thumb with moderate effort
9-15	stiff	1.0-2.0	0.5-1.0	Readily indented by thumb but penetrated only with great effort
16-30	Very stiff	2.04.0	1.0-2.0	Readily indented by thumbnail
>30	Hard	>4.0	>2.0	Indented with difficulty by thumbnail

---

*TSF- Tons per square foot

- 7. **Soil Texture and Structure:** Description of particle size distribution, arrangement of particles into aggregates, and their structure. This description includes joints, fissures, slicken sides, bedding, veins, root holes, debris, organic content, and residual or relict structure, as well as other characteristics that may influence the movement or retention of water or contaminants.

- 8. **Relative Permeability:** An estimate of the permeability based on visual examination of mate rials (e.g., high permeability for coarse sand and gravel versus low permeability for silty clay). The estimate should address presence and condition of fractures (open, iron-stand, calcite-filled, open but clay-lined, etc.), as well as fracture density and orientation.

- 9. **Local Geologic Name:** Any specific local name or a generic name (i.e., alluvium, loess).

- 10. **Group Symbol:** Unified Soil Classification System of symbols (see Exhibit 8.3-2).

The soil logs should also include a complete description of any tests run in the borehole; placement and construction details of piezometers, wells, and other monitoring equipment; abandonment records; geophysical logging techniques used; and notes on readings obtained by air monitoring instruments.

8.3.5.2.4 Rock Methods

When coring in rock, keep the log on a standard rock core log form (see Exhibit 8.3-4). Basic information should be entered on the heading, as described in the soil section. The following technical information is entered in the log:

- Depth
- Core length
- Coring rate in minutes per foot
- Fluid gain or loss
- Core loss
- Percentage of recovery
- Core breakage due to discontinuities
- Total core breakage
- Number of breaks per foot
- Rock classification and lithology

In addition to the items listed above, pertinent observations concerning drilling rate, equipment operation, or unusual conditions should be noted. Such information might include the following:

- Casing type and diameter
- Type of drilling fluid
- Rig reactions

Exhibit 8.3-4
ROCK CORE LOG

SHEET ____ OF ____

PROJECT NUMBER

ROCK CORE LOG

PROJECT ____________________ LOCATION ____________________

DRILLING METHOD ____________________ DRILLERS & EQUIPMENT ____________________

ELEVATION __________ ORIENTATION ____________________ **BORE HOLE:** __________

WATER LEVEL __________ DATE: __________ START: __________ FINISH: __________ INSPECTOR __________

DEPTH	COMMENTS	CORE RUN LENGTH AND RECOVERY (%)	CORE LOSS ZONE	BOX NUMBER	DISCONTINUITIES			LITHOLOGY		GRAPHIC LOG
	TESTS INSTRUMENTATION CORING RATE AND SMOOTHNESS CORING FLUID LOSS				RQD	FRACTURES PER FOOT	**DESCRIPTION** TIGHTNESS PLANARITY SMOOTHNESS FILLING, STAINING ORIENTATION	MINERALOGY CLASSIFICATION COLOR GRAIN SIZE ALTERATION	CEMENTATION HARDNESS WEATHERED STATE	

FORM D 2113A 5/78

- Depth and percentage of fluid losses
- Material changes
- Zones of caving

8.3.5.2.5 Rock Classification

The description of rock should be done in an orderly and systematic fashion. The following order is recommended:

- 1. Lithology and Texture Geological name of the rock and Its mineral composition (the geological name, such as granite, basalt, or sandstone, usually describes the rock's origin). Description of how grains are arranged or bound together (Le., Interlocking, cemented, or laminated-foliated; Deere, 1983)
- 2. Color: The basic color of the rock, modified by light, medium, or dark,
- 3. Hardness: Terms used to describe hardness are given on subsequent pages,

Descriptive Term	Defining Characteristics
Very hard	Cannot be scratched with knife. Does not leave a groove on the rock surface when scratched.
Hard	Difficult to scratch with knife. Leaves a faint groove with sharp edges.
Medium	Can be scratched with knife. Leaves a well-defined groove with sharp edges.
Soft	Easily scratched with knife. Leaves a deep groove with broken edges.
Very soft	Can be scratched with a fingernail.

- 4. Weathering: Terms used to describe weathering are described below

Descriptive Term	Defining Characteristics
Fresh	Rock is unstained. May be fractured, but discontinuities are not stained.
Slightly	Rock is unstained. Discontinuities show some staining on the surfaces of rocks, but discoloration does not penetrate rock mass.
Moderate	Discontinuity surfaces are stained. Discoloration may extend into rock along discontinuity surfaces.
High	Individual rock fragments are thoroughly stained and can be crushed with pressure hammer. Discontinuity surfaces are thoroughly stained and may be crumbly.
Severe	Rock appears to consist of gravel-sized fragments in a "soil" matrix. Individual fragments are thoroughly discolored and can be broken with fingers.

- 5. **Grain Size:** Term that describes fabric as fine-grained, medium-grained, or coarse-grained.

- 6. **Description of Bedding or of Joint or Fracture Spacing:** Description should be according to the following:

Spacing	Joints	Bedding or Foliation
< 2 in.	Very close	Very thin
2 in. to 1 ft	Close	Thin
1 ft to 3 ft	Moderately close	Medium
3 ft to 10 ft	Wide	Thick
> 10 ft	Very wide	Very thick

(after Deere, 1963)

- 7. **Discontinuity Descriptions:** Terms that describe number, depth, and type of natural discontinuities. Also describe orientation, staining, planarity, alteration, joint or fracture fillings, and structural features.
- 8. **Local Geological Name:** Term used to assign local geological name, if appropriate, and to identify stratigraphic equivalents, if applicable.

The rock logs should also include a complete description of the mineralogy of the rock, of any tests run in the bore hole, and of placement and construction details of piezometers, wells, and other rig monitoring devices.

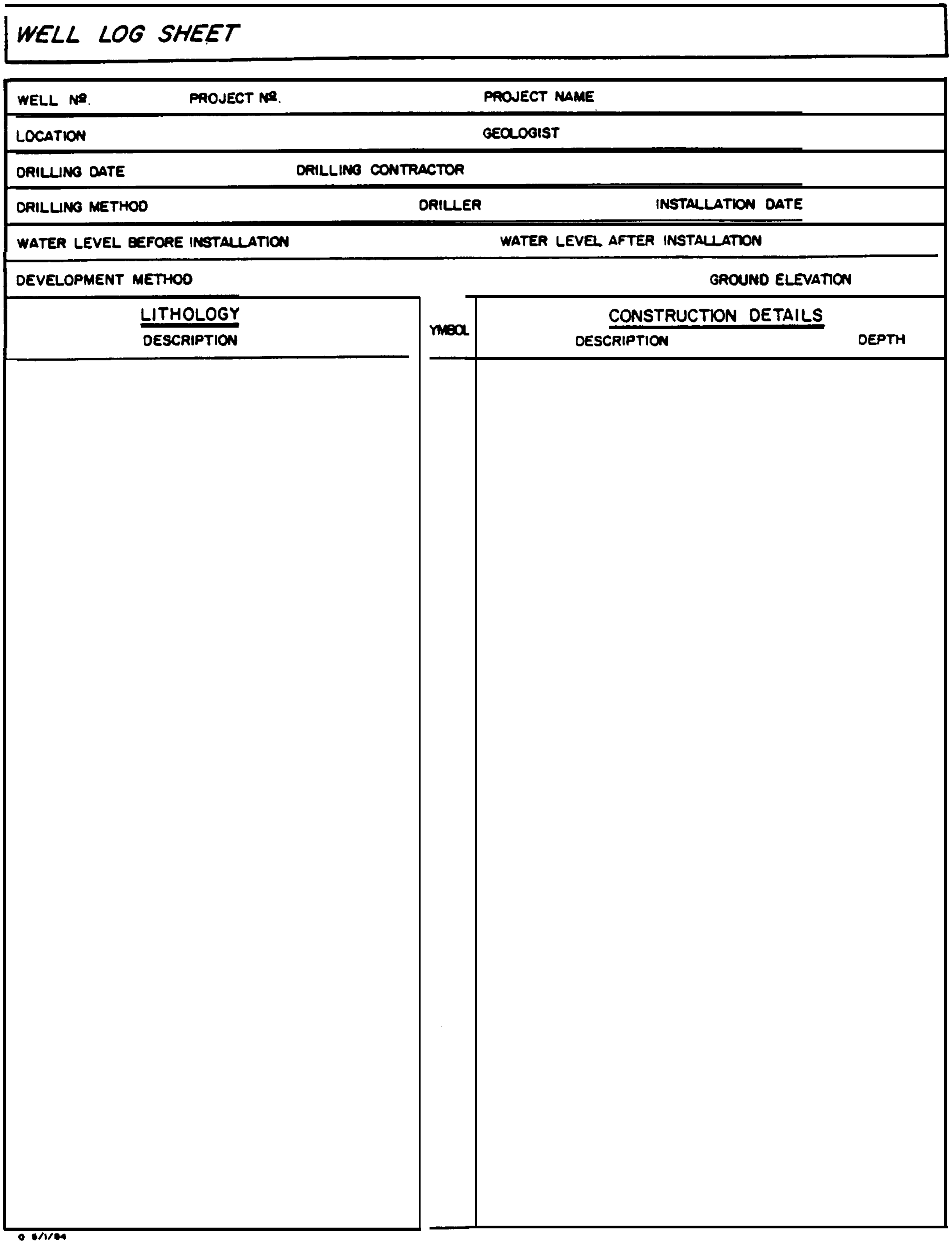
8.3.5.2.6 Well Completion Diagrams

For each monitoring well installed, a monitoring well completion diagram or well log should be submitted. This form (Exhibit 8.3-5) should contain information in the appropriate column as follows:

- Well number
- Project number and name
- Location
- Geologist or engineer
- Ground elevation
- Well installation date
- Drilling contractor
- Drilling methods
- Water levels before and after development
- Development method

Columns for a summary of the lithologies encountered during drilling, lithologic or USCS symbols, and construction details are shown on the form. The construction details include depth of well, screen, and riser; appropriate pipe diameters; backfill types and elevations; and pipe materials (e.g., polyvinyl chloride (PVC), stainless, black).

Exhibit 8.3-5
BLANK WELL LOG SHEET



WELL LOG SHEET

WELL Nº.

PROJECT Nº.

PROJECT NAME

LOCATION

GEOLOGIST

DRILLING DATE

DRILLING CONTRACTOR

DRILLING METHOD

DRILLER

INSTALLATION DATE

WATER LEVEL BEFORE INSTALLATION

WATER LEVEL AFTER INSTALLATION

DEVELOPMENT METHOD

GROUND ELEVATION

LITHOLOGY		CONSTRUCTION DETAILS	
DESCRIPTION	YMBOL	DESCRIPTION	DEPTH

0 8/1/84

Exhibit 8.3-6
COMPLETED WELL LOG SHEET

WELL LOG SHEET

WELL Nº. MW.3 PROJECT Nº. 0758.16 PROJECT NAME SWOPE OIL CO.

LOCATION PENNSAUKEN, N.J. GEOLOGIST SJ CONTI

DRILLING DATE 6-21-84 DRILLING CONTRACTOR HYDRO GROUP

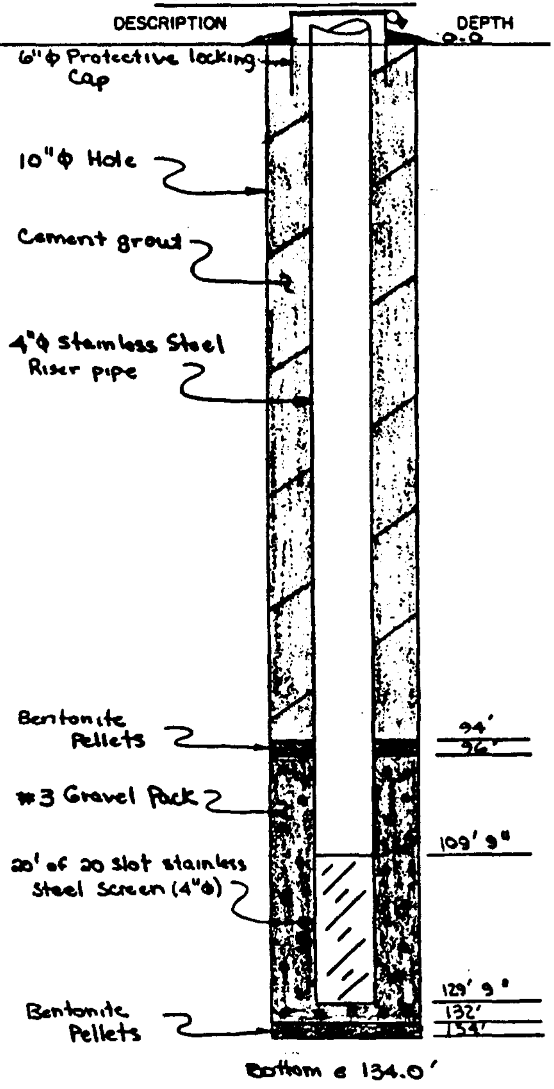
DRILLING METHOD MUD ROTARY DRILLER JOE YOST INSTALLATION DATE 6-25-84

WATER LEVEL BEFORE INSTALLATION WATER LEVEL AFTER INSTALLATION 82.55 7-6-84

DEVELOPMENT METHOD COMPRESSED AIR GROUND ELEVATION

LITHOLOGY DESCRIPTION	SYMBOL
-5-Loose, Orange Brown Silty Sand, Some gravel-Trace Organic Matl.	SM
35-Medium Dense to Dense, Yellow Brown Gray, Alternating layers of sandy clay and clayey sand. Sand content increasing with depth.	SC
5-54-Loose to Medium Dense, Yellow Brown, Medium to Coarse Sand, trace clay lenses Subangular sand grains.	SP
54-64-Loose yellow brown, Clayey Sand Trace fine gravel. Subangular Sand grains	SC
64-79 - Loose to Medium Dense, Yellow Brown, Fine to Medium Sand, Trace clay and Fine gravel. Subangular Sand grains.	SM
-83 - Dense, Light gray Brown, Medium to coarse Sand, trace fines and gravel. (Subangular grains.)	SP
83-84 - Stiff, v. light gray clay lens	CL
84-125-Medium Dense to Dense Brown gray medium to coarse Sand-Trace fine gravel and trace clay. Sub-angular to subrounded sand grains	SP
5-132- Dense Brown gray Sand and gravel, trace of clay lenses. Subangular to subrounded grains.	SW
2-136 Very Stiff, Very light gray Silty clay-Trace fine Sand.	CL

CONSTRUCTION DETAILS



© 8/1/84

Exhibit 8.3-6 is an example of a completed well log sheet. This form accompanies the rock core and soil boring logs to provide detailed information on borehole stratigraphy and monitoring well installation.

8.3.6 Region-Specific Variances

Site-specific conditions and project objectives will be the main criteria for methods used for geological reconnaissance and logging. No regional variations in the methods described above are known, but variations in reporting formats do exist. However, some regions prefer the Burmeister soil identification system. Because information on variances can become outdated rapidly, users of this section should consult the EPA region in which the logging will be done. Future changes will be incorporated in Revision 01 of this compendium.

8.3.7 Information Sources

American Geological Institute. *Glossary of Geology.* Washington, D.C. 1974.

American Society for Testing and Materials (ASTM) D2487 - *Standard Test Method for Classification of Soils for Engineering Purposes.* 1983.

ASTM D2488 - *Standard Recommended Practice for Description of Soils* (Visual-Manual Procedure). 1983.

Burmeister, D.M. *Identification and Classification of Soils—An Appraisal and Statement of Principles.* ASTM STP113. 1951

Compton, R.R. *Manual of Field Geology.* John Wiley and Sons, Inc. 1962.

CH2M HILL. *PMO Field Manual for Subsurface Exploration.* 1982.

Deere, D.U. *Technical Description of Rock Cores for Engineering Purposes.* Rock Mechanics Engineering Geology. 1963.

Hunt, R.E. *Geotechnical Engineering Investigation Manual.* McGraw-Hill: New York, 1964.

8.4 GEOPHYSICS

8.4.1 General Considerations

8.4.1.1 Scope and Purpose

This document provides general guidance for the planning, selection, and implementation of geophysical surveys that may be conducted during investigations of hazardous waste sites. Each of six commonly used methods are discussed from the standpoint of applicability to site investigation, procedures for implementation, survey design, and miscellaneous method-specific considerations. Emphasis is placed on the practical understanding of each method with a minimal amount of theoretical explanation being offered in the main body of the text. For those readers who may desire a more rigorous understanding, however, theoretical considerations have been Included in the appendix.

8.4.1.2 Definitions

Amplitude

The maximum vertical displacement from equilibrium in a wave.

Anomaly

An electromagnetic (EM) reading that deviates from the typical site background reading and is generally caused by the presence of an irregularity or target.

API

American Petroleum Institute.

Array

The configuration of electrodes in resistivity surveys.

Body Wave

A “seismic wave” that travels through the interior of the earth and is not related to any boundary surface. A body wave may be either longitudinal (P-wave) or transverse (S-wave). (Glossary of Geology)

Bulk Density

The weight of an object or material divided by its volume, including the volume of its pore spaces.

Circuit Potential

Measured electrical voltage drop or gain.

Compressional Wave

That type of seismic body wave that involves particle motion (alternating compression and expansion) in the direction of propagation. it is the fastest of the seismic waves and is also known as a P-wave.

Confidence” interval

The statistical level of probability of accomplishing a given task, such as detecting a target.

Critical Angle

The least “angle of incidence” at which there is total reflection when electromagnetic radiation passes from one medium to another, less refracting medium. (Glossary of Geology)

Critical Distance

In refraction seismic work, that source-to-receiver distance at which the direct wave in an upper medium is matched in arrival time by that of the refracted wave from the medium below, the refracted wave having a greater velocity.

Crossover Distance

The source to receiver distance beyond which head waves from a deeper refractor arrive ahead of those from a shallower refractor.

Cultural

An anomaly or feature that is attributable to human development, such as buried drums or utility lines.

Dead Time

Measurement errors in nuclear logging occurring from the inability to record all of the pulse energy within the resolving time.

Density

Mass per unit volume (g/cm^3). Bulk rock densities vary mainly because of porosity and range from 1.9 to 2.8 g/cm^3.

Dynamic Correction

Seismic data must be corrected for normal moveout (NMO), which Is the increase in arrival time of a reflection event, resulting from an increase in the distance from source to receiver or from dip of the reflector. Each trace has to be shifted by a different amount at different travel time to lineup the primary reflections.

Echo Profile

The graphic representation of time-delayed Ground Penetrating Radar (GPR) impulses.

Effective Porosity

The porosity that involves those pore spaces which are interconnected and, therefore, effective in transmitting fluids.

Electric Logs

The generic term for a well log that displays electrical measurements of induced current flow between electrodes. Electric logs discussed in this sub-section include only single-point Resistivity and spontaneous potential.

Electrodes

A ground-contacting metallic conductor used to apply current or measure the circuit potential.

Fall-Off Rate

The rate of decay of an anomaly with respect to distance.

Fermat's Principle

A seismic wave will follow the path that takes less time between two points rather than follow variations of this path. Such a path is called a minimum-time path.

Gamma

A unit of magnetic field. 1 gamma = 10^{-5} gauss = 10^{-9} tesla. In the International System of Units (SI units), 1 tesla = 1 kg amp sec^2.

Law of Reflection

The angle of incidence equals the angle of reflection.

Logging Speed

The speed at which the sonde traverses the borehole (typically in feet per minute).

Magnetic Dipole

A pair of magnetic poles of opposite signs and equal strengths that are close together so that the interaction of these poles is detectable.

Magnetic Monopole

A single magnetic pole of either positive or negative sign that is spatially separated from a magnetic pole of opposite sign so that there is no detectable interaction between the poles.

Magnetic Moment

The strength of a magnetic dipole.

Magnetic Susceptibility

A measure of the degree to which a substance maybe magnetized.

Multichannel Seismic

Geophone groups and shotholes used in various combinations so that reflections are recorded from the same portion of the subsurface a number of times. Also referred to as common-depth point (CDP) shooting.

Noise

Variation in data because of an undesirable influence.

Nuclear Logs

The generic term for a well log that either measures natural or induces and measures radioactive isotopes in the borehole environment. Discussion in this text is limited to natural gamma, gamma-gamma, and neutron.

Ray Parameter

A function *P* that is constant along a given seismic ray when horizontal velocity is constant.

Defined as:

$$\frac{\sin i}{\mathrm{VI}} = 1$$

where velocity = *V* and *i* is the angle of wave incidence.

Resistivity

The ability of a material to resist the flow of electrical current.

Shear wave

A seismic body wave propagated by a shearing motion that involves oscillation perpendicular to the direction of propagation. The shear wave doesn’t travel through liquids, and it arrives later than the *P-wave.* It is also known as an *S-wave.*

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor’s employee (see Subsection 1.1).

Snell's Law

When a seismic wave encounters a boundary between two layers of different seismic velocities, the direction of wave propagation changes so that the sine of the angle of wave incidence (i) divided by the seismic velocity (V_0), of the overlying medium equals the sine of the angle of wave refraction (i_r), divided by the seismic velocity (V_1), of the underlying medium.

$$P = \frac{\sin i}{V_0} = \frac{\sin i_r}{V_1} = \frac{\sin i_r}{V_0}$$

where (i_r) is the angle of wave reflection and (p) is the ray parameter.

Sonde

The elongated cylindrical tool assembly used in a borehole to acquire well log information.

Specific Yield

The ratio of the volume of water that a given mass of saturated rock or soil will yield by gravity, to the volume of that mass.

Spectrum

Amplitude and phase characteristics as a function of frequency for the components of a seismic wavelet.

Static Corrections

Corrections applied to seismic data to compensate for the effects of variations in elevation, and weathered layer thickness by referencing ail data to a datum plane. Such ‘corrections are independent of time, the amount of shift being the same for all points on any trace.

Surface Wave

A "seismic wave" that travels along the surface of the earth or parallel to the earth's surface. Surface waves include Rayleigh waves, Love waves, and coupled waves.

Target

The specific focus (or purpose) of an EM survey, such as buried drums or trench boundaries.

Thermal Convection

The transfer of heat by vertical movements in the borehole because of density differences caused by heating from below.

Total Porosity

The ratio of the void volume of a porous medium to the total volume. This is generally expressed as a percentage.

8.4.1.3 Responsibilities

The SM, in conjunction with the EPA RPM, must clearly define the objectives and information desired from the geophysical efforts. Site Managers are responsible for determining which geophysical techniques will provide data to permit meeting the established objectives. Site Managers are also responsible for coordinating safety considerations, planning fieldwork, arranging for quality assurance/quality control (QA/QC), and providing technical assistance. Geophysical task leaders are responsible for site reconnaissance, identification of potential problems, estimation of project effectiveness, acquisition of equipment, onsite supervision, and data interpretation.

Electromagnetic techniques have been adapted for downhole applications. These can be useful in defining the vertical extent of a contaminant zone. Some systems work inside PVC or Teflon monitoring well casings. For further information on airborne, borehole, or surface EM instruments, the reader should consult the subsections on theory and interpretation and the manufacturer references listed later in this compendium.

8.4.1.4 Records **and Inspection**

8.4.1 .4.1 Calibration

Dated records of geophysical equipment calibration, whether performed in the field or in the laboratory, should be kept in the equipment management files and in the appropriate project file. Calibration is used to establish the reliability and accuracy of the equipment; it typically includes an internal circuit check and actual field trials (e.g., testing over a known target). Equipment that historically exhibits fluctuation in calibration should always be checked before and after field use. The equipment serial number should be recorded on the calibration records. If equipment is recalled by the manufacturer, the recall should be explained in the proper file. The various techniques and instruments available make it prohibitive to outline in this compendium the specific calibration procedures to be followed for each instrument. For those details, the reader should consult the manufacturer’s manual pertaining to the particular instrument in use.

8.4.1 .4.2 Field Notes

Data and notes should be entered into a bound field logbook with sequentially numbered pages. At a minimum, each logbook page should include the names of the equipment operators; who kept the notes, if different from operator; survey date; name and project number of the site; line number; position (station) number survey direction (heading north or south); raw data; and any specific notes that relate to the survey (such as surface metal, weather conditions, and topographic changes. This data logbook should be entered into the project field and stamped “original.” Typed copies of the data may be included with the survey report. At the conclusion of field activities, a report specifying the dates of fieldwork, observations, personnel, and equipment involved should be submitted to the project file.

8.4.1 .4.3 Data Reduction

There are several accepted ways to present geophysical data. Data profiles can be useful for estimating anomaly depth and lateral extent along a survey line. For defining site patterns and lateral extent between lines, a contour map may be more useful than a profile. Three-dimensional maps are becoming more common (generated with the aid of computers) and can be extremely useful for site characterization. Computer programs should be examined for accuracy, because many programs that are unsuitable are available, particularly those programs with contouring functions. A percentage (such as 10 percent) of computer-plotted points should be manually checked for accuracy.

Specific calculations can involve differential and integral calculus; however, these equations may become theoretical, time consuming, and subject to interpretation. In general, graphic analysis may be more straightforward, cost effective, and not as likely to be challenged in litigation. Very detailed interpretations of some data are possible but should be attempted only by experienced personnel. Theoretically, it is possible to determine such things as size, shape, orientation, and depth of a conductor.

Parallel survey lines can be used to define long linear features such as contaminant plumes or faults. Some features are mapped by only a few anomalous readings; others are mapped by looking for anomalous trends. The decision to search for a few anomalous readings or trends is based mainly on the detail of the survey grid and the size (and type) of the feature. Conclusions based on single-point anomalies should be used cautiously, because these anomalies may be solely the result of a transcription error and not some site feature. A full discussion of interpretation theory and calculations is beyond the scope of this compendium.

8.4.1.5 **Use of Geophysics**

Project management personnel should view geophysical methods as a tool to guide investigations of hazardous waste sites. Geophysics is **a** proven indirect investigative technique that should not be viewed as an absolute answer, because the methods are not part of an exact science. The final product of a successful geophysical survey is an experienced geophysicist's interpretation, which is not always definitive or conclusive. The results are interpretative and need to be routinely checked and confirmed by direct physicai confirmation methods ("ground truthing," such as test pit excavation, drilling, and so forth).

Geophysics can be a cost-effective tool in providing extensive low-cost information and project guidance about successive, more costly phases.

8.4.1.6 **Procedures**

The SM should confer with the staff geophysicist to determine the applicability of the method to site-specific conditions and objectives. To identify site-specific technical problems, the geophysicist should examine site reports, drilling logs, air photos, and other data that may exist. in addition, the SM and the geophysicist should conduct a site reconnaissance to identify any problems that may inhibit the study. Cultural features such as power lines, surface metal, and radio transmitters may have a detrimental effect on the data acquisition or interpretation. Identification of these potential problems during a site reconnaissance may have such an impact on the survey that the survey area may be modified, or geophysics may not be selected for use at that particular site. Finally, the Site Manager should inform the geophysicist of any related or dependent phases of work so that the geophysical survey may be completed in a timely manner and the interpretation may be used to provide guidance for subsequent tasks.

Most geophysical surveys are carried out over a grid or a series of lines within the study area. Stations at which measurements are taken or energy put into the ground (for those methods that involve an outside source of energy) are usually spaced at regular intervals designed by the geophysicist to produce optimum results for the study objectives. Although initial line placement can be done at the project management Ievel, detailed line placement and surveying should be done only by qualified technical staff members.

All fieldwork should be done under the supervision of the staff geophysicist with daily data reduction and review being mandatory. The geophysicist should also supervise the daily reporting of all field data, which at a minimum should include all field notes, maps, work sheets, and raw data tabulation (including any any coordinates and measured values).

8.4.1.7 Information Sources

Information sources and references are ‘listed in the following subsections at the end of the discussion on each geophysical method.

8.4.2 Geophysical Methods

8.4.2.1 Electromagnetic

The electromagnetic (EM) method provides a means of measuring the electrical conductivity of subsurface soil, rock, and groundwater. Electrical conductivity is a function of the type of soil and rock, its porosity, its permeability, and the fluid composition and saturation. In most cases the conductivity of the pore fluids will be responsible for the measurement. Accordingly, the EM method applies both to assessment of natural geohydrologic conditions and to mapping of many types of contaminant plumes. In addition, trench boundaries, buried wastes, drums, and utility lines can be located with EM techniques.

8.4.2.1.1 Applicability

Although EM is not a definitive technique, it is useful for several reasons. First, an EM survey can be conducted over an entire site very quickly. In addition, EM methods are generally Inexpensive, even for coverage of large areas. Often, 100 acres or more may be surveyed in just a few days time (depending on desired detail). More importantly, EM data can be used to direct the more expensive phases of an investigative project, potentially resulting in **a** large cost savings. For example, rather than drilling several dozen monitoring wells while searching for groundwater contamination, an EM conductivity unit may be used to survey for a conductive (or resistive) plume. Several EM survey lines may be run to provide definition of the plume and an indication of its source area, reducing the number of exploratory wells required. This approach could potentially result in better well placement at a significant cost savings, Another reason why EM should be considered is to fill in data gaps and to reduce the risk of missing a facet of the Investigation, such as the presence of previously undetected refuse trenches, buried drums, or changing hydrologic conditions.

Electromagnetic methods may be used in many situations for a variety of purposes. The following list includes major uses related to investigations of hazardous waste sites:

- Defining the location of a contaminant plume (This could lead to the identification of downgradient receptors, source areas, and flow directions if the conductivity of the plume (target) is distinct in comparison to the host (background) hydrogeologic setting.)
- Locating buried metal objects (e.g., drums, tanks, pipelines, cables, monitoring wells)
- Addressing the presence or location of bedrock fault/ fracture systems (This is important for identification of preferential pathways of water flow in bedrock.)
- Mapping grain size distributions in unconsolidated sediments
- Mapping buried trenches
- Defining lithological (unit) boundaries
- Determining the rate of plume movement by conducting multiple surveys overtime

The above list is only partial; in fact, EM methods may be used wherever a significant change in conductance can be measured. EM theory will be discussed later; however, in general, EM should be considered for use when any suspected target is anticipated to have a conductivity significantly different from background values. Factors such as cost, site-specific conditions, and equipment availability should also be evaluated before deciding to proceed with an EM survey.

8.4.2.1.2 Procedures

A. Objectives

The reader should evaluate the objectives of hazardous waste site investigations in light of EM geophysical capabilities. If the purpose of the site study is simply to confirm the presence of contaminants with minimal effort, EM methods may provide too much detail and no direct evidence; direct methods, such as installing a few wells or limited sampling, may be more suitable. If a site is to be characterized in detail and if assessment of geohydrologic conditions and identification of all source areas, plumes, and receptors are a priority, then EM (and other geophysical methods) may be a cost-effective way of selecting strategic locations for monitoring wells, directing test pit operations, efficiently selecting sampling points, and providing information between site sampling points.

B. Existing Data

If EM equipment is identified as theoretically capable of providing the type of information desired, the user should further evaluate the equipment to determine whether it is appropriate for use under the conditions found at a particular site. Evaluation of existing data can identify problems that may be encountered in the field:

- Variations in geohydrologic conditions (e.g., varied water table conditions or changes in rock or sediment) can result in a conductivity range that envelopes the response of the target (e.g., plume) and effectively masks or blocks out any signals.
- Scattered, near-surface metal may mask buried targets such as drums or trenches.
- Near-surface layers of extreme conductivity (high or low) such as a clay lense or surficial frost zone may mask the signal from a deeper target.

An analysis of the site history might more closely define a survey area, thereby cutting survey costs by reducing the size of the survey. Deep targets may be out of the penetration range of many EM units, and specialized equipment may be required. It may be difficult for many EM systems to detect a groundwater contaminant plume through 100 feet of unsaturated over burden. A site reconnaissance should be conducted to identify any other site conditions that may affect the data. Drastic topography changes can affect the quality of EM data obtained with some systems, and this possibility should be considered at each site.

8.4.2.1.3 Survey Design

Once the EM survey objectives have been clearly defined, the existing information has been reviewed, and reconnaissance of the site has been conducted, attention should be given to the design of the geophysical survey. The detail required of an EM survey is a primary factor in designing and planning fieldwork. If the purpose of performing EM work onsite is to define a large geologic feature, then a grid using a wide (100- to 1,000-foot) line spacing may be needed. Some instruments are capable of providing a continuous data profile, which makes them less likely to miss small conductors than the typical discrete measurement EM instruments. The importance of designing and implementing a grid system tied into existing "permanent" features (such as roads and buildings) cannot be overstated. This permanent feature will allow the grid to be reoccupied in the field to place drill holes and monitoring wells. Furthermore, additional surveys may be conducted on the site using other geophysical techniques or the same technique to provide an indication of plume movement. These surveys will help in orienting maps and diagrams that are produced later and in defining targets.

For most detailed enforcement-related efforts, a 98 to 100 percent confidence interval should be maintained. For example, if the target area is only 1 percent of the total survey area, then 130 readings would be required for the 98 percent confidence interval. For an accurate definition of an EM anomaly profile (useful in interpretation), four or more anomalous readings are recommended.

A. Background Noise

Background noise can be a significant factor in the success of an EM survey. Evaluation of existing data and a site reconnaissance will help to identify the probable background noise level. A high noise level can make interpretation difficult and may actually cause an anomaly to be overlooked. It would be practically impossible to delineate a slightly conductive contaminant plume contained in overburden that has a wide natural variation in conductivity. Noise sources can be divided into two groups: (1) natural, such as changing grain size distributions, steeply dipping strata, undetected mafic dikes, drastic topography, unexpected fault zones; and (2) cultural, such as powerlines, houses, railroads, surface metal debris, cars, and radio transmission towers. Some instruments are more sensitive to certain types of noise sources than others. Because there is little published information on this subject, experience is important.

B. Limitations

All EM instruments have varying limitations with regard to sensitivity and penetration. Published references, operator's manuals, and field experience should be used to evaluate instrumentation versus capability. Exhibit 8.4-1 lists several commercially available instruments along with factors that control their productivity.

Some systems are designed for one operator, some for two operators, and some are flexible and allow one or two operators. Generally, EM coverage for 50-foot readings range from 8,000 line feet per day to 22,000 line feet per day in average terrain, Some instruments are more suited to rugged terrain (steep hills, thick woods, brush, swamps) than others because of equipment configuration. When definition of deep bedrock features is the primary objective of a survey, large equipment along used brush-cut lines (typical in mineral exploration) may be needed. (Note: Productivity will be greatly diminished with higher levels of protection; the productivity factors shown are for unencumbered, unprotected workers in a "clean" area.)

C. Instrumentation

The following matrix (Exhibit 8.4-2) provides guidance for EM equipment selection. These instruments may or may not be suitable to specific site conditions and investigation objectives; a full discussion of factors affecting their suitability is beyond the scope of this compendium. In addition, a combination of instruments is commonly used to assess site conditions. This discussion includes only some of the currently common instrumentation owned by hazardous waste investigative agencies,

Electromagnetic techniques have also been adapted for downhole applications, These techniques can be useful in defining the vertical extent of a contaminant zone. Some systems work inside polyvinyl chloride (PVC) or Teflon monitoring well casings. For further information on airborne, borehole, or surface EM instruments, the reader should consult the subsections on theory and interpretation and the manufacturer references shown later in this compendium.

Exhibit 8.4-3 compares some of the more common EM systems. The CEM and Max Min II systems are not commonly used for hazardous waste site investigations (they are more commonly used in minerals exploration), but the systems are included for comparative purposes.

Exhibit 8.4-1

FACTORS CONTROLLING PRODUCTIVITY OF SOME COMMON EM UNITS

Instrument	Manufacturer	No. Operators	Typical Daily Line Miles (50-ft readings)	Notes
EM-16-R	Geonics	2	2	2
EM-16	Geonics	1	3 4	2
EM-31-D	Geonics	1 or 2	3	2
EM-34-3	Geonics	2	2	2
VLF-3	Scintrex	1	3	2
GENIE (SE-88)	Scintrex	2	N/A	1
RADEM-VLF	Crone	1	3 4	2
CEM	Crone	2	2	1
Max Min II	Apex	2	3	1
EM-38	Geonics	1	3	2
EM-33	Geonics	N/A	100 +	1 (for helicopter use)

NOTES: (1) Primarily useful for geological features only.
(2) Useful for geological and cultural features.

Designation such as EM-16 or EM-31 are the manufacturer's model numbers and do not imply equipment complexity or capability.

Exhibit 8.4-3
COMPARISON OF COMMON EM SYSTEMS

	VLF-3 EM-16	EM-16R	EM-31	EM-34	EM-38	CEM	Max Min II
Operators	1	1 or 2	1 or 2	2	1	2	2
Typical In saturated sands (meters)	20-30	20-30	less than 5	see below	less then 2	Sea below	see below
Source (Ix)	Navigational signals continuously broadcast by U.S. Navy		setf-contained coil	self-contained coil	self-contained coil	2 self-contained coils	self-contained coil
Receiver (Rx)	Entire unit Is Rx (2-antennae)		self-contained coil	self-contained coil	self-contained coil	2 self-contained coils	self-contained coil
Frequency	Interchangeable Rx crystals 15-25 kHz		9.8 kHz	10 meter 6.4 kHz 20 meter 1.8 kHz 40 mater 0.4 kHz	13.2 kHz	390 Hz 1830 Hz	variable 222 Hz 888 Hz 1222 Hz
Tx-Rx spacing	Unlimited		3.6 meters	10, 20,40 meters	1 meter	100,200,400 feet	100,200,400,800 feet
Notes	Receives only specified frequencies. Will not read most noise. Penetration depends on formation resistivity. Maximum penetration is over 100 meters.		Continuous reading with a strip chart recorder. Can be used as a horizontal or vertical dipole for control of penetration.	Penetration varies with coil separation and with orientation. Maximum penetration is 50 meters.	Lightweight	Can take vertical and horizontal readings. Each coil is used as a source and then a receiver (shootback). Maximum penetration is approximately 50 meters.	Survey corrections are applied for topography while reading is being taken. Maximum penetration is approximately 100 meters.

Electrical resistity surveys involve the use of metal electrodes that are driven into the ground and long cables that drag along the ground. Set-up time can be long if the electrode spacing is large. Special handling and decontamination procedures will be required at hazardous waste sites.

8.4.2.2.2 Procedures

Electrodes are typically arranged in one of several patterns, called electrode arrays, depending on the desired information. Electrical Resistivity techniques can determine the vertical subsurface Resistivity distribution beneath a point. In this type of survey, called vertical electrical soundings, the electrode array is expanded systematically and symmetrically about a point. For each set of electrode spacings, apparent Resistivity is determined from measurements of potential and input current. The resultant plot of apparent Resistivity versus electrode spacing is interpreted to provide the subsurface Resistivity with depth distribution at that one particular point. Examples of three common arrays are given in Exhibit 8.4-5, The Wenner and Schlumberger arrays are somewhat more common than the Dipole-Dipole and other arrays. These arrays (Wenner, Schlumberger) start with a small electrode spacing that is increased to permit deeper penetration for sounding.

The manner in which the apparent Resistivity changes with the electrode separation can be used to determine formation conductivity and layer thickness. To increase accuracy, the user should evaluate the interpretation of Resistivity data against the existing subsurface information. With any set of apparent Resistivity reading, a number of solutions are possible, so existing data must be used to select the one that fits best. A formation Resistivity may be assigned, but without geological control the material is not known. Resistivity electrode arrays can also be used with constant inner-electrode spacing and to develop a lateral picture of the site through profiles. Stratigraphic control is even more important when mapping lateral changes with constant electrode spacings, because layer thickness changes alone can cause changes in apparent Resistivity. The desired resolution is a major factor in deciding how closely to space measurements for a given survey.

In practical application, a Resistivity survey target (such as a plume or clay lens) should have a Resistivity contrast (positive or negative) over 20 percent from background. This change in Resistivity should be 50 percent or more to provide proper detection and delineation. For example, if a Resistivity survey were being conducted to delineate a groundwater contaminant plume (in overburden) with a Resistivity of 200 ohm meters, a background-saturated over burden Resistivity of over 400 ohm meters (for a conductive plume) or under 100 ohm meters (for a resistive plume) would probably by detected, providing other factors (such as depth) are not detrimental.

When depth sounding, resolution of individual layers has an accuracy generally around 20 percent; accuracy can be substantially more or less depending on the site conditions and operator expertise. Vertical Resistivity sounding is usually less accurate than seismic refraction work, which is often conducted within a 10 percent error tolerance. However, geologic units maybe distinguishable (by geophysics) only with the use of Resistivity methods at some site.

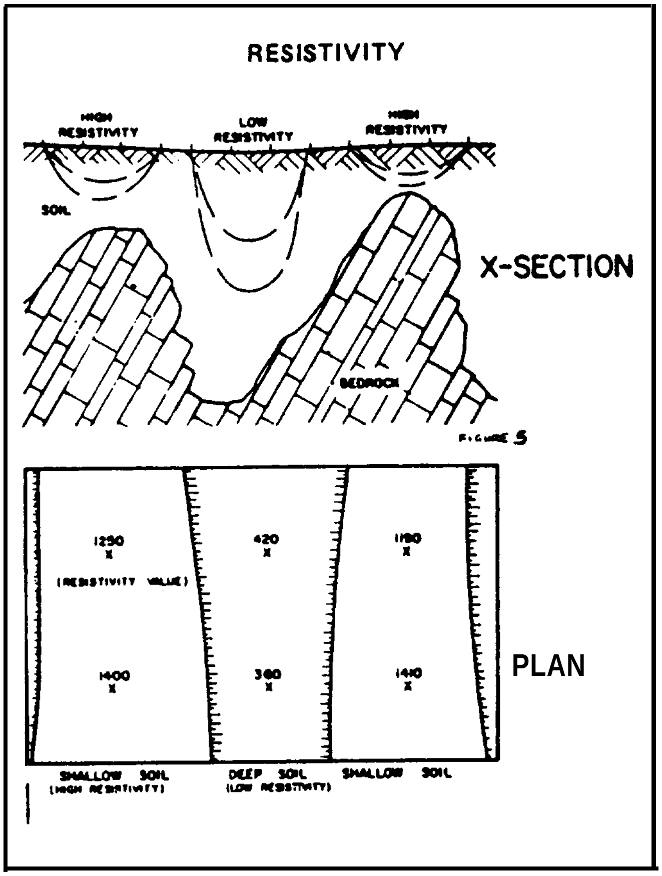
8.4,2.2.3 Survey Design

Data can be collected at randomly located stations or along survey lines. If vertical electrical soundings are performed to obtain Resistivity changes with depth, then the soundings are positioned where the information is most useful. If measurements are made to map lateral Resistivity changes, then the survey is best performed on a grid or on survey lines. The station spacing will be determined from the target size.

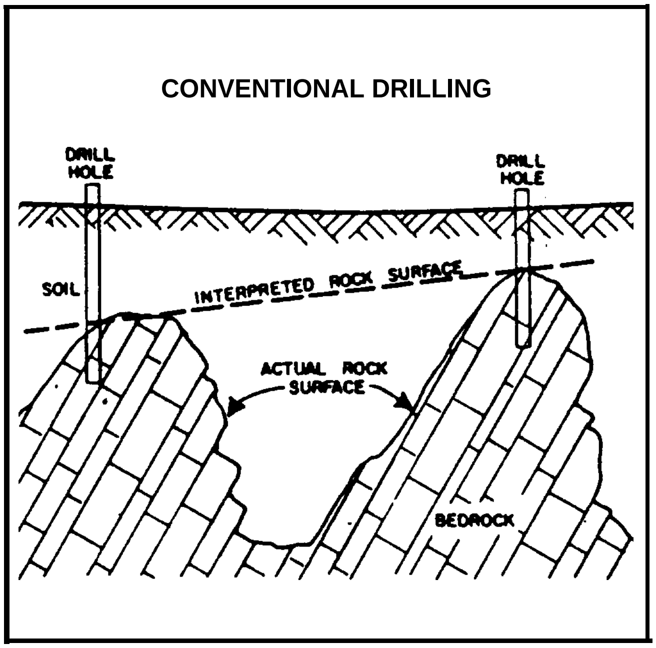
A. Background Noise

Evaluation of existing data and a site reconnaissance will help to identify the possible background noise level. A high noise level can make interpretation difficult and may actually mask

Exhibit 8.4-4
POTENTIAL EFFECTIVENESS OF RESISTIVITY VS. DRILLING



Resistivity measurements in an area with a variable bedrock surface can give qualitative depth information and can be used to define problematic zones.

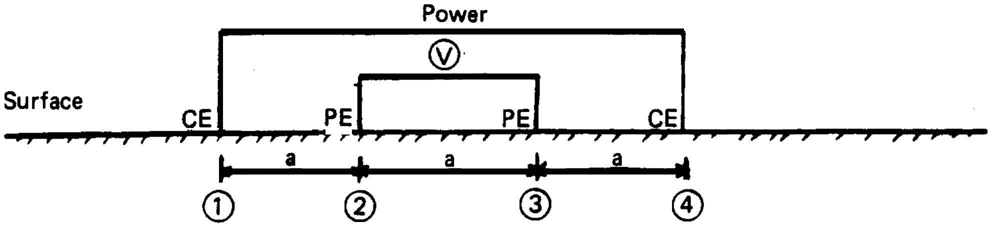


Conventional drilling programs provide information at a single point only. Information between drill holes is missing and can lead to serious, sometimes critical, interpretation errors.

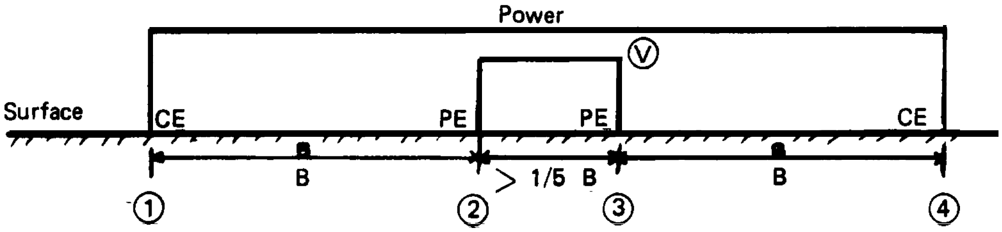
SOURCE: J. R. Peffer and P. G. Robelen, Affordable: Overburden Mapping Using New Geophysical Techniques, 1983.

Exhibit 8.4-5
EXAMPLES OF COMMON ER ARRAYS

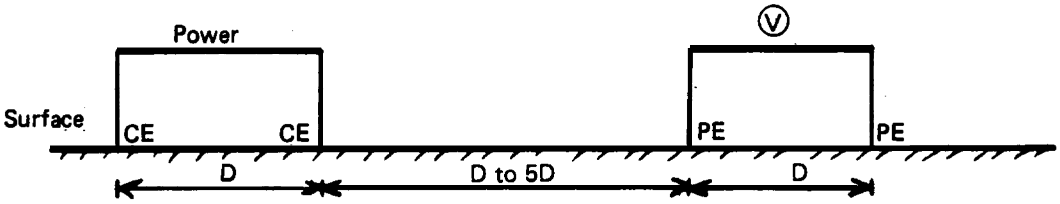
WENNER ARRAY



SCHLUMBERGER ARRAY



DIPOLE-DIPOLE ARRAY



①	Electode Number
PE	Potential Electrode
CE	Current Electrode
Ⓥ	Voltmeter

SOURCE: Based in part on W. M. Telford et al., Applied Geophysics, 1976, and R. E. Sheriff, Encyclopedic Dictionary of Exploration Geophysics, 1984.

an anomaly. It would be practically impossible to delineate a slightly conductive contaminant plume contained in overburden that has wide natural variation in conductivity. Noise sources can be divided into two groups: natural, such as discontinuous clay layers, undetected mafic dikes, drastic topography, unexpected fault zones, variable water table, and lightning; and cultural, such as powerlines, railroad tracks, and radio transmission towers. Some instruments are more sensitive to certain types of noise sources than others. Since there is little published information on instrument noise sensitivity, experience is important.

B. Depth of Investigation

As a rule of thumb when lateral Resistivity is being conducted, the array should be four or five times the distance from the ground surface down to the desired target. For vertical sounding, this suggested spacing should be about ten times the anticipated target depth. These suggestions should be used only as general guidance.

8.4.2.2.4 Miscellaneous Considerations

A. Instrumentation

For most shallow work at hazardous waste sites, practically any Resistivity system will suffice. Generally, equipment capability becomes important only when the desired investigative depth exceeds 70 to 100 feet. Larger power sources are needed to provide a measurable electrical potential with a wider electrode spacing. Some newer Resistivity units are capable of electronic data storage, and other features. Often, the peripheral capabilities of an ER system maybe the deciding factor when purchases are considered.

Borehole Resistivity equipment has been used (in uncased boreholes) to determine relative formation porosity and other factors. For more information on this equipment, the reader should refer to the borehole geophysics subsection of this compendium.

B. Calibration

ER equipment requires calibration, either in the field or in the laboratory dated records of this calibration should be kept in the equipment management file and in the appropriate project file. Calibration is used to establish the reliability and accuracy of the equipment; calibration typically includes an internal circuit check or actual field trials (e.g., tests over a known target). Equipment that historically exhibits fluctuations in calibration should not be used. The equipment serial number should be recorded on the calibration records. If the manufacturer recalls equipment, this fact should be explained and documented for instrument maintenance in the proper file. The current source and potentiometer must be calibrated on any type of Resistivity equipment. The instrument's current source may be calibrated by placing a reference ammeter in series with the electrode cables. The reading obtained on the reference ammeter is compared with the value read from the instrument's current source ammeter. The current source ammeter is then adjusted accordingly.

The potentiometer is calibrated by either of two methods. The preferred field method, which is similar to the calibration of the current source, is done by comparing the instrument's indicated potential to that potential measured with an independent voltmeter. An alternative means of calibration, which can be performed in the laboratory, involves placing a precision resistor of a known value in series with the current load. A potentiometer is then placed across the resistor. The potential measured should be equal to the product of the known resistance and indicated current.

C. Data Reduction

The raw data are the measured potential produced by a known current. To calculate the rho_{app} (apparent resistivity), these above known quantities are used. (See Exhibit 8.4-5, Common ER Arrays.) The electrode configuration is also used in the determination of apparent resistivity, which is defined by:

$$rho_{app} = (2 \times \pi \times V/I) / (1/r_1 - 1/r_2 - 1/R_1 + 1/R_2)$$

where:

V = The circuit potential (voltage)
I = Applied current (amperage)
r_1 = Distance between electrode #1 and #2 (meters)
r_2 = Distance between electrode #3 and #4 (meters)
R_1 = Distance between electrode #1 and #3 (meters)
R_2 = Distance between electrode #3 and #4 (meters)
rho_{app} = Apparent resistivity

Apparent resistivity is the resistivity measured at the ground surface and usually has units of ohmmeters or ohmfeet. The apparent resistivity is a function of the distribution of actual ground resistivities and the electrode geometry. Interpretation and reduction of the resistivity sounding are beyond the scope of this compendium; interpretation and reduction often involve curve matching or computer analysis. For further information, the reader should refer to the references listed in Appendix 8.4B, particularly Zohdy (1975).

8.4.2.3 Seismic Methods Applicable to Hazardous Waste Site Characterization

Seismic techniques have been useful in some instances for assessing subsurface geohydrologic conditions such as depth to bedrock; depth, thickness, dip, and density of lithologic units; horizontal and vertical extent of anomalous geologic features (folds, faults, and fractures); the approximate depth to the water table; and, in conjunction with geophysical well log data, the porosity and permeability of lithologic units. Seismic techniques have also been used to delineate the boundaries of subsurface bulk waste trenches and the depth of landfills.

8.4.2.3.1 Applicability

Seismic Refraction and Reflection Techniques

The method of seismic refraction consists of measuring the travel times of compressional waves that are generated by a surface source and that are critically refracted from subsurface refraction interfaces and received by surface receivers. First-arrival travel times of seismic energy plotted against source-to-receiver distance on a time-distance curve are characteristic of the material through which they travel. The number of line segments on the time-distance plot indicates the number of layers. The inverse slope of the line segments indicates the velocities of the layers.

The method of seismic reflection consists of measuring the two-way travel times of compressional waves that are generated by a surface source and that are reflected from subsurface reflecting interfaces. Depths to each reflecting interface can be deduced from reflection two-way travel times integrated with layered velocity information.

Higher subsurface resolution of shallower layers is possible with shallow reflection techniques. Modern multichannel engineering seismographs have digital filtering capabilities that allow later arriving wide-angle reflections to be detected from earlier refraction arrivals.

Seismic velocities obtained from a refraction survey over an area do not always agree with those obtained from a reflection survey over the same area. This variance may be because refraction velocities are obtained from rays traveling parallel to the top of a layer, whereas, reflection velocities are obtained from waves traveling perpendicular to the strata at the bottom of a layer.

The technique of seismic refraction has been used to a greater extent than seismic reflection in the subsurface characterization of hazardous waste sites.

8.4.2.3.2 Procedures

Preliminary Considerations

The planning, selection, and implementation of a shallow seismic survey require careful consideration by qualified, experienced personnel. At a minimum, the following steps are required:

- 1, Review existing site, area, and regional subsurface geologic and hydrogeologic “reformation including physical and chemical soil characteristics.
- 2. Define known hazards posing a threat to the safety of personnel who are conducting the seismic survey and topographic survey.
- 3. Define the purpose of the subsurface investigation.
- 4. Choose the appropriate seismic method to be conducted.
- 5. Define anticipated survey area from either USGS 7.5-minute quadrangle maps or published base maps of the particular site.
- 6. Add survey coordinates and elevations of all shot and geophone locations to be used before the actual survey. Static elevations corrections are applied later to raw seismic data to compensate for travel time differences because of elevation changes along seismic lines.

Survey Design

A. Seismic Refraction

The length of a seismic refraction line must be at least four times the maximum penetration depth desired. This length will ensure that head-wave energy will be received from refractors down to the maximum penetration depth. The spacing between individual geophones controls the degree of resolution available, and a spacing of 3 to 15 meters is commonly used. Closer spacings may be used for very shallow, high-resolution profiles. Long seismic lines are shot using the method of continuous in-line reversed refraction profiling, whereby the entire seismic line is shot in segments. Shot points are located at each end of and at intermediate points along each spread segment. The end shot point of each spread segment coincides with an end or intermediate position shot point of the succeeding spread segment. After a spread segment is shot, the geophone spread is moved to the next succeeding spread segment. The procedure is repeated until the complete reversed seismic refraction profile along the line has been developed.

B. Seismic Reflection

The major application of seismic reflection is in the mapping of the overburden bedrock interface where over burden thickness exceeds 30 meters. Reflections from the overburden-bedrock interface show UP prominently on seismograms where large contrasts between acoustic layer velocities exist. To minimize the effect of low-frequency refraction arrivals, the investigator should use geophones with natural frequencies higher than those used In refraction work. Filtering capability and amplifier gain control of modern seismic data acquisition units allow these reflection events to be enhanced, making it possible for a high degree of accuracy when mapping bedrock attitude.

Exhibit 8.4-6 represents the time-distance curve for bedrock at a depth of 90 meters with a *P*-wave velocity of 5 km/see overlain by an overburden layer with a P-wave velocity of 1.5 km/see, The dark ground roll area on the curve is an area of shot-generated surface-wave energy that travels along the surface of the ground and tends to mask reflection events. The amplitude distance curve for rays reflected from the bottom of the overburden layer (Exhibit 8.4-6) increases at critical distances for ***P***- and S-waves and remains uniform at small source-to-receiver distances.

At wide angles of Incidence, or large source-to-geophone distances, reflection events are subject to interference effects from earlier arriving refracted events. To eliminate interference effects caused by ground roll and earlier refraction arrivals, it is desirable to obtain an optimum shot to first geophone distance at which to place geophones in shallow reflection work. This optimum "Windo"' is empirically developed in the field by observing seismograms recorded at different shot-to-first-receiver distances. The optimum window for recording reflections from bedrock at a depth of 90 meters is shown in Exhibit 8.4-6. This window is at a shot-to-receiver distance range over which the reflected P-wave amplitude remains relatively uniform.

Part A of Exhibit 8.4-7 is a seismic record that was recorded on a portable 12-channel signal-enhancement seismic data-acquisition unit with digital filtering capability. Drill logs from the area over which the record was obtained indicate that bedrock is at a depth of 91 meters and Is overlain by glacial till and a surface layer of silt. The selected distance of optimum source to first geophone was 22.9 meters with a geophone spacing of 7.6 meters. Two hammer blows were necessary to enhance the record, and no digital filtering was applied. The direct P-wave through the over burden layer is clearly visible as a first break on each trace. The reflected *P*-wave from the base of the overburden layer is clearly visible in the 120 to 130 millisecond range. The first trace from a geophone 22.9 meters away from the source illustrates masking effects caused by ground roll. The actual shot-to-first-receiver distance should be increased slightly to obtain optimum representation of the reflected event. Part B of Exhibit 8.4-7 is a seismic record obtained from virtually the same location as in A, but low-cut digital filtering has been applied to further enhance the data.

The next step in this procedure is to move the shot point and geophone spread along a line and repeat the procedure. This step allows for multiple coverage and is known as comrnon-depth-point (CDP) profiling.

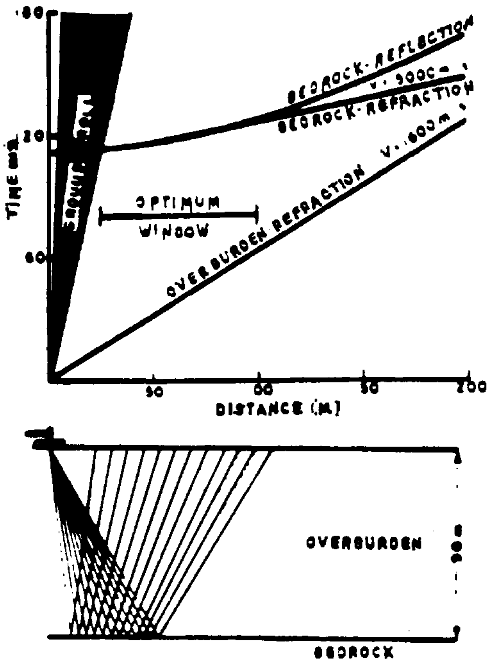
8.4.2.3.3 Miscellaneous Considerations

A. Instrumentation

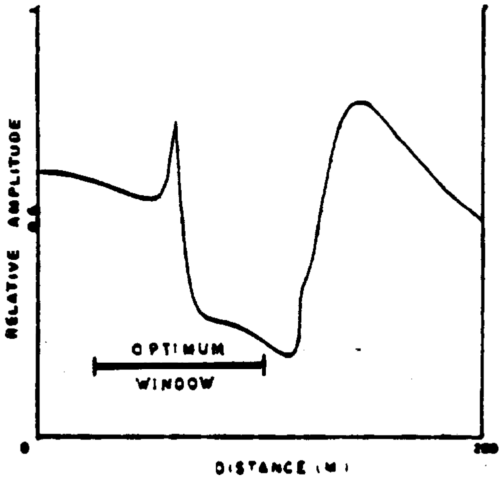
Shallow seismic surveys conducted at hazardous waste sites generally do not require large energy sources and can be either mechanical or explosive in nature.

Exhibit 8.4-6
TIME-DISTANCE AND AMPLITUDE-DISTANCE CURVES

A.



B.



SOURCE: J. A. Hunter (1982).

Mechanical and contained explosive sources are used in populated areas or when desired penetration depths are less than 100 to 300 feet. Hammer surveys are conducted by striking a steel plate coupled to the ground with a sledge hammer. An inertial switch on the hammer is connected to the seismic data acquisition system with a cable, enabling the moment of hammer impact to be accurately recorded. Another technique commonly used is the weight drop or "tlhumper" technique. Typically, a truck-mounted 3-ton weight is dropped from a height of 10 feet. The instant of group impact Is determined by a sensor on the weight. A seismic energy source developed by EG&G Geometries involves an air-powered piston striking a steel plate coupled to the ground. This method has the trade name Dynasource. The Betsy seisgun is a weak mechanical energy source in which a shotgun shell is detonated inside a chamber that is coupled to the ground surface. The Dinoseis method uses a confined chemical explosion in a truck-mounted explosion chamber to drive a steel plate against the bottom of the chamber, transmitting a pressure pulse into the ground.

Explosive sources are used sparsely in populated areas or when penetration depths are greater than 100 to 300 feet. Two types of chemical explosives, gelatin dynamite and ammonium nitrate, are commonly used In explosion surveys and are detonated in seated boreholes. Gelatin dynamite is a mixture of gelatin, nitroglycerin, and an inert binder material that can be used to vary the strength of the explosion. Ammonium nitrate is a fertilizer that is mixed with diesel fuel and is detonated by the explosion of a primer. A charge of about 1 pound of explosives is usually sufficient to obtain penetration depths ranging from approximately 100 to 300 feet. Explosive sources generate wave fronts that are very steep and show up as distinct arrivals on seismograms. These sharp pulses, however, are more likely to cause damage to nearby structures. It may not be advisable to use explosive sources at hazardous waste sites where unknown gases or buried containers may be present.

A complete seismic recording system or seismograph detects, records, and displays ground motion caused by the passage of a seismic wave. A geophone (Exhibit 8.4-8) is commonly a moving-coil electro-mechanical transducer that detects ground motion. The moving coil is free to move in the annular gap between the poles of the permanent magnet, creating an output voltage that is proportional to the actual ground motion or to the motion of the outer geophone case. At frequencies below the resonant frequency of the coil or outer case suspension, the coil and outer case move together and output voltage falls off rapidly. The selected resonance frequency or natural frequency of a geophone must be below that of the lowermost frequency anticipated.

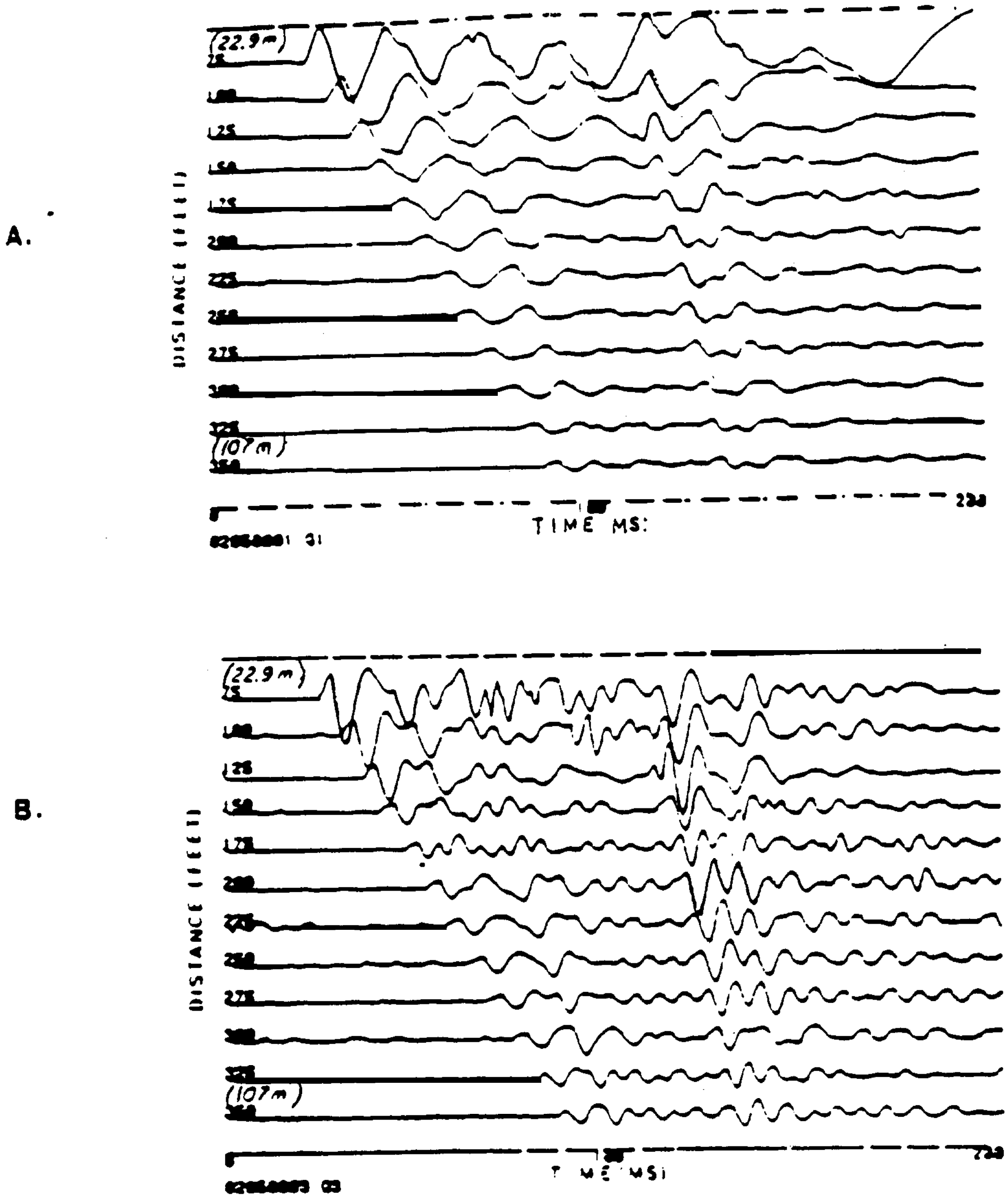
Each geophone detects ground motion at a point on the surface and passes this information through a single recording channel as a frequency modulated signal. This signal is transformed into the time domain and appears as one trace on the resulting seismogram.

Single-channel systems are used in small-scale engineering surveys, and the source and receiver are successively moved to create the characteristic travel-time curve. Multichannel systems consisting of 12, 24, 48, and 96 channels are in more common use today. These systems are capable of recording energy generated by a single source that Is detected by a series of geophones at various distances.

Seismic recording systems are equipped with amplifiers that have individual gain controls, which are set as high as possible, and with digital filters that exclude frequencies outside the useful signal range between 20 and 200 Hz. A galvanometers converts the current generated by the output voltage from each geophone Into the time domain. This information is then recorded onto ultraviolet sensitive paper for analysis.

Most seismic data-acquisition systems in use today have the ability to sort and sum waveforms from repeated shots at the same shot point. This feature is known as signal enhancement and

Exhibit 8.4-7
SEISMIC RECORDS



SOURCE: J. A. Hunter (1982).

is desirable because it serves to cancel out much of the systematic shot-generated and random background noise from the characteristic waveform. This method is also known as stacking of the individual wave traces. The following are some of the more common seismic data-acquisition units in use today:

1. EG&G Geometries
   a. Nimbus 125–2-channel signal-enhancement seismograph
   b. Nimbus 1210F – 12-channel signal-enhancement seismograph
   c. Nimbus 2415 –24-channel signal-enhancement seismograph

2. BISON Instruments, Inc.
   a. "Geo Pro" Models 8012A and 8024-12 and 24-channel seismic data-acquisition and processing unit
   b. Model 1580-6-channel signal-enhancement seismograph
   c. Model 157C– single-channel signal-enhancement seismograph

3. Weston Geophysical Corporation
   a. WesComp 11 –digital seismic data-acquisition and processing unit
   b. USA 780 – 24-channel amplifiers

4. Dresser Industries
   a. SIE RS-4– 12-channel refraction seismograph

B. Data Interpretation and Reduction

1. Corrections Applied to Refraction Data

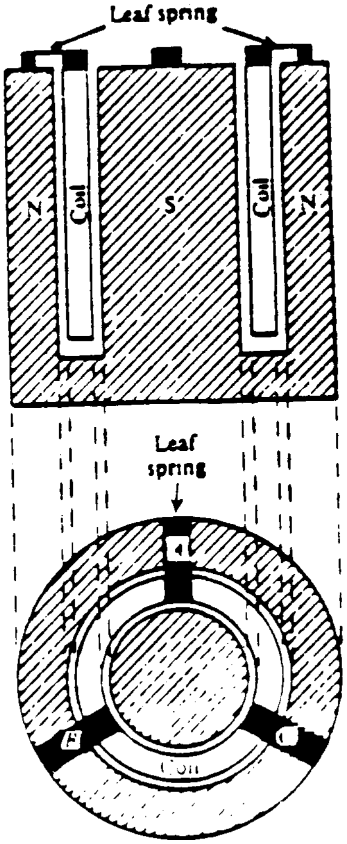
It is usually necessary to apply static elevation and weathering corrections to refraction data to correct for variations in surface receiver elevations and effects of the low-velocity layer (LVZ). A reference datum below the LVZ is usually selected, and travel-time corrections are calculated in reference to this datum surface. This process has the effect of placing the source and group of receivers directly on the datum surface. Various methods exist for correcting for near-surface effects, and the reader should refer to Telford et al., 1976, for a more detailed discussion.

2. Errors Inherent to Refraction Interpretation

Errors in refraction interpretation result from incorrect reading of the data, incorrect geologic interpretation of layer velocities derived, and incorrect underlying assumptions. At larger offset distances, the seismic signal decreases in amplitude as the higher frequency components of the signal attenuate more rapidly. The probability of picking the incorrect first arrival at a geophone increases with increasing distances. This error may cause an inappropriate velocity to be assigned to a refractor and may also lead to an erroneous estimate of the number of refractors present. Incorrect intercept times may then be chosen, which will cause wrong estimates of refractor depths and dips.

Seismic velocities that are determined are average values over the entire path traveled by the head-wave. The relationship between the velocity of **a** refractor and the geology may be complex. Detailed knowledge of the relationship between seismic velocity and lithologic markers, facies boundaries, and geologic time markers are necessary for accurate conclusions to be drawn from a refraction survey.

Exhibit 8.4-8
GEOPHONE SCHEMATIC



SOURCE: Telford et al., (1976).

The primary assumption made in refraction interpretation is that the seismic velocity of a layer is constant and increases with layer depth. If the velocity of a layer is less than that of the layer immediately overlying it, no head-wave is returned to the surface from the layer, and the layer is not represented on the time-distance curve. Velocity reversals with depth, if undetected, lead to depth estimates that are too deep. If the seismic velocity of a layer varies laterally, dip calculations will be affected. Another assumption is that all velocity layers are recognizable as first arrivals at geophones. This assumption is not always correct, however; some layers may not register as first arrivers. The effect of this condition is opposite to that of a velocity reversal with depth and will lead to depth estimates that are too shallow. finally, a refractor must be sufficiently thick for it to be detected. These conditions may lead to incorrect paring of segments of the time-distance curve for reversed refraction profiles and may lead to incorrect estimates of refractor dip.

3. Corrections Applied to Reflection Data

Static elevation and weathering corrections must be applied to reflection data. These corrections are easier to apply to reflection data because reflection raypaths are primarily vertical as opposed to refraction raypaths. Reflection data must be corrected for normal moveout. Compressional wave energy that is generated from a surface source and reflected from a subsurface interface arrives at a near-source geophone earlier than it arrives at a geophone located a distance away from the source. This difference in time is the normal moveout. Normal rnoveout must be removed to enhance primary reflection events. Dip moveout can be calculated from reversed reflection sections and is the quantity $td/\Delta x$ in Exhibit 8.4-9. Migrated reflection sections are those for which we assume that the seismic line is perpendicular to layer dip, the true dip to be calculated from the dip moveout. These corrections are dynamic corrections; more complete discussion can be found in Dobrin, 1960, and Kleyn, 1983.

The main objective in the method of seismic reflection is to detect the reflected P-wave from a background of random ambient noise and systematic shot-generated noise. The higher the signal-to-noise ratio, the more reliable the recording of the arrival time of the reflected phase. In reflection work, only vertical high- frequency geophones are used. These geophones are sensitive to the vertical component of ground motion, which is high for P-waves and small for P-waves, thus eliminating much of the systematic noise caused by S-waves. Shot-generated noise is further reduced through the use of stacking of records from identical subsurface sections. Ambient noise is reduced through the use of seismometer patterns and multcoverage techniques.

8.4.2.4 Magnetics

Magnetometer surveys are used to identify areas of anomalous magnetic field strength. Although natural conditions may cause anomalies, shallow-buried ferrous metal objects (i.e., drums or other waste-related metal) exhibit strong anomalies that are rarely confused with natural sources.

8.4.2.4.1 Applicability

The magnetic methods described in this subsection are applicable to locating buried drums and other buried ferrous metal objects; locating waste pits that contain metal; locating underground utilities such as pipelines, cables, tanks and abandoned well casings; clearing drilling sites; and identifying geologic features that exhibit sufficient magnetic contrast.

Exhibit 8.4-9
REVERSED REFLECTION PROFILE

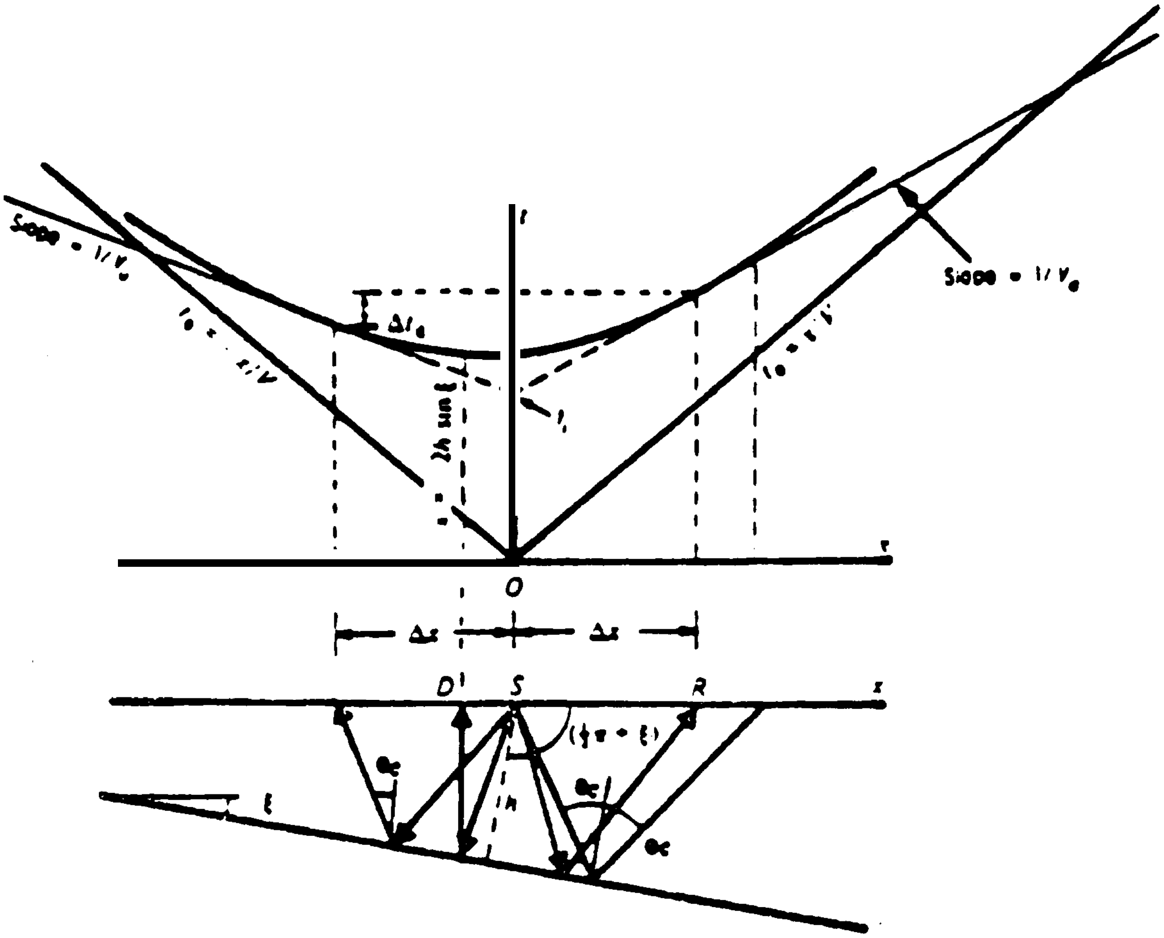


Exhibit 8.4-10

MAGNETIC SUSCEPTIBILITIES OF ROCK MATERIALS’

Material	Magnetic Susceptibility (K10^6, CGS units)
Magnetite	300,000-800,000
Pyrrhotite	125,000
Ilmenite	135,000
Franklinite	36,000
Dolomite	14
Sandstone	17
Serpentine	14,000
Granite	28-2,700
Diorite	46
Gabbro	68-2370
Porphyry	47
Diabase	78-1,050
Basalt	680
Olivine-Diabase	2,000
Peridotite	12,500

---

[1] Adapted from C.A. Helland, "Geophysical Exploration" (from Costello, 1980

Metal location and depth of burial can be inferred from the shape and width of the anomaly. The location of metal using magnetometry facilitates safe excavation without puncturing metal containers. Underground utilities, which are traceable with magnetics, often lie within loosely filled trenches that may provide permeable pathways for groundwater flow. Magnetrometry is used in clearing drilling sites to select locations that are free of drums, detectable under ground utilities, and other ferrous obstructions.

Under certain conditions where sufficient contrasts in magnetic susceptibilities between geologic units exist, magnetic methods may be useful in identifying geologic structures such as folding, faulting, buried drainage channels, bedrock topography, and igneous intrusions. The magnetic susceptibilities of some rock materials are presented in Exhibit 8.4-10.

8.4.2.4.2 Procedures

Preliminary Considerations

Before conducting a magnetometer survey at a hazardous waste site, the following tasks should be conducted:

- Review historical waste disposal practices to identify target and nontarget buried ferrous objects.
- Establish the minimum size target of interest.

- Conduct onsite reconnaissance to evaluate the suitability of the method, possible interferences, and terrain features.

- Review site geology to determine if any natural anomalies might exist.

- Estimate anticipated anomaly intensities.

For clearing drilling sites, utility maps should always be consulted.

Onsite reconnaissance is conducted to identify possible interferences and to evaluate accessibility of the areas to be surveyed. Interferences may result from surface metal, fences, buildings, and powerlines.

Metal near the sensor may produce an anomaly great enough to mask an anomaly produced by a buried object below it, depending on the relative anomaly strengths.

The presence of variable geologic conditions, such as mafic intrusions and local magnetite sand accumulations, may give rise to natural interferences. Geologic features that produce anomalies often lie below the depth of burial of the target objects and thus may not affect detection of the targets significantly.

The following tasks are involved in the magnetometer survey

- Establishing a survey grid over the study area

- Establishing a base station

- Collecting magnetometer measurements at each station

8.4.2.4.3 Survey Design

Magnetic measurements are usually taken either at equally spaced stations located across a rectangular grid or at equal intervals along several profile lines. The spacing of the stations depends on the target size. In general, the spacing between stations should be approximately one-fourth of the lateral extent of the target. For a single 55-gallon drum, the maximum distance at which the station can be detected is typically 10 to 15 feet, and the grid spacing can be designed accordingly. The closer the stations are spaced, the better the resolution becomes and the better the probability of detecting anomalies. More stations are required to cover the same area, however, and the time required to conduct the survey increases correspondingly.

It is helpful to lay out the survey grid so that the lines are oriented perpendicular to the strike of the target. If this orientation is not known, then north-south grid lines are preferable.

An accuracy of 5 percent is generally adequate for station locations for a magnetometer survey; hence, a hand transit (Brunton compass) and tape measure are sufficient to survey the station locations. Wooden stakes or other nonmetallic station markers should be used.

Magnetic Measurements

Magnetic measurements are taken by placing the magnetometer at a station, orienting the sensor properly, and taking the reading in accordance with the operating instructions for the particular instrument used. The instrument operator should be free of any magnetic material such as keys, belt buckles, steel-toed shoes, metal rim glasses, and so forth. To avoid effects of rocks that maybe naturally magnetic and to avoid the effects of topography, it is important to hold the magnetometer sensor above the ground while taking measurements. The sensor should be held at the same height above the ground for each measurement.

Interferences

Interferences from surface metals, fences, powerlines, and other aboveground sources, which generally lie closer to the magnetometer sensor than buried targets, may mask the targets and sometimes cannot be corrected for. In some cases, data obtained near such interferences must be excluded. Corrections for interferences from geologic conditions and surface objects that have small magnetic moments in comparison to the target maybe possible. Some instruments have filters that eliminate powerline interferences.

Total Field Versus Vertical Gradient

Two types of magnetic measurements are generally used: total field and vertical gradient. The total magnetic field intensity is a scalar measurement, or simply the magnitude of the earth's field vector independent of its direction. The magnetic field gradient is a measurement of the difference in the total magnetic field between two sensors having a fixed distance between them. The gradient equals the change in total magnetic field over distance (sensor spacing). For vertical gradient measurements, the sensors are separated vertically. Gradient measurements may be made by using a gradiometer, which is a magnetometer with two sensors built in, or by using a normal total field magnetometer and taking two separate readings at different heights. The gradiometer takes measurements at the two sensors simultaneously, whereas measurements using a total field magnetometer have a small time separation. The sensitivity of vertical gradient measurements is variable and depends in part on the vertical separation of the two sensor positions. Commonly, vertical separations of one-half, 1, and 2 meters are used.

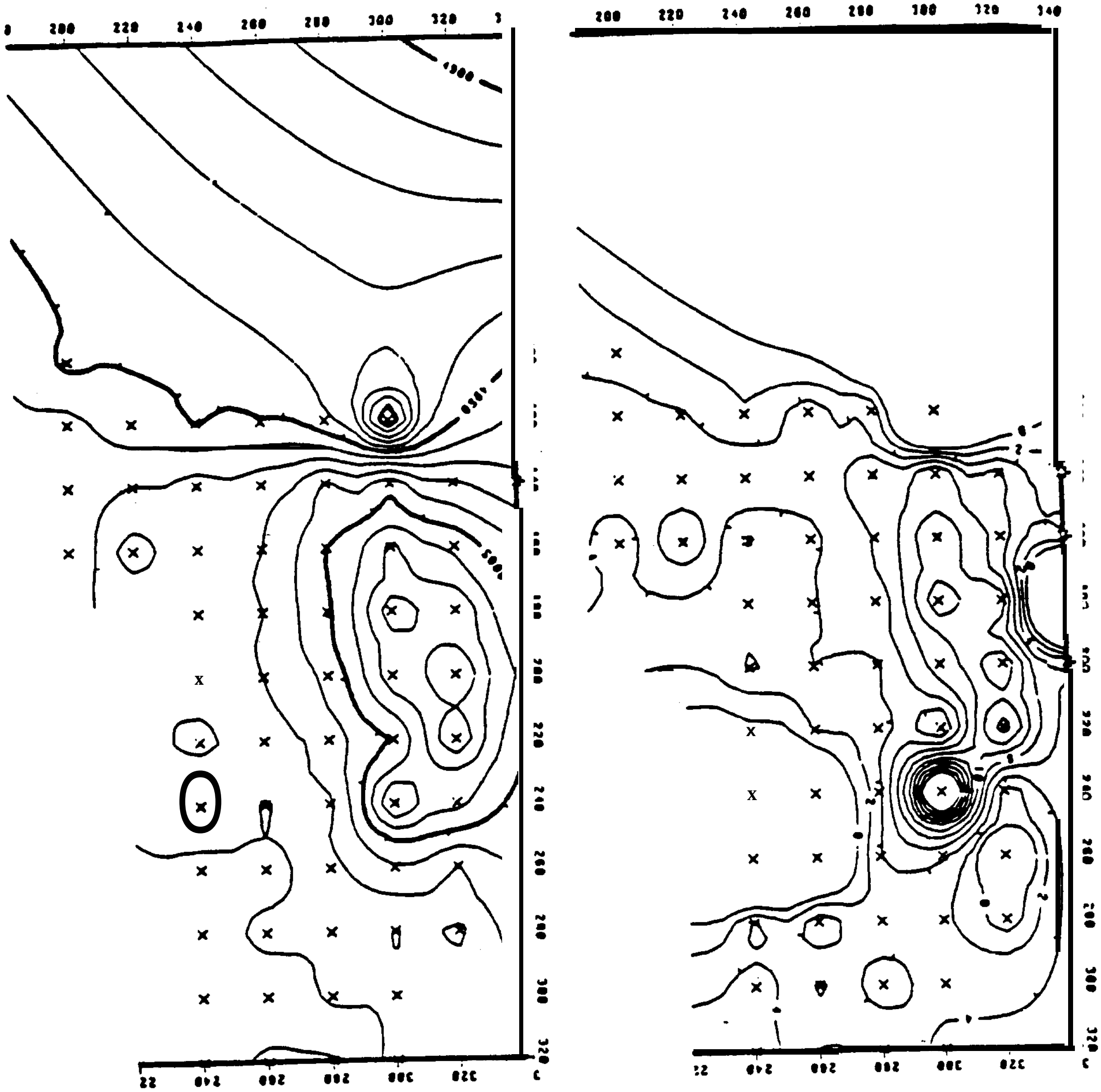
Vertical gradient measurements include several advantages over total field measurements:

- The measurements give finer resolution of complex anomalies,
- The measurements require no corrections for diurnal variation, micropulsations, and magnetic storms. Measurements at the two sensors are made simultaneously or nearly so, these temporal variations affect both readings essentially equally and are, therefore, removed on the differential.
- The regional magnetic field affects measurements at both sensors equally, and these variations are removed on the differential.
- Gradient measurements provide vector direction as well as magnitude and can be used for more quantitative determination of anomaly location, depth, shape, and magnetic moment.

The following are disadvantages of the gradiometer and reasons why total field measurements%ay be preferred:

- Gradiometers have a smaller radius of detection and thus require closer spacing of measurement points to achieve their potential for finer resolution of anomalies. Finer grid spacing requires more time. In some cases, targets at depth may be beyond the radius of detection for a gradiometer, but not for a total field magnetometer.

Exhibit 8.4-11
CONTOUR MAPS OF TOTAL FIELD AND VERTICAL GRADIENT MEASUREMENTS



TOTAL MAGNETIC FIELD

Contours are in gammas +50,000

VERTICAL GRADIENT

Contours are in gamma/0.5 meter

- Gradient readings using a total field magnetometer take longer to do than a simpler field measurement.
- Calculations that are based on vector properties of gradient measurements to precisely determine source location may be very complex and time consuming.

In summary, total field measurements are suitable for reconnaissance surveys because they enable coverage of a larger area in a shorter amount of time than do vertical gradient measurements; they also provide good information on the location, depth, shape, and magnetic moment of buried ferrous objects. Vertical gradient measurements are best for detailed studies over small anomalies where more detailed characterization of buried ferrous objects may be required. Contour maps of both total field and vertical gradient measurements over a small anomaly are presented in Exhibit 8.4-11. Vertical gradient measurements were taken at the same grid spacing as total field measurements, but the finer resolution of the vertical gradient data is evident.

Data Interpretation

Interpretation of the data can yield location and depth of the magnetic sources. Interpretation is best performed using computer modeling techniques. Reasonable estimates of depth can be made by using methods described in Appendix 8.4D. Almost ail interpretations are made using data profiles. Contour maps establish the distribution of the source.

8.4.2.5 **Ground Penetrating Radar**

8.4.2.5.1 Applicability

Ground penetrating radar (GPR) data are used to produce a continuous subsurface profile through the use of a linear strip chart recorder. However, while GPR is useful to define subsurface conditions, it is more limited in application than most other geophysical techniques. The following is a partial list of major uses related to hazardous waste site investigations:

- Define or locate buried drums, tanks, cables, and pipelines.
- Define boundary of disturbed versus original ground (and strata), such as a landfill or a trench.
- Map water table (limited reliability).
- Delineate stratigraphic layers, such as clay, till, or sands.
- Define natural subsurface features, such as buried stream channels (preferential pathways), lenses, and voids (caves).

In addition, GPR may be used whenever a significant change (or differential) in electrical properties is encountered and when a change should be mapped. For more specific information on these properties, the reader should refer to the theory or information sources subsections in this compendium.

Although GPR cannot provide definitive information on subsurface conditions, the data are desirable for several reasons. GPR can quickly provide subsurface information about a hazardous waste site. Typical productivity with conventional graphic recording GPR equipment on low-relief terrain is several line miles per day. Often, this productivity rate makes GPR a very cost-effective reconnaissance method. For example, if the objective of an investigation is to define suspected locations of buried drums, then GPR (or other geophysical methods, electromagnetic, or magnetics) can be used to define suspected areas. Test pit excavation (or other direct methods) can be used to further explore suspected areas and can provide control for GPR data.

8.4,2.5.2 Procedures

Preliminary Considerations

A. Objectives

GPR capabilities should be evaluated against the objectives of hazardous waste site investigations. If the site study is simply to substantiate the possibility of buried drums on a site with minimal effort, then typical radar surveys will provide only localized detail and no direct evidence. If, however, a site is to be characterized in detail and the identification of any drum location Is a priority, GPR alone or in conjunction with other geophysical methods (such as magnetometry) may be a cost-effective way of directing test pit operations and selecting sampling points, etc.

B. Existing Data

If radar equipment is identified as theoretically capable of providing the type of information desired, further evaluation should be made to determine if the equipment is appropriate to use with the conditions found at a particular site. Evaluation of existing data can identify problems that may be encountered in the field, such as the presence of buried electrical” cables or a near-surface conductive clay layer. Conditions such as these can cause noise in the data or even “mask” (block out) the radar signal from a deeper target. An analysis of the site history might aid in further defining a survey area and might result in a cost savings. Deep targets may be out of the practical range of many typical GPR units. For example, most radar antennae that are in general use would probably yield poor results if they were used to define the top of a bedrock surface underlying 300 feet of highly conductive overburden.

8.4.2.5.3 Survey Design

A. Define Survey

Once the GPR survey objectives have been clearly defined, the existing information has been reviewed, and reconnaissance of the site has been conducted, attention should be given to the design of the geophysical survey. The detail (coverage, resolution) required of a radar survey is a primary factor in designing and planning fieldwork. If the survey is to provide reconnaissance Information on the possibility of buried drums onsite, then a grid using a wide (50- to 200-foot) line spacing may be appropriate. If the purpose is to define as many drum locations as possible (such as for removal), then a detailed survey is probably required (1 O- to 20-foot line spacing). The importance of designing and implementing a grid system tied into existing “permanent” features (such as roads and buildings) cannot be overstated. This design will allow the grid to be reproduced (if required) for enforcement purposes and will also help to locate anomalous areas for future fieldwork (such as sampling, drilling, or digging test pits) by use of the grid for points of reference. Under certain circumstances, a reproducible grid may not be needed, such as if the raw field data are going to be used to direct other field operations, but this situation is not typical.

The anticipated size of the target compared with the proposed survey area should have an impact on the detail of the GPR survey grid. To reliably locate a suspected target would require more effort (such as denser line spacing or use of a higher resolution transmitter antennae) for a smaller target than would be required for a larger one. In this compendium, a discussion of reliably locating a target refers to the probability of the GPR unit passing over the surface expression of a target. Reliably locating a target does not mean that the target will be clearly defined in the data. Site-specific factors such as poor field methods, target depth, and background noise may cause a target to be overlooked or misinterpreted.

B. Background Noise

Background noise can be a significant factor in the success of a GPR survey. Evaluation of existing data and a site reconnaissance will help to determine the probable background noise level. A high noise level can make interpretation of data difficult. Noise often varies across a large (several hundred acres) site as different site conditions (soils, overburden stratigraphy, etc.) are encountered. if the natural soils have a wide variation In electrical properties, it would be difficult to pick out a subsurface boundary between backfill material and natural undisturbed soils. Noise sources can be divided into two groups: natural, such as surface water, discontinuous clay layers, extremes in topographic relief, and steeply dipping strata; and cultural, such as powerlines, surface metal, and two-way radios. Experience is important, because there is little published information on instrument sensitivity to different noise sources. Generally, however, the more conductive a target is above (or below) the normal background noise, the easier targets are to define and interpret.

C. Limitations

GPR instruments are limited with regard to sensitivity, resolution, and penetration. Field experience, published references, and operator’s manuals should be used when an evacuation of instrumentation versus capability is desired.

interpretation of radar data generally becomes more complex as the contrast in electrical properties (between background areas and target areas) becomes less. Several small closely spaced targets may not be sensed as multiple anomalies but as one large anomaly. This inaccuracy is a result of the inherent resolution capabilities of the equipment. Penetration of the signal varies with transmitter frequency, electrical conductivity, changes in conductivity, noise, and so forth. Because there are many imitations with GPR equipment and methods, the SM should consult a geophysicist before conducting the actual radar survey (as outlined in the responsibilities subsection).

8.4.2.5.4 Miscellaneous Considerations

A. Calibration

Geophysical instruments require calibration; GPR is no exception. Because the often subtle changes in the profile record chart can be interpreted in various ways, GPR equipment should be subject to an intensive calibration process.

Because the internal timing mechanism is used to estimate depths, it should be checked periodically with an internal or external timer. Because electrical properties (inherent to travel times) are quite variable between sites, the radar unit should be calibrated to each condition (strata) found at the site. This calibration can be as simple a process as taking some readings on top of a conductor at a known depth, such as a buried pipeline, and seeing how this reading translates to the strip chart profile. GPR subcontractors commonly make statements such as “on the strip chart, 1 inch equals so many feet.” Statements like these should be viewed skeptically because if materials vary across a site, then so do their corresponding electrical properties, which are directly responsible for travel time and depth calculations. Records of the calibrations and procedures that are used should be entered in the appropriate equipment and/or project file.

Interpretation

The interpretation of GPR data requires professional training and experience and is beyond the scope of this compendium. However, buried metal targets, such as steel drums, maybe easily recognized by the novice. Exhibit 8.4-12 has been included to give an example of radar data and to show how evident buried metal targets can be. The ground surface is at the top of the page; depth increases toward the bottom of the page. On the far left side (OE) of the profile, a strong signal is received at the bottom of the profile (at depth). In the middle of the line (75E to 100E), however, the reflected signal is weak and badly distorted. In this location, penetration does not extend to the bottom of the figure.

8.4.3 BOREHOLE GEOPHYSICS

Borehole geophysical techniques provide subsurface information on rock and unconsolidated sediment properties and fluid movement. Although the oil and mineral industries have been using these borehole geophysics for many years, only recently have the techniques been adopted to the assessment of site hydrogeologic conditions. This subsection provides an introduction to the basic borehole geophysical techniques as they might be applied to a hazardous waste site investigation. References are included to complement and expand on the technical interpretation of the logging results.

8.4.3.1 **Applicability**

Discussion in this subsection will introduce a variety of borehole geophysical methods. The general logging categories discussed are electrical, nuclear, sonic, and mechanical. Although other borehole techniques are available, such as three-dimensional vertical seismic profiling, borehole televiewing, and a variety of crossbore techniques, these are not discussed in detail in this compendium. A combination of surface and borehole techniques offers a three-dimensional understanding of subsurface conditions, but that approach is also beyond the introductory detail in this compendium.

A very basic description of the log, the parameters that affect response, and the sensing devices are presented here to aid in evacuating the applicability of logging functions.

A number of techniques are not discussed in this compendium; information on these techniques may be obtained from the references at the end of this subsection. While examining the techniques that are included in the following discussion, the reader should refer to Exhibit 8.4-13, which was taken in part from the D’Apollonia report to the U.S. Army (1980). The exhibit presents each logging function and information obtained for a variety of geologic and hydrologic parameters.

8.4.3.1.1 Electrical

Electrical logging includes spontaneous potential and single point resistance.

Spontaneous Potential (SP): The response is the result of small differences in voltage caused by chemical and physical contacts between the borehole fluid and the surrounding formation. These voltage differences appear at lithology changes or bed boundaries, and their response is used quantitatively to determine bed thickness or formation water Resistivity. Qualitative interpretation of the data can help identify permeable beds.

In a consolidated rock aquifer system where groundwater flow is controlled by secondary permeability (i.e., fractures), SP response may be generated from a streaming potential caused by a zone gaining or losing water.

The SP log is a graphic plot of potentials between the downhole sonde and a surface electrode. The system consists of a moveable lead electrode (located In the sonde) that traverses the borehole and a surface electrode (mud plug) that measures potentials in millivolts. Noise and anomalous potentials are relatively common in SP logs and are discussed in electric log anomalies later in this compendium.

Single-Point Resistance: This technique is based on the principle of Ohm's Law (E = Ir) where E is voltage measured in volts, I is current measured in amperes, and r is resistance measured in ohms. Single-point resistance measures the resistance of in situ materials (of the rock and the fluid) between an in-hole electrode and a surface electrode. Resistance logging has a mail radius of investigation and is very sensitive to the conductivity of the borehole fluid and changes in hole diameter (caving, washouts, and fractures). This condition is advantageous for the operator in that any change in the formation (resistance or fractures) will produce a corresponding change in resistance on the log. These changes in resistance are interpreted to be a result of lithology changes. The single-point log is very desirable for geologic correlation because of its special response to lithology changes.

In crystalline rock (high resistance formations), single-point resistance logs are useful in locating fractures and often appear as mirror images (opposite deflections) to the caliper log. Hole enlargement, caving, washouts, and fractures appear as excursions to the left (indicating less resistance in normal operation) of the more typical response observed in this log.

The principle of the function is quite simple. The current (I) remains constant while the voltage (E is measured between the movable lead electrode and the surface electrode. Voltage is then converted internally to resistance using Ohm's Law. A diagram of this arrangement can be found in Exhibit 8.4-14. SP and single-point resistance logs are designed to be run simultaneously since single-point resistance operates in alternating current (AC) (110 volt) while the SP operates in direct current (DC).

8.4.3.1.2 Nuclear

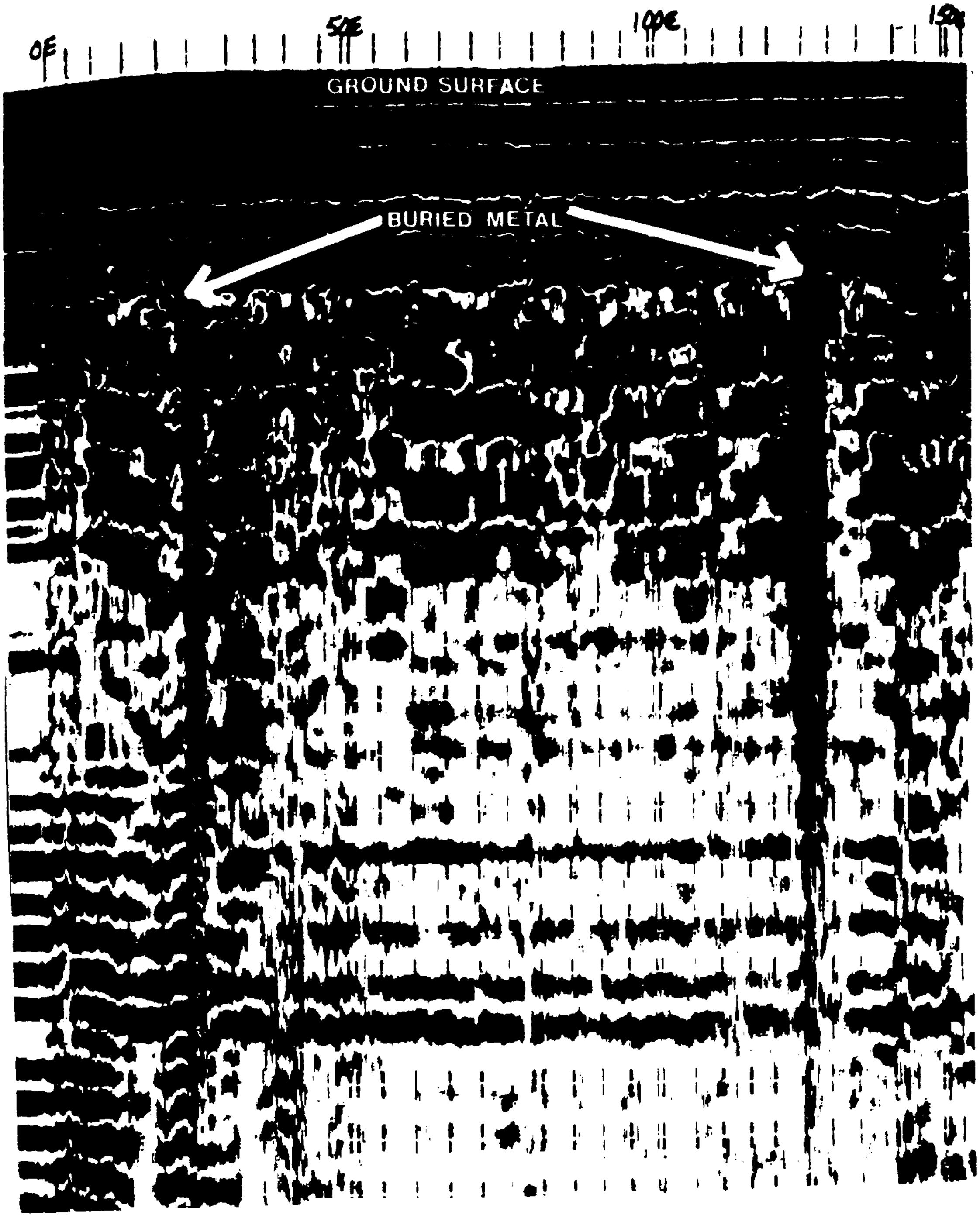
Nuclear logging includes natural gamma, gamma-gamma, and neutron.

Natural Gamma: This log measures the total of naturally occurring gamma radiation that is emitted from the decay of radioisotopes normally found in rocks. Typical elements that emit natural gamma radiation and cause an increase on the log are potassium 40 and daughter products of the uranium and thorium decay series. The primary use of natural gamma logging is lithology identification in detrital sediments where the fine-grained (most often clay) units have the highest gamma intensity. A natural gamma log can be quite useful to the hydrologist, hydrogeologist, or geohydrologist, because clay tends to reduce permeability and effective porosity within a sedimentary unit. This log can also be used to estimate (within one geohydrologic system) which zones are likely to yield the most water.

The sensing device is a scintillation-type receiver that converts the radioactive energy into electrical current, which is transmitted to the instrument and generates the natural gamma log.

Natural gamma logs can be run in open or cased boreholes filled with water or air. The sensing device is often built into the same sonde that conducts SP and single-point resistance logs. In essence, three functions are available from the use of one sonde.

Exhibit 8.4-12
TYPICAL GPR PROFILE



Gamma-Gamma: This nuclear log uses an activated source and measures the effect of the induced radiation and its degradation. Gamma-gamma logs are widely used to determine bulk density from which lithologic identification is based. They may also be used to calculate porosity when the fluid and grain density are known. The radius of investigation is dependent on two factors: source strength and source-detector spacing. Typically, 90 percent of the response is from within 6 to 10 inches of the borehole.

Neutron: The neutron log response is primarily a function of the hydrogen content in the borehole environment and surrounding formation. This content is measured by introducing neutrons into the borehole and surrounding environment and by measuring the loss of energy caused by elastic collision. Because neutrons have no electrical charge and have approximately the same mass as hydrogen, hydrogen atoms are, therefore, responsible for the majority of energy loss. Neutron logging is typically used to determine moisture content above the water table and total porosity below the water table. information derived from this log is used to determine lithology and stratigraphic correlation of aquifers and associated rocks. Inferred data can be used to determine effective porosity and specific yield of unconfined aquifers. Neutron logging is also very effective for locating perched water tables.

The equipment is Identical to that described for the gamma-gamma log except for use of a different source and the fact that the equipment must be able to handle higher count rates.

8.4.3.1.3 Mechanical

Mechanical logging includes caliper, temperature, fluid conductivity, and fluid movement.

Caliper: This log is defined as a continuous record of the average diameter of a drill hole. Caliper sondes can have from one to four arms. The two basic types are bowstring units, which are connected at two hinges, and finger devices, which have single hinges (see Exhibit 8.4-15).

Caliper resolution is broken into two categories: horizontal and vertical. The horizontal resolution is the ability of the tool to measure the true size of the hole regardless of its shape (circular or elliptical). Vertical resolution is controlled by the length of the feeler contact on the borehole wall.

Traditionalliy, caliper logs have been run to correct other logging functions. if this is the primary reason for running caliper, the bowstring or single-hinged unit will both provide adequate data. Calipers using single-hinged feelers provide the best vertical resolution. interchangeable arms are availabie for the single-hinged tools and should be selected on the basis of the hole diameter. Single-hinged tools can be used to identify fractures in igneous and metamorphic rocks and solution openings in limestone.

Temperature: The temperature log provides continuous records of the borehole fluid environment. Response is caused by temperature change of the fluid surrounding the sonde, which generally relates to the formation water temperature. The borehole fluid temperature gradient is highly influenced by fluid movement in the borehole and adjacent rocks. In general, the temperature gradient is greater in low-permeability rocks than high-permeability rocks, which is probably the result of groundwater flow. Therefore, temperature logs can provide the hydrologist with valuable information regarding groundwater movement.

Logging speed should be slow enough to allow adequate sonde response with depth, because there is a certain amount of lag time. The probe is designed to be run from top to bottom (downward) in the borehole to channel water past the sensor. Because some disturbance is inevitable when the sonde moves through the water column, repeat temperature logs should be avoided until the borehole fluid has had time to reach thermal equilibrium.

Exhibit 8.4-13

EVALUATION OF GEOPHYSICAL METHODS APPLIED TO GEOLOGICAL AND HYDROLOGICAL CONDITIONS

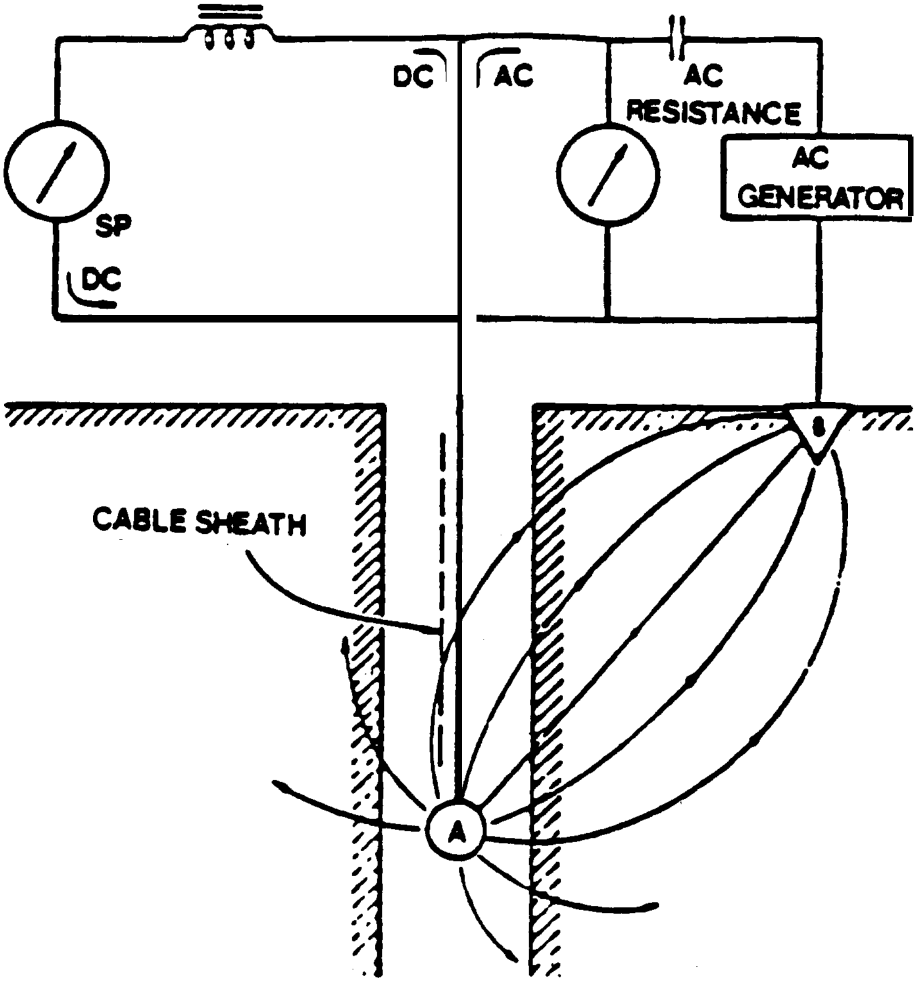
GEOPHYSICAL METHOD EVALUATION

Geophysical Method Evaluation	
●	Best Information
○	Good Information
◓	Partial Information
▲	Inferred Information
☐	No Information

GEOPHYSICAL METHODS		STRATIC ^PHY			GEOLOGIC STRUCTURE						AQUIFER PROPERTIES				
		Lithology	Lithologic Correlation	Surficial Materials	Folding	Faulting	Fracturing	Dissolution Features	Buried Drainage and Topography	Igneous Features	Porosity and Permeability	Potentiometric Surface	Flow Direction and Rate	Temperature	Water Chemistry
BOREHOLE LOGGING	Spontaneous Potential	◓	◓	◓	▲	▲			▲				◓		
	Resistance	●	●	●	▲	▲	●		▲		▲		◓		◓
	Natural Gamma Radiation	●	●	●	▲	▲			▲		○		◓		◓
	Gamma-Gamma	○	○	◓		▲	○	○	▲		●		◓		
	Neutron	○	○	◓		▲	○	○	▲		●		◓		
	Caliper	▲					○	○							
	Fluid Movement										▲	▲	◓		
											▲	▲	◓	●	
	Sonic	○	○	○			○				●		◓		
	Fluid Conductivity														○

SOURCE: Army Toxic and Hazardous Materials Agency 1980.

Exhibit 8.4-14
CONVENTIONAL SIMULTANEOUS-SINGLE-ELECTRODE RESISTANCE AND SPONTANEOUS-POTENTIAL LOGGING SYSTEM



SOURCE: Guyod (1952).

Fluid Conductivity These logs provide a continuous measurement of the conductivity of the borehole fluid between two electrodes. The contrast in conductivity can be associated with water quality and possibly with recharge zones. Conductivity logs are helpful when interpreting electric logs, because both are affected by fluid conductivity.

The most common sonde measures the AC voltage drop across closely spaced electrodes. These electrodes actually measure the fluid Resistivity (which is the reciprocal of conductivity), but they are called fluid conductivity logs to avoid confusion with resistivity logs. Simply, conductivity logs actually measure the resistance of the borehole fluid; resistance logs measure the resistance of the rocks and the fluid they contain.

Fluid Movement: Fluid movement logging can be broken into two components: horizontal and vertical. Horizontal logging uses either chemical or radioactive tracers, is most often unacceptable for hazardous waste investigations, and will not be discussed in detail.

‘Vertical movement of fluid in the borehole is measured by either an impeller flowmeter or chemical tracers. Tracers will not be discussed in this subsection for the reason mentioned above. The impeller flowmeter response is affected by the change in **vertical** velocity within the borehole. The best application of this log is defining fluid movement in a multiaquifer artesian system.

The sonde consists of a rotor or vanes housed inside a protective cage or basket. This log should be run both downhole and uphole. The logs should be compared side by side; only those anomalies that have mirror (opposite) deflections are the zones that are providing the vertical movement (Exhibit 8.4-1 6).

Sonic: This logging (also called acoustic logging) uses sound waves to measure porosity and to identify fractures in consolidated rock. Two general types of measurements are internal transit time, which is the reciprocal of velocity, and amplitude, which is the reciprocal of attenuation. The amplitudes of the P- and S-waves are directly related to the degree of consolidation and porosity and to the extent and orientation of fractures.

The instrumentation of acoustic logging is very complex; it includes a downhole sonde with a transmitter and two to four receivers. Sound waves are emitted from the transmitter and their propagation is measured by the receivers.

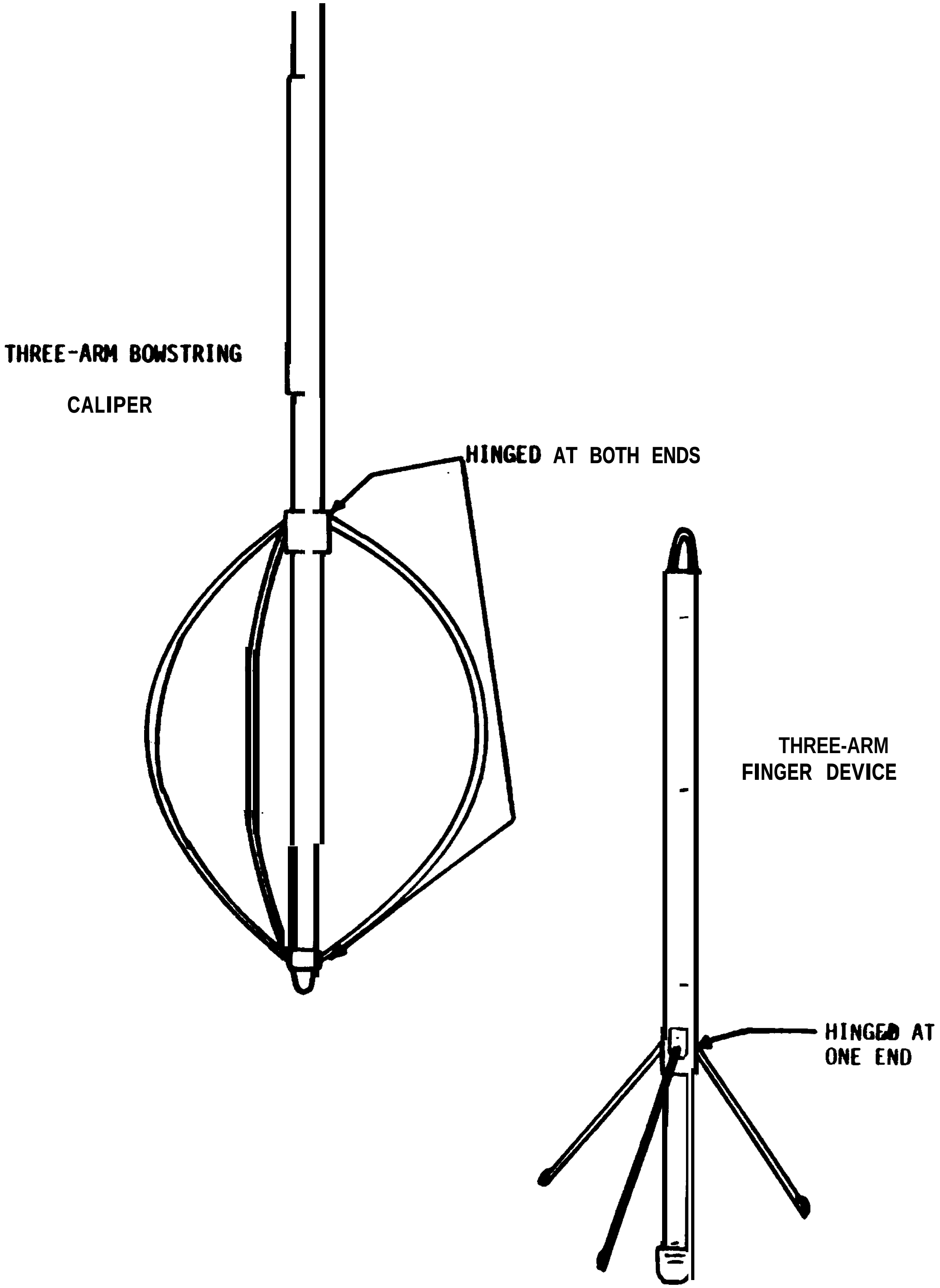
8.4.3.2 **Procedures**

8.4.3.2.1 Preliminary Considerations

Equipment discussed in this compendium is capable of performing electric, nuclear, and mechanical logging. This equipment is available from a variety of vendors and can usually be rented for short periods of time or leased on a long-term basis. In any case, the application of these techniques is quite complex, and the project geophysicist should be contacted to provide input for planning and implementing borehole programs.

The study objectives must be defined clearly before the user can identify the proper equipment needs. For instance, the Site Manager (SM) must generally understand the subsurface environment to determine which logs are applicable. After evaluating this determination and the site-specific limiting factors (i.e., access to well, well diameters, etc.), the SM can select the proper equipment.

Exhibit 8.4-15
TWO TYPES OF CALIPER SONDES



The following general types of information could be expected from borehole measurements:

- Vertical changes in porosity
- Relative vertical changes in permeability and transmissivity
- Lithology and structure
- Lithologic conditions
- Vertical distribution of leachate plumes
- Groundwater gradients, flow direction, and rate
- Water quality parameters

To determine a logging program that will enhance evaluation of the site, the SM must thoroughly evaluate two key items. First, the SM must identify the regional bedrock geology (i.e., igneous, sedimentary, metamorphic) and typical surficial units. Then the SM must gather as much local information as possible regarding geologic units (i.e., boring logs of monitoring wells, domestic water supply depths, and well yields) and any hydrogeologic reports or information.

Second, the SM must identify which logs are applicable in the site's geologic setting and which logs will provide the required information for meeting program objectives. Exhibit 8.4-17 is a general guide to data collection objectives that will aid in the selection process. However, each function under consideration must be researched in more detail using publications listed in information sources in this compendium and consulting with borehole geophysical logging specialists.

There are, of course, limiting factors for each of the logging techniques. Exhibit 8.4-18 identifies some limiting factors for the logs.

Once the geologic environment has been evaluated and the logging functions narrowed, the SM must select the appropriate equipment. Portable units that can be carried on a backpack enable access to most well locations; however, they are limited to logging functions requiring low power operation (e.g., battery packs).

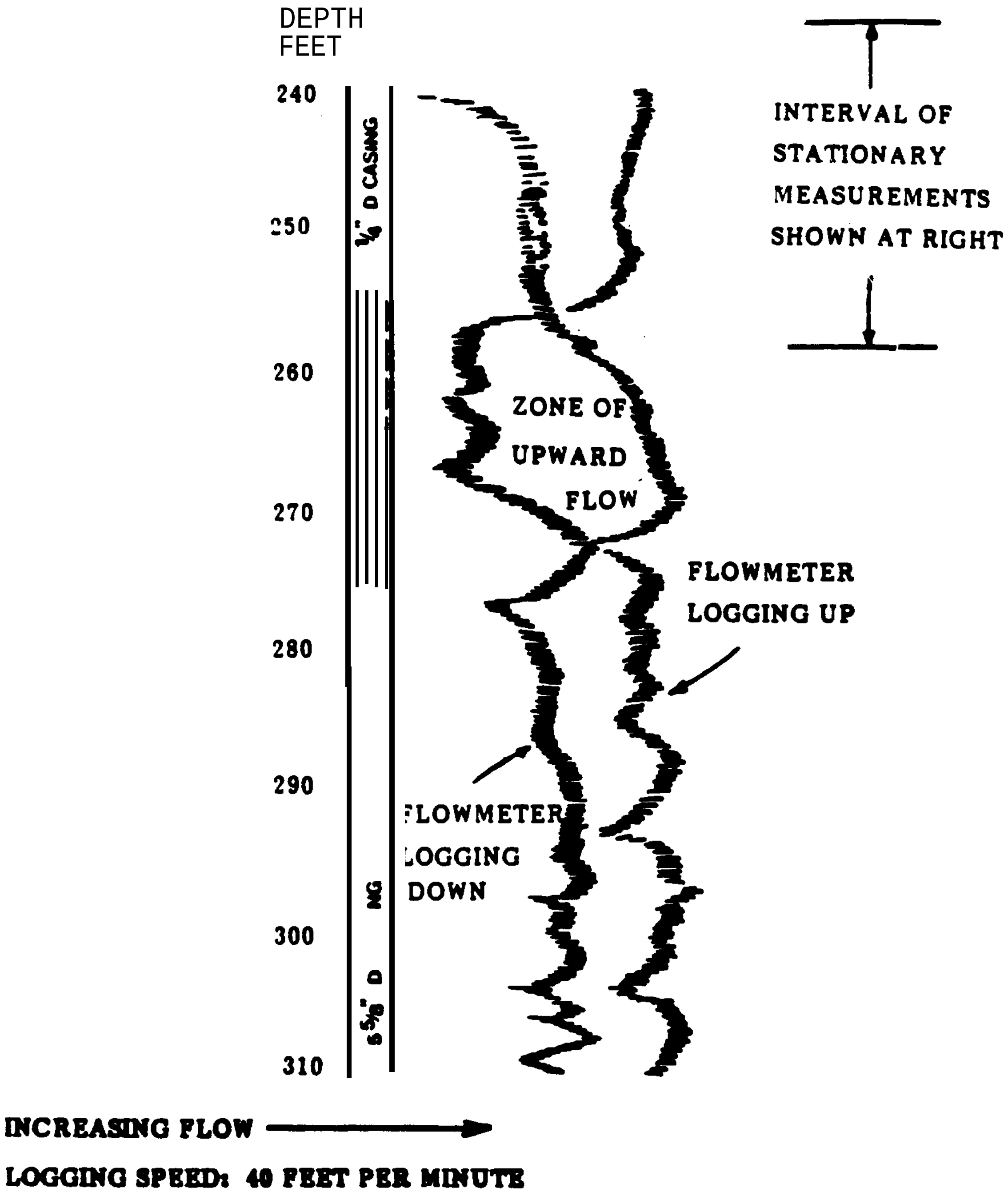
Functions that require 110 volt AC usually operate from a larger unit that is typically mounted in a vehicle. These units cost considerably more, and access to well locations can present problems in swampy areas. However, these units are able to run the majority of log functions available today. Exhibit 8.4-19 shows a generalized schematic diagram of geophysical well-logging equipment.

8.4.3.3 Survey Design

8.4.3.3.1 Log Selection

Once the SM has defined the logging program and has identified the general category of logs that will supply the necessary information, the specific logging functions(s) can be selected. Exhibit 8.4-20 describes the type of log, a basic description, and the primary use of the technique.

Exhibit 8.4-16
CONTINUOUS FLOWMETER LOG USED TO LOCATE ZONES OF FLOW



SOURCE: Techniques of Water Resources Investigations of the United States Geological Survey, Chapter E1 page 110.

Exhibit 8.4-17
GENERAL GUIDE TO DATA COLLECTION OBJECTIVES

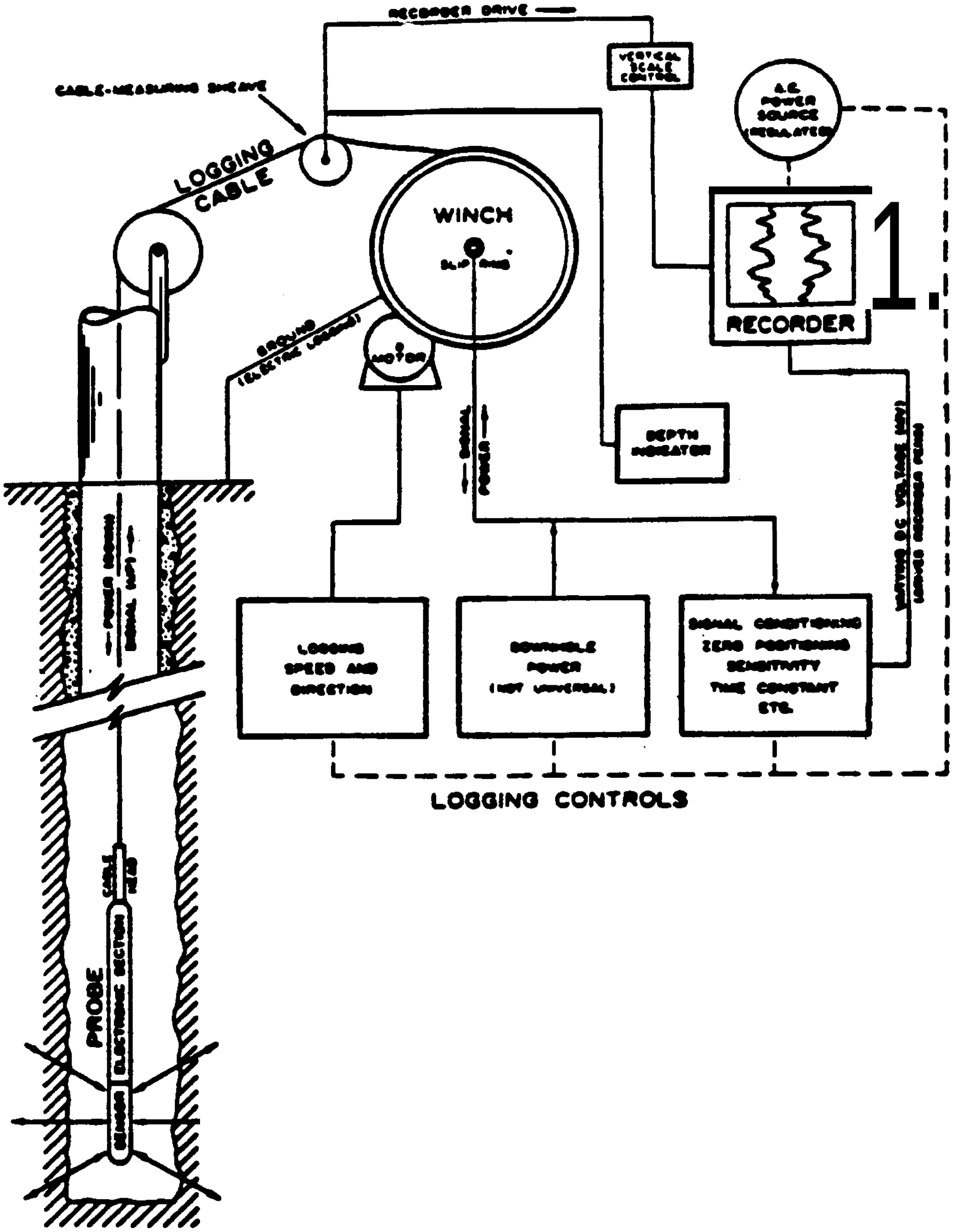
Data Collection Objectives	Available Techniques
Lithology and stratigraphic correlation	Electric, caliper, nuclear, and sonic
Total porosity or bulk density	Gamma-gamma, neutron, and sonic
Effective porosity or true Resistivity	Long-normal resistivity (records the Resistivity beyond the invaded zone)
Clay or shale content	Natural gamma
Secondary permeability (fractures, solution openings)	Caliper, electric, sonic, and borehole televiewer
Specific yields of unconfined aquifer	Neutron
Water level and saturated zones	Electric, neutron, gamma-gamma temperature, and fluid conductivity
Moisture content	Neutron
Dispersion, dilution, and movement of waste	Fluid conductivity and temperature
Groundwater movement through a borehole	Flowmeter (vertical) and chemical tracers (horizontal)
Cementing	Caliper, temperature, gamma-gamma, and sonic
Casing corrosion	Caliper

Exhibit 8.4-18
"LOGGING FUNCTIONS BOREHOLE LIMITATIONS

	Limiting Factors		
Logging Function,	Uncased Open Boreholes	Minimum Diameter (inches)	Fluid Filled
Spontaneous potential	X	2.5	X
Single-point resistance	x	2.5	X
Natural gamma		2.5	
Gamma-gamma		2.5	
Neutron		2.5	
Caliper		2.0	
Temperature		2.0	
Fluid conductivity		2.5	
Fluid movement		2.5	
Sonic		2.5	

X = Required condition

Exhibit 8.4-19
SCHEMATIC BLOCK DIAGRAM OF GEOPHYSICAL WELL-LOGGING EQUIPMENT



SOURCE: Techniques of Water Resources Investigations of the United States Geological Survey, Chapter E1 page 22.

Exhibit 8.4-20
TYPES OF LOGS, DESCRIPTIONS, AND USES

Type of Log	Description	Primary Utilization
Caliper	A caliper produces a record of the average diameter of drill hole.	Used for correction of other logs, identification of lithology changes, and locations of fractures and other openings in bedrock
Single-Point Resistivity	This log measures the resistance of the earth material lying between an in-hole electrode and a surface electrode.	Used to determine stratigraphic boundaries, changes in lithology, and the identification of fractures in resistive rock
Spontaneous Potential (SP)	SP is a graphic plot of the small differences in voltage that develop between the borehole fluid and the surrounding formation.	Used for geologic correlation, determination of bed thickness, and separation of nonporous from porous rocks in shale-sandstone and shale-carbonate sequences
Natural Gamma	This log measures natural gamma radiation emitted from potassium 40, uranium, and thorium decay series elements.	Used for lithology identification and stratigraphy correlation; most advantageous in detrital sediment environments where the fine-grained units have the highest gamma intensity
Gamma-Gamma	Gamma photons are induced in the borehole environments, and the absorption and scattering are measured to evaluate the medium through which they travel.	Used for identification of lithology, measurements of bulk density, and porosity of rocks

Exhibit 8.4-20
(continued)

Type of Log	Description	Primary Utilization
Neutron	Neutrons are introduced into the borehole, and the loss of energy is measured from elastic collision with hydrogen atoms.	Used to measure the moisture content above the water table and the total porosity below the water table
Temperature	A temperature log is the continuous record of the thermal gradient of the borehole fluid.	Used to determine seasonal recharge to a groundwater system
Fluid Conductivity	This log provides a measurement of the conductivity of the in-hole fluid between the electrodes.	Used primarily in-conjunction with electric logs to aid in their interpretation; useful for identifying saltwater intrusion into freshwater systems; can be useful in evacuating water quality
Acoustic (sonic)	A transmitter and a receiver or series of receivers that use various acoustic frequencies. These signals are introduced into the borehole, and the elastic waves are measured.	Used to measure porosity and identify fractures in igneous and metamorphic rock.

There are many combinations of logging functions. The reader should refer to Exhibit 8.4-12 (D'Apollonia, 1980) for more information on logging functions. Generally, several borehole techniques are performed simultaneously or in a series to define any one of the geologic or hydrologic parameters.

8.4.3.4 Interferences /Anomalies

Electrical: Both SP and resistance logs are susceptible to the same types of interference. Buried cables, pipelines, magnetic storms, and the flow of groundwater can all cause anomalous readings. The most common noise in the SP logs is known as the battery effect and is caused by the polarization of the wetted cable. This condition is most troublesome in highly resistive surface formations. A common interference with the resistance log is the result of ground currents from powerlines and other electrical sources that interfere with the alternating current used in logging. This interference appears as a sine wave superimposed on the resistance curve.

Some common equipment problems with electric logs are presented in Exhibit 8.4-21.

Nuclear: The most common problems with nuclear logs are that they are all affected by borehole diameter changes and changes in borehole media (air, water, mud). These problems are why caliper logs are essential to correlate the results. A natural gamma log is the sum of the radiation emitted from the formation and does not distinguish between elements (i.e., potassium, uranium, thorium). In quantitative applications of nuclear logs, the calibration, standardization, and correction for dead time are essential. However, when the logs are used for qualitative interpretations (e.g., stratigraphic correlation), such corrections may be unnecessary.

Mechanical: Caliper logging is a straightforward mechanical technique and exhibits few anomalies. Instrumental malfunctions are more likely to cause anomalous readings than borehole parameters.

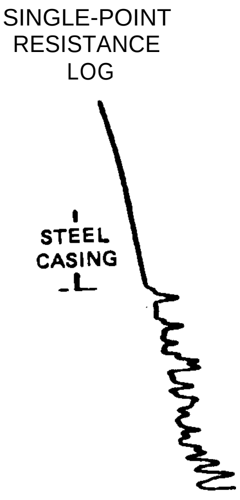
Impeller flow anomalies are most often caused by varying the probe position radially in the borehole. Bouncing of the probe from side to side will erroneously indicate flow. Corrective action may include a device that would hold the sonde in the middle of the borehole.

Temperature logs are susceptible to thermal lag time, self-heating, drift from the electronics in the sonde, and borehole conditions. A slow logging speed and additional logging functions (i.e., caliper, fluid conductivity) can aid in temperature log interpretation. Another problem with temperature logs is that after one pass of the sonde, the thermal gradient is disturbed and repeat logs may not be representative. In large diameter wells, convection can cause a disturbance of the thermal gradient.

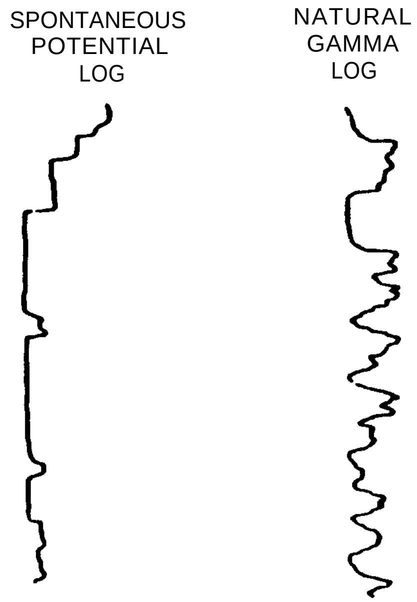
Disturbances to the borehole fluid caused by changes in fluid density and thermal convection can cause an erroneous log. Since fluid conductivity response is affected by the water chemistry, chemical equilibrium must be reached before measurements are taken. Well water may take months to obtain chemical equilibrium with the surrounding formation after drilling, and water wells with much internal movement may never reach chemical equilibrium. Repeat logs are not usually representative because the sonde disturbs the water column.

Cycle skipping is the most obvious unwanted signal in acoustic logging. It is caused by excessive signal attenuation in the fluid or by equipment malfunction. A problem with interpreting acoustic logs is that the velocity is dependent on a variety of lithologic factors, and the widely used time-average equation does not account for most of the factors.

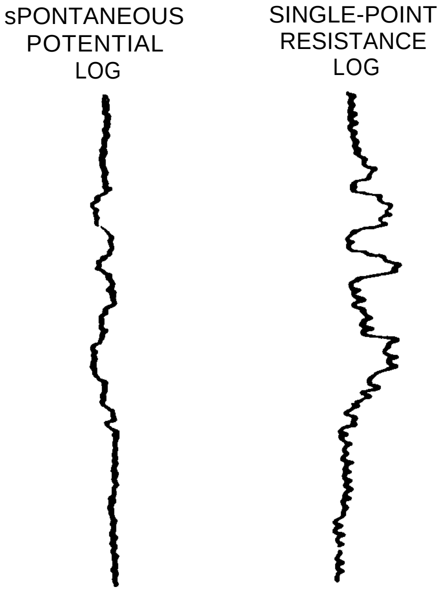
Exhibit 8.4-21
GEOPHYSICAL LOGS SHOWING SOME COMMON EQUIPMENT PROBLEMS



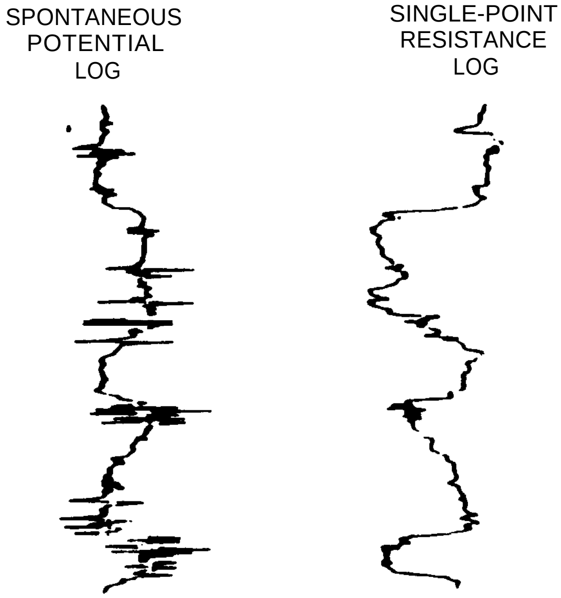
Drift Eliminator not operating properly



Different logs on the same recorder amplifier Pan drive sticking or amplifier gain lee low



Simultaneous logs Regular noise due to 60-cycle AC



Simultaneous logs Intermittent noise probably caused by drilling equipment of the well

SOURCE: Techniques of Water Resources Investigations of the United States Geological Survey, Chapter E1, page 23.

APPENDIX 8.4A

ELECTROMAGNETIC (EM) INSTRUMENT

THEORY

The conductivity value resulting from an electromagnetic (EM) instrument is a composite; it represents the combined effects of the thickness of soil or rock layers, their depths, and the specific conductivities of the materials. The instrument reading represents a combination of these effects, extending from the surface to the depth range of the instrument. The resulting values are influenced more strongly by shallow materials than by deeper layers, and this influence must be taken into consideration when interpreting the data. Conductivity conditions from the surface to the instrument's nominal depth range contribute generally 75 percent of the instrument's response. However, contributions from highly conductive materials lying at greater depths may have a significant effect on the reading.

EM instruments are calibrated to read subsurface conductivity in millimhos per meter (mm/m). These units are related to Resistivity units in the following manner:

1,000/(millimhos/meter) = 1 ohmmeter
1,000/(millimhos/meter) = 3.28 ohmfeet

The advantage of using millimhos/meter is that the common range of resistivities from 1 to 1,000 ohmmeters is covered by the range of conductivities from 1,000 to 1 millimhos/meter.

Most soil and rock minerals, when dry, have very low conductivities (Exhibit 8.4A-1). On rare occasions, conductive minerals like magnetite, graphite, and pyrite occur in sufficient concentrations to greatly increase natural subsurface conductivity. Most often, conductivity is overwhelmingly influenced by water content and by the following soil / rock parameters

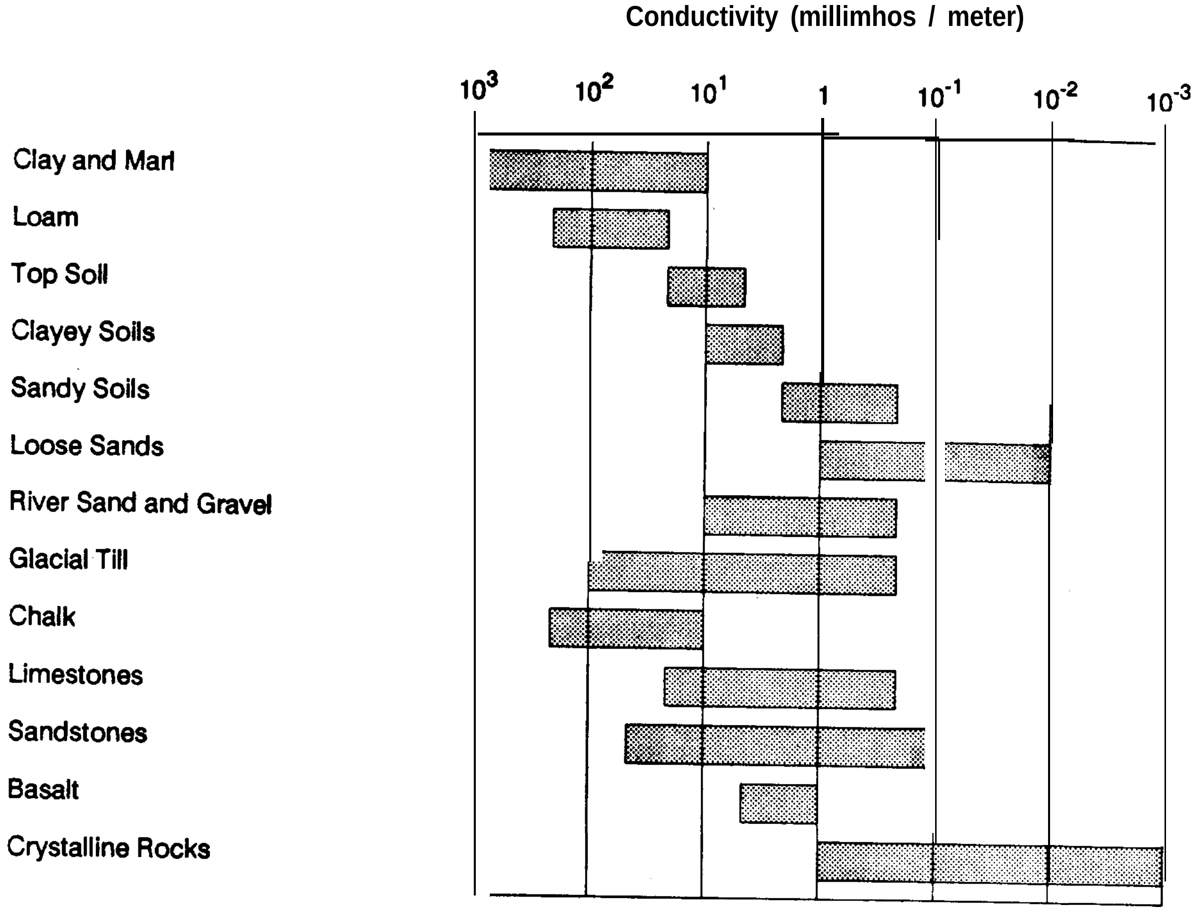
- The porosity and permeability of the material
- The extent to which the pore space is saturated
- The concentration of dissolved electrolytes and colloids in the pore fluids
- The temperature and phase state (i.e., liquid or ice) of the pore water

A specific conductivity value cannot be assigned to a particular material, because the interrelationships of soil or rock composition, structure, and pore fluids are highly variable.

In areas surrounding hazardous waste sites, contaminants may escape into the soil and the groundwater system. in many cases, these fluids contribute large amounts of electrolytes and colloids to both the unsaturated and saturated zones. in either case, the ground conductivity maybe greatly affected, sometimes increasing by one to three orders of magnitude above background values. However, if the natural variations in subsurface conductivity are very low, contaminant plumes of only 10 to 20 percent above background may be mapped.

in the case of spills involving heavy nonpolar, organic fluids such as diesel oil, the normal soil moisture may be displaced, or a sizeable pool of oil may develop at the water table. In these cases, subsurface conductivities may decrease, causing a negative EM anomaly. ,

Exhibit 8.4A-1
CONDUCTIVITY (MILLIMHOS / METER)



SOURCE: Benson (1983). (Range of electrical conductivities in natural soil and rock, modified after Culley et al.)

INFORMATION SOURCES

The following list of sources has been categorized into specific groups for easy use. A partial list of equipment manufacturers follows the references:

Electromagnetic (EM) Theory and Interpretation

Textbooks

Grant, F. S., and G.F. West. *Intepretation Theory in Applied Geophysics.* McGraw Hill Book Company. 1965.

Griffiths, D. H., and R.F. King. *Applied Geophysics for Geologists and Engineers.* Pergamon Press. 1981.

Parasins, D.S. *Principles of Applied Geophysics* (3rd edition). Chapman and Hall Publishers. 1979.

Telford, W. M., LP. Geldard, R.E. Sheriff, and D.A. Keys. *Applied Geophysics.* Cambridge University Press.

Wait, J.R. *Geo-Electromagnetism.* Academic Press. 1982.

Journals

Hanneson, J. E., and G.F. West. "The Horizontal Loop Electromagnetic Response of a This Plate in a Conductive Earth: Part I and II." *Geophysics,* Vol. 49, no. 4, pp. 411-432.

McNeill, J.D. “Electrical Conductivity of Soils and Rock.” Technical Note #5. Mississauga, Canada: Geonics Limited. 1960.

McNeill, J.D. “Electromagnetic Terrain Conductivity Measurement at Low Industion Numbers.” Technical Note *#6.* Mississauga, Canada: Geonics Limited. 1980.

McNeill, J.D. “Interpretative Aids for Use with Electromagnetic (Non Contacting) Ground Resistivity “Mapping.” Paper presented at European Association of Exploration Geophysicists Annual Meeting. Hamburg, Germany. 1979.

Wait, J.R. “A Note on the Electromaghetic Response of a Stratified Earth.” *Geophysics,* Vol. *21,* pp. *382-385.*

EM General Manuals

Benson, R. C., R.A. Glaccum, and M.F. Noel. “Geophysical Techniques for Sensing Buried Wastes and Waste Migration.” Las Vegas, Nevada U.S. Environmental Protection Agency, Environmental Monitoring Systems laboratory. 1983.

EM Case Histories and Examples

Journals

Fox, R. L., and D.A. Gould. "Delineation of Subsurface Contamination Using Multiple Surface Geophysical Methods." Presented at the NWWA Eastern Regional Groundwater Conference (Technology Division). Newton, Massachusetts. 1984.

Glaccum, R. A., R.C. Benson, and M.R. Noel. "Improving Accuracy and Cost-Effectiveness of Hazardous Waste site Investigations. ***Ground Water Monitoting Rewview.*** Summer 1982.

McNeill, J.D. "Electromagnetic Resistivity Mapping of Contaminant Plumes." Presented at the National Conference on Management of Uncontrolled Hazardous Waste Sites-contact HMCRI. Silver Spring, Maryland.

Rudy, R. J., and J.A. Caoile. "Utilization of Shallow Geophysical Sensing at Two Abandoned Municipal/ Industrial Waste Landfills on the Missouri River Floodplain." ***Ground Water Monitoring Review.*** Fall issue, 1984.

Slaine, D. D., and J.P. Greenhouse. "Case Studies of Geophysical Contaminant Mapping at Several Waste Disposal Sites." Presented at the NWWA Second National Symposium on Aquifer Restoration and Ground Water Monitoring. Columbus, Ohio. 1982.

Steward, M.T. "Evaluation of Electromagnetic Methods for Rapid Mapping of Salt-Water Interfaces in Coastal Aquifers." ***Ground Water,*** Vol. 20. September-October 1982.

Manufacturers

Aerodat Limited
3883 Nashua Drive
Mississauga, Ontario L4V 1R3
416/671 -2446 (airborne EM systems)

Crone Geophysics Limited
3607 Wolfedale Road
Mississauga, Ontario L5C 1V8
416/270-0096 (surface EM systems)

Geonics Limited
1745 Meyerside Drive
Mississauga, Ontario L5T IC5 .
416/676-9580 (borehole and surface EM systems)

Phoenix Geophysics Limited
200 Yorkland Boulevard
Willowdale, Ontario M2J 1R5
416/493-6350 (surface EM systems)

Scintrex
222 Snidercroft Road
Concord, Ontario L4K 165
416/669-2280 (surface EM systems)

APPENDIX 8.4B

RESISTIVITY

THEORY

The ability to conduct (or resist) current is dependent on the nature of the material to which the current is applied. Geologic materials, such as clays or iron-rich saturated sands, are generally quite conductive but are **poor resistors, while organic-rich soils and grantie bedrock are typically poor conductors and good** resistors. The electrical resistivities in naturally occurring materials run a range of magnitudes whose extreme values differ by almost a factor of 10 to the 20th power (Grant and West). Exhibit 8.4B-1 gives some examples of how water content and geologic material can affect Resistivity.

Although ER instrumentation is variable In design and operation, the basic principles are constant. Electrical resistivity has as its foundation Ohm's Law, which states that the electrical potential between two points is defined by the supplied current multiplied by the circuit resistance. Mathematically, Ohm's Law could be represented as follows:

$$E = I R$$

In the above equation,

E = potential of the circuit (volts)
z · current (amperes)
R = the measured resistance (ohms), the desired parameter.

In practice, current *(I)* is introduced to the ground by conduction through **(generally) two** current electrodes. Generally, two potential electrodes *(E)* are put a set distance from the current electrodes, and the potential drop in current is measured. From this relationship, Resistivity is calculated (Exhibit 8.4B-2). To supply the electrical current, a power source such as batteries or a generator can be used, but for most work done at hazardous waste sites, a DC battery supply will suffice.

INFORMATION SOURCES

The following list of sources has been categorized into specific groups for easy use and includes a partial list of equipment manufacturers.

Electrical Resistivity (ER) Theory and Interpretation

Textbooks

Griffith, D. H., and R.F. King. *Applied Geophysics for* Geologists *and Engineers.* **Pergamon press. 1981.**

Grant, F. S., and F.G. West. *Interpretation Theory in Applied Geophysics.* **McGraw-Hill. 1965.**

Telford, W. M., et al. *Applied Geophysics.* Cambridge University Press. 1976.

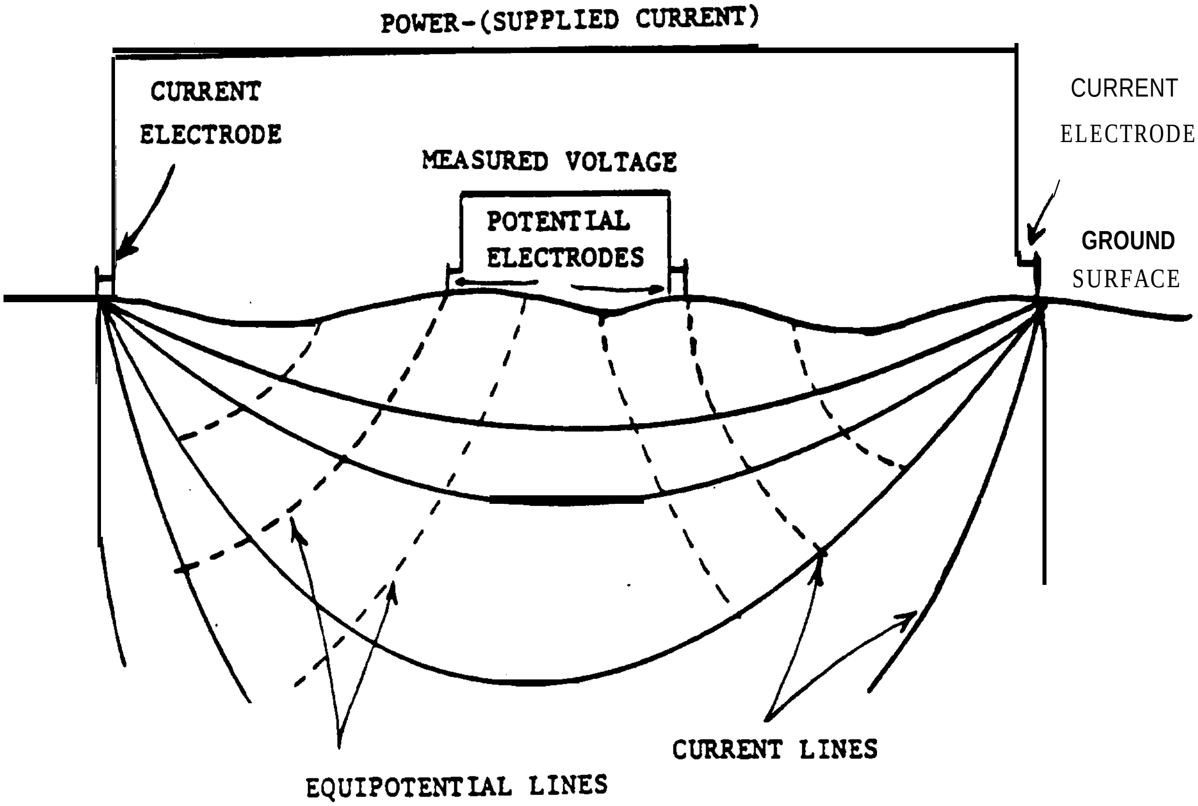
Exhibit 8.46-1
NATURAL VARIATIONS IN RESISTIVITY BECAUSE OF MATERIAL AND WATER CONTENT

Rock Type	Water Content (percent H_2O)	Typical Resistivity (ohmmeter)
Siltstone	0.54	1.5 x 10^4
Siltstone	0.38	5.6 x 10^8
Coarse Grain Sandstone	0.39	9.6 x 10^5
Coarse Grain Sandstone	0.18	10^8
Graywacke Sandstone	1.16	4.7 x 10^3
Graywacke Sandstone	0.45	5.8 x 10^4
Dolomite	2.0	5.3 x 10^3
Dolomite	0.96	8 x10^3
Peridotite	0.1	3 X10^3
Peridotite	0	1.8 x10^7
Granite	0.31	4.4 x 10^3
Granite	0	10^{10}
Basalt	0.95	4 x 10^4
Basalt	0	1.3 x 10^8
Olivine-Pyrex.	0.028	2 x 10^4
Olivine-Pyrex.	0	5.6 x 10^7
Material		
Clays		1-100
Sands		10-800
Sea Water		0.2
Groundwater (bedrock)		0.5-100
Groundwater (overburden)		100

Based on W.M. Telford, et al. Applied Geophysics, 1976.

Exhibit 8.4B-2

THEORY OF ELECTRICAL RESISTIVITY MEASUREMENTS



Journals

Zohdy, A.A.R. “Automatic Interpretation of Schlumberger Sounding Curves Using Modified Dar Zarrovk Functions.” ***U.S. Geological Survey Bulletin*** 1313E. Washington, D.C. 1975.

ER General Manuals

Benson, R, D., R.S. Glaccum, and M.R. Noel. ***Geophysical Techniques for Sensing Buried Wastes and Waste Migration.*** Prepared by Technos, Incorporated, for the U.S. Environmental Monitoring Systems Laboratory, Las Vegas, Nevada. 1983.

Costello, R.L. ***Identification and Description of Geophysical Techniques.*** Prepared by D’Appolonia for U.S. Army Toxic and Hazardous Materials Agency. Aberdeen Proving Ground, Maryland. ***1980.***

Greenhouse, J.P. Surface ***Geophysics in Contaminant Hydmgeology.*** Manual for the Hydrology Field School through the University of Waterloo, Ontario, Canada. 1982.

Peffer, J. R., and P.G. Robelen. ***Affordable: Overburden Mapping Using New Geophysical Techniques.*** **Pit** and Quarry. August 1983.

Technos, Incorporated. ***Application Guidelines for Selected Contemporary Techniques for Subsurface Investigations. (No*** publication date given.)

ER Case Histories and Examples

Journals

Bradbury, K, R., and R.W. Taylor. “Determination of the Hydrologic Properties of Lakebeds Using Offshore Geophysical Surveys.” ***Ground Water,*** Vol. 22, No. 6. ***1984.***

Evans, R. B., and G.E. Schweitzer. “Assessing Hazardous Waste Problems.” ***Environmental Science Technology,*** **Vol. 18, No. 11. 1964.**

Pennington, D. “Selection of Proper Resistivity Techniques and Equipment for Evaluation of Groundwater Contamination.” Presented at the NWWA Conference on Surface and Borehole Geophysical Methods in Groundwater investigation. Fort Worth, Texas. February **1965.**

Ringstad, C.A., and D.C. Bugenig. “Electrical Resistivity Studies to Delimit Zones of Acceptable Ground Water Quality.” ***Ground Water Monitoring Review.*** Fall 1984.

Underwood, J.W., K.J. Laudon, and T.S. Laudon. “Seismic and Resistivity Investigations near Norway, Michigan.” ***Ground Water Monitoring Review.*** Fall **1984.**

Manufacturers

ABEM-Atlas Copco
Distributed by Geotronics Corp.
10317 McKalla Place
Austin, Texas 78758

Bison Instruments, Inc.
5708 West 36th Street
Minneapolis, Minnesota 55416

BRGM-Syscal
Distributed by EDA Instruments
5151 Ward Road
Wheat Ridge, Colorado 80033

Phoenix Geophysics Limited
200 Yorkland Boulevard
Willowdale, Ontario M2J 1R5

Scintrex Limited
222 Snidercroft Road
Concord ('Toronto), Ontario L4K 1B5

APPENDIX 8.4C

SEISMICS

THEORY

SEISMIC REFRACTION

Compressional waves (P-waves), shear waves *(S* waves), and surface waves are generated by a seismic disturbance such as a chemical explosion or weight drop; these waves propagate through the earth at seismic velocities determined by the physical properties of the subsurface material through which they travel (Exhibits 8.4C-1 and 8.4C-2). Particle motion associated with P-waves occurs in the direction of wave propagation as a series of compressions and refractions. The P-wave velocity diminishes markedly when the *P-wave* encounters water bearing strata. Layer density can be empirically deduced from the observed *P-wave* velocity by using the Nafe-Drake relation (Exhibit 8.4C3).

Particle motion associated with *S-waves* occurs in a plane perpendicular to the direction of wave propagation. *S* waves travel at slower seismic velocities than P-waves, S waves always arrive at surface receivers after P-waves, and S-waves will not travel through fluids.

Surface waves are known as guided waves because they travel along a free surface of discontinuity within the earth. Particle motion and seismic velocity for these waves depend on the type of surface waves generated, but they ail travel at lower velocities than either *P*- or S-waves. Whenever a *P*- or S-wave strikes an interface at an oblique angle, both reflected and refracted *P*- and S-waves are generated, sewing to further complicate the identification of later arriving phases.

Shallow refraction surveys conducted in hazardous waste site investigations are run at high amplifier gain settings to record accurate arrival times of the first-arriving P-waves or the “first breaks.” No effort is made to correlate arrival times of later-arriving phases.

P-waves travel along ray paths that are determined by Fermat’s Principle, Huygen’s Principle, a, and Snell’s Law. *P* waves arrive at receivers with seismic wave amplitudes that are determined by the geometrical rate of spreading of the wave and the attenuation of the spectral components of the wave form as a result of the imperfect elasticity of earth materials. The direct ray travels directly from source to receiver through the uppermost subsurface layer (layer 1 in Exhibit 8.4C-4) at P-wave velocity *Vie.* The total time taken by this ray to travel through layer 1 is given by:

$$t_{dir} = X/V_0$$

where *X* is the shot-to-receiver distance.

This equation describes straight line segment 1 of the travel-time curve in Exhibit 8.4C-4, which has slope $1/V_0$ and passes through the origin.

When a P-wave encounters a boundary between two layers of different seismic velocities, part of the original wave energy is reflected back into the underlying layer at an angle of reflection i_r that is equal to

Exhibit 8.4C-1
SEISMIC VELOCITIES OF COMPRESSIONAL AND SHEAR WAVES

Material	Velocity (km/sec)		Velocity (1000 ft/sec)		Remarks
	α	β	α	β	
Alluvium	0.5–2.0		1.64–6.56		Near surface
	3.0–3.5		9.84–11.48		2000 m depth
Clay	1.1–2.5		3.61–8.20		
Loam	0.8–1.8		2.62–5.91		
Loess	0.3–0.6		0.98–1.96		
Sand					
Loose	0.2–2.0		0.66–6.56		
Loose	1.0	0.4	3.28	1.31	Above water table
Loose	1.8	0.5	5.91	1.64	Below water table
Calcareous	0.8		2.62		
Wet	0.75–1.5		2.46–4.92		
Weathered layer	0.3–0.9		0.98–2.95		
Glacial					
Till	0.43–1.04		1.41–3.41		Unsaturated
Till	1.73		5.67		Saturated
Sand and gravel	0.38–0.50		1.25–1.64		Unsaturated
Sand and gravel	1.67		5.48		Saturated
Sandstone-shale					
Tertiary	2.1–3.5		6.89–11.48		
Cretaceous	2.4–3.9		7.87–12.80		Depth range
Pennsylvanian	2.9–4.4		9.51–14.44		0.3–3.6 km
Ordovician	3.3–4.5		10.83–14.76		0.3–2.1 km
Sandstone	1.4–4.3		4.59–14.11		
Sandstone					
Conglomerate	2.4		7.87		Australia
Limestone					
Soft	1.7–4.2		5.58–13.78		
Hard	2.8–6.4		9.19–21.00		
Solenhofen	5.97	2.88	19.59	9.45	
U.S. midcontinent	—	2.75		9.02	
and Gulf Coast	3.4–6.1	—	11.15–20.01		
Argillaceous, Texas	6.03	3.03	19.78	9.94	∥ to bedding
Argillaceous, Texas	5.71	3.04	18.73	9.97	⊥ to bedding
Dolomitic, Penn.	5.97	—	19.59		
Cement rock, Penn.	7.07	—	23.20		
Crystalline, Texas, N.M., Okla.	5.67–6.40	—	18.60–21.00		
Dense, U.S.S.R.	5.90–7.00	3.03–3.59	19.36–22.97	9.94–11.78	
Salt, cornallite, sylvite	4.4–6.5	—	14.44–21.38		
Caprock, salt, anhydrite, gypsum, limestone	3.5–5.5	—	11.48–18.04		
Anhydrite, midcontinent and Gulf Coast	4.1	—	13.45		
Gypsum	2.0–3.5	—	6.56–11.48		
Chalk, U.S.,	2.1–4.2	1.07 SV	6.89–13.78	3.51 SV	
Germany, France,	2.58	1.13 SH	8.46	3.71 SH	⊥ bedding
Austin, Texas	3.05	—	10.01		∥ to bedding
Slate, Mass.	4.27	2.86	14.01	9.38	
Hornfels slate	3.5–4.4	—	1.61–14.44		
Magnetite ore	5.50	—	18.04	10.81–10.49	V_P/V_S = 1.67–1.72
Marble	3.75–6.94	2.02–3.86	2.30–22.77	6.63–12.66	46 samples
	5.78	3.22	18.96	10.56	Average of 46 samples
Quartzite	6.1	—	20.01	—	
Wet clay, U.S.S.R.	1.50–1.65	—	4.90–5.41	0.36–1.20	$V_P/V_S \sim$ 4.5–13.7
Impermeable argillaceous clay	2.00	0.59	6.56	1.94	
Soil	0.11–0.20	—	0.36–0.66	0.59–1.27	$V_P/V_S \sim$ 1.7–2.0
Tuff	2.16	0.83	7.09	2.72	

Source. These values have been selected from the compilation by Frank Press in the *Handbook of Physical Constants*, rev. ed., Memoir 97, and are printed with permission of the Geological Society of America. Copyright © 1966.

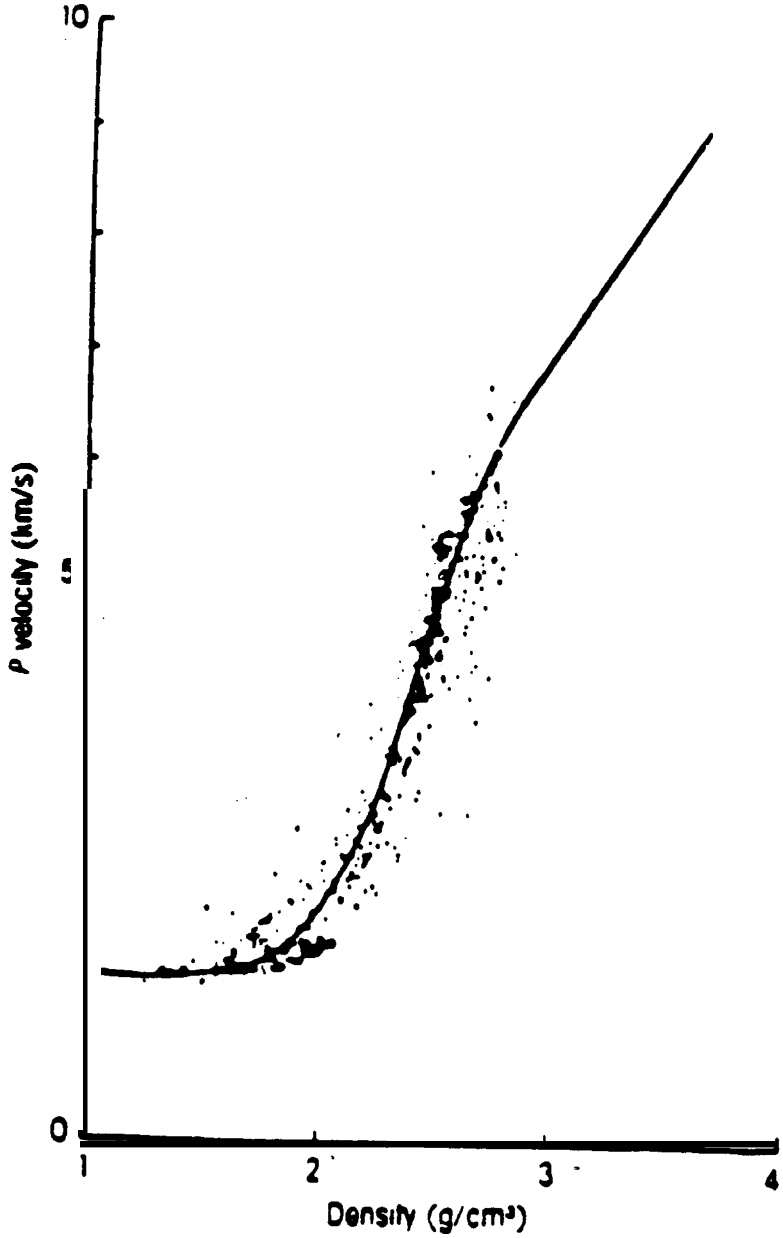
Exhibit 8.4(2-2
SEISMIC VELOCITIES OF COMPRESSIONAL
IN NEW ENGLAND

MATERIALS	P-wave velocity KM/sec	 10^3 ft/sec	REMARKS
Overburden	0.09-0.30	0.3-1.0	Very loose unsaturated silts, humus and fill.
	0.30-0.61	1.0-2.0	Loose unsaturated coarse gravel and ground moraine
	0.92-1.37	3.0-4.5	Compact, dense glacial till.
	1.46-1.62	4.8-5.3	Compact saturated flurioglacial deposits.
	1.83-2.44	6.0-8.0	Very dense glacial till.
Bedrock	1.52-2.44	5.0-8.0*	Highly weathered, highly fractured with high permeability.
	2.44-3.66	8.0-12.0	Slightly to moderately weathered.
	3.66-3.96	12 .0-13.0	Unweathered massive bedrock.

* Bedrock velocities in the range of 5,000 to 8,000 ft/sec may be highly fractured and be indicative of layers of extensive groundwater flow.

SOURCE: These values were compiled by the Weston Geophysical Corporation and listed in the Seismic Refraction Study of the Tinkhams site in Londonderry N.H.

Exhibit 8.4C-3
NAFE-DRAKE CURVE



RCE: R. E. Sheriff (1984)

Best available copy

the angle of incidence *i*. The remainder of this energy Is refracted into the underlying layer at an angle of refraction i_r

When a P-wave strikes an interface between two layers at an angle $i = i_c$ so that sin $i_c = V_1/V_2$ and $i_r = 90$, a pulse of small amplitude Is generated In the overlying layer. This pulse is called the "head wave" and travels along the upper boundary of the underlying layer. The angle i_c is the critical angle of refraction, and seismic rays striking the interface as angles of incidence greater than i_c are totally reflected back into the overlying layer. The greater the velocity contract between the two layers, the greater the proportion of incident wave energy returned to the surface In the form of the reflected ray and the smaller the amplitude of the head wave.

Time-distance or travel-time curves are constructed from seismic data by plotting the source-to-receiver travel time against the source to receiver distance X. Exhibit 8.4C-4 is the travel-time curve for a series of horizontal refractors, each of which has a greater seismic velocity than the layer immediate y overlying it.

$$t_1 = \frac{X}{V_1} + \frac{2Z_1\,(V_1^2 - V_0^2)^{1/2}}{V_0V_1} = \frac{X}{V_1} + t_{i1}$$

In Exhibit 8.4C4 the total time taken by the head wave to propagate through layers 1 and 2 is given by the following equation:

$$Z_1 = \frac{t_{i1}\ V_0V_1}{2\,(V_1^2 - V_0^2)^{1/2}}$$

This equation describes straight line segment 2 of the travel-time curve, which has slope $1/V_1$ and time intercept t_{i1}. The thickness of layer 1 is given by the equation below

This is also the depth to layer 2.

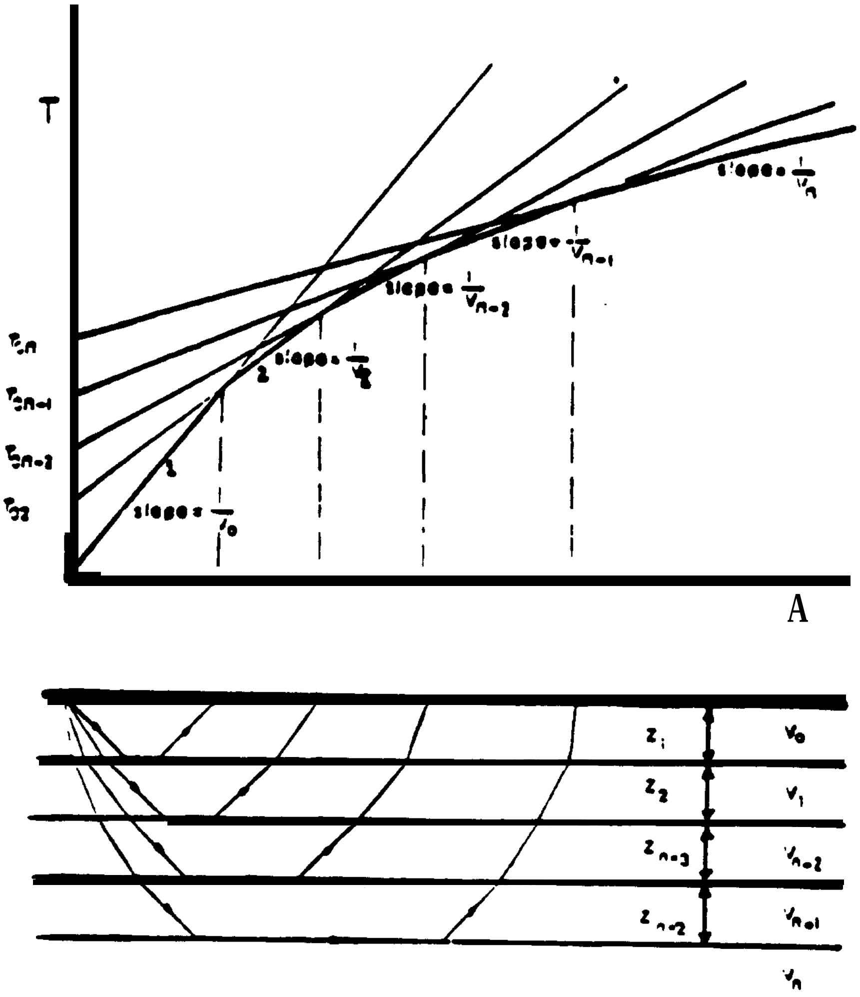
$$\frac{X_{c1}}{V_0} = \frac{X_{c1}}{V_1} + \frac{2Z_1(V_1^2 - V_0^2)^{1/2}}{V_1V_0}$$

Straight line segments 1 and 2 intersect at point X_c, t_c; therefore,

$$Z_1 = \frac{X_{c1}}{2}\left[\frac{V_1 - V_0}{V_1 + V_0}\right]$$

and

Exhibit 8.4C-4
RAY PATHS AND TRAVEL-TIME CURVE FOR HORIZONTAL REFRACTORS



This equation uses the critical distance X_c to determine the thickness of layer 1.

The travel-time curve changes significantly for dipping refractors, and the above travel-time depth relations are no longer valid. Reversed sesmic proofiles yield travel-time curves that reveal dipping refractors. Exhibit 8.4C5 represents the cross section through a dipping refractor and the reversed travel-time curve associated with it.

$$i_c = \frac{1}{2}\left[\sin^{-1}\frac{V_0}{V_d} + \sin^{-1}\frac{V_0}{V_u}\right]$$

$$\theta = \frac{1}{2}\left[\sin^{-1}\frac{V_0}{V_d} - \sin^{-1}\frac{V_0}{V_u}\right]$$

The dip angle θ and critical angle i_c can be computed from velocities measured from straight line segments of the reversed travel-time curve.

$$\text{(A)} \quad Z_d = \frac{V_0 t_{i1d}}{\cos i_c}$$

The downdip and up-dip intercept times can then be measured to calculate the downdip and up-dip

$$\text{(B)} \quad Z_u = \frac{V_0 t_{i1u}}{\cos i_c}$$

thickness of the dipping layer

and,

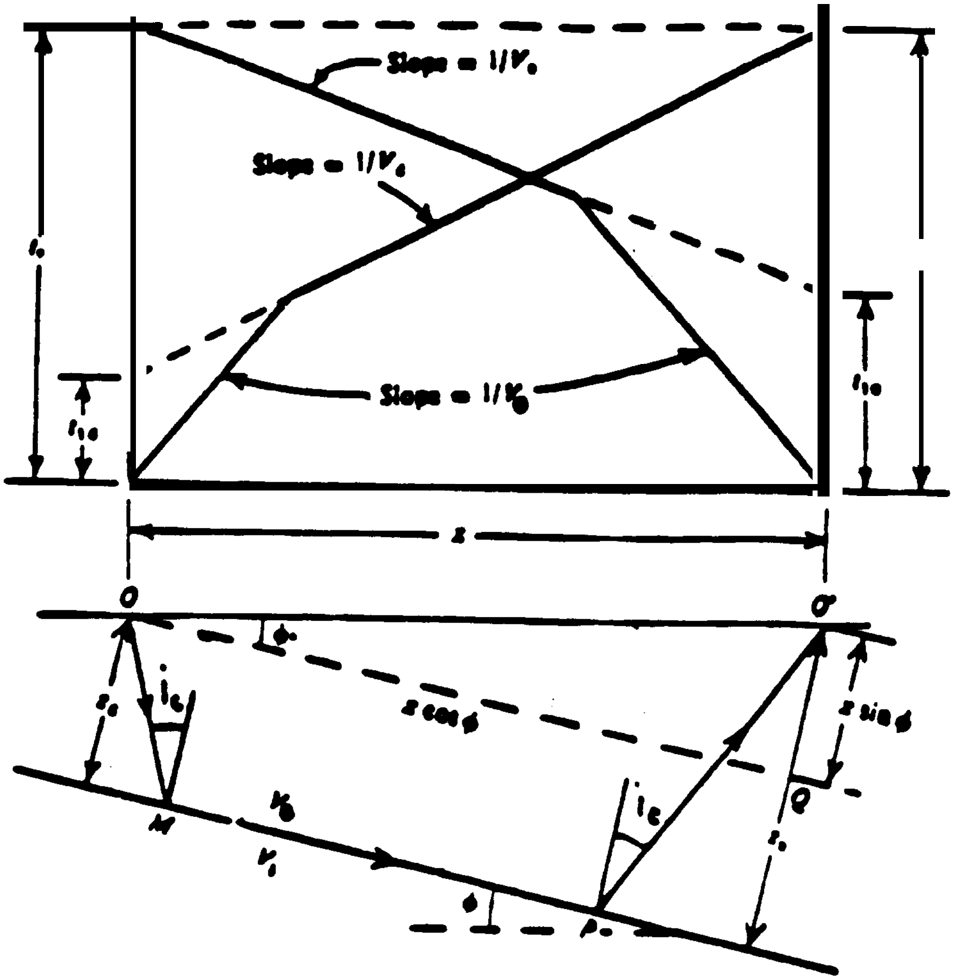
When the dip angle is very small, equations (A) and (B) can be approximated by letting cos of i_c equal 1.

Lateral variations in refractor velodty are manifested in reversed travel-time curves, and examples of some of these situations are illustrated in Exhibit 8.4C-6.

Seismic Reflection

Refraction time-distance curves for the case of three velocity discontinuities is illustrated in Exhibit 8.4C-7, along with the related set of reflection time-distance curves. The segment of the time-distance curve for rays that are reflected from the bottom of layer *"n"* approaches the straight-line segment of the time-distance curve for rays that are critically refracted from the top of this layer asymptotically at large shot-receiver distances. This similarity is because the ray paths traveled by these rays become identical at

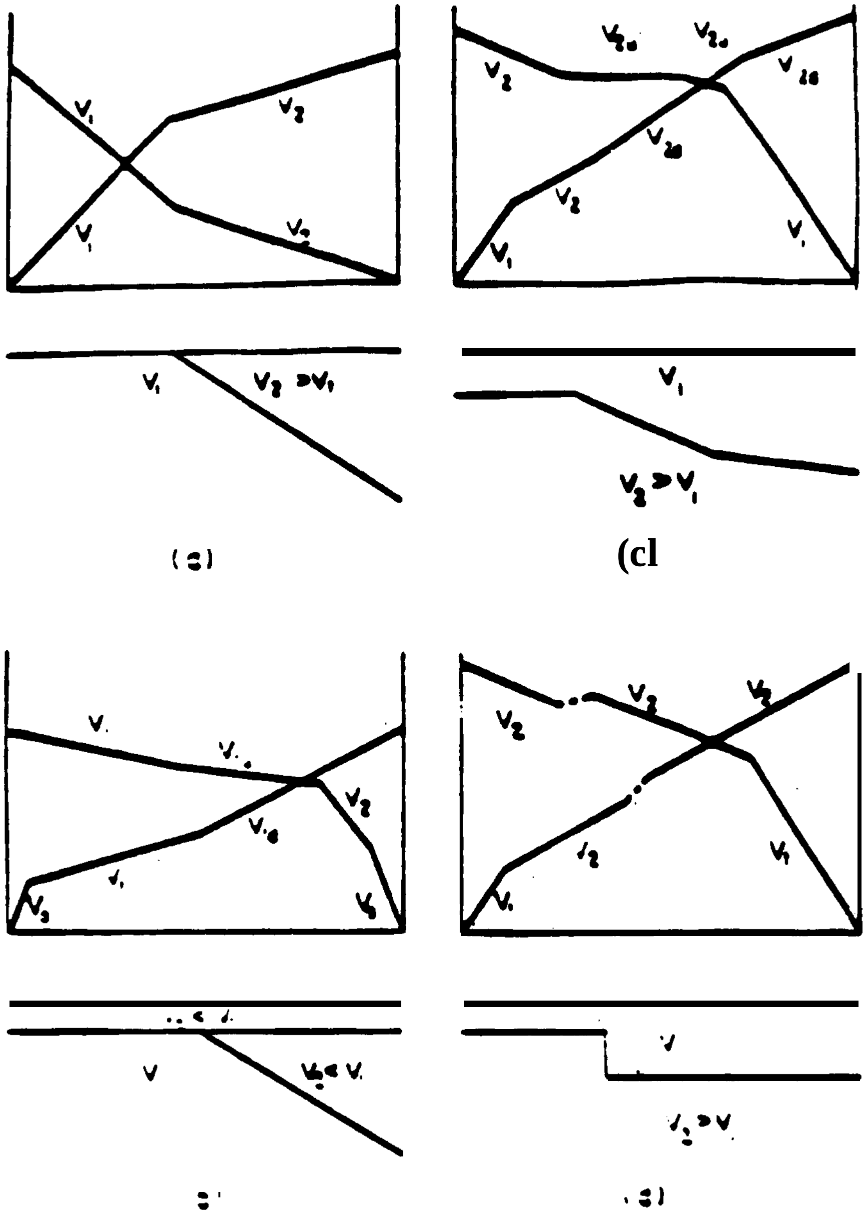
Exhibit 8.4C-5
RAY PATH AND TRAVEL-TIME CURVES FOR A DIPPING REFRACTOR



SOURCE: Telford et al. (1978).

Best available copy

Exhibit 8.4C-6
LATERALLY DISCONTINUOUS STRUCTURES AND SCHEMATIC REVERSED REFRACTION TRAVEL-TIME GRAPHS ASSOCIATED WITH THEM

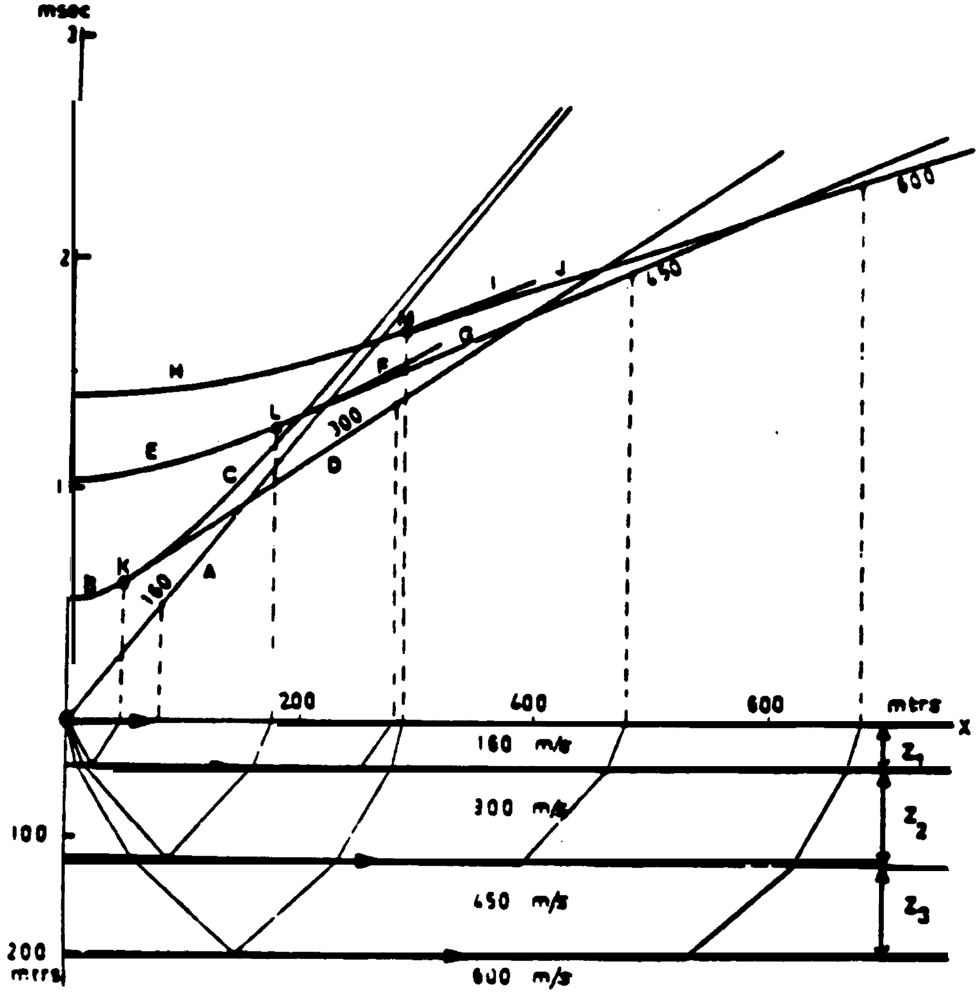


Some examples of simple laterally discontinuous structures and schematic reversed refraction travel-time graphs that would be associated with them. (a) A lateral velocity change. The *t*-*x* graph is unchanged for any dip of the boundary so long as the higher velocity material overlies the lower. (b) If $V_2 < V_1$, branches of apparent velocities V_{1d}, V_{1u} are produced. The effect of an additional low-velocity surface layer is also shown. (c) An increase of refractor dip can also lead to a low velocity branch V_{2d} following one of higher velocity V_2. Note that a plane-layer interpretation is possible only if the branches $V_{2d}-V_{2u}$ and $V_{2u}-V_{2d}$ can be correctly paired. It will usually be easier to use the "plus-minus" approach (eqns. 3.11, 3.12). (d) The dipping segment of (c) is here steepened to a fault-like step. The steps in the *t* – *x* graphs are less sharp because of diffraction effects, and are offset

Best available COPY

Exhibit 8.4C-7

REFLECTION-Refraction GEOMETRY FOR A FOUR-LAYER CASE



A. Direct ray through layer 1.
B. Reflections from bottom of layer 1.
C. Wide-angle reflections from bottom of layer 1.
D. Refracted rays from layer 2.
E. Reflections from bottom of layer 2.
F. Wide-angle reflections from bottom of layer 2.
G. Refracted rays from layer 3.
H. Reflections from bottom of layer 3.
I. Wide-angle reflections from bottom of layer 3.
J. Refracted rays from layer 4.
K., L., M., Critical distances for layers 1, 2 and 3.

these distances. The straight-line segment of the time-distance curve for rays critically refracted from the top of the underlying $n + 1$ is tangential to the curve for rays reflected from layer n.

At the critical distance X_{cr}, travel times for rays reflected from the bottom of layer n equal the travel time for rays critically refracted from the top of the underlying layer $n + 1$. At this distance, rays reflected from the bottom of layer n are reflected at the critical angle. The critical distance for the existence of head waves from a layer is given by the following equation:

$$X_{cr} = 2 Z_n \tan i_c$$

At distances less than X_{cr}, no head waves exist from the top of the underlying layer $n + 1$. At distances greater than X_{cr} the head wave from the underlying layer exists and arrives at surface receivers ahead of the ray received at distances greater than X_{cr}, which are referred to as "wide angle reflections." Reflected rays from the bottom of layer n undergo a large increase in amplitude near X_{cr} for that layer because of the constructive interference of the head wave refracted from the top of the underlying layer with the reflected ray. Other large increases in the amplitude of the reflected ray occur at crossover points for wide-angle reflections where two or more wide-angle reflections constructively interfere.

In this method, the source-to-receiver travel time of reflection events are squared and plotted against the square of the source-to-receiver distance. Velocity is obtained from the square root of the inverse slope of the straight line segment. The depth to the reflecting layer is obtained from the velocity and time intercept.

INFORMATION SOURCES

Backus, M.M. "Water Reverberations: Their Nature and Elimination." *Geophysics*, Vol. 24, pp. 233-261. 1959.

Campbell, F.F. "Fault Criteria." *Geophysics*, Vol. 30, pp. 348-361. 1965.

Carmichael, R.S. *Handbook of Physical Properties of Rocks*. Vol. 2. Boca Raton, Florida: CRC Press. 1982.

Costello, R.L. *Identification and Description of Geophysical Techniques*. D'Appolonia Consulting Engineers, Phase I Report. 1980.

Dobrin, M.B. *Introduction to Geophysics Prospecting*. New York: McGraw-Hill. 1960. 446 pp.

Dix, C.H. "Seismic Velocities from Surface Measurements." *Geophysics*, Vol. 20, pp. 68-86. 1955.

Faust, L.Y. "Seismic Velocity as a Function of Depth and Geologic Time." *Geophysics*, Vol. 16, pp. 192-206. 1951.

Garland, G.D., and R.F. King. *Applied Geophysics for Geologists and Engineers*. Pergamon Press.

Hagerhorn, J.G. "A Process of Seismic Reflection Interpretation." *Geophysical Prospecting*, Vol. 2, pp. 85-127. 1954.

Howell, B.F. *Introduction to Geophysics*. New York: McGraw Hill. 1959.

Hunter, J.A, R.A “Bums, R.L Good, H.A MacAulay, and R.M. Gagne. “Optimum Field Techniques for Bedrock Reflection Mapping with the Multi-Channel Engineering Seismogram.” Current *Research Part B.* Geological Survey of Canada, Paper 82-1 B, pp. 125-129. 1982.

Kleyn, AH. Seismic *Rejection Interpretation.* Elsevier, New York. 1983.269pp.

Kramer, F. S., R.A. Peters, and W.C. Wafter. Seismic Energy Sources *1%8 Handbook.* Bendix United Geophysical. 1968.

Musgrave, AW., and R.H. Bratton. “Practical Application of Biondeau Weathering Solution in Seismic Refraction Prospecting.” Society of *Exploration Geophysics,* pp. 132-246. 1967.

Nettleton, L.L. *Geophysical Prospecting Oil. New York:* McGraw Hill. 1940.

Parasins, D.S. *Principles of Applied Geophysics. New York Wiley* and Sons. *1979. 275* pp.

Scheider, W.A., K.L Lamer, J.P. Burg, and M.M. Backus. “A New Data Processing Technique for the Elimination of Ghost Arrivals on Reflection Seismograms.” Geophysics, Vol. 26, pp. *783-805. 1964.*

Steinhart, J. S., and R.P. Meyer, “Minimum Statistical Uncertainty of the Seismic Refraction Profile.” *Geophysics,* Vol. 26, pp. 574-587. 1961.

Telford, W. M., L.P. Geldart, R.E. Sheriff, and D.A. Keys. *Application Guidelines Selected Contemporary Techniques for Subsurface Investigations.* Technos, inc. Miami, Florida: Cambridge University Press. 1976.

Treitel, S., and E.A. Robinson. “Optimum Digital Filters for Signal-to-Noise Enhancement.” *Geophysical Prospecting* Vol. 17, pp. 248-293. 1969.

Watkins, J. S., LA. Walters, and R.H. Godson. “Dependence of in Situ Compressional-Wave Velocity on the Porosity in Unsaturated Rocks.” *Geophysics,* Vol. 37, pp. 417430. 1972.

Wyllie, M. R.J., A.R. Gregory, and LW. Gardiner. “Elastic Wave Velocities in Heterogeneous and Porous Media.” *Geophysics,* Vol. 21, pp. 41-70. 1956.

Zohdy, A.A.R., G.P. Eaton, and D.R. Mabey. “Application of Surface Geophysics to Groundwater investigations.” *Techniques of Water Resoumes Investigations.* USGS Book 2, pp. 1-116. 1974.

APPENDIX 8.4D

MAGNETICS

THEORY

Earth's Magnetic Field

A magnetometer measures the intensity of the earth's magnetic field. The earth's magnetic field, or flux lines, resemble the lines of a bar magnet, with the magnetic poles being located near the geographic north and south poles (Exhibit 8.4D-1). The intensity of the magnetic field varies; at the poles it is approximately twice that at the equator, or approximately 80,000 and 30,000 gammas, respectively (Exhibit 8.4D-2).

The inclination of the magnetic field also varies with latitude, being horizontal at the equator and vertical at the poles (Exhibits 8.4D-1 and 8.4D-3). Thus, the intensity of the earth's magnetic field at a given study area is dependent on its location.

At a given location, fluctuations occur in the earth's magnetic field because of effects of the solar wind. Normal diurnal (daily) variations occur in the magnetic field and maybe as large as 100 gammas or more. Superimposed on any diurnal variations are short-period micropulsations that are more random in behavior, are generally smaller in amplitude, and may occur at any time. Micropulsations may have durations between 0.1 seconds and several tens of minutes with amplitudes from 0.001 gamma to several tens of gammas. Magnetic storms, causing rapid variation of several hundred gammas in the magnetic field, may occur as often as several days per month and have durations from one to several days.

A recording base station magnetometer is used to make corrections from diurnal variations and for micropulsations, and to identify magnetic storms. The base station is located in an area where representative measurements of the background magnetic field can be obtained on a continuous basis. A magnetometer survey should not be conducted during a magnetic storm. The U.S. National Oceanographic and Atmospheric Administration (NOAA) has regional observatories that monitor the earth's magnetic field and can provide information on the occurrence of magnetic storms.

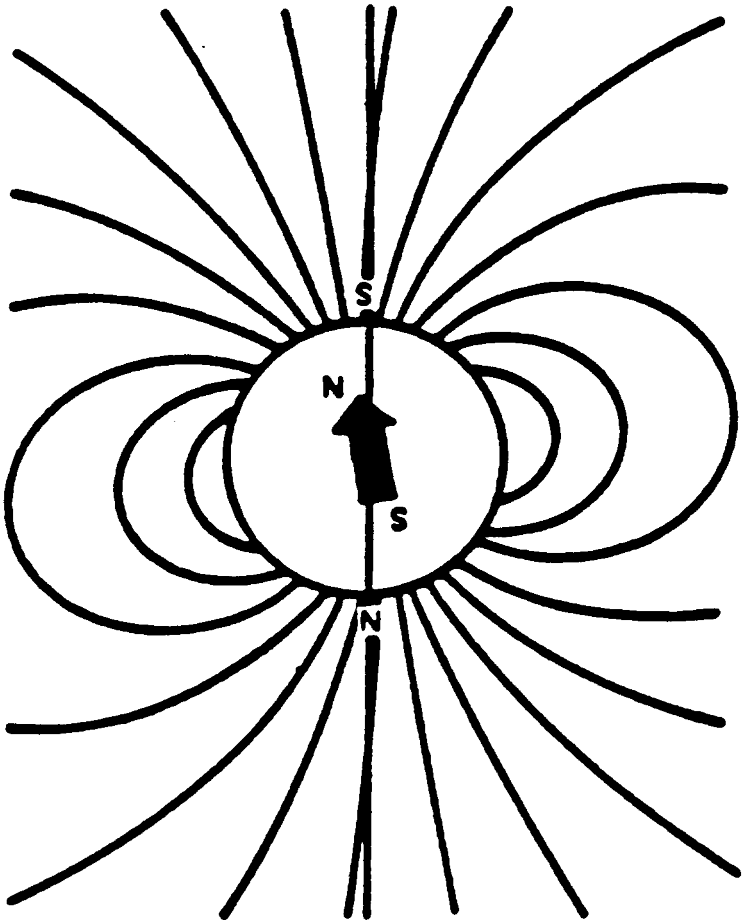
Types of Portable Magnetometers

Three main types of portable magnetometers are in use:

- Proton precession magnetometer
- Flux gate magnetometer
- Optical-pumping magnetometer

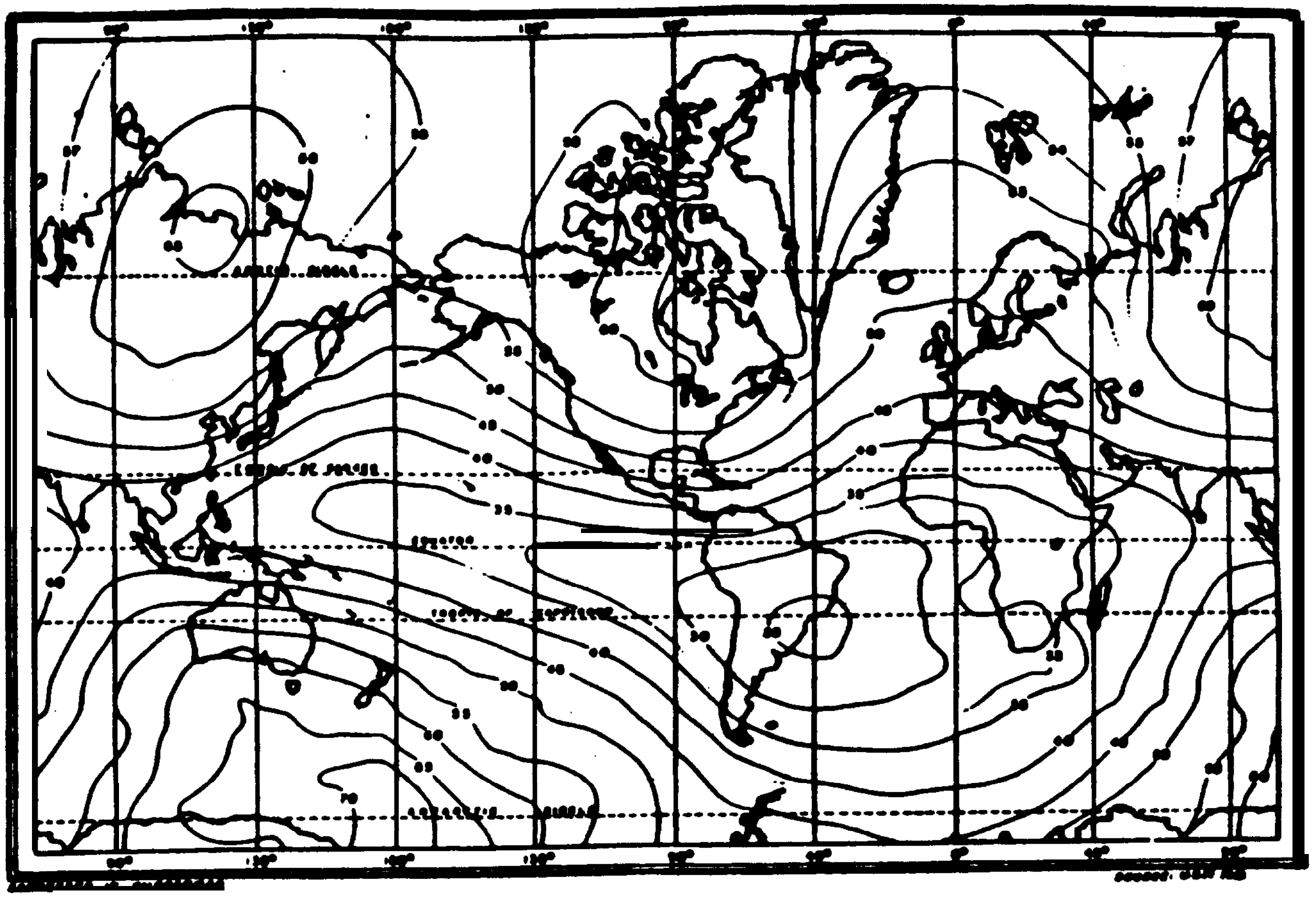
The proton precession magnetometer consists of a coil wound around a bottle of proton-rich fluid, such as water or hydrocarbon fluid. Sufficient current is introduced through the coil to induce within the fluid an external magnetic field about 100 times stronger than the earths magnetic field. As a result, the magnetic moment of the protons will cause them to align themselves with the new field. When the external field is removed, the magnetic moment of the protons returns, by precession, to its original orientation with

Exhibit 8.4D-1
EARTH'S MAGNETIC FIELD



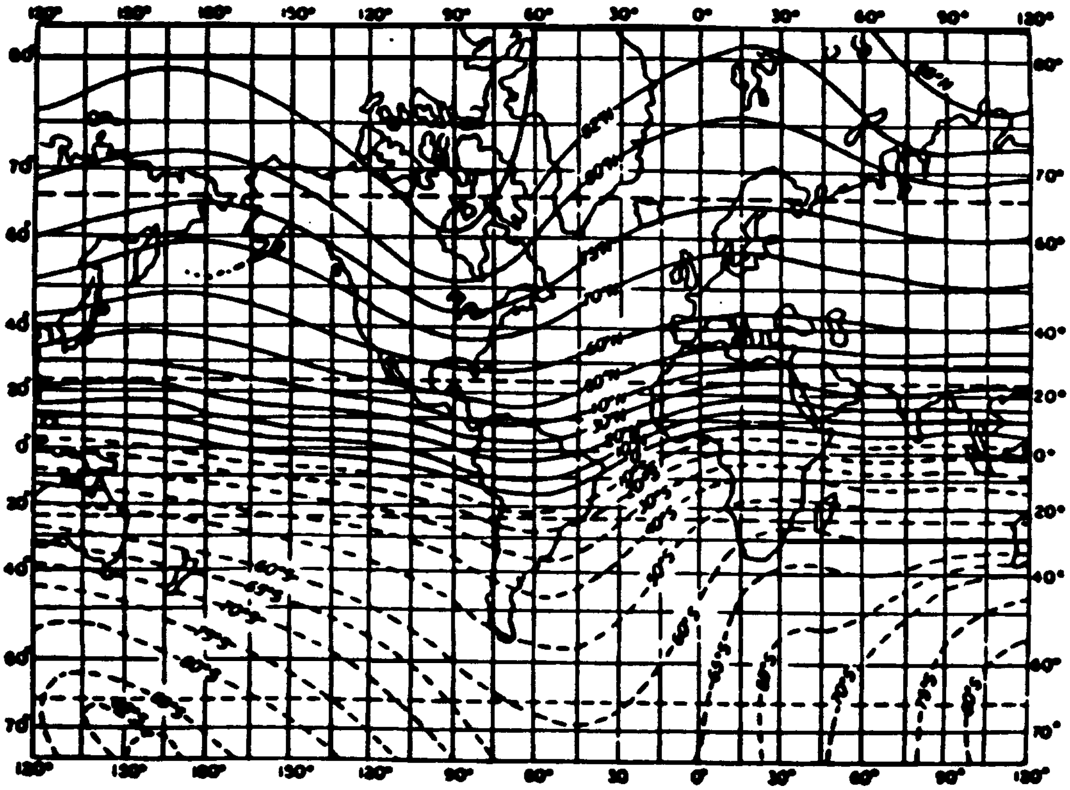
SOURCE: Breiner (1973).

Exhibit 8.4D-2
THE TOTAL INTENSITY OF THE EARTH'S MAGNETIC FIELD



NOTE: CONTOURS ARE IN THOUSANDS OF GAMMAS(KILOGAMMAS).

Exhibit 8.4D-3
THE GEOMAGNETIC INCLINATION IN DEGREES OF ARC FROM THE HORIZONTAL



SOURCE: U.S.N.H.O.

SOURCE: Breiner (1973).

the earth's field. The precessional oscillation will induce a voltage in a second coil wound around the bottle, and the total field strength is determined by measuring the frequency of the induced voltage. Typical sensitivity for this this of magnetometer is one gamma or better.

The flux-gate magnetometer is used to measure any desired vector component of the earth's magnetic field. This instrument uses a ferromagnetic element of such high susceptibility that the earth's field can induce a magnetization which is a substantial proportion of its saturation value. With a sufficiently large alternating current flowing through a coil around the element, the combined field will saturate the element. For decreasing strength of the earth's field, more current will be required to saturate the element and vice versa. The place in the energizing cycle at which saturation is reached gives a measure of the earth's field. In actual practice, two parallel elements with oppositely wound coils connected in series are employed. The magnetic field component that is parallel to the elements will reinforce the field created by one coil and oppose the field of the other. Typical sensitivity for this type of magnetometer is 10 gammas. Some flux-gate magnetometers provide continuous readings as well as spot readings.

The optical-pumping magnetometer is based on quantum theory. In the absence of a magnetic field, the valence electron of an alkali-metai atom (such as rubdium or cesium) has two states: Level A (the normal level) and Level B (the excited level). In the presence of a magnetic field, Level A splits into two sublevels, Al and A2. The energy difference between these levels is in the radio frequency range and is proportional to the strength of the magnetic field. By irradiating a gaseous sample of the metal with light from which spectral line A2B has been removed, electrons in Sublevel A2 will not be excited. When the excited electrons fall back to the ground state, they may return to either sublevel, but if they fall to Sublevel Al, they can be removed by excitation to Level B again. The result is an accumulation of electrons in Sublevel A2, and the gaseous sample becomes transparent to the irradiating light beam. This technique of overpopulating one energy level is known as optical pumping. To determine the energy difference between Al and A2 and, hence, the strength of the magnetic field, radio waves of continually varying frequency are passed through the sample until electrons start moving from A2 to Al and the optical pumping process is reinitiated. The resumption of optical pumping is indicated by a sharp drop in sample transparency. The energy difference between Al and A2 can be determined by measuring the corresponding frequency of the radio waves. The optical-pumping magnetometer measures total magnetic field strength with atypical sensitivity of 0.01 gamma.

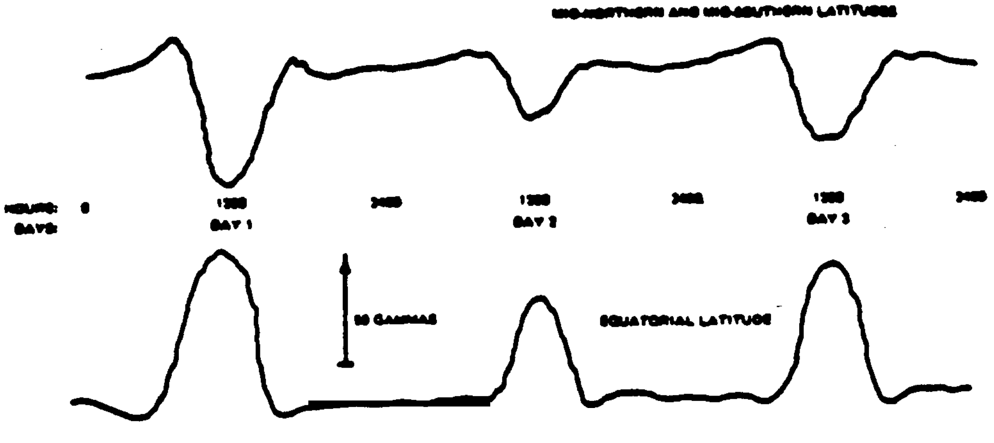
Base Station

Base stations are one method used to remove diurnal variations from the data. Other methods involve the use of tie-lines. If a base station is used, it should be located in an area free of magnetic anomalies and away from roads, buildings, or other areas where cars may pass or electrical disturbances may occur. The base station location may be screened by taking vertical gradient readings in the area. The vertical gradient at the base station location should be near zero. It Is best to have a separate base station magnetometer that will record total field measurements continuously throughout the field survey. Many manufacturers of field and base station magnetometer systems allow for automatic correction for temporal variations in the magnetic field. For automatic recording base stations, a reading interval of 30 seconds to 2 minutes is recommended. If only one magnetometer is available, readings should be obtained at the base station location periodically (i.e., every one-half hour) throughout the field survey.

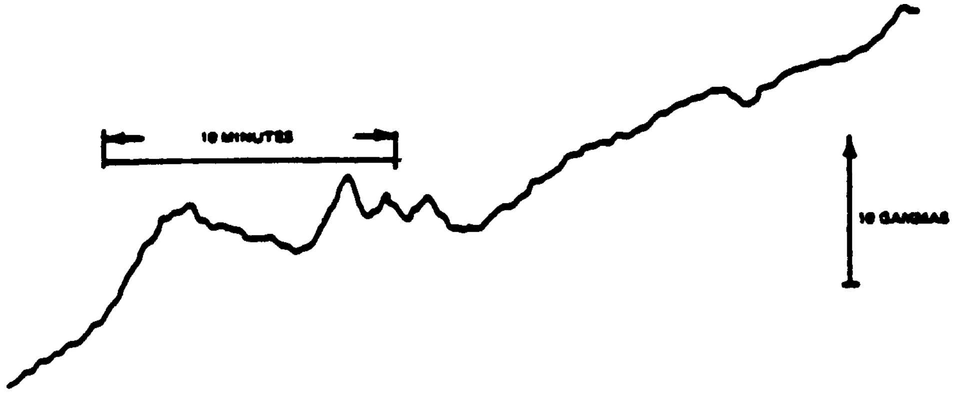
Correction of Diurnal Variations

Corrections for diurnal variations are made by plotting base station readings on a time-versus-total-field graph (Exhibit 8.4D-4); total-field values for times in between actual readings are interpolated. A datum value for total field is chosen, and the differences (ΔT) between the base station total-field reading and the

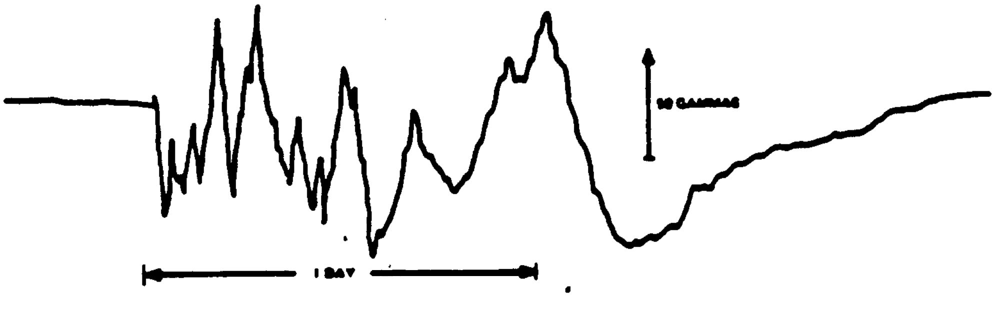
Exhibit 8.4D-4
TIME VARIATIONS OF THE EARTH'S TOTAL MAGNETIC FIELD – DIURNAL VARIATIONS, MICROPULSATIONS, AND MAGNETIC STORM



a) TYPICAL DIURNAL VARIATIONS IN TOTAL FIELD INTENSITY



b) TYPICAL MICROPULSATIONS



c) TYPICAL MAGNETIC STORM

SOURCE: Breiner (1973).

be determined for any time during the survey. The corrected total-field reading for the ned by adding ΔT to the total-field reading.

es from Total Field

The width of a magnetic anomaly is proportional to the depth (or distance) of the source from the magnetometer sensor; the deeper the source, the broader the anomaly (Exhibit 8.4D-5). This relationship is of primary importance in interpreting the results of a magnetic survey. The proportion between the width of an anomaly and the depth of the source is a function of the fall-off rate, or the variation of anomaly amplitude with distance(d). For a dipole, the total-field anomaly amplitude varies as $1/d^3$, and for a monopole as $1/d^2$. In actual practice, source orientation and other factors may result in fall-off rates from $1/d$ to $1/d^3$. The shape of the magnetic profile of an anomaly and knowledge of the source object help in selecting the proper fall-off rate for depth estimation. A range of depths determined from several fall-off rates may be the most appropriate way to present depth estimates. In general, the anomaly width is on the order of one to three times the depth of the source. Thus, for an anomaly with a width of 100 feet, the source probably lies between 30 and 100 feet deep (or distant). Several methods, including the half- width rule and the slope technique, can be used to estimate source depths from total field profiles.

Half-Width Rule

The half-width ($x_{1/2}$) of an anomaly on a total field profile is the horizontal distance between the principal maximum (or minimum) of the anomaly (assumed to be over the center of the source) and the point where total field value is exactly one-half of the principal maximum (Exhibit 8.4D-6). A profile that is used for depth estimation by using the half-width rule should be oriented perpendicular to the long axis of the anomaly to give the narrowest profile. This rule is valid only for forms such as spheres, cylinders, and other simple shapes. For example, a single upright 55-gallon steel drum can be approximated as a vertical cylinder (monopole) and the depth (d) $= 1.3\,x_{1/2}$. A buried trench filled with drums can be approximated by a horizontal cylinder, where $d = 2x_{1/2}$.

Slope Techniques

Depth of the source can be estimated using the slope of the anomaly at the inflection points of the profile. The horizontal extent (X_z) of the "straight" portion of the slope is determined as shown in Exhibit 8.4D-7. The depth is then estimated by the equation,

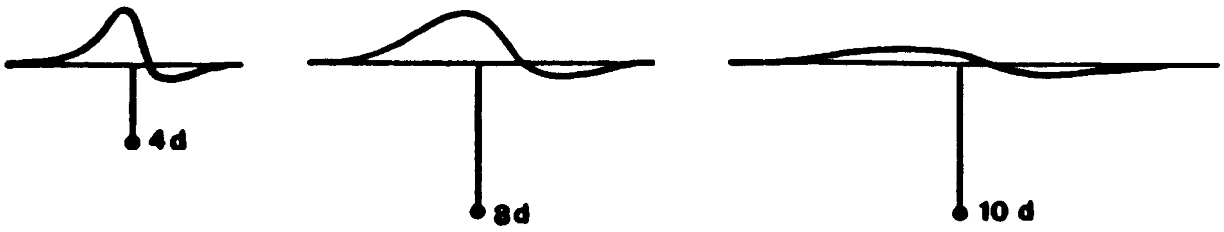
$$d = KX_z \quad \text{where} \quad 0.5 < K < 1.5$$

Calculation of Magnetic Moment and Mass

$$(1) \qquad T = \frac{M}{d^n}$$

The basic expression for relating anomaly intensity (T, in gauss), magnetic moment (M, in cgs units), depth (d, in centimeters), and the fall-off rate factor (n) of a magnetic source object is;

Exhibit 8.4D-5
THE EFFECT OF DEPTH ON WIDTH AND AMPLITUDE OF A DIPOLE ANOMALY

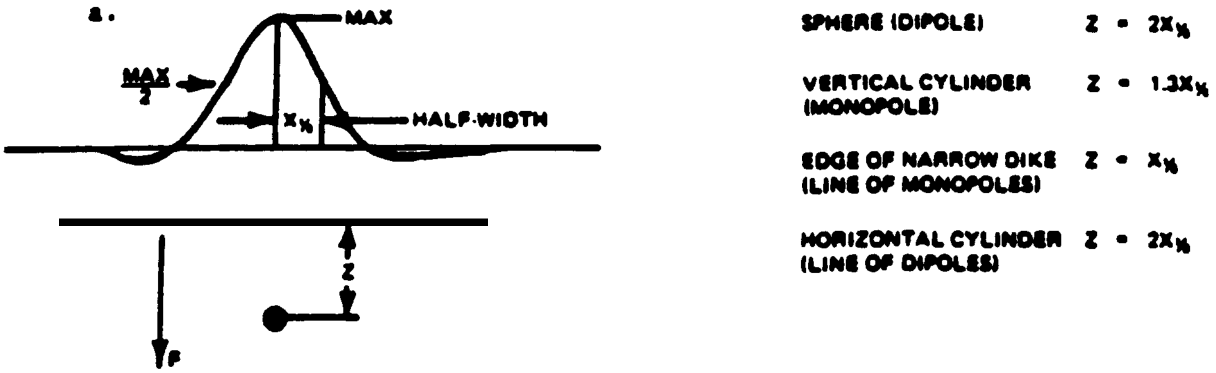


Depth/Amplitude Behavior of Dipole Anomalies

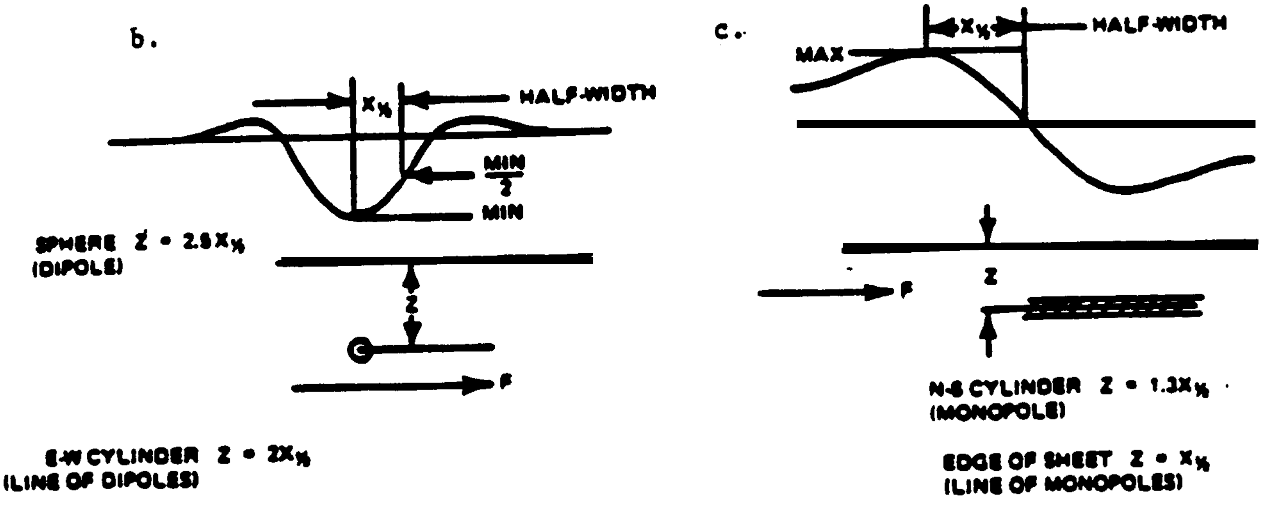
SOURCE: Breiner (1973).

Exhibit 8.4D-6
HALF-WIDTH RULES FOR VARIOUS GEOMETRIC SHAPES FOR BOTH VERTICAL AND HORIZONTAL MAGNETIC FIELDS

NOTE: Z = depth



a) HALF-WIDTH RULES - VERTICAL FIELD

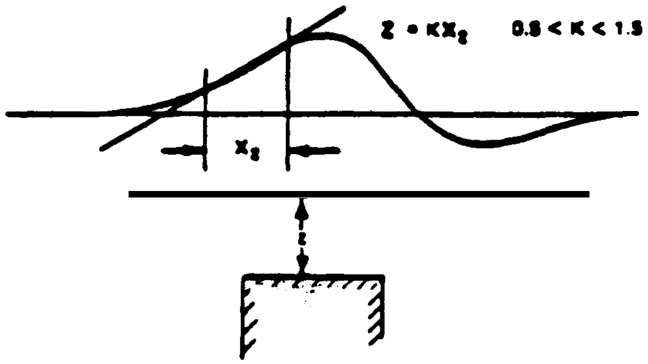


b) HALF-WIDTH RULES - HORIZONTAL FIELD (EQUATORIAL)

SOURCE: Breiner (1973).

Exhibit 8.4D-7

APPLICATION OF THE SLOPE TECHNIQUE TO A DIPOLE MAGNETIC PROFILE



NOTE: Z = depth

SOURCE: Breiner (1973).

Exhibit 8.40-8
MAGNETIC SUSCEPTIBILITIES OF ROCK MATERIALS[1]

Material	Magnetic Susceptibility (Kx10^{6}, CGS Units)
Magnetite	300,000-800,000
Pyrrhotlte	125,000
Ilmenite	135,000
Franklinlte	38,000
Dolomite	14
Sandstone	17
Serpentine	14,000
Granite	28-2,700
Diorite	48
Gabbro	88-2,370
Porphyry	47
Diabase	78-1,050
Basalt	680
Olivine-D&base	2,000
Peridotite	12,5000

---

[1] Adapted from C.A. Holland,"Geophyscial Exploration" (from Costello, 1980).

Depth Estimates from Vertical Gradient

The vertical gradient is the change In total field over a fixed distance. The vertical gradient is the derivative of this equation with respect to distance (d):

$$(5) \qquad dT/dd = \frac{-3M}{d^4}$$

Solving equation (1) for M,

$$(6) \qquad M = Td^3$$

and substituting equation (6) into equation (5),

$$(7) \qquad dT/dd = \frac{-3Td^3}{d^4} = \frac{-3T}{d}$$

Salving equation (7) for depth (or distance) to the source,

$$(8) \qquad d = \frac{-3T}{dT/dd}$$

Thus, using equation (8), the depth to the source of a (dipole) anomaly can be determined by knowing the anomaly intensity (T) above background, and the vertical gradient (dT/dd). For **a monopole source,**

$$(9) \qquad d = \frac{-2T}{dT/dd}$$

In equation (5), note that the fall-off rate for vertical gradient is proportional to $1/d^4$ **for dipole, whereas in equation (1), the fall-off rate for total field Is proportional to** $1/d^3$**. This difference explains why vertical gradient measurements provide finer resolution, but less range In detecting anomalies.**

Exhibit 8.40-8 shows magnetic susceptibilities of rock materials.

APPENDIX 8.4E

GROUND PENETRATING RADAR

THEORY

Ground penetrating radar (GPR) systems are similar to electromagnetic (EM) systems in that a source and a receiver are needed. A radar antenna (source) emits an EM pulse several times a second. These EM impulses are then directed into the ground in the form of waves. As the waves penetrate deeper through the geologic material, contrasts in electrical properties are encountered with changes in strata. These electrical contrasts (anomalies) cause some of the wave to be reflected back toward the surface, where it is received by an antenna, while some of the wave continues downward. When enough anomalies have been encountered, there is very little remaining of the signal (to be reflected); this condition is what is termed the effective penetration depth. The time interval between the point when the EM signal is emitted to when it is reflected and received is dependent on the properties of the material and on the depth at which the signal is reflected. The radar impulse travels in water at about 10 percent of the speed of light; in dry sands it travels to as much as 50 percent of the speed of light. Variations in impulse travel speeds are also noticeable when observing a material in a disturbed versus an undisturbed state (less dense). Knowledge of site geology can be used to estimate the properties of the material (and travel time) so that the depth of the target can be determined.

The contrasts in electrical properties are a function of the composition of the materials and moisture contents. Generally, good conductors, such as metal drums, reflect the entire radar signal (EM wave), so there is no penetration below this point. Poor conductors (good resistors), such as unsaturated sands, will generally allow for a deeper radar signal penetration than good conductors such as saturated clays or saline water. For examples of natural variations in Resistivity (the opposite of conductivity), the reader should refer to Exhibit 8.4E-1. One possible way to increase penetration is to use a transmitter antenna of lower frequency. The effect of frequency changes upon penetration is an inverse square relationship. As the frequency is doubled, penetration is reduced to one-quarter (but resolution increases).

Typical GPR antennae range in frequency from 10 megahertz (MHz) to 1,000 MHz, with 300 to 800 MHz being considered as standard. The lower the frequency, the larger the antenna, so that some lower-frequency antennae are commonly towed by vehicles, while the higher-frequency ones can be towed by a technician. While lower-frequency antennae permit deeper penetration, they lack the resolution of the higher-frequency antennae. Typical penetration in stratified saturated sands for the 300 MHz antenna is perhaps 50 feet, and for the 600 MHz antenna it is perhaps 25 feet. These depth penetration estimates are for guidance and should be used only for that purpose.

GPR equipment does not sense just straight below the antenna; instead, it senses forward, backward, and to the sides at various angles. For this reason, some objects can be detected without having the equipment pass directly overhead.

Exhibit 8.4E-1

NATURAL VARIATIONS IN RESISTIVITY BECAUSE OF MATERIAL AND WATER CONTENT

Rock Type	Water Content (percent H_2O)	Resistivity (ohmmeter)
Siltstone	0.54	1.5×10^4
Siltstone	0.38	5.6×10^8
Coarse Grain Sandstone	0.39	9.6×10^5
Coarse Grain Sandstone	0.18	108
Graywacke Sandstone	0.16	4.7×10^3
Graywacke Sandstone	0.45	5.8×10^4
Dolomite	2.0	5.3×10^3
Dolomite	0.96	8×10^3
Peridotite	0.1	3×10^3
Peridotite	0	1.8×10^7
Granite	0.31	4.4×10^3
Granite	0	10^{10}
Basalt	0.95	4×10^4
Basalt	0	1.3×10^8
Olivine-Pyrox.	0.028	2×10^4
Olivine-Pyrox.	0	5.6×10^7
Material		
Clays		1-100
Sands		10 - 800
Sea Water		0.2
Groundwater (bedrock)		0.5 - 100
Groundwater (overburden)		100

Based on W.M. Telford, et al. Applied Geophysics, 1976.

NOTE: Resistivity is the inverse of conductivity.

INFORMATION SOURCES

The following list of sources has been categorized into specific groups for easy use.

Ground Penetrating Radar (GPR)

Books

Uriksen, P.F. *Application of ImpuLse Radar to Civil Engineering.* Distributed by Geophysical Survey Systems, inc. Hudson, New Hampshire. 1982.

Journals

Morey, R.M. "Continuous Subsurface Profiling by Impulses Radar." Presented at the ASCE Conference--Engineering Foundation Conference on Subsurface Exploration for Underground Excavation and Heavy Construction. 1974.

Wright, D.L, G.R. Olhoeft, and R.D. Watts. "Ground- Penetrating Radar Studies on Cape Cod." Denver Federal Center, Colorado: U.S. Geological Survey. 1983.

GPR General Manuals

Benson, R. C., R.A. Glaccum, and M.R. Noel.*Geophysical Techniques for Sensing Buried Wastes and Waste Migration.* Prepared by Technos, Inc., for the U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory. Las Vegas, Nevada. 1983.

Costello, R.L *Identification and Description of Geophysical Techniques.* Prepared by D'Apollonia for U.S. Army Toxic and Hazardous Materials Agency. Aberdeen Proving Ground, Maryland. 1980.

Manufacturers

Geophysical Survey Systems, Inc. 15 Flagstone Drive Hudson, New Hampshire 03051

APPENDIX 8.4F

BOREHOLE GEOPHYSICS

INFORMATION SOURCES

Borehole Theory and Interpretation

Costello, R.L. *Identification and Description of Geophysical Techniques.* Prepared by D'Apollonia for the U.S. Army Toxic and Hazardous Materials Agency. 1980.

Dresser Industries. *Log Interpretation Fundamentals.* Houston, Texas. 1975. 125 pp.

Keys, W.S., and L.M. MacCary. "Application of Borehole Geophysics to Water-Resources Investigations." *Techniques of Water-Resources Investigations of the United States Geological Survey.* Chapter El, Book 2. Washington, D.C.: U.S. Government Printing Office. 1971.

Pirson, S.J. *Handbook of Well Log Analysis.* Englewood Cliffs, New Jersey: Prentice-Hall.- 1963.

Sammel, E.A. "Convective Flow and Its Effect on Temperature Logging in Small-Diameter Wells." *Geophysics.* Vol. 33, No. 6, pp. 1004-1012. 1968.

Schlumberger Limited. *Log Interpretation.* Vol. 1. New York, New York. 1972.

Schlumberger Limited. *Log Interpretation.* Vol. 2. New York, New York. 1974.

Telford, W.M., L.P. Geldart, R.F. Sheriff, and D.A. Keyes. *Applied Geophysics.* Pp. 774-781. Binghamton, New York: Vail-Ballou Press, Inc. 1980.

Wheatcraft, S.W., J.W. Hess, and W.M. Adams. *Equipment and Techniques Applicable to Subsurface Sensing and Monitoring at Hazardous Waste Sites.* U.S. Environmental Protection Agency, Environmental Monitoring Systems Laboratory, Office of Research and Development. Las Vegas, Nevada.

U.S. Bureau of Mines. "Calibration Models for Geophysical Borehole Logging." USBM RI 8148. Washington, D.C.: U.S. Department of the Interior. 1976. 21 pp.

U.S. Geological Survey. "Application of Electrical and Radioactive Well Logging to Ground Water Hydrology." Geological Survey Water Supply Paper 1544-D. Washington, D.C.: U.S. Government Printing Office. 1963. 60 pp.

U.S. Geological Survey. "Methods of Flow Measurement in Well Bores." Geological Survey Water-Supply Paper 1544-C. Washington, D.C.: U.S. Government Printing Office. 1962. 28 pp.

Borehole Logging Instrument Manufacturers

Comprobe, Inc.
9632 Crowley Road
Crowley, Texas 76036
817/293-7333

Gearhart-Owen
P.O. Box 1936
Fort Worth, Texas 76101
817/293-1300

Geotronic Corporation
10317 McKalla Place
Austin, Texas 78758

McPhar Geophysics
55 Tempo Avenue
Willowdale, Ontario M2H 2R9
416/497-1700

Mount Sopris Instrument Company
P.O. Box 449
Delta, Colorado 81416
303/874-4852

8.5 GROUNDWATER MONITORING

8.5.1 Scope and Purpose

This subsection provides general information on equipment and materials used in groundwater monitoring programs.

8.5.2 Definitions

Site Manager (SM)
The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

All other terms in this subsection are in common usage.

8.5.3 Applicability

Almost every investigation of hazardous waste sites entails groundwater sampilng and monitoring. Since each site is different, experienced hydrogeologists and geochemists should be consulted to establish the most suitable type of monitoring for a particuiar site. Monitoring well placement and sampling requirements for each site are detailed in a site-specific sampling plan. The procedures described below have all been used successfully on hazardous waste sites.

8.5.4 Responsibilities

The SM is responsible for determining the type and placement of groundwater monitoring networks. The SM is assisted by experienced hydrogeologists and geochemists. As discussed earlier in Section 8, an experienced hydrogeologist will supervise the installation of monitoring wells.

8.5.5 Records

Field notes are kept in a bound, weatherproof logbook. Entries are made chrologically in indelible ink on numbered pages, with the date, time, and notetaker's initials recorded for each entry. Certain forms used in groundwater monitoring are discussed in the fallowing subsections and in Sections 3, 4, 5, and 17 of this compendium.

8.5.6 Procedures

8.5.6.1 Water Wells

Production or traditional wells are often used to obtain samples in ambient groundwater monitoring programs. Designed to yield large quantities of turbidity-free water for potable or irrigation supplies, these wells generally tap the more permeable portions of an aquifer. They may be screened in unconsolidated material. Chemical data obtained from these wails depict the quality of water being delivered to the user community. Because water pumped from these wells is often a composite of water from different strata in the aquifer systems, the presence of relatively narrow or mail plumes of polluted water maybe masked by dilution with water obtained from unaffected portions of the aquifer.

Production or traditional wells should not be used for the more detailed source, case-preparation, and research types of monitoring. Such detailed monitoring efforts call for wells designed to determine the groundwater quality at a given location and depth within the geologic materials being monitored. All available geologic and hydrologic information for the site of interest should be reviewed prior to the selection of preliminary locations and depths for monitoring wells. The Potential paths of pollutant movement from the site should be estimated, and walls should be placed to define contaminant plumes. information gained during the drilling process should be used to modify the monitoring plan to make it more effective.

8.5.6.1.1 Monitoring Wail Components

The principal reason that monitoring wells are instructed is to collect groundwater samples that, upon analysis, can be used to delineate a contaminant plume and track movement of specific chemical or biological constituents. A secondary consideration is the determination of the physical characteristics of the groundwater flow system to establish flow direction, transmissivity, quantity, etc. The spatial and vertical locations of monitoring wells are important. Of equal importance are the design and construction of monitoring wells that will provide easily obtainable samples and yield reliable, defensible, meaningful information. in general, monitoring well design and construction follow production well design and construction techniques. However, emphasis is placed on the effect these practices may have on the chemistry of the water samples being collected rather than on maximizing well efficiency.

From this emphasis, it follows that an understanding of the chemistry of the suspected pollutants and of the geologic setting in which the monitoring wells are constructed plays a major role in determining the drilling technique and materials used.

There are several components to be considered in the design of a monitoring well including location, diameter, depth, casing, screen, sealing material, and well development. As these components are discussed in detail, it may be helpful to refer to Exhibit 8.5-1, which portrays two typical well instaliations: one for water supply and the other for groundwater quality monitoring.

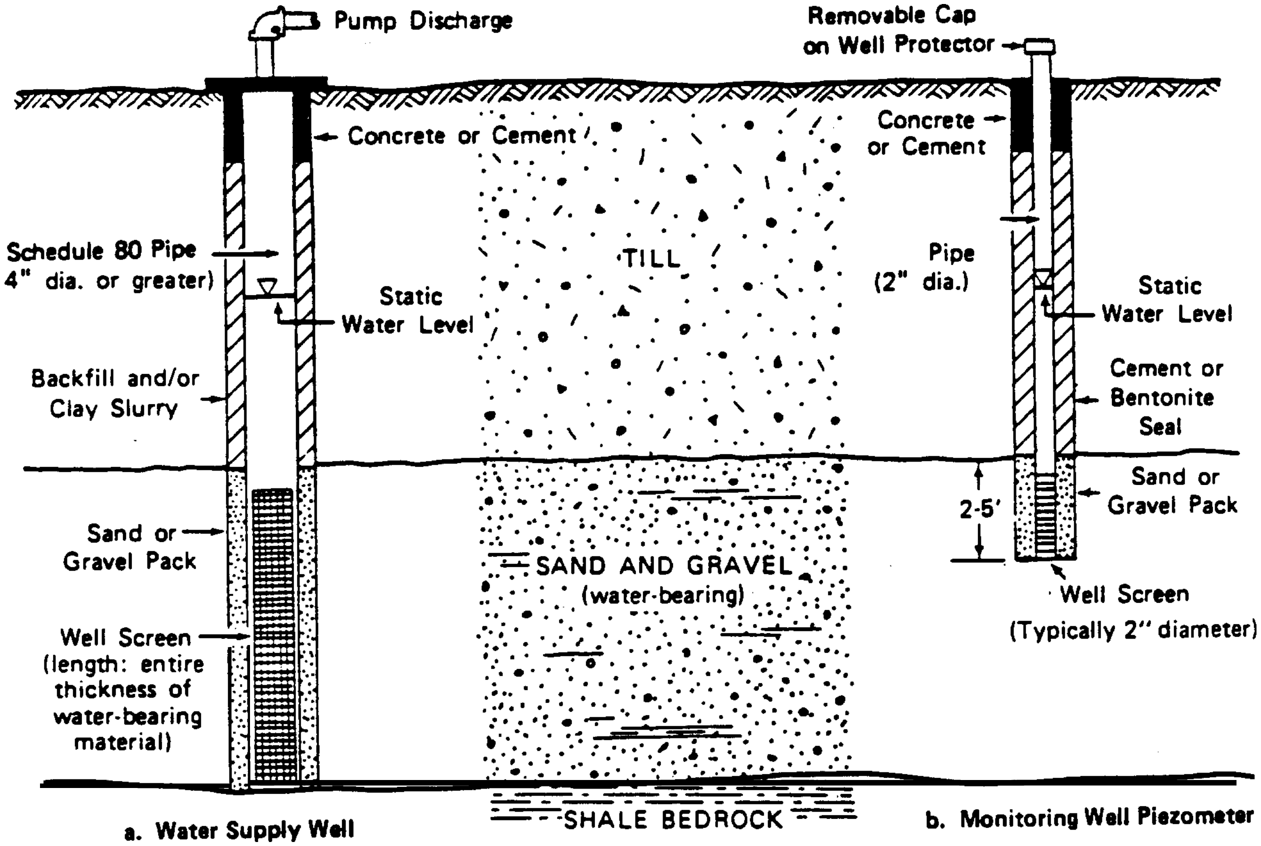
8.5.6.1.2 Well Location

The location of a monitoring wail should be selected on the basis of the purpose of the sampling effort. This purpose may be to verify predictions of contaminant migration; to detect contaminants in drinking water supplies and thus to protect public health; to activate a contingency plan, such as a program for leachate collection; to protect the operation to reassure the public by demonstrating that water quality is being monitored; or to define a contaminant plume. Each of these purposes will require a somewhat specialized array of monitoring points and a somewhat different sampling program as defined by the project sampling plan. The monitoring system must be designed to suit the purpose(s) in mind.

8.5.6.1.3 Wail Diameter

A domestic water supply well is commonly 4 or 6 inches in diameter to accommodate a submersible pump capable of delivering 5 to 10 gallons per minute (gpm). Centrifugal and jet pumps are also used. Municipal and industrial supply wells have greater diameters to handle larger pumps for greater pumping capacity. As in water supply wells, the diameter of a monitoring well is largely determined by the size of the sampling device or pump. Pumping one or more well volumes of water from a large-diameter monitoring well may present a problem, because large quantities of water must be disposed of or contained. With the

Exhibit 8.5-1
TYPICAL INSTALLATIONS OF (a) WATER SUPPLY WELLS AND (b) MONITORING WELLS



advent of several commercially available small-diameter pumps (less than 2 inches outside diameter) capable of lifting water from several hundred feet, it is rarely necessary to construct monitoring wells larger than 2 inches in diameter. Additionally, the smaller the diameter, the less it will cost for drilling and construction. Small diameter wells with corresponding low-vdume pumps may be preferable for sampling for volatile organics, because they create less turbulence and provide a sample that is more representative of aquifer conditions. Monitoring wells in high-transmissivity aquifers may be larger than 2 inches in diameter if pumping test methods are used to determine aquifer characteristics. Larger diameter, high-capacity pumps are needed to conduct pumping tests; these pumps require larger diameter wells.

8.5.6.1.4 Well Depth

The depth of each monitoring well is usually determined by the geohydrologic conditions at the site being monitored. Most "detective" monitoring wells are completed in the first relatively permeable water-bearing zone encountered, since potential pollution sources are frequently at or near ground surface. Locating the monitoring well in the first relatively permeable zone, therefore, yields an indication of the migration of pollutants in most situations. However, care must be taken to ensure that the well is completed at a depth sufficient to allow for seasonal water table fluctuations. Under confined or semi-confined (leaky) conditions, the water level will rise above the top of the water-bearing zone. in this instance, the well should be finished in the water-bearing zone and not above it.

if the water-bearing zone is thick (greater than 10 feet) or contamination is known or suspected in deeper formations, muitiple wells completed at different depths should be used. For sampling at various depths, some geologists have nested several wells in a single borehole. This requires drilling a large-diameter hole and exercising special care to ensure that the vertical Integrity of the sampling points Is main tained. It may be more costly to drill separate wells, but the reduction of potential for cross contamination often offsets the added expense. Formation samples (cuttings or core) would be taken only during boring of the deepest well.

Where multiphase or nonaqueous phase liquids are suspected at a site, multilevel wells within a single aquifer may also be needed. For example, if oil or gasoline is the contaminant, monitoring at the top of the aquifer is needed. In contrast, sites with "sinking" contaminants, such as trichloroethylene, may warrant monitoring at the base of the aquifer.

Monitoring wells should be constructed so that they are depth discrete (i.e., able to sample from one specific formation or zone without interconnection to others). Where multiple aquifers exist, it may be desirable to set multiple casing strings to ensure isolation of deeper aquifers from shallow, potentially contaminated ones. This procedure, called telescoping, is identical to that used in the oil and gas business and necessitates the setting and cementing of successively smaller diameter casing strings until the target aquifer is reached. Care must be taken with each casing string to cement with returns to surface to ensure no interconnection between aquifers. Grout can be placed above and if necessary, below the intake portion of the well to make it depth-discrete.

8.5.6.1.5 Well Design and Construction Materials.

The type of material used for monitoring well casing may have a distinct effect on the quality of the water samples collected. Galvanized casing will impart iron, manganese, zinc, and cadmium to many waters. Steel casing may impart iron and manganese to the water samples. Polyvinyl chloride (PVC) pipe has been shown to release and absorb trace amounts of various organic constituents to water after prolonged exposure. PVC solvent cements used to attach sections of PVC pipe have also been shown to release significant quantities of organic compounds. Teflon and glass are among the most inert materials that have been considered for monitoring well construction. Glass, however, is very difficult and expensive to use under most field conditions. Stainless steel has also been found to work satisfactorily under most monitoring conditions. Fiberglass-reinforced plastic has recently been used at sites where organic contaminants are present. This material is not as expensive as stainless steel and does not have as strong a tendency to sorb or release contaminants as PVC does. A detailed discussion of materials is presented In later portions of the text.

All well screens should allow free entry of water. They should also produce clear, silt-free water. This is especially Important with regard to drinking water supplies, because sediment in the raw water can create additional pumping and treatment costs and can lead to the general unsuitability of the finished water. Also, in monitoring wells, sediment-laden water can greatly lengthen filtering times and create chemical interferences with the collected samples.

Commercially manufactured well screens generally work best providedd the proper slot size is chosen. in formations where fine sand, silt, and clay predominate, sawed or torch-cut slots will not retain the material, and the wail may dog. if practical, it may be helpful to have well screens of several slot-sizes availabfe onsite so that the correct screen can be placed in the hole after the water-bearing materials have been inspected. The use of sawed or torch-cut slotted screens is not recommended; indeed, most EPA regions do not permit the use of such screens. Customized screens limit the reproducibility of data. Gravel-packing materials compatible with the selected screen size and aquifer grain size will further help retain fine materials and will also allow freer entry of water into the well by creating a zone of higher permeability around the well. The backfill material must be free of contaminants.

Wail screen length Is an Important consideration. The transmissivity of the aquifer will be used to establish the length of screen. Low yield aquifers may require greater screen lengths to permit the collection of adequate sample volumes in a timely manner. A monitoring program to describe contaminant plume geometry requires the sampling of discrete intervals of the water-bearing formation. in this situation, screen lengths of no more than 5 feet (1.5 m) should be used. Thick aquifers would require completion of several wells at different depth intervals. in some situations, only the first water-bearing zone encountered will require monitoring. Here the “aquifer" may be only 6 inches to a few feet (0.2 to 2 m) thick, and the screen length should be limited to 1 or 2 feet (less than 1 m). in other circumstances where an aquifer with a potable water supply is monitored, the entire thickness of the water-bearing formation should be screened to provide an integrated water sample comparable to that found In the drinking water supply. Monitoring for low-density organic solvents or hydrocarbons that may float on the surface of the water creates a special problem. In such a case, the screen must be long enough to extend above the water level in the formations so that these lighter substances can enter the well. Some companies have developed probes or samplers that can be placed in a single borehole to monitor several zones simultaneously. The units are limited to low flow conditions, which necessitates longer sampling times. However, the low cost of Instaliation of these units (techniques are similar to monitoring well instaliation) can be a factor in selecting these devices.

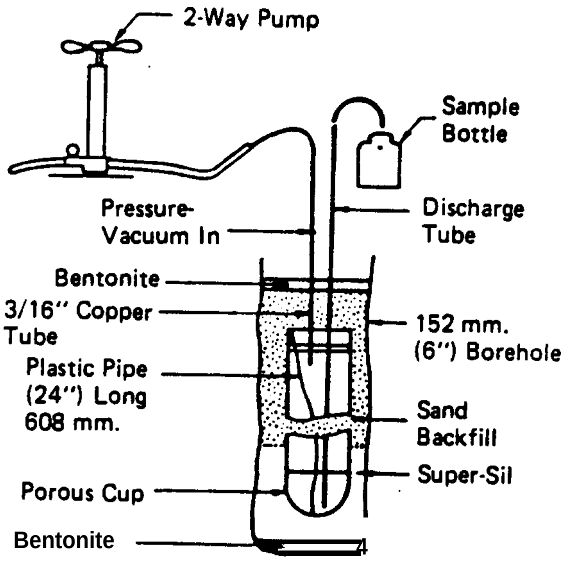
it is critical that the screened potion of each monitoring wail have access to the groundwater from a specific depth intend. Vertical movement of water in the vicinity of the Intake and around the casing must be prevented to obtain samples representative of the formation of interest. Specifically, rainwater can infiltrate backfill materials and dilute or contaminate samples collected from the screened portion of the well. Vertical seepage of leachate or contaminated water from adjacent formations along the well casing may also produce unrepresentative samples for the depth interval being sampled. More importantly, the creation of a conduit in the annulus of a monitoring well that ,could contribute to or hasten the spread of contamination should be avoided.

8.5.6.2 Iysimeters

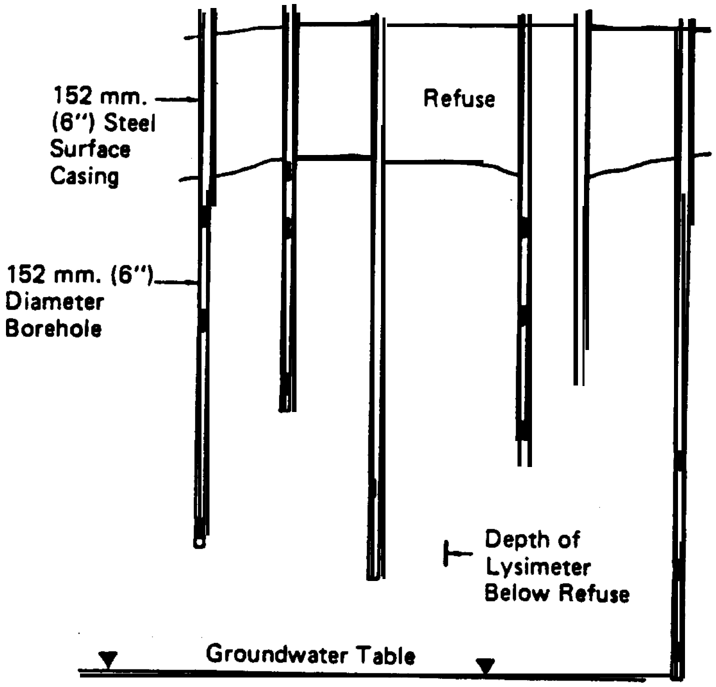
Pressure-vacuum Iysimeters may be used to obtain samples of in situ soil moisture. They are used predominantly in the unsaturated zone (i.e., above the water table, as shown in Exhibit 8.5-2). In its most improved form, this device consists of a porous ceramic cup capable of holding a vacuum, a small-diameter sample accumulation chamber of PVC pipe, and two sampling tubes leading to the surface.

Exhibit 8.5-2

PRESSURE-VACUUM LYSIMETER INSTALLATION



Cross Section of a Typical Pressure-Vacuum Lysimeter Installation



Cross Section of a Lysimeter Network

Once the lysimeter is in place, a vacuum is applied to the cup. Soil moisture moves into the sampler under this gradient, and a water sample gradually accumulates. Care must be taken in using samples from suction lysimeters for water quality assessments. The application of the vacuum to drive the water may remove volatile-organics or alter carbonate chemical equilibrium. When the vacuum is released and inert gas pressure is applied, the accumulated water is forced to the surface through the sampling tube. A typical pressure-vacuum lysimeter installation is shown in Exhibit 8.5-2.

8.5.6.3 Piezometers and Tensiometers

The terms "Piezometer' and "observation well" are commonly used interchangeably however, there is a significant difference between them. As implied by its name, a piezometer is a pressure-measuring device that is frequently used for monitoring water pressure in earthen dams, under foundations, or in aquifers.

A piezometer that is used to monitor earthen dams or foundations resembles a porous tube or plate. A piezometer that is used to monitor aquifers resembles a screened well or open hale. An impermeable clay or cement seal isolates the piezometer from other pressure environments. If the well screen is properly isolated by an impermeable seal placed immediately above the screen, a piezometer can also be used to measure vertical head differences under unconfined conditions. Any wail constructed without this seal cannot be considered a piezometer. In practice, piezometers are similar to the monitoring wells described in Subsection 8.5.6.1. If the well is going to be used only for water level measurements, it is generally called a piezometer. in that case, well construction materials are less critical.

Piezometers are not suitable for the measurement of pressure above the water table since water in the unsaturated zone is held in the soil pores under surface-tension forces. The pressure head in the unsaturated zone is called the tension head or suction head. Tensiometers are used to indirectly measure the pressure head in the unsaturated zone to help determine the groundwater gradients and the flow in the unsaturated zone.

Typically, a tensiometers consists of a porous cup attached to an airtight, water-filled tube. The porous cup is inserted into the soil at the desired depth, where it comes into contact with the soil water and reaches hydraulic equilibrium. The equilibrium process involves the passage of water through the porous cup from the tube into the soil. The vacuum created at the top of the airtight tube is a measure of the pressure head in the soil. The pressure head is usually measured by a vacuum gauge attached to the tube above the surface of the ground. To obtain the hydraulic head, the negative value indicated by the vacuum gauge on the tensiometers must be added algebraically to the elevation of the point of measurement. In practice, the tensiometers is a tube with a gauge and a porous cup at the base; the piezometer is an open pipe with a well point at the base.

8.5.6.4 Groundwater Sampling Equipment

The type of system used to collect groundwater samples is a function of the type and size of well construction, pumping level, type of pollutant, analytical procedures, and presence or absence of permanent pumping fixtures. Ideally, sample withdrawal mechanisms should be completely inert; economical to manufacture; easily decontaminated, cleaned, and reused; able to operate at remote sites in the absence of external power sources; and capable of delivering continuous but variable flow rates for flushing and sample collection.

Most water supply wells contain semi-permanently mounted pumps that limit the options available for groundwater sampling. Existing in-place pumps may be line shaft turbines, commonly used for high-capacity wells; submersible pumps commonly used in domestic wells for high-head, low-capacity applications and, more recently, for municipal and industrial uses; and jet pumps commonly used for shallow, low-capacity domestic water supplies. The advantages of in-place pumps are that water samples are readily available and that nonrepresentative stagnant water in the wall bore is generally not a problem. The disadvantage is that excessive pumping can dilute or increase the contaminant concentrations so that they are not representative of the sampling point. Another possible disadvantage is that water supply wells may produce water from more than one aquifer and contamination or adsorption may be a problem when sampling for organics.

The advantage to collecting water samples from monitoring well without in-place pumps lies in the fact that the selection of equipment and procedures is flexible. The principal disadvantage lies in the possibility of obtaining a nonrepresentative sample either through collecting stagnant water that is In the well bore or through introducing contamination from the sampling equipment or procedures. Some commonly used sampling systems are described below.

8.5.6.4.1 Ballers

One of the oldest and simplest methods of sampling water wells is the use of bailers. A bailer maybe a weighted bottle, a capped length of pipe on a rope, or some modification thereof that is lowered and raised, generally by hand. Two examples are the modified Kemmerer sampler and the Teffon bailer represented in Exhibits 8.5-3 and 8.5-4. The modified Kemmerer sampler is more often used for sampling surface water than groundwater. The Teflon baller was developed specifically for collecting groundwater samples for volatile organic analysis. Bailers are also made of PVC, copper, or stainless steal. The sampling plan will specify equipment materials, and procedures used in sampling. The material best-suited to the purpose of the project should be selected.

The advantages of using a bailer areas follows:

- A bailer can be constructed from a wide variety of materials that are compatible with the parameter of interest.
- It is economical and convenient enough that a separate one maybe dedicated to each well to minimize cross contamination.
- It does not require an external power source.
- Its low surface-to-volume ratio reduces outgassing of volatile organics.

The following are disadvantages of using a bailer:

- It is sometimes impractical to evacuate stagnant water in a well bore with a bailer.
- An open-top bailer may allow nonaquifer material to enter the bailer as it is withdrawn from the well (i.e., mat from casings).
- The transfer of a water sample from the bailer to the sample bottle can result in aeration.
- Cross contamination can be a problem if bailers are not adequately cleaned after each use.
- Care must be exercised in handling the bailer rope to prevent introducing contamination into the well.

Exhibit 8.5-3
MODIFIED KEMMERER SAMPLER

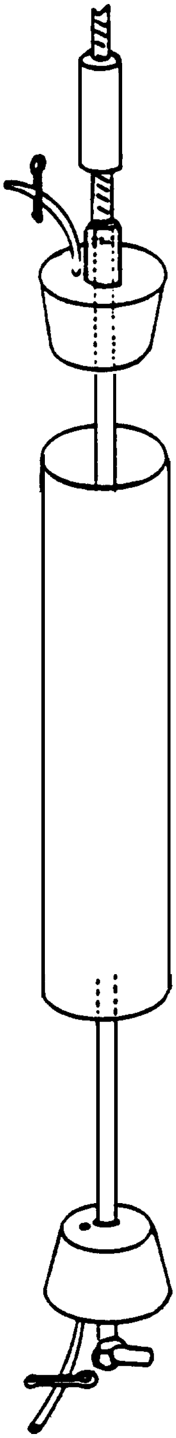
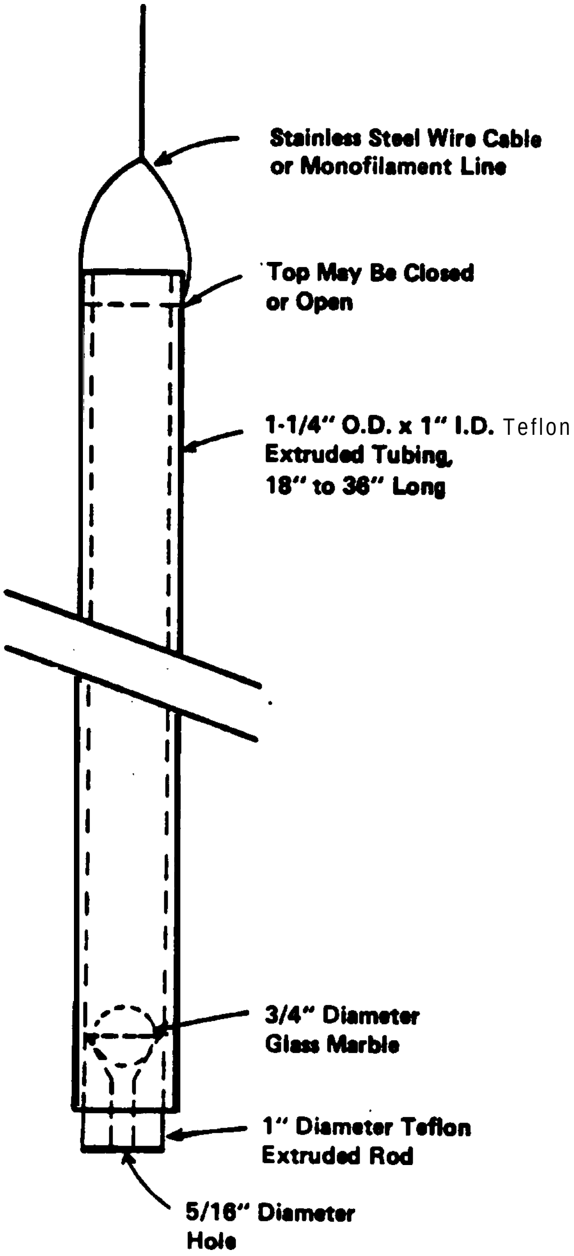


Exhibit 8.5-4

TEFLON BAILER



8.5.6.4.2 Suction-Lift Pumps

A variety of pumps can be used to flush wells prior to sampling or, in limited instances, to obtain samples. When the water table is about 20 to 28 feet from the surface, a suction-lift pump can be used. Centrifugal pumps are the most commonly available type of suction-lift pump, are highly portable, and have a pumping rate of from 5 to 40 gpm. Most Centrifugal pumps require a foot valve on the end of the suction pipe to aid in maintaining a prime.

Peristaltic pumps are generally low-volume suction pumps suitable for sampling shallow, small-diameter wells. Their pumping rates are generally low but can be readily controlled within desirable limits. The low pumping rates are a significant limitation in flushing out the well bore. Another limitation is that electrical power is required.

Hand-operated diaphragm pumps are available that can be operated over a wide range of pumping rates, which facilitates rapid evacuation of a well bore initially and prvides lower controlled pumping rates for subsequent sampling. One major advantage of such pumps is their portability. A disadvantage is that sampling Is limited to groundwater situations where water levels are less than about 20 feet.

Suction pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds.

8.5.6.4.3 Portable Submersible Pumps

Groundwater investigations routinely require the collection of samples from depths that exceed the capabilities of the systems discussed above. One alternative system consists of a submersible pump that can be lowered or raised in an observation well, using as much as 300 feet of hose that supports the weight of the pump, conveys the water from the well, and houses the electrical cable and an electrical winch-and-spool assembly. A portable generator provides electricity for both the pump and the winch, and the entire assembly can be mounted in a pickup or van.

The following are advantages of using submersible pumps:

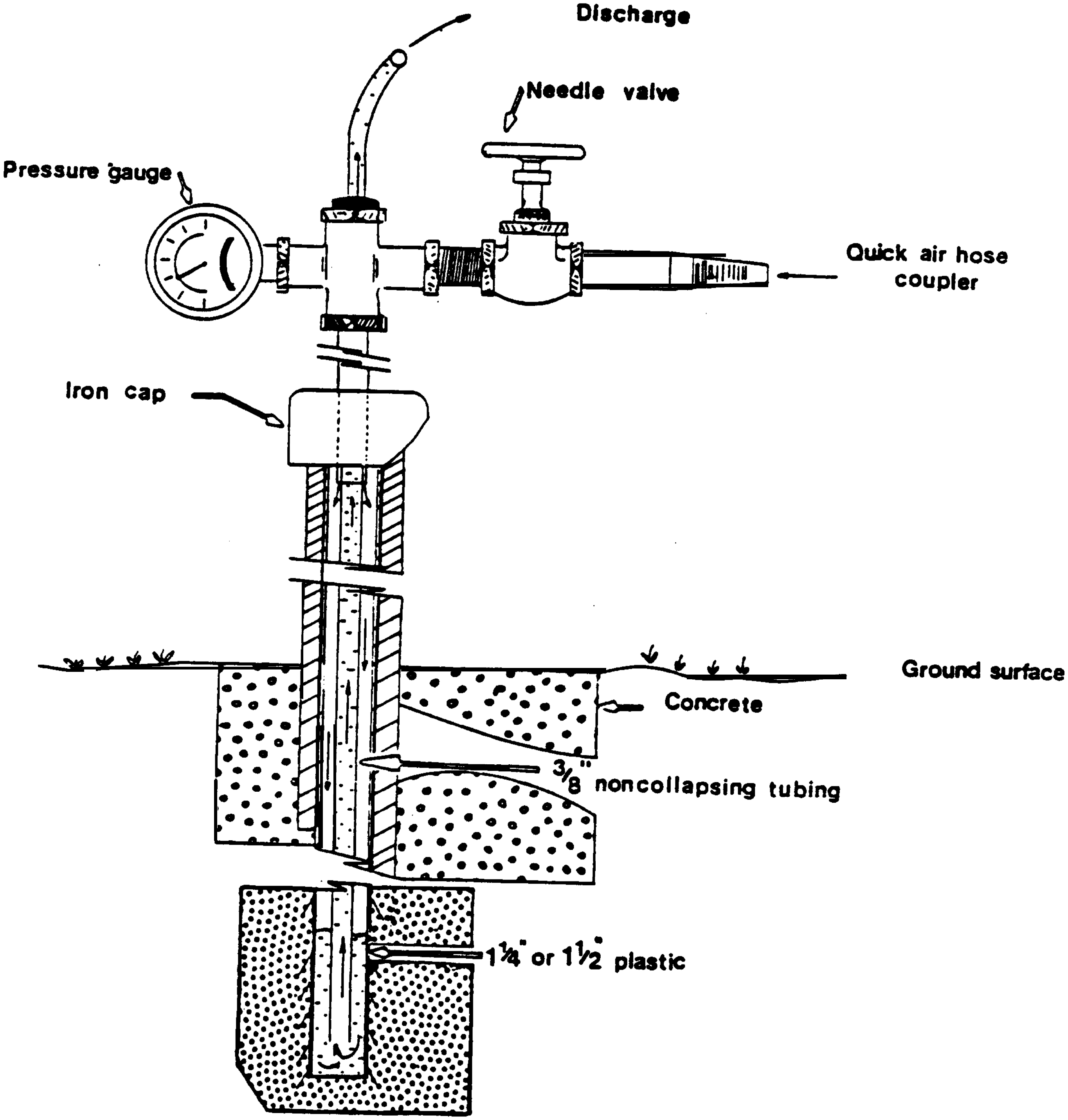
- They are portable and can be used to sample several monitoring wells in a brief period of time.
- Depending upon the size of the pump and the pumping depths, relatively high pumping rates are possible.

Existing bladder-type submersible pumps will operate in 2-inch. monitor wells and are constructed of materials to permit water quality samples from monitor wells. The pumps require dedication to a single well or vigorous decontamination between sampling sites.

8.5.6.4.4 Air-lift Samplers .

The basic method of applying air pressure to a water well can be adapted to force a water sample out of the discharge tube. A high-pressure hand pump and any reasonably flexible tubing can be used as a highly portable sampling unit. A small air compressor or compressed air cylinder and somewhat more elaborate piping arrangements may be required at greater depths, as shown in Exhibit 8.5-5. The primary limitations of the air-lift sampler are the potential alteration of water quality parameters, the amount of air pressure that can be safely applied to the tubing, and the identification of a suitable source of compressed air.

Exhibit 8.5-5
AIR-LIFT SAMPLER



The following are advantages of using the air-lift sampler:

- It can be used as a portable or permanently installed sampling system.
- It can be used both to flush the well and to sample.

Its disadvantages areas follows:

- It is not suitable for pH-sensitive parameters such as metals.
- It can damage the integrity of the filter pack around the well screen if the well is evacuated under high pressure and if the intake of the sample line is located within the screened interval.
- If air or oxygen is used, oxidation is a problem
- Gas stripping of volatile compounds may occur.

8.5.6.4.5 Nitrogen-Powered, Continuous-Delivery, Glass-Teflon Sampler

Sampling groundwater for trace organic pollutants requires a noncontaminating, nonadsorbing pump. Basing their work on an initial design by Stanford University, developers at Rice University created a groundwater sampling system that consists of a two-stage, all-glass pump connected by Teflon tubing and powered by nitrogen gas. The system (shown in Exhibit 8.5-6) contains four basic units: (1) a two-stage glass pump, (2) a solenoid valve and electronic timer, (3) a nitrogen tank and regulator, and (4) columns for removal of organics from the groundwater.

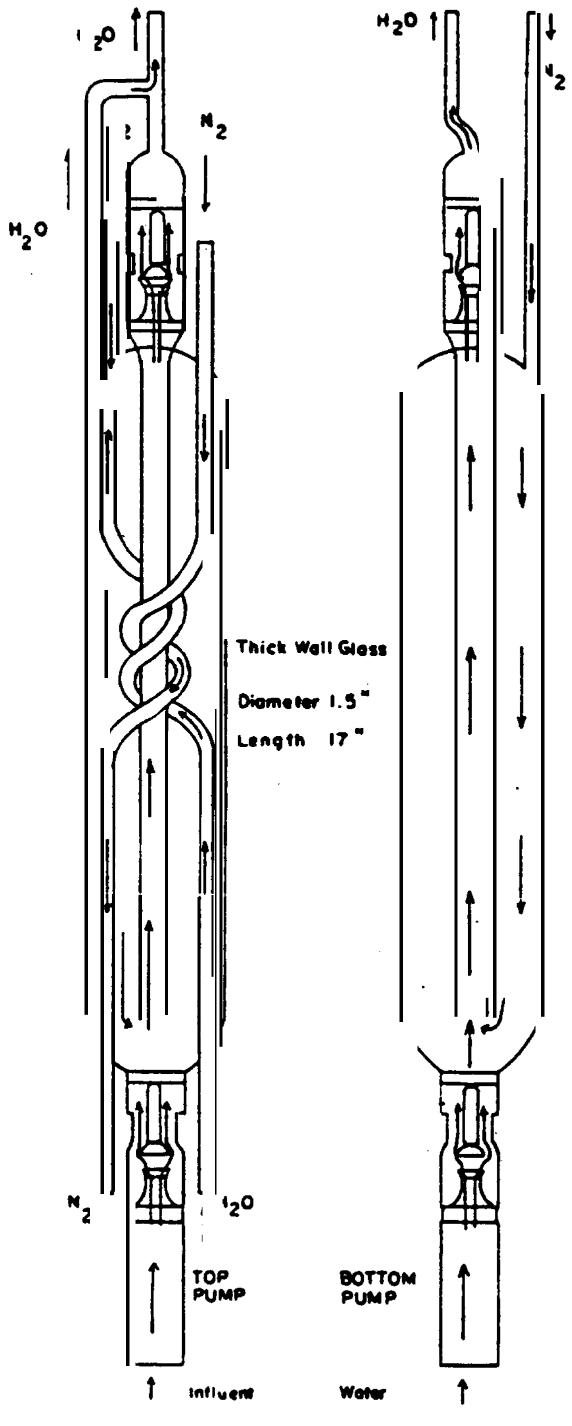
The following are advantages of using the glass-Teflon sampler:

- It is portable; AC power is not required
- It is constructed of noncontaminating, nonadsorbing materials.
- Variable flow rates up to 45 gallons per hour are obtainable.
- It can be used in well casings with minimum diameters of about 2 inches.

Its disadvantages are as follows:

- it requires high-purity nitrogen gas.
- Glass construction is somewhat more fragile than other materials.
- Stripping of CO_2 from water maybe a problem for pH-sensitive parameters.
- Gas stripping of volatile compounds may occur.
- Generally low pumping rates are experienced.

Exhibit 8.5-6
NITROGEN-POWERED, GLASS-TEFLON PUMP



8.5.6.4.6 Gas-Operated Squeeze or Bladder Pump

These systems consist of a collapsible membrane inside a long, rigid housing; a compressed gas supply; tubing; and appropriate control valves. When the pump is submerged, water enters the collapsible membrane through the bottom check valve. After the membrane has filled, gas pressure is applied to the annular space between the rigid housing and the membrane, forcing the water upward through a sampling tube. When the pressure is released, the top check valve prevents the sample from flowing back down the discharge line, and water from the well again enters the pump through the bottom check valve. A diagram of the basic unit is shown in Exhibit 8.5-7.

The following are advantages of using the gas-operated squeeze or bladder pump:

- A wide range in pumping rates is possible
- A variety of materials can be used, depending on the parameters of interest.
- The driving gas does not contact the water sample, eliminating possible contamination or gas stripping.
- The pump can be constructed in diameters as small as 1 inch, permitting the use of small, economical monitoring wells.
- The pump is highly portable.

Disadvantages of the system areas fallows

- Large gas volumes and long cycles are necessary for deep operation. Pumping rates cannot match rates of submersible, suction, or jet pumps.
- Commercial units are relatively expensive (approximately $1,000 for currently available units).
- Use of the pump requires careful selection of bladder and tubing material, some of which is expensive.

8.5.6.4.7 Gas-Driven Piston Pump

This pump is a double-acting piston type operated by compressed gas (Exhibit 8.5-8). The driving gas enters and exhausts from the gas chambers between the two pistons and the intermediate connector that joins them. Built-in check valves at each end of the pump allow water to enter the cylinders on the suction stroke and to be expelled to the surface, on the pressure stroke. Current designs are constructed basically of stainless steel, brass, and PVC. Pumping rates vary with the pumping head, but pumping rates of 2.5 to 8 gallons per hour have been noted at 100 feet of pumping head.

The following are advantages of using the gas-driven piston pumps:

- It isolates the sample from the operating gas.
- It requires no electrical power source.

Exhibit 8.5-7
GAS-OPERATED SQUEEZE PUMP

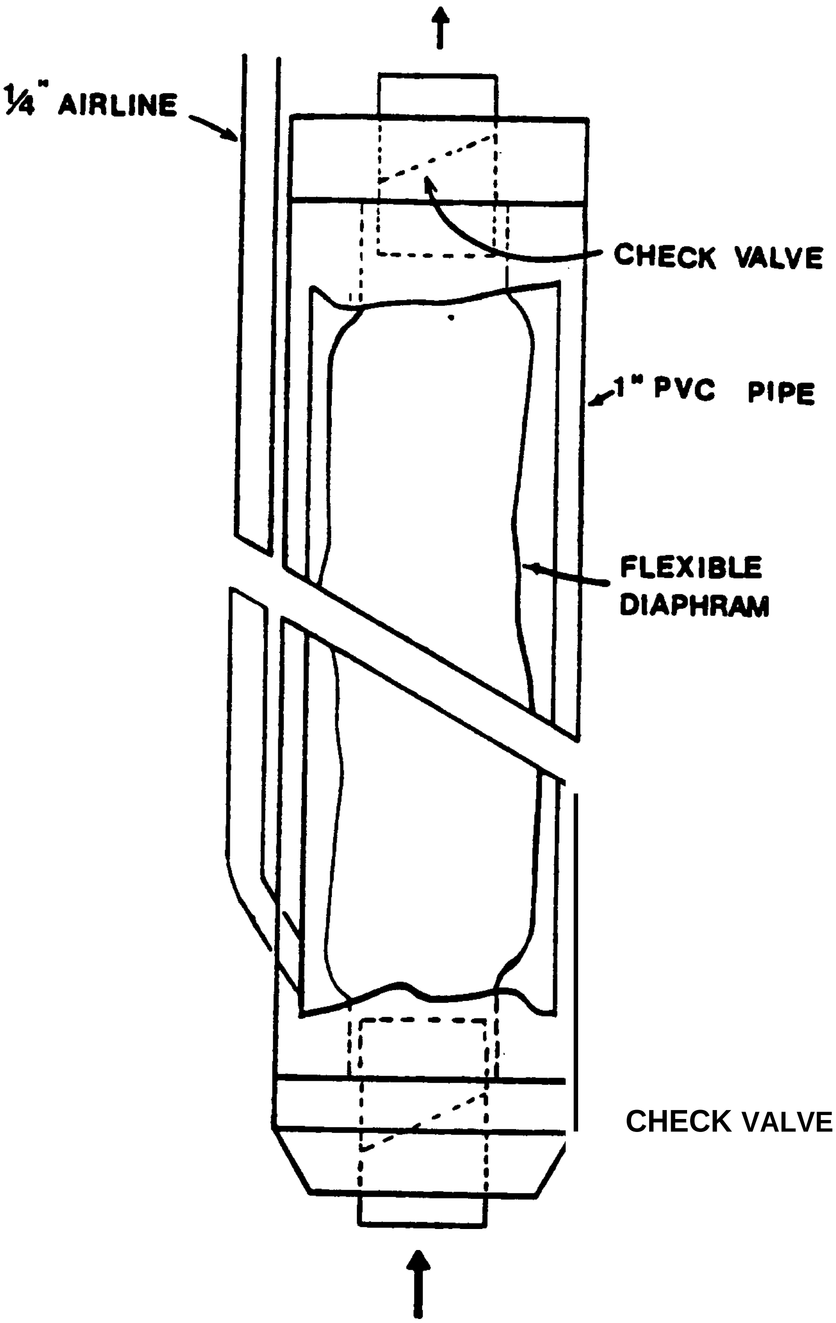
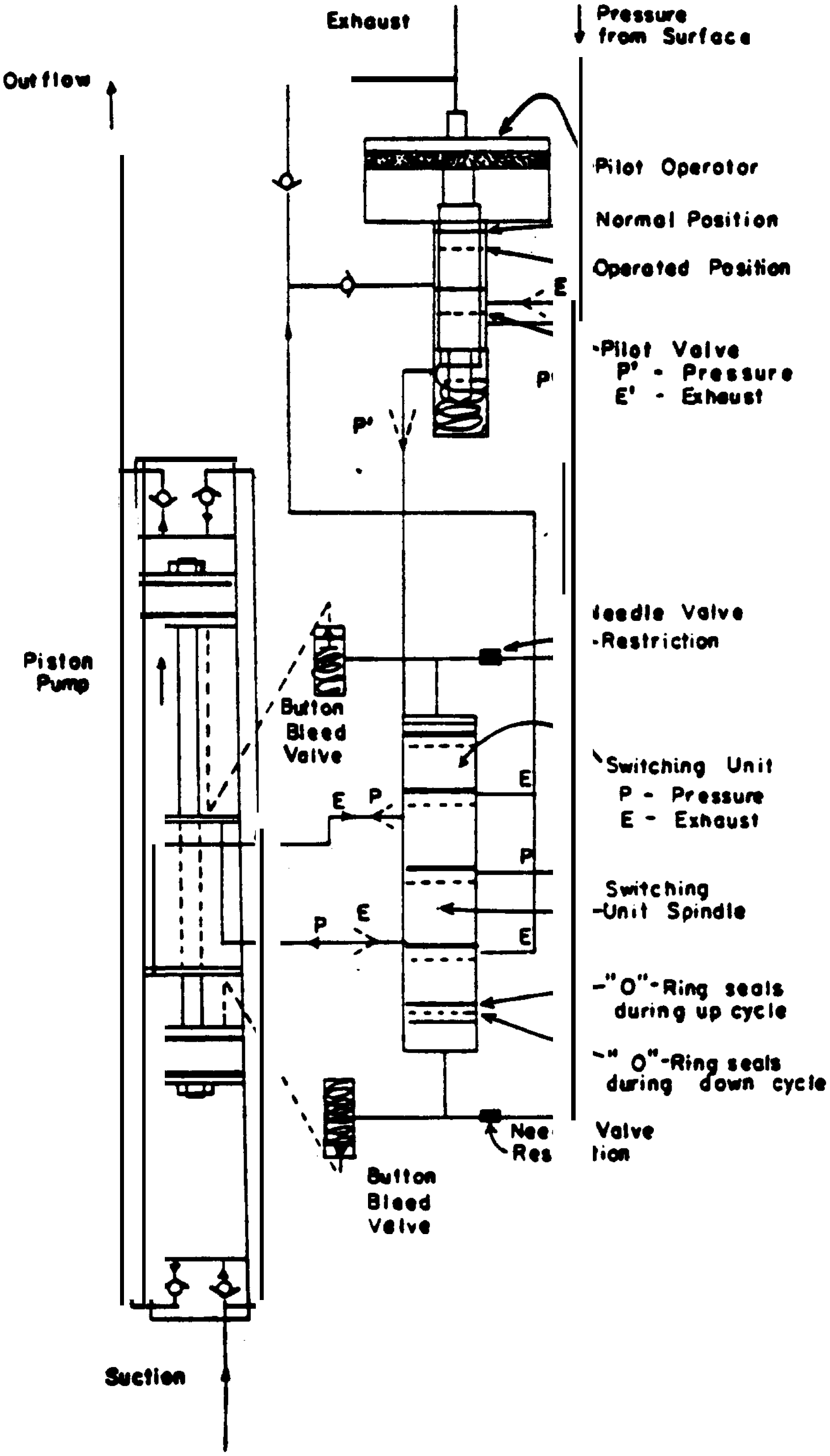


Exhibit 8.5-8
GAS-DRIVEN PISTON PUMP



- It operates continuously and reliably overextended periods of time.
- It uses compressed gas economically.
- It can be operated at pumping heads in excess of 500 meters.

Disadvantages of the pump areas fallows

. Particulate material may damage or Inactivate the pump unless the suction line is filtered.

. Low pumping rates are experienced.

8.5.6.4.8 Special Sampling Considerations for Organic Samples

sampling for organic parameters is not a standardized procedure at this time. Some of the equipment and methods In use are in the research stage. However, the concepts are fundamental, and any particular item or method can be modified to suit actual field needs. Furthermore, expensive and sophisticated procedures may not be necessary for sampling or monitoring all areas. The points that must be kept in mind include the potential for sample contamination and the extremely fine detail, subject to expert rebuttal, that may be necessary to support a legal action.

Grab samples of groundwater for nonvolatlie analysis may be collected by using the system shown in Exhibit 8.5-9. This system Is used where the water table is within suction lift; the sampled water contacts only sterile glass and Teflon. More sophisticated versions of the sampling configuration are available commercially. The sampled water Is then carefully transferred to appropriate glass sample containers for shipment to the laboratory.

For sampling at depths beyond suction lift, a noncontaminating submersible pump should be used to pump the groundwater to the surface through scrupulously clean Teflon tubing directly into appropriate sample containers.

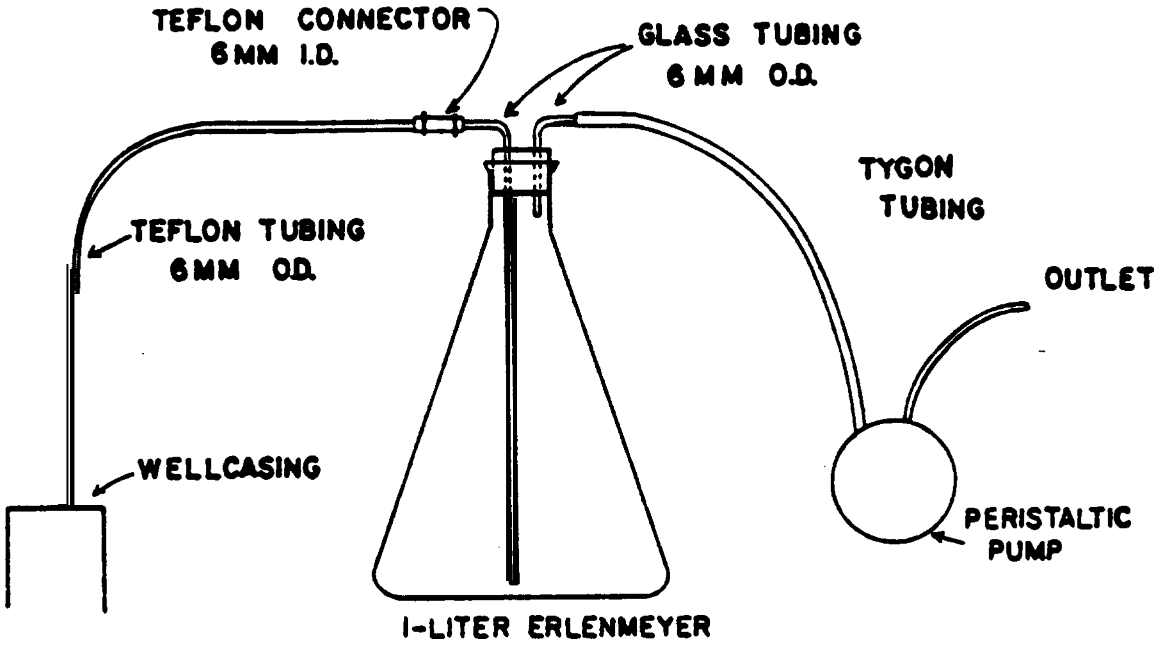
The most commonly employed sample containers are 40-ml glass vials for analyses requiring small sample volumes, such as total organic carbon, and 1 gallon jugs for analyses requiring relatively large volumes, such as extractable organics. Both types of containers are equipped with Teflon-lined screw caps. Like all glassware used in the sampling and analytical procedures, sample containers are thoroughly cleaned before use by washing with detergent, rinsing extensively with tap water, rinsing in high-purity deionized water, and heating to 105°C for 2 hours. The bottles are most easily obtained from the EPA CLP Sample Bottle Repository. The reader should refer to Section 6 of this compendium.

Grab samples of groundwater to be analyzed for highly volatiie organics by the Bellar-Lichtenberg volatile organic analysis (VOA) method are usually obtained by using a Teflon bailer, as noted in Exhibit 8.54. Bailers are used for VOA samples because of the possibility of stripping highly volatile constituents from the sample under the reduced or elevated pressure occurring in the systems that use pumps.

Continuous procedures, using selected absorbents to concentrate and recover organic constituents from rellatively large volumes of groundwater, may be employed to sample organic pollutants when the analytical sensitivity and sample uniformity attainable by grab sampling are inadequate. These procedures are applicable for most organic pollutants except those of very high volatility.

Exhibit 8.5-9

SYSTEM FOR GRAB SAMPLING



A special sampling system is shown in Exhibit 8.5-10. In this illustration, water is pumped directly from the well through Teflon tubing (6 mm outside diameter (OD)) to two glass columns of adsorbent in series. A peristaltic pump is located on the outlet side of the columns for sampling with suction lift. A noncontaminating submersible pump may be used at greater depths and may be superior for practically all sampling uses.

All components of the system that contact the water sample before emergence from the second column are, with the exception of the adsorbent, glass or Teflon. Exhibit 8.5-11 shows a typical sampling system installed In specially constructed housing to form self-contained sampling units that are easily transported and set up in the field.

Columns prepared from macroreticular resin,activated carbon, and polyamide particles have been employed in sampling systems. Of these materials, macroreticular resin (XAD-2, Rohm and Haas Company, Phiiadelphia, Pennsylvania) has been the most convenient and generally useful and is the current adsorbent of choice.

Sampling is conducted by continuously pumping groundwater through the sampling system at flow rates usually ranging from 10 to 30 ml per min. The volumes sampled are dependent on the desired sensitivity of analysis. Sampling 50 liters of water is sufficient to provide a sensitivity of at least 1 *ug* per liter (1 part per billion (ppb)) for almost all compounds of interest using gas chromatographic techniques. Volumes sampled are determined by using calibrated waste receivers to measure the water leaving the sampling systems.

8.5.6.4.9 Volatile Organics in the Unsaturated Zone

Water should be sampled In the unsaturated zone to detect and follow pollutants migrating toward the water table. Highly volatiie compounds, which include the low-molecular- weight chlorinated hydrocarbons such as trichlorethylene, are difficult to detect. These compounds are released in significant quantities into the environment, exhibit carcinogenicity, and are implicated in numerous cases of groundwater pollution.

Soil-water samples may be collected using the device depicted in Exhibit 8.5-12, which consists of a sampler, a purging apparatus, and a trap connected to sources of nitrogen gas and a vacuum. The soil-solution sampler consists of a 7/8-inch OD (2.2-cm) porous ceramic cup, a length of 3/4-inch OD Teflon or PVC pipe, and a Teflon stopper fitted with 3-mm OD Teflon exhaust and collection tubes. The length of the pipe is dictated by the depth of sampling desired, which is limited to a maximum of about 20 feet. The device is basically a suction lysimeter with the attendant imitations. The purging apparatus and trap are parts of the Tekrnar LSC-1 liquid-sample concentrator to which have been added Teflon valves and "Tape-Tite” connectors. The purging apparatus is borosilicate glass, while the trap consists of Tenax-GC porous polymer (60/80 mesh), packed in a 2-mm x 28-cm stainless steel tube plugged with silane-treated glass wool. The purge gas is ultrahigh purity, oxygen-free nitrogen. The vacuum is provided by a peristaltic pump.

Before the sample is collected, the purging apparatus is cleaned with acetone and distilled water and then baked at 105°C to I08°C for at least an hour. In the field, the device is rinsed thoroughly with distilled or organic-free water between samples, and special care is taken to force the rinse water through the glass frit.

The soil-solution sampler is driven to the bottom of a pre-augered 19-mm (0.75-inch) diameter hole. This procedure is done very carefully to ensure intimate contact between the ceramic cup and the soil.

Before collecting a sample, the exhaust tube is opened to the atmosphere, and the collection tube is disconnected and pumped to remove any solution that may have leaked into the tube through the porous

Exhibit 8.5-11
SELF-CONTAINED SAMPLING UNIT FOR ORGANICS

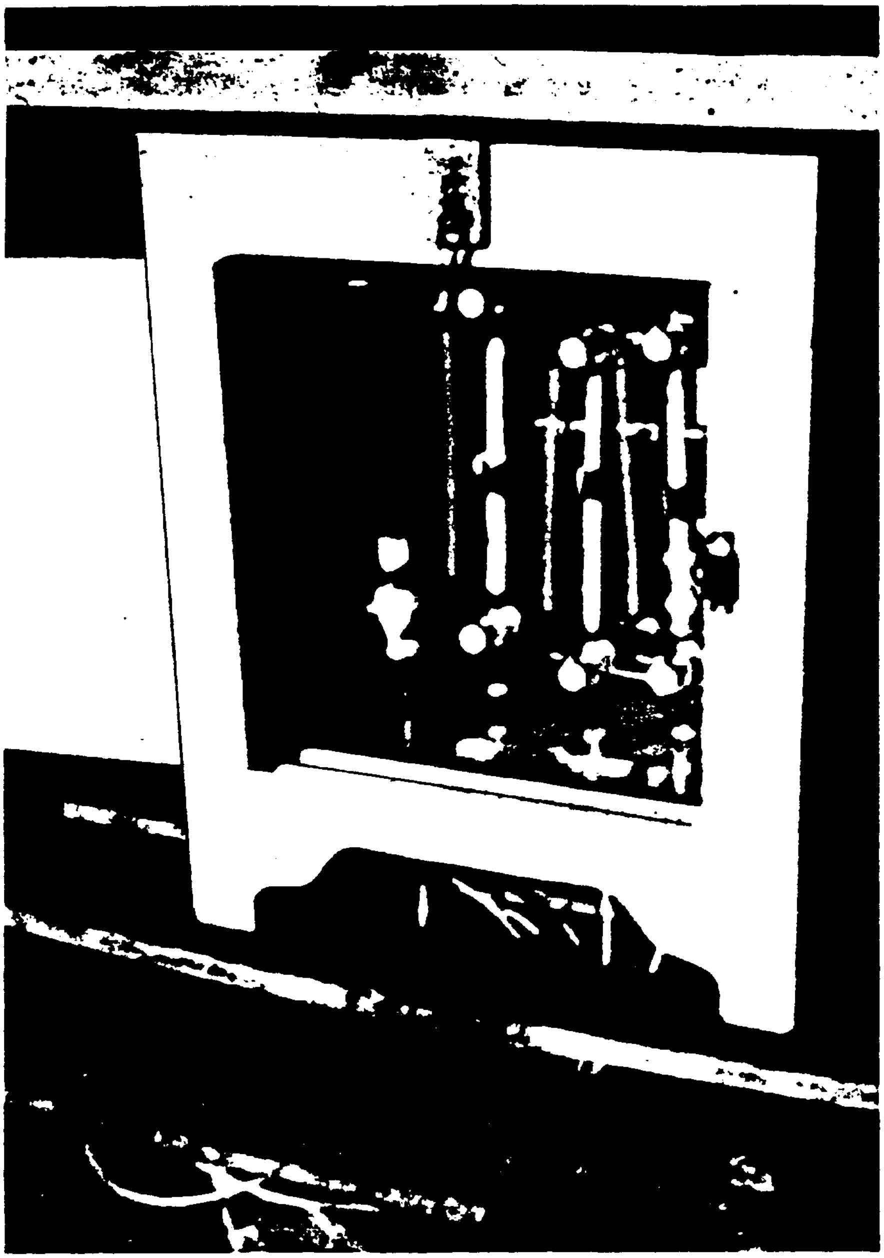
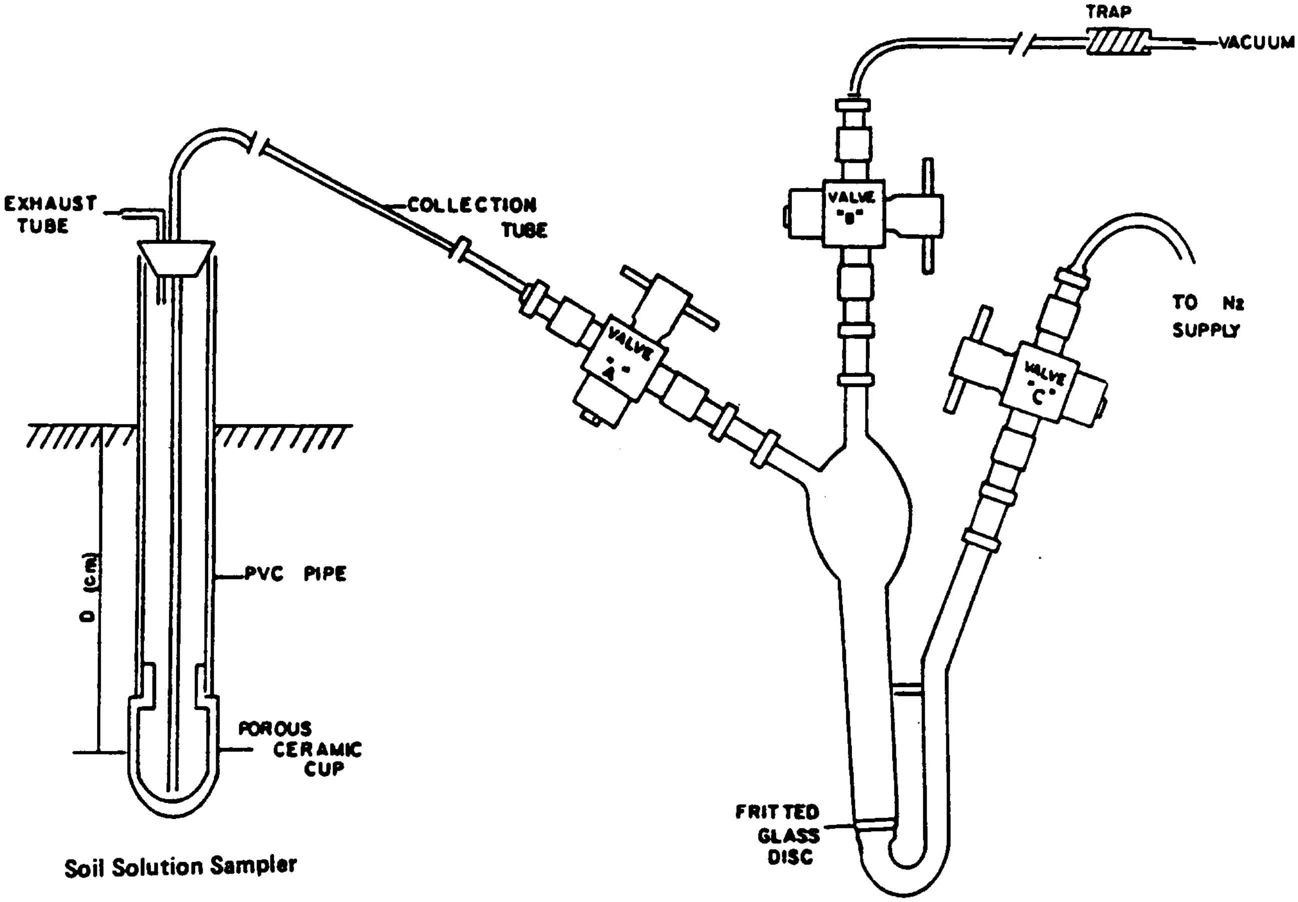


Exhibit 8.5-12
SOIL-WATER SAMPLING DEVICE FOR VOLATILE ORGANICS



Soil Solution Sampler

Purging Apparatus

cup. Then the collection tube is reconnected to the purging appartus, the exhaust tube Is dosed with a pinch damp, and 5 to 10 ml of solution is collected by closing valve C and opening valves A and B (see Exhibit 8.5-12). After sample collection, the exhaust tube Is opened to remove from the sampler and collect on the trap any of the compounds that may have voltilized In the sampler. Following this procedure, valve A Is dosed and valve C is opened. Nitrogen gas Is then bubbled through the solution at a rate of 40 ml per minute for 10 minutes to purge volatile organics from the solution. Traps are capped and returned to the laboratory for analysis within 6 hours of collection or for storage at 20% for later analysis. Chemical concentrations are determined according to procedures based on the Bellar-Uchtenberg method.

8.5.6.5 WtMor-Level Measurement Devices

Water-level indicatorsq are portable Instruments used to determine the water level In boreholes, wells, and other open underground structures. Generally, outside power sources are not required to operate these devices. However, many require that batteries be replaced or recharged periodically. Measurements may be made with a number of different devices and procedures. Measurements are taken to a scribed point placed by a surveyor on the Inner well casing. The reader should refer to Section 14 of this compendium.

8.5.6.5.1 Steel Tape

The chalked steel tape with a weight attached to the lower end Is one of the most accurate procedures for measuring water levels. The weight keeps the tape taut and helps lower it into the well (see Exhibit 8.5-13). The tape can be chalked with carpenter's chalk, ordinary blackboard chalk, or other chalk. The line where the color changes on the tape indicates the length of tape that was immersed In water. Subtracting this length from the reading at the measuring point gives the depth to water. Cascading water In a well may mask the mark of the true water level. However, this situation usually occurs only In a well that is being pumped. Another method of measuring may then be required. In small-diameter wells, the volume of the weight may cause the water level to rise In the pipe, causing the measurement to be somewhat inaccurate. Another problem associated with the steel tape measurement is that chalk or Impurities in the chalk may contaminate a monitoring well. If the Integrity of a groundwater sample is critical, another method of measuring the water level may have to be used.

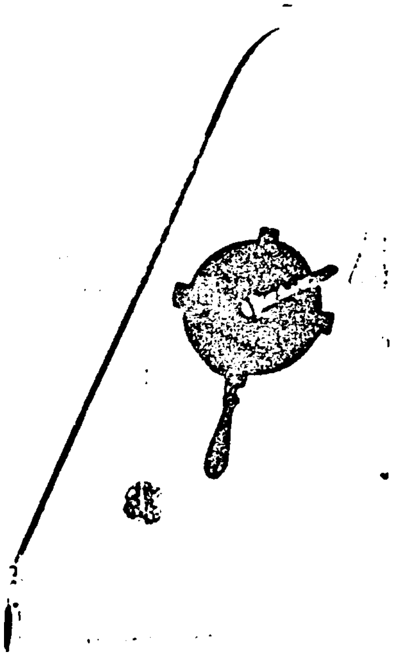
8.5.6.5.2 Electric Sounders

Electric sounders may also be used to measure the depth to water in wells (Exhibit 8.5-13). There are a number of commercial models available, none of which is entirely reliable. Many sounders use brass or other metal Indicators damped around a conductor wire at 5-foot Intervals to Indicate the depth to water when the meter indicates contact. The spacing of these indicators should be checked periodically with a surveyor's tape to assure accurate and reliable readings.

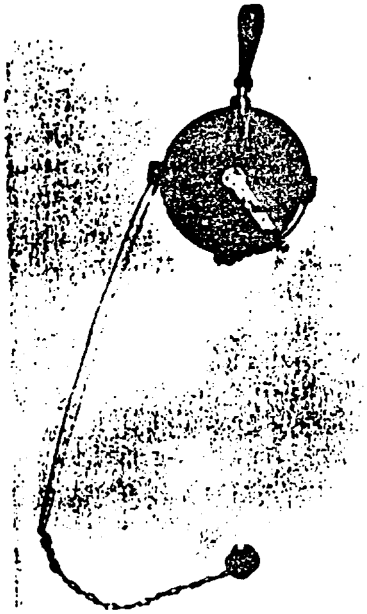
Some electrlc sounders use a single-wire line and probe, and rely on grounding to the casing to complete the circuit; others use a two-wire line and double contacts on the eleactrode. Most sounders are powered with flashlight batteries, and the closing of the circuit by Immersion in water is registered on a milliammeter. Experience has shown that two-wlre circuits with a battery are by far the most satistactory ELectrlc sounders.

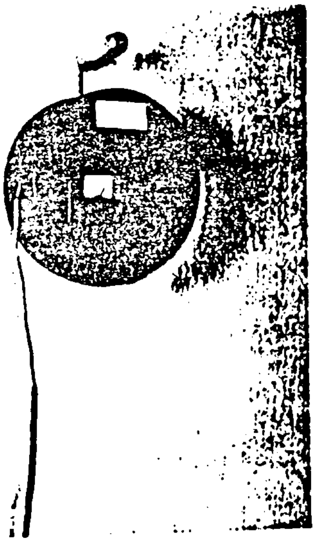
Electric sounders are generally more suitable than other devices for measuring the depth to water in wells that are being pumped because they generally do not require removal from the well for each reading. However, when there Is oil on the water, water cascading into the well, or a turbulent water surface In the wall, measuring with an electric sounder may be difflcult. 0il not only Insulates the contacts of the probe but it will also give an erroneous reading if there is a considerable thickness of oil.

Exhibit 8.5-13
WATER-LEVEL MEASUREMENT DEVICES

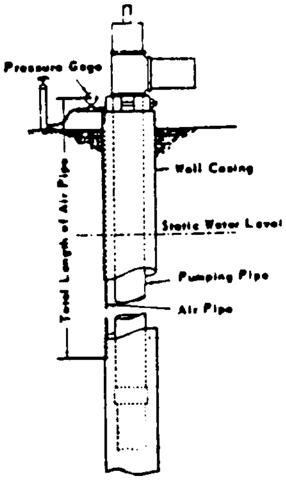


Chalked Steel Tape





Electric Sounder



Air Line

In some instances, it may be necessary to insert a small pipe in the well between the column pipe and the casing from the ground surface to about 2 feet above the top of the pump bowls. This pipe should be plugged at the bottom with a cork or similar seal that is blown out after the pipe is set. Measurements with the electric sounder can then be made in the smaller pipe where the disturbances are eliminated or dampened, the true water level is measured, and the insulating oil is absent. When oil is present, it is necessary to determine the thickness and density of the oil layer before calculating the true water level.

Exhibit 8.5-14 illustrates a convenient arrangement for direct measurement of drawdown during pumping tests. A marker on the sounder wire is referred to a value on the tape, and the same marker is used as a reference to determine drawdown through changes on the tape when contact with the water is made. A new marker is used each time the water level drops by an increment of 5 feet.

8.5.6.5.3 Poppers

A simple and reliable method for measuring the depth to water in observation holes between 1-1/2 and 6 inches in diameter is the use of a steel tape with a popper (see Exhibit 8.5-13). The popper is a metal cylinder that is 1 to 1-1/2 inches in diameter and 2 to 3 inches long with a concave undersurface; the popper is fastened to the end of a steel tape. When the popper is raised a few inches and dropped to hit the water surface, it makes a distinct "pop." Adjusting the length of tape determines the point at which the popper just hits the surface. Poppers are generally not satisfactory for measuring pumping wells because of the operating noise and lack of clearance, and they are not effective if the water surface is opposite the well screen.

8.5.6.5.4 Floats

Float devices are similar to poppers for measuring depth to water. The popper is replaced with a small float, and the depth to water is determined by the slack created by the tape when the float hits the surface of the water.

8.5.6.5.5 Air Lines

Permanent pump installations should always be equipped with an access hole for probe insertion or for an air line and gauge, or preferably both, to measure drawdown during pumping. An air line is accurate only to about 0.5 foot unless it is calibrated against a tape for various drawdowns, but it is sufficiently accurate for checking well performance.

Artesian wells with piezometric heads above the surface of the ground are conveniently measured by capping the well with a cap that has been drilled, tapped, and fitted with a plug that is removed for the insertion of a Bordon gauge or mercury manometer stem. The static level is determined from the gauge or manometer reading after the pressure has stabilized.

For continuous records, a recording pressure gauge may be used.

8.5.6.5.6 Pneumatic Piezometers

Pneumatic piezometers are used to measure pore pressures or pore pressure changes within boreholes or embankments (see Exhibit 8.5-15). Pneumatic piezometers are usually connected to the surface with flexible tubing. To operate a pneumatic piezometer, a portable readout unit is usually required (see Exhibit 8.5-16). The readout unit contains an internal pressure tank and data gauge. The pneumatic piezometer measures hydrostatic pressure in a manner similar to that of a simple air line.

Exhibit 8.5-14
DIRECT DRAWDOWN MEASUREMENT BOARD

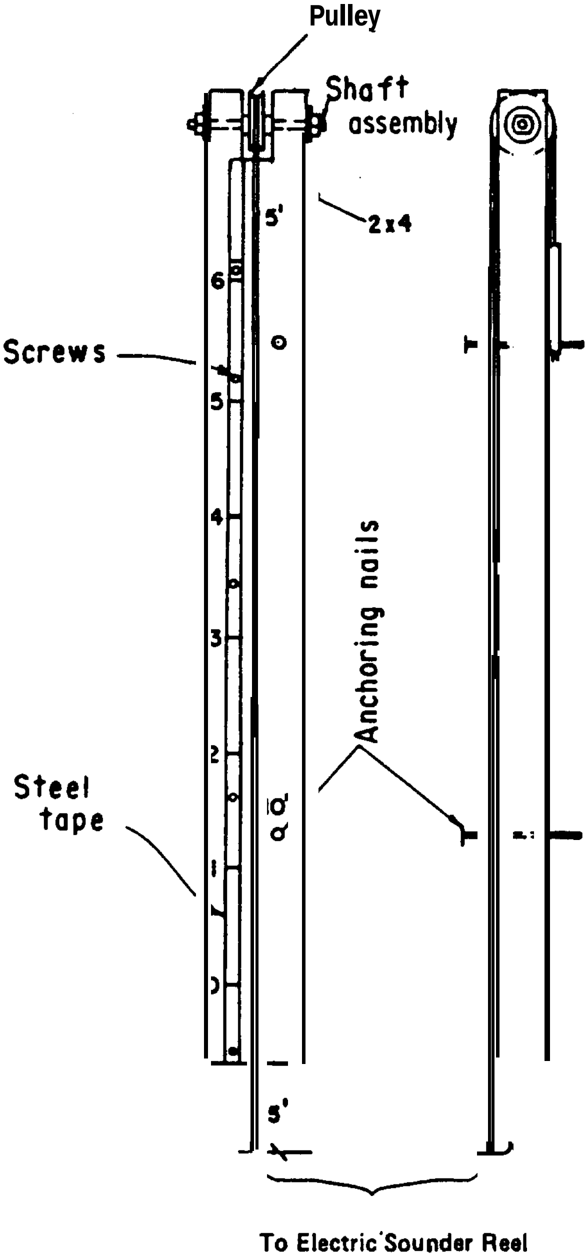


Exhibit 8.5-15
PNEUMATIC PIEZOMETER

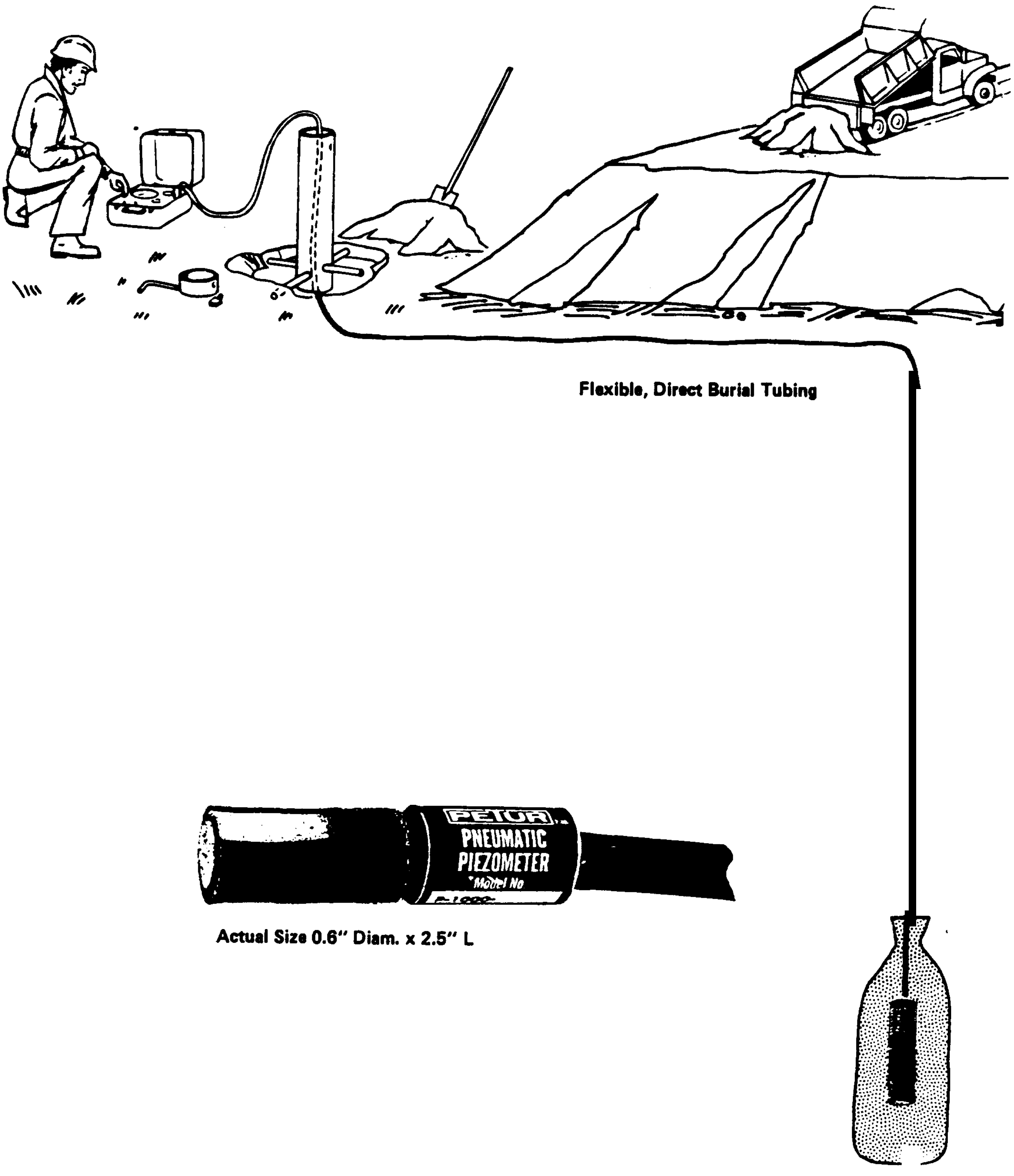


Exhibit 8.5-16
PORTABLE PNEUMATIC PRESSURE READOUT UNIT

The two primary advantages of using a pneumatic piezometer instead of a standpipe piezometer are that a pneumatic piezometer eliminates filter tip plugging and time lag. These two interdependent problems, inherent in all stand pipes, result from the large volumetric change and the time required for groundwater to permeate through the soil and fill the pipe to the piezometric head. In low-permeability soils, the time lag can become so long that it is impossible to obtain meaningful pore pressure data with a standpipe. Instrument time lag is completely eliminated when pneumatic piezometers are used. Since the time lag problem is eliminated, pneumatic piezometers are very useful for monitoring fast water level changes that occur during pump tests or other hydraulic conductivity tests. Since this procedure may be model-specific, the manufacturer's recommendations for the equipment to be used should be called out in the QAPjP.

8.5.6.5.7 Continuous Water Level Recorders

There are a large number of different models of continuous water level recorders. Typically, these recorders use floats, electric sounders, pneumatics, or other devices previously described. A float-balance continuous recorder is shown in Exhibit 8.5-17.

8.5.6.5.8 Sonic Water Level Measurement

Under proper conditions, depth to water in a well can be measured by a sonic device. This device uses a compressed air charge or fires a blank shell to generate a sonic wave down the well. The round-trip wave travel time is measured, and the depth to water is calculated. Care must be taken in reading the wave charts because discontinuities in the casing or in other well construction components may generate anomalous wave forms and may cause inaccurate determinations of water level depth.

8.5.6.6 Field Parameter Measurements

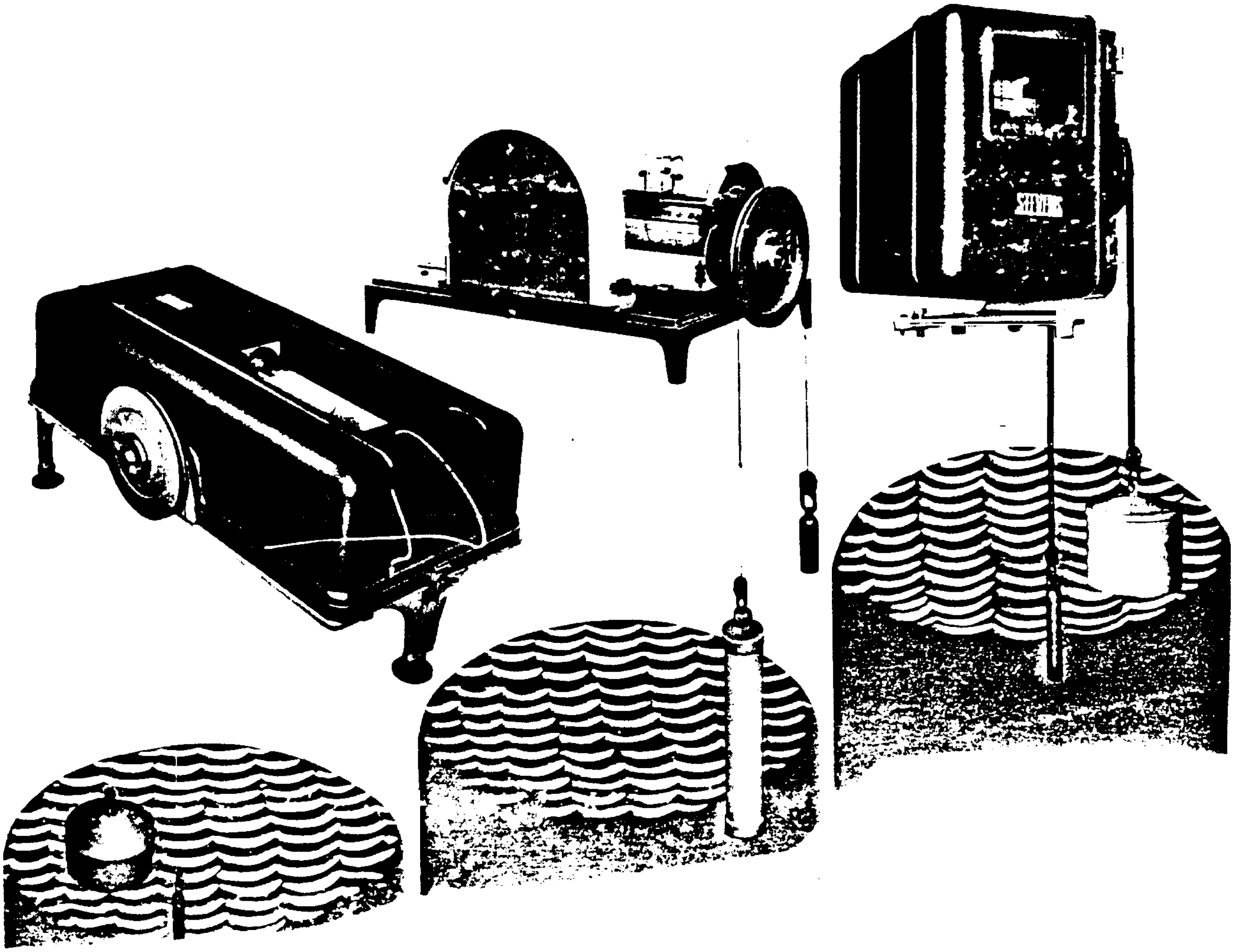
8.5.6.6.1 Measurement and Interpretation of pH

The pH of natural water is ordinarily determined by measuring the potential between a glass electrode and a reference electrode immersed in the solution. The potential must be measured with a sensitive electrometer or similar device that does not permit a significant flow of current. The design of pH meters has been greatly improved in recent years, and equipment now available measures pH to the nearest 0.01 pH unit with excellent stability and consistency either In the field or laboratory. Because the pH is a logarithm, measurements to two decimal places may still be Imprecise as compared to the usual measurements of concentrations of the other solute species.

The equilibria in a groundwater system are altered when the water Is taken into a well and pumped to the surface. A pH measurement taken at the moment of sampling may represent the original equilibrium conditions in the aquifer satisfactorily; however, if the water is put into a sample bottle and the pH is not determined until the sample is taken out for analysis (days, weeks, or months later), the measured pH may have no relation to the original conditions. Besides gaining or losing carbon dioxide, the solution may be influenced by reactions such as oxidation of ferrous iron, and the laboratory pH can be a full unit different from the value at the time of sampling. A laboratory determination of pH can be considered as applicable only to the solution in the sample bottle at the time the determination is made. Accurate measurement of pH in the field should be standard practice for all groundwater samples.

Typical procedures for calibrating the instrument and for obtaining the pH vary with manufacturer and model. Equipment should be recalibrated at each sample location and when ambient temperature changes significantly. Equipment manuals provide guidance for calibration.

Exhibit 8.5-17
CONTINUOUS WATER-LEVEL INDICATORS



8.5.6.6.2 specific Electrical Conductance

Electrical conductance, or conductivity, is the ability of a substance to conduct an electric current. The American Society for Testing and Materials (ASTM) has defined electrical conductivity of water as "the reciprocal of the resistance in ohms measured between the opposite faces of a centimeter cube of aqueous solution at a specified temperature." This definition further specifies that units for reporting conductivity shall be "micromhos per centimeter at temperature °C." Geophysical measurements of Resistivity, however, are commonly expressed in ohmmeters, referring to a Cube 1 meter on a side, so it should be emphasized that conductance of water refer to a centimeter cube. The standard temperature for laboratory measurements is 25°C, but some values taken at other temperatures exist: thus it is important to specify the temperature.

Because conductance is the reciprocal of resistance, the units in which specific conductance is reported are reciprocal ohms, or mhos. Natural waters have specific inductances much less than 1 mho; to avoid inconvenient decimals, data are reported in micromhos. That is, the observed value in mhos is multiplied by 10^6.

The specific conductance of a groundwater sample is dependent upon the total dissolved solids (TDS) content of the sample. Typically, the ratio of TDS (mg per 1) to specific conductance (mmhos per cm) is between 0.6 and 0.8. Because the TDS concentration and specific conductance of a sample maybe pH-dependent, measurements of specific conductance should occur in the field along with the measurement of pH. Accuracy in both measurements is important. Before the start of sampling for chemical analysis, the measurements for temperature, specific conductance, and pH should be stable over two or three well volumes. Equipment manuals should be referenced for proper calibration and operation of all field analytical equipment.

8.5.6.6.3 Oxidation-Reduction Potential (Eh) Measurement

The ability of a natural environment to bring about an oxidation or reduction process is measured by a quantity called its redox potential and is designated as Eh. Eh is a measure of the ability of an environment to supply electrons to an oxidizing agent or to take up electrons from a reducing agent. The redox potential system is a measure of the cumulative redox potential of a number of individual oxidation-reduction reactions.

The measurement of redox potential is not simple or unambiguous. Some reactions that determine redox potentials are slow, so instantaneous readings with the platinum electrode do not give true equilibrium potential differences. This slowness means that most redox potential measurements in nature give only qualitative or semi-quantitative information. When accurate determinations of redox potential are necessary, it is desirable to measure the concentrations of redox couples, such as SO^{-2}_4/H_2S, CO_2/CH_4, Fe^{+3}/Fe^{+2}, NO_3^-/N_2, and so forth.

Qualitative measure of Eh is conducted using a noble metal (usually platinum) and a reference electrode system or a combination electrode using a specific-ion meter that will measure in millivolt units. Reference solutions with known Eh are used to obtain the potential and to check the accuracy of the electrode system.

If Eh is to be measured, it should be measured in the field using the following procedures:

- Prepare and calibrate equipment according to manufacturer's specifications.
- Bring the reference ZoBeil solution to sample temperature and record temperature.

- Measure potential, in millivolts, of the ZoBell solution at sample temperature ($Eh_{ZoBell(obs)}$) and check against theoretical value at measured temperature (should be ±10 millivolts) ($Eh_{ZoBell+Ref}$).

- Place electrode in Eh cell and allow readings to stabilize (20 minutes plus).

- Turn off water flow to prevent streaming potential and immediately take reading.

- Record data (Eh_{obs}) and calculate Eh relative to standard hydrogen electrode.

Calculate system Eh as follows:

$$Eh_{sys} = Eh_{obs} + Eh_{ZoBell+Ref} - E_{ZoBell(obs)}$$

Report Eh to the nearest ±10 millivolts. It should be noted that oil and grease in the sampled solution may coat the noble-metal electrode and provide erroneous readings.

8.5.6.7 Flitration

The need and desirability of filtering samples is dictated by the objectives of the study and sampling as specified in the investigation sampling plan. If the objective is to assess migration mechanisms in conjunction with migration pathways, then it is necessary to know the concentration of dissolved versus total constituents. This comparison permits an assessment of mobility in a true dissolved state as opposed to a particulate or colloidal state. The assessment of the former requires the analysis of filtered samples; the latter requires analysis of both filtered (for dissolved) and unfiltered (for total) samples. The difference permits a determination of suspended contribution.

Filtering is necessary to analyse samples for inorganic constituents, many of which are acidified before or during analysis. This acidification may release ions held on particles and change the constituent chemistry of the solution.

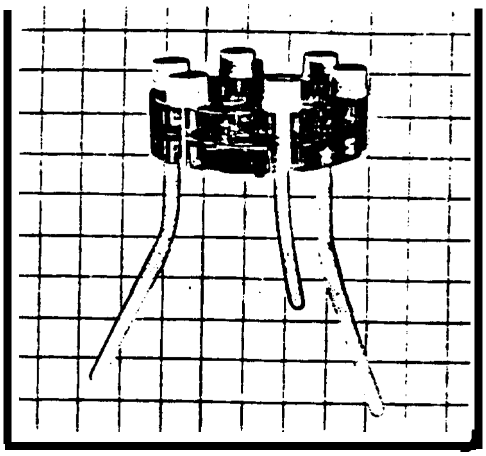
The removal of suspended solids maybe accomplished through several techniques. Filtration through a 0.45-micron micropore membrane filter is the most common field method used to remove suspended solids. This filter permits a reasonable and practical distinction between true solute material and material that may be considered particulate or not in true solution. For extremely turbid samples, large particulate can be removed with a coarse filter before the 0.45-micron filter is used. Large-capacity 0.45 micron filters exist but are expensive when a large number of turbid samples must be collected.

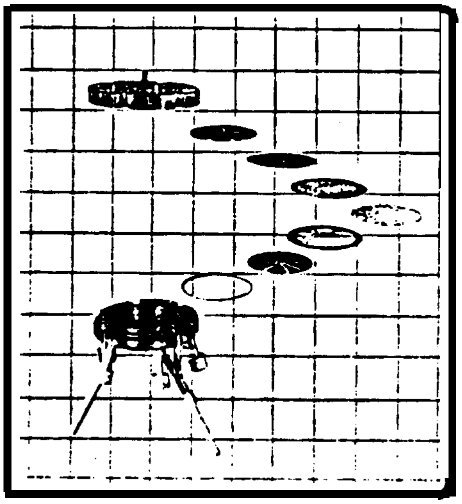
Pressure and suction filtering devices are commonly used in the field, Atypical filter holder is shown in Exhibit 8.5-18. Small peristaltic pumps are commonly used with this type of filtering device (see Exhibit 8.5-18), Inert gas pressure-filter devices are preferred to suction or compressed air pumps. Hand pump filtering apparatuses have been used.

8.5.6.8 Materials for Well Construction

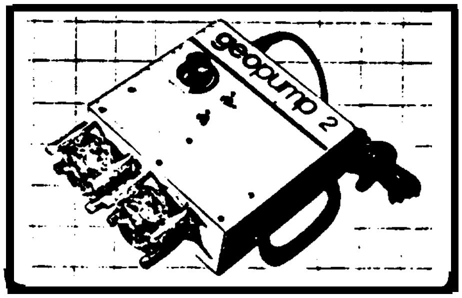
The selection of materials for well construction and sample collection, handling, and storage is a critical consideration in planning the monitoring program. The materials should retain their structural integrity for the duration of the monitoring program under subsurface conditions. The material should neither adsorb nor leach chemical constituents. The material combinations must also be compatible with each other and with the goals of the sampling effort. (The reader should refer to Exhibit 8.5-19 for a typical monitoring well installation.)

Exhibit 8.8-18
FILTERS AND PERISTALTIC PUMP



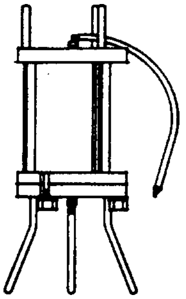


BACKFLUSH FILTER HOLDER
Parts Break Down

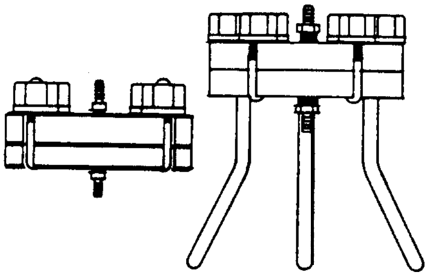


PERISTALTIC PUMPS
Electric or Hand Powered

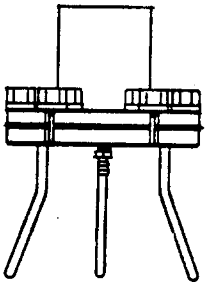
GEOTECH MEMBRANE
FILTER HOLDERS



PRESSURE



BACKFLUSHING



VACUUM

8.5.6.8.1 Overview of Subsurface Conditions

Most common piping materials (steel, polyvinyl chloride, and iron) meet the structural requirements needed for well casings to withstand normal subsurface pressures for depths of up to approximately 30 meters (90 feet). In deeper monitoring situations, the use of corrosion-resistant metallic casing for large-diameter (greater than 10 centimeters or 4 inches) may be required to provide necessary structural integrity. The practices of local water well construction and regional EPA requirements should serve as a guide.

Metallic corrosion problems may be encountered under either oxidizing or reducing conditions and are aggravated by high dissolved-solids content. Other materials (thermoplastics) may deteriorate under the influence of dissolved chemical substances or direct contact with wastes. Whether the well construction retains its integrity or not, there are also potential problems because of microbial attachment and growth and the sorptive capacity of the exposed materials for the chemical species of interest. Representative sampling depends on the choice of materials that can retain their integrity over the entire length of a well casing, from the aerobic, unsaturated surface zone to the unusual conditions in the saturated zone

8.5.6.8.2 Chemical Properties of Water and Their Effects on Various Materials

A groundwater monitoring network is designed and constructed with the casing and materials that are compatible with the subsurface environment. The materials should be compatible with probable mixtures of groundwater and chemical substances from the contaminant source. Compatibility must be judged from a structural and chemical standpoint. Structural considerations are treated in detail in the 1980 National Water Well Association publication, *Manual on the Selection and Installation of Thermoplastic Water Well Casing.* The main criterion for chemical compatibility should be that the long-term interaction of the casing or sampling materials with the groundwater will not cause an analytical bias in the ‘interpretation of the chemical analysis of the water samples.

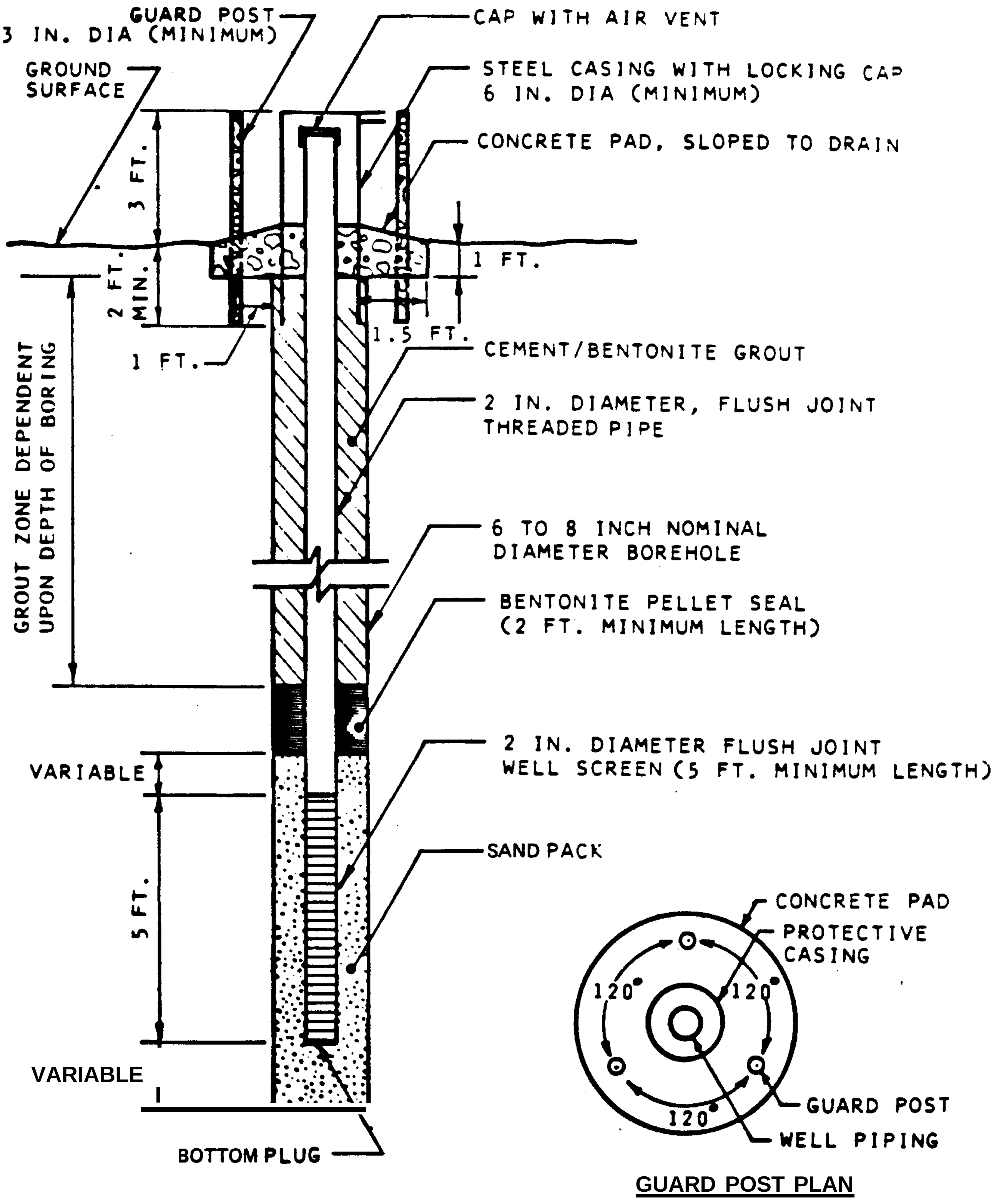
The study of the effects of water or aqueous solutions on materials (and vice versa) presents many obstacles to the investigator. For leaching effects alone, there are at least six critical system variables that must be controlled or considered, including chemical composition of the solution, temperature, rate of flow, and composition of the material (its age, pretreatment, and the surface area exposed). For purposes of material selection for ground water monitoring, static or flowing tests with solutions approximating the expected range of solution composition should be sufficient.

Well casing materials are rigid and nonporous. They present a very low surface area to water in the wellbore relative to that of the adjacent soil or aquifer particles. An extensive body of literature deals with sorptive interactions of dissolved chemical species in natural waters with solid surfaces. Most of these studies describe the adsorption of trace metals or organic compounds (adsorbates) on mineral particles (absorbents). Surface area (or particle size) and the organic content of the solid phase are cited almost universally as important variables in the adsorption process. Mineral phases such as quartz, aluminum, hydrous metal oxides, and clays, as well as natural sediments, have been studied with surface areas ranging from 5 to more than 250 square meters per gram. These active surfaces have been observed to routinely absorb up to several hundred micro grams of adsorbate per square meter of surface area. The applicability of laboratory adsorption experiments to the condensed media of the subsurface is a matter of some controversy. However, a simple qualitative comparison of well casing versus subsurface solids should suffice to discount adsorptive interferences from materials selection considerations.

8.5.6.8.3 Teflon Well Casing

Teflon represents a nearly ideal well construction material. inertness to chemical attack, poor sorptive properties, and low leach potential are clear advantages of rigid Teflon for well screens and casing.

Exhibit 8.5-19
TYPICAL MONITORING WELL INSTALLATION



However, Teflon is expensive compared to other materials. When situations allow, using Teflon casing and screens in the saturated zone with another suitable material as the upper casing may be a viable, less expensive alternative. The structural properties of Teflon are sufficient for the most exacting environments, giving Teflon a clear advantage over glass. Teflon has not been reported to contribute to or remove or ganic or inorganic contaminants from aqueous solutions.

8.5.6.8.4 Stainless Steel Well Casing

Stainless steel has been the material of choice for casing and screens when subsurface conditions require a durable corrosion-resistant material or when organic adsorption problems might exist. In tests, type 316 stainless steel proved better for use as a well casing than type 304. The principal compositional difference between the two types is the inclusion of 2 to 3 percent molybdenum in type 316. The molybdenum content gives type 316 stainless steel improved resistance to sulfur-containing species and sulfuric acid solutions. Resistance to oxidizing acids Is somewhat poorer than other chromium-nickel steels. However, reducing conditions are more frequently encountered in well-casing applications. The type 316 stainless steels are less susceptible to the pitting or pin-hale corrosion caused by organic acids or halide solutions. They are the materials of choice in Industries, such as pharmaceuticals, in which excessive metal contamination of process streams must be avoided. Provided that surface coating residues from manufacture or storage are removed, stainless steel well casing, screen, and fittings can be expected to function nearly as well as Teffon in most monitoring applications. Chromium or nickel contamination may result after long exposure to very corrosive conditions. However, physical failure of the casing would probably accompany or precede such an occurrence. Proper well purging before sampling should be sufficient to minimize problems with these materials.

8.5.6.8.5 Polyvinyl Chloride Well Casing

Polyvinyl chloride (PVC-Type 1) thermoplastic well casing is composed of a rigid, unplasticized polymer formulation that has many desirable properties for monitoring well construction. It has very good chemical resistance except to low-molecular-weight ketones, aldehydes, and chlorinated solvents. PVC is a close second to Teflon and type 316 stainless steel in its resistance to acid solutions, and it may be expected to outperform any of the ferrous materials in acidic environments of high ionic strength. There may be potential problems when PVC is used in contact with aqueous organic mixtures or under conditions that might encourage leaching of substances from the polymer matrix. Manufacturers, however, do not recommend the use of threaded schedule 40 PVC well casing because of potential mechanical failures. Schedule 80 threaded PVC well casing is sufficiently durable for most well construction applications.

All well casings should, at a minimum, be cleaned with detergent and rinsed with clean water before well construction to remove processing lubricants and release agents. This procedure is particularly necessary for PVC well casing, which may be coated with natural or synthetic waxes, fatty acids, or fatty acid esters. In addition, more thorough cleaning maybe required; steam cleaning is often used.

Threaded joints are the preferred’ means of connecting sections of PVC well casing. In this way, problems associated with use of solvent primers and cements can be avoided. Threaded joints on PVC well casing (or pipe) can be provided in three ways: (l.) by solvent cementing a molded thread adapter to the end of the pipe (not recommended), (2) by having molded flush-threaded joints built into each pips section, and (3) by cutting tapered threads on the pipe with National-Pipe-Thread sized dies. The latter method is recommended only by the industry for schedule 80 PVC well casing or pipe.

Furthermore, manufactured casing and screen is preferable to off-the-shelf PVC pipe. The practice of sawing slots in the pipe (e.g., homemade screens) should be avoided since this procedure exposes fresh surfaces of the material, increasing the risk of releasing compounding ingredients or reaction products. In addition, it is very difficult to properly slot casing materials by sawing them.

8.5.6.8.6 Casing Made From Other Ferrous Materials

Ferrous metal wail casing and screen materials, with the exception of stainless steels, include carbon steel, low-carbon or copper (0.2 percent) steels, and various steels with a galvanized coating. The carbon steels were formulated to improve resistance to atmospheric corrosion. To achieve this increased resistance, it is necessary for the material to undergo alternate wetting and drying cycles. For noncoated steels buried in soils or in the saturated zone, the difference between the corrosion resistance of either variety is negligible. Both carbon- and copper-steel wail casings may be expected to corrode, and corrosion products may include oxides of Fe and Mn (and trace constituents), as well as various metal sulfides. Under oxidizing conditions, the principal products are solid hydrous oxides of these metals, with a large range of potential particle sizes. The solids may accumulate in the well screen, at the bottom of the well, or on the casing surface. The potential also exists for the production of stable colloidal oxide particles that can pass through conventional membrane filtration media. Reducing conditions will generally provide higher levels of truly dissolved metallic corrosion products in well storage waters. Galvanized steels are protected by a zinc coating applied by hot dipping or electroplating processes. The corrosion resistance of galvanized steel Is generally improved over conventional steels. However, the products of initial corrosion will include ken, manganese, zinc, and trace cadmium species, which may be among the analytes of interest in a monitoring program.

Corrosion products from conventional or galvanized steels represent a potential source of adsorptive interference. The accumulation of the solid products has the effect of increasing both the activity and the exposed surface area for adsorption, reaction, and resorption processes. Surface interactions can, thereby, cause significant changes in dissolved-metal or organic compound concentrations in water samples. Flushing the stored water from the well casing may not be sufficient to minimize this source of bias because the effects of the disturbance of surface coatings or accumulated products in the bottom of the well would be difficult, if not impossible, to predict. In comparison with glass, plastic, and coated-steel surfaces, galvanized metal presents a rather active surface for adsorption of orthophosphate. The age of the surface and the total area of exposure have been found to be important variables in the adsorption process. However, adsorption is not a linear function of the galvanized-metal surface area.

Field data for conventional and galvanized steels provide additional reasons for the use of caution when choosing these materials for well casings or screens. The water well Industry routinely chooses alternative nonconductive or corrosion-resistant materials in areas where normal groundwater conditions are known to attack the common steels. Regional or local practices in the selection of water well construction materials provide valuable preliminary guides for routine monitoring efforts.

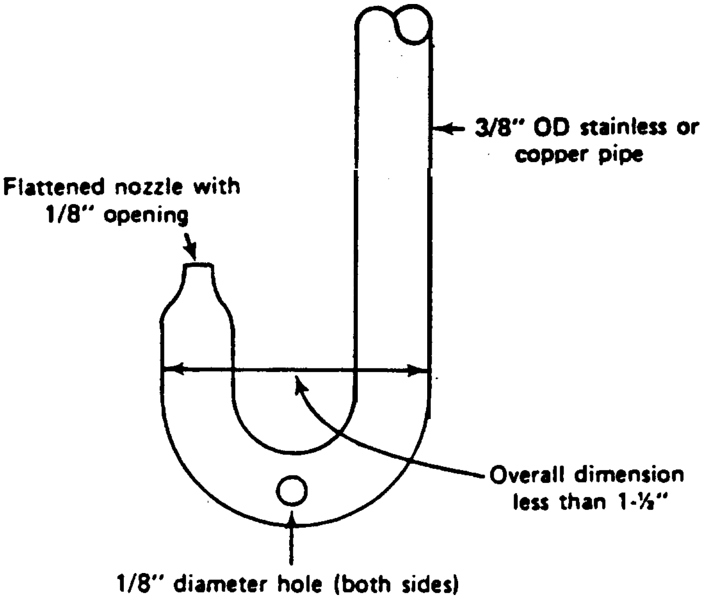
8.5.6.8.7 Pumps Used in Development

The large variety of centrifugal, peristaltic, impeller, and submersible pump designs precludes an in-depth discussion of their potential effects on the results of groundwater monitoring efforts. According to the situation, the compatibility of the materials found in high-capacity pumps with subsurface conditions must be carefully considered. The methodology of monitoring wail development (see Exhibit 8.5-20) is probably far more critical than the pumping mechanism or water-contacting materials. Use of a Teflon, air-driven, well-development device with filtered air or compressed breathing-grade air minimizes the potential effects on groundwater monitoring.

8.5.6.8.8 Grouts, Cements, Muds, and Drilling Fluids

Various drilling aids, cements, and sealant formulations are used to achieve two main goals: (1) to maintain an open borehole in rotary and cable tool operations in unconsolidated formations, and (2) to effect a seal between the surface or overlying formations and the casing or screened intervals so that runoff or other sources of water do not enter the wellbore.

Exhibit 8.5-20
AIR-DRIVEN, WELL-DEVELOPMENT DEVICE



Water-based drilling fluids are usually used In freshwater applications where the total-dissolved-solids content of groundwater is below 10,000 mg per liter. The fluids are introduced for several purposes including coding and lubricating the bit, suspending and removing cuttings, stabilizing the borehole by building up a cake on the sides of the hole, and minimizing formation damage that results from water loss or penetration of solids.

There are three main types of freshwater muds (1) bentonite, attapulgite, or clay-based muds with pH adjusted to between 9 and 9.5 with caustic; (2) polymer-extended day (organic) muds; and (3) inhibited day muds that use lignosulfonates or lignin to counteract the effects of contaminants that would otherwise destabilize the slurry and prevent effective cutting removal. The first two types of mud are used most frequently in water-wail drilling applications. Both of these mud formulations and a spectrum of combined compositions have been used in the construction of monitoring wells. The main distinction between bentonite and organic muds is the addition of natural or synthetic organic polymers to adjust consistency, viscosity, or surface tension.

For monitoring applications where conditions permit, augering, air-rotary, or clear-water rotary drilling techniques have a distinct advantage over the use of drilling muds. it is preferable to introduce the least possible amount of foreign materials into the borehole. Compressor lubricants for air-rotary rigs may rule out this method for trace organic monitoring work, although filters are available to minimize such problems. in geologic situations in which water-based drilling fluids are a necessity, the predominantly inorganic clay muds are preferable over those containing organic materials, because the Introduction of these organics can lead to substrates microbial activity that can seriously affect the integrity of water samples. The decomposition of the organic components of drilling muds may be expected to be a function of their chemical structure, the microbial populations, the presence of nutrients, and various physical and chemical factors controlling the distribution of organic substances in the subsurface.

inorganic day muds do have disadvantages. if these materials are not completely removed during the development process, attenuation of organic and metal contaminants in the groundwater may be caused by the highly sorptive bentonite muds. in zones where concentrations of contaminants are in the low parts per billion (ppb) range, this phenomenon maybe very important.

Seals, grouts, and cements are the primary safeguards against the migration of water from the surface and from overlying or adjacent formations into monitoring wells. Faulty seals or grouts can seriously bias the analytical results on water samples from the formation of interest, particularly if water quality conditions vary or surface soils are badly contaminated. The impact of leaking seals may go far beyond the realm of analytical interferences or nonrepresentative samples. A leaky wellbore may act as a conduit to permit rapid contaminant migration that otherwise would not have occurred. This aspect of a groundwater monitoring program should not be left to an unsupervised drilling crew, and last-minute substitutions for preferred materials should not be made. Surface seals must also be completed with concern for the security at the wellhead by including casing sheaths and locking caps. Most seals between the formation of interest and regions above or below are made by adding day materials or cement.

Bentonite day can increase in volume by 10 to 15 times after wetting with deionized water. Variations in the composition of the contacting solution can severely reduce the swelling of clay seals. Swelling volumes of 25 to 50 per cent of the maximum values are not uncommon. The organic content of the solution in contact with the clay can have a dramatic effect on the integrity of the seal, Organic compounds can cause significant disruption of normal shrinking, swelling, or dehydrating of the day lattice during alternate wetting and drying cycles. Alcohols, ketones, and other polar organic solvents have a significant potential for these changes. On the microscopic level, these phenomena can materially increase the permeability of the clay seal. This active area of research has wide application in the fields of well construction, landfill liners, and slurry or grout cutoff walls. Macroscopic changes in the permeability of clay or cement seals can occur because of solution channeling by aggressive solvents, compaction or subsidence, and freezing and thawing processes at the surface. Chemical-resistant and expanding cement formulations effectively minimize these problems.

8.5.6.8.9 Evaluation of Sample Collection Materials

The choices of sample collection devices, procedures, and all materials that ultimately contact water samples are probably the most critical considerations in a groundwater monitoring program. The monitoring program planner must evaluate the collection mechanisms and all materials to determine whether they would introduce interference or bias into the final analytical result. For example, a collection mechanism that creates turbulent transfer of the sample and the opportunity for gas exchange (e.g., air-lift pumping mechanisms) is clearly inappropriate in sampling for volatile organic compounds and pH- or redox-sensitive chemical species.

The following are desirable attributes for sample collection materials:

- Durability
- Ability to be decontaminated and cleaned effectively to prevent cross-contamination between sampling points (i.e., low permeation of material by contaminants)

Verified low potential for introducing contamination, bias, or interferences into the analytical results

Each of these attributes plays an important role in the overall performance of monitoring efforts and bears directly on the successful retrieval of representative water samples. The combinations of components in pumps (or other samplers) and the properties of polymeric and elastomeric materials for tubing or transfer lines make the selection of the sample collection apparatus difficult.

Apart from the actual sampling mechanisms, the materials used for a sampler are of prime importance. Fortunately, most devices are constructed in different models for specific situations. For example, bailers are fabricated in Teflon, stainless / Teflon, stainless / PVC 1, or PVC 1. These materials satisfy the major specifications. Problems arise with nonrigid components of samplers. A single pair of O-rings may limit the application of a device.

Teflon incorporates most of the characteristics of an ideal sampling material. It is, however, a difficult material to machine, and threaded components are easily damaged. For chemical resistance and durability, several materials other than stainless steel may be expected to perform satisfactorily in low-organic environments. These materials include polypropylene, linear polyethylene, plasticized PVC, Viton, and conventional polyethylene. Viton is a preferred material for elastomeric parts since it may be expected to give improved chemical resistance over silicone and neoprene.

Tubing and transfer lines are available in a variety of polymeric or elastomeric materials. Certain applications (e.g., peristaltic or bladder pumps) demand a high- resiliency material, and it may be necessary to sacrifice chemical resistance to achieve the desired structural performance. The bulk of common tubing materials, except for Teflon, contains a wide range of additives. Plasticizers, lubricants, antistatic agents, tackifiers, and other ingredients may be present in flexible synthetic materials. In general, true polymers (e.g., polyolefins like polyethylene and polypropylene) contain much lower amounts of such ingredients. Formulations change frequently as manufacturers strive to keep production costs low, so a particular material may show significant variation from lot to lot. Plasticizers are frequently present at levels between 15 and 50 percent of the total weight of flexible products. As a result of this fact and because of the widespread use of plastic, major plasticizers, such as phthalate esters, have been consistently identified in environmental samples.

Teflon is the tubing material of choice in monitoring for low-level organic compounds in complex, chemically aggressive environments. Polyethylene and polypropylene are clearly superior plastic materials when Teflon is not cost-effective. Silicone rubber tubing for moving components is a special case in which alternate choices of material may not be feasible. The material is available in several grades that have widely varying compositions and additives. Metallic contamination from certain laboratory grades of silicone rubber tubing can be quite serious at the ppb level, Iron and zinc concentrations two to file times those of control samples are not uncommon even after short contact times. Medical grade silicone rubber tubing is, however, relatively free of unreacted organic initiators (peroxides) or zinc. Silicone rubber tubing is generally a poor choice of sampler for detailed organic analytical schemes. Other elastomeric materials, such as natural rubber, latex neoprene, or chloroprene, are not recommended for transfer lines or surfaces that contact groundwater samples.

Little information is available on the performance of flexible materials in groundwater applications. From the available observations, Teflon, polypropylene, and linear polyethylene may be expected to outperform plasticized PVC, since they have superior chemical resistance over a range of environments and are less likely to cause contamination or bias problems. Microbial transformation of additives in plastics introduces another dimension to the problem posed by materials with high concentrations of additives. There are a number of reports on the microbial colonization of flexible PVC and the degradation of plasticizers from the polymer matrix.

8.5.6.9 Groundwater Sampling Considerations

The importance of proper sampling of wells cannot be overemphasized. Even though the well being sampled may be correctly located and constructed, special precautions must be taken to ensure that the sample taken from that wail is representative of the groundwater at that location and that the sample is neither altered nor contaminated by the sampling and handling procedures.

To select proper sampling procedures, it is essential that sampling objectives be firmly established before field activities begin. These objectives will dictate the parameters to be measured, the reliability of the water quality data, and the analytical methodology, which determines the sampling procedures necessary to meet these objectives. In addition, the physical limitations of the well, depth to water, length and location of the well screen, availability of power, and accessibility of the well site all have a bearing on the practical application of various sampling procedures.

Sample withdrawal mechanisms should be completely inert; economical to manufacture; easily cleaned, sterilized, and reused; able to be operated at remote sites in the absence of external power sources; and capable of delivering continuous but variable flow rates for well flushing and sample collection. Sampling equipment is described in Subsection 8.1. The physical characteristics of the well largely determine the sampling mechanism to be used for inorganic and nonvolatile organic analysis. Volatile organics are usually sampled with Teflon or stainless steel bailers, and extra care should be used to handle samples.

Before use, all sampling devices should be carefully cleaned. A dilute hydrochloric acid rinse followed by successive rinses with deionized water, acetone, and distilled organic-free water is routinely used. In badly contaminated situations, a hot-water detergent wash before the above rinsing procedure may be necessary. Hexane rinses before the final distilled inorganic water rinse will aid in the removal of sparingly soluble organic materials before sampling for low-level organic pollutants.

The static water level should be measured and recorded at the time of sampling. Water levels can be obtained using one of the devices discussed previously. In alder wells not previously sampled, the bottom of the well should be established by sounding.

To obtain a representative sample of the groundwater, a Volume of stagnant water in the wellbore must first be purged. The recommended length of time required to pump or bail a well before sampling depends on the well and aquifer characteristics, the type of sampling equipment being used, and the parameters being sampled. A common procedure is to pump or bail the well until at least three to five bore-volumes have been removed. A more reliabfe method is to pump or bail until the measurements of pH, temperature, and specific conductance have stabilized over three well volume.

in the case of monitoring wells that will not yield water at a rate adequate to be effectively flushed, different procedures must be followed. One suggested procedure includes removing water to the top of the screened interval to prevent the exposure of the gravel pack or formation to atmospheric conditions. The sample is then taken at a rate that would not cause rapid drawdown. The wails may also be pumped dry and allowed to recover. The samples should be collected as soon as a volume of water sufficient for the intended analytical scheme reenters the wail. Exposure of water entering the well for periods longer than 2 to 3 hours may render samples unsuitable and unrepresentative of water contained within the aquifer system. in these cases, it may be desirable to collect mail volumes of water over a period of time, each time pumping the well dry and allowing it to recover. Whenever full recovery exceeds 3 hours, samples should be collected in order of their volatility as soon as sufficient volume is availablefor a sample for each analytical parameter or compatible set of parameters. Parameters that are not pH-sensitive or subject to loss through volatilization should be collected last. Few reliabie data exist on when to choose one sampling method over another in "tight" formations.

To collect a sample for other than volatile organics analysis, the cap should be removed carefully from the previously decontaminated sample bottle. The person doing the sampling should not lay the cap down or touch the inside of the cap. At no time should the inside of the bottle come in contact with anything other than the sample. The bottle should be filled, in a manner to minimize aeration, to within 2.5 cm (1 inch) of the top. The cap should be replaced carefully, and the bottle should be placed in a cooler (4°C to 10°C) unless the sample is going to be processed immediately in the field. Sampling equipment should be decontaminated between samples. For volatile organic analysis, the bottles should be filled in a manner to minimize aeration of the samples so that no headspace exists in the bottle. No air bubbles should be trapped in the bottle.

8.5.7 Information Sources

Barcelona, M.J., J.P. Gibb, and R.A. Miller. *A Guide to the Selection of Materials for Monitoring Well Construction and Ground-Water Sampling.* ISWS Contract Report 327. Champaign, Illinois: Illinois State Water Survey. 1983. 78 pp.

Gillham, R.W., M.L. Robin, J.F. Banker, and J.A. Cherry. *Groundwater Monitoring and Sample Bias.* API. 1983.

Scalf, M.R., J.F. McNoll, W.N. Dunlop, R.L. Cosby, and J. Fryberger. *Manual of Groundwater Sampling Procedures.* NWWA/EPA Series. Ada, Oklahoma: U.S. Environmental Protection Agency.

U. S. Environmental Protection Agency. *Practical Guide to Groundwater Sampling.* EPA 800/2-85-I04. Ada, Oklahoma: MIS, ERL

U.S. Environmental Protection Agency. RCRA *Groundwater Monitoring Technical Enforement Guidance Document.* EPA 530/SW-88-055 NTIS. September 1988.

SECTION 9

EARTH SCIENCES LABORATORY PROCEDURES

9.1 SCOPE AND PURPOSE

Section 9 identifies the laboratory procedures used to determine the physical and chemical properties of soil materials. Procedures are given for volumetric, strength, and transport relationship tests and for testing chemical properties.

The purpose of Section 9 is to provide general guidance for the planning and implementation of laboratory testing of earth science materials for hazardous waste projects. This section provides both a broad overview of the types of routine laboratory techniques available for use and a brief, general discussion of their purpose and applicability. It also lists references to specific testing techniques and standards, where available. The reader should refer to Exhibit 9-1 for an Index of test parameters as related to test methods.

Test types and techniques presented herein cover routine methods that may be applicable at the site investigation, feasibility study, predesign, design, or construction phases of hazardous waste projects.

This section Is not Intended to be all-inclusive, because the application of laboratory testing to a particular project, demands careful and knowledgeable planning and experimental design. Detailed specification is required for all work, for quality assurance (QA) and/or sampling plans, and for each laboratory testing request, both for the U.S. EPA Contract Laboratory Program (CLP) and for private laboratories. The specifications should be included in work plan, QA plan, and/or sample plan.

9.2 DEFINITIONS

Definitions may be found in ASTM D853-82, *Standard Definitions of Terms and Symbols Relating to Soil and Rock Mechanics* and in some of the individual test method terminology subsections.

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. This person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor’s employee (see Subsection 1.1).

9.3 APPLICABILITY

Soil samples collected durongm field investigations may be analyzed using the procedures identified in this section. ‘The analyses will determine the physical and chemical soil properties”listed here. The results of these procedures can be used in soils engineering determination, contaminant migration evaluation, and design considerations. Health and safety aspects of using these test procedures on contaminated materials must be addressed in a site-specific, or laboratory health and safety plan.

Exhibit 9-1

TEST PARAMETER VERSUS TEST METHOD

9.6.3 Physical Properties		
9.6.3.1 Soil		
9.6.3.1.1	**Index Property Tests**	
	Visual Classification	ASTM D 2488-84
	Moisture Content	ASTM D 2216-80
	Atterberg Limit	ASTM D 4318-84
	Grain Size	ASTM D 422-63
	Specific Gravity	ASTM D854-83
	Soil Classification	ASTM D 2487-85
	Sand Equivalent	ASTM D 2419-74
	Centrifuge Moisture	ASTM D 425-79
	Capillary--Moisture Relationship	ASTM D 2325-68 ASTM D 3152-72
9.6.3.1.2	**Density Tests**	
	Unconfined Compression	ASTM D 1587-83 ASTM D 3550-84
	Moisture-Density Relationship	ASTM D 698-78 ASTM D 1557-78
	Relative Density	ASTM D 4253-83 ASTM D 4254-83
9.6.3.1.3	**Strength Tests**	
	Unconfined Compression	ASTM D 2166-85
	Direct Shear	ASTM D 3080-72
	Triaxial Compression	ASTM D 2850-82
	Vane Shear	ASTM D 2573-72
	Moisture Penetration Resistance	ASTM D 1558-84
	Bearing Ratio	ASTM D 1883-73
9.6.3.1.4	**Deformation Tests**	
	One-Dimension Consolidation	ASTM D 2435-80
	Swell Test	ASTM D 4546--85
9.6.3 .1..5	**Permeability Tests**	
	Undisturbed Samples (cohesive)	
	Recompacted Samples	ASTM D 2434-68
9.6.3.2 Rock		
9.6.3.2.1	**Index Property Tests**	
	Apparent Specific Gravity	ASTM C 127-83
	Soundness	ASTM C 88-83
9.6.3.2.2	**Strength Tests**	
	Uniaxial Compressive Strength	ASTM C 170-85
	Direct Tensile Strength	ASTM D 2936-84
	Splitting Tensile Strength	ASTM D 3967-81
	Flexural Strength	ASTM C 99-85

Exhibit 9-1
(continued)

9.6.3.3 Materials

9.6.3.3.1 Concrete

Compressive Strength	ASTM C 39-83
Extrained Air	ASTM C 231-82
	ASTM C 173-78
flexural Strength	ASTM C 78-64
	ASTM C 293-79
Specific Gravity	ASTM C 642-82
Splitting Tensile Strength	ASTM C 496-85

9.6.3.3.2 Soil Cement

Miscellaneous	ASTM D 2901-82
	ASTM D 606-74
	ASTM D 1632-63
	ASTM D 1633-84
	ASTM D 1634-63
	ASTM D 1635-63
	ASTM D 558-82
	ASTM D 559-82
	ASTM D 560-82

9.6.3.3.3 Portland Cement

Blended Hydraulic Cement	ASTM C 150-85a

9.6.3.3.4 Asphalt Cement

9.6.3.3.5 Asphalt Stabilized Soils

ASTM D 4223-83

9.6.3.3.6 Geotextiles

Fabric Weight	ASTM D 3773-84
	ASTM D 3774-84
	ASTM D 3775-85
	ASTM D 3776-85
Fabric Thickness	ASTM D 3777-64
Grab Strength and Elongation	ASTM D 1682-64
Abrasion Resistance	
Puncture Resistance	ASTM D 751-79
Mullen Burst Strength	ASTM D 3786-80a
Trapezoid Tearing Strength	ASTM D 1117-80
Equivalent Opening Size (EOS)	U.S. Army COE
Planar Flow	
Normal Permeability	
Coefficient of Friction (soil to fabric)	
Coefficient of Friction (fabric to fabric) ,	
Alkali or Acid Stability	
Thermal Shrinkage	
Ultraviolet Stability	

Exhibit 9-1
(continued)

9.6.3.3,7 Geomembranes	
Thickness	ASTM D 1593-81 ASTM D 412-83
Specific Gravity	ASTM D 792-66
Tensile Strength	ASTM D 882-83 ASTM D 412-83 ASTM D 638-84
Elongation	ASTM D 882-83 ASTM D 412-83 ASTM D 638-84
Tear Resistance	ASTM D 1004-66 ASTM D 624-86 ASTM D 751-79
Dimensional Stability	ASTM D 1204-84
Bonded Seam Strength	ASTM D 3083-79 ASTM D 751-79
Peel Adhesive	ASTM D 413-82
9.6.4 Chemical Properties of Soil and Rock	
9.6.4.1 Waste Evacuation Procedures	
1.1 ignitability	EPA SW-846 1010, 1020
1.2 Corrosivity	EPA SW-846 1110
1.3 Reactivity	EPA SW-846
1.4 Extraction Procedure	EPA SW-846 1310
1.5 Mobility	EPA SW-846 1410
9.6.4.2 Pollutant Analysis	
2.1 Organics	EPA SW-846 8010-8310 3510-3550
2.2 Metals	EPA SW-846 7040-7951 3010-3060
2.3 Total and Amenable Cyanide	EPA SW-846 9010
2.4 Total Organic Halides (TOX)	
2.5 pH	Ref.
2.6 Lime Requirement	Ref.
9.6.4.3 Other Tests	
3.1 Cation Exchange Capacity	Ref.
3.2 Extractable Cations	Ref.
3.3 Exchangeable Hydrogen	Ref.
3.4 Total Soluble Salts-- Electrical Conductivity	Ref.
3.5 Carbon Total Organic and inorganic	U.S. Army COE
3.6 Sulfides	EPA SW-846 9030
3.7 Total Nitrogen	Ref.
3.8 Extractable Phosphorus	Ref.
3.9 Total Phosphorus	U.S. Army COE
3.10 Mineralogy	Ref.

Exhibit 9-1
(continued)

9.6.5 Compatibility Testing
9.6.5.1 Soil
- 1.1 Clay
- 1.2 Silt
- 1.3 Sand
- 1.4 Gravels/Aggregates

9.6.5.2 Rock

9.6.5.3 Materials
- 3.1 Concrete
- 3.2 Soil-Cement
- 3.3 Portland Cement
- 3.4 Asphalt Cement
- 3.5 Asphalt Stabilized Soils
- 3.6 Metal Products
- 3.7 Plastic Products
- 3.8 Wood Products
- 3.9 Geotextiles
- 3.10 Geomembranes
- 3.11 Synthetic Drainage Media

9.6.6 Laboratory/Analysis Records

9.6.6.1 Sample Log
- 6.1 Data Sheets
- 6.2 Recordkeeping

9.4 RESPONSIBILITIES

The SM or designee is responsible for ensuring that these procedures are followed. The SM may appoint the project Geotechnical engineer or soil scientist as the responsible person.

9.5 RECORDS

Records will be kept in a bound notebook with numbered pages (see also Sections 6 and 17). Information to be recorded includes the following:

- Project name and number; EPA work authorization number
- Date of sample collection
- Collector's name
- Sample location and depth
- Method of collection (see Section 8, Earth Sciences)
- Date of laboratory analysis
- Name of laboratory

Other laboratory records specific to certain test procedures are discussed in the following subsections.

9.6 PROCEDURES

9.6.1 Introduction

Most of the procedures described below are derived from the 1984 *American Society of Testing and Materials (ASTM) Book of Standards,* Section 4-Construction, Volume 04.08 *Soil and Rock Building Stones* (ASTM, 1916 Race Street, Philadelphia, Pennsylvania 19103. 734 pages). Revisions to some of these procedures are due soon. in addition, certain procedures listed below have been found to be not wholly satisfactory for work on highly contaminated materials. Users of this compendium should review the most recent ASTM procedures for changes. Applicable ASTM standards should be included in work, QA, and sample plans. The subsection below discusses the evacuation of the suitability of a laboratory to conduct the procedures, and it discusses the various tests. The standards are listed in the categories of sample handling; physical tests (volumetric, strength, and transport relationships); chemical tests (mineralogy, cation exchange capacity, and distribution coefficient); and laboratory records.

9.6.2 Laboratory Selection

9.6.2.1 Evaluation of Agencies (Laboratories)

The evaluation of agencies engaged in testing and inspecting materials used in engineering design and construction is important to quality assurance goals.

This subsection discusses criteria for the evaluation of a testing or inspection agency's organizational, human, and physical resource capabilities. These criteria require disclosure of those factors on which the objectivity of the agency can be judged.

The reader should refer to ASTM D 3740-60 *Standard Practice for the Evaluation of Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction* and ASTM E 329-77 (1963) *Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in Construction.*

9.6.2.2 Sample Integrity

Methods of sample handling In the laboratory may affect the physical and chemical state of samples and the reliability of the test results. Special attention should be given to how samples are transported, stored, and prepared for laboratory testing. Guidance is available in some ASTM standards for particular tests.

Provisions for handling samples generally include the following:

- Temperature and humidity controls in the laboratory environment and storage areas
- Provisions for opening and resealing sample containers
- Tools for trimming and preparing samples

Where sample quantity is limited, it may be possible to perform sequence testing so that the same sample can be used in multiple analyses." However, some sample types and some tests preclude reuse in subsequent analyses because of irreversible alteration of the sample.

9.6.2.3 Laboratory Safety

The safe handling of samples in the laboratory depends on several factors that include design of the laboratory facilities; laboratory policies and procedures for sample handling, analysis, and disposal; and training of laboratory personnel in the safe handling of samples, personal protection, and emergency procedures.

Earth sciences laboratories engaged in analyzing hazardous materials should have secure, ventilated storage and disposal areas with controlled access; readily available safety equipment (e.g., fire extinguishers, self-contained breathing apparatus, safety shower, eye wash station, first aid kit); ventilated hoods for the handling and testing of samples; an emergency ventilation system in case of accidental release of hazardous gases; routine inspection and maintenance of laboratory equipment (including safety equipment); fire-resistant walls, doors, and windows an emergency alarm system: and access to a telephone with emergency numbers displayed.

Laboratory policies should be established for using protective clothing and equipment; appropriate training and medical surveillance of employees; collecting and disposing of hazardous or toxic wastes; monitoring the laboratory atmosphere and equipment; investigating and reporting laboratory accidents; and working alone. Spill prevention plans and a list of emergency procedures should be placed in a prominent place, and employees should be familiar with the procedures.

9.6.3 Physical Properties

9.6.3.1 soil

9.6.3.1.1 Index Property Tests

Visual Classification

Purpose The visual classification of soils allows convenient and consistent comparison of soils using a standard descriptive method. The use of this classification method provides a basis for comparing soils from widespread geographic areas.

Synopsis: By visual observation, a soil is assigned to one of three primary groups: coarse-grained soils (gravels and sand); fine-grained soils (silts and clays); and organic soils (soils containing organic matter, such as decayed roots, leaves, grasses, and other fibrous vegetable matter). After the soil is assigned to one of the primary groups, other visual and, physical characteristics are observed, such as color, odor, moisture condition, and structural characteristics.

Methods: ASTM D 2488-84, Standard Practice for Description of Soils (Visual-Manual Procedure).

Limitations and Precautions: The ability to visually classify soils requires practice and experience. Laboratory test ASTM D 2487-85 should verify visual classifications.

Moisture Content

Purpose: The moisture content test determines the mass of water contained in a given mass of Soil. The results are usually presented as the mass of water divided by the mass of dry solids, expressed as a percentage. Moisture content (along with unit weight and specific gravity of solids) provides the basis for determining the phase relationships of a soil. A comparison of the field moisture content of a soil with its index properties (such as Atterberg Limits) may be useful in estimating soil consistency, compressibility, and strength.

Synopsis: A sample of the soil is weighed as received, dried for 24 hours at 105°C, and then weighed again. The difference in mass is attributable to water loss during drying. Results are presented as the water mass divided by the dry solids mass, expressed as a percentage.

Methods: ASTM D 2216-80, Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.

Limitations and Precautions: It is important to prevent moisture content changes during sampling, shipping, and handling. Precautions may include sealing the sample in wax, foil, plastic, or a combination thereof or shipping the entire sample in the Shelby tube used for sampling.

Organic soil that contains items such as wood, fibers, or decayed vegetation demands careful monitoring, since drying at high temperature may destroy some of the organic matter. Organic chemicals may be driven off and their mass mistaken as water.

Atterberg Limits

Purpose: The Atterberg Limits include liquid limit (LL), plastic limit (PL), and plasticity index (Pi), which are used for the fallowing:

- **To assist in classification of soils**
- **To indicate soil consistency (when compared with natural moisture content)**
- **To provide correlation to soil properties, including compressibility and strength**

Synopsis: LL is the moisture content at which a soil becomes liquid and flows to close standard-size groove when subjected to 25 impacts in the standard test device. PL is the moisture content at which soil becomes plastic, as demonstrated by the moisture content causing incipient crumbling to occur in the soil when it is roiled into 1/8-inch threads. PI is the difference between the LL moisture content and the PL moisture content; it represents the range between plastic and liquid states of the soil.

A soil sample is prepared by starting the test at either natural or air-dried moisture content.

Methods: ASTM D 4318-84, Test Method for Liquid Limit, Plastic Unit, and Plasticity Index of Soils.

Limitations and Precautions: Soils may exhibit different liquid and plastic limits if they are prepared from air-dried or natural moisture conditions. The liquid limit device must be calibrated before use. Operator error in applying insufficient or excessive pressure or improper roiling rates while performing the plastic limit procedure may affect results.

Grain Size

Purpose: Grain size distribution is used to assist in classifying soils and to provide correlation with soil properties that include permeability and capillarity. In addition, grain-size analyses are essential for adequate assessment and design of such specific features as granular drains, filters, well screens, and gravel pack materials.

Synopsis: Three general procedures used to determine the grain-size distribution of soil include sieve analysis, hydrometer analysis, and a combined analysis. A sieve analysis consists of shaking soil through a stack of progressively finer meshed screens, each with a known opening size, and determining the portion (by weight) of particles retained on each sieve. The hydrometer analysis is based on Stoke's Law for the velocity of a freely failing sphere; the method determines the setting rate of soil particles by measuring the density of the soil-water solution and calculating the particle size in suspension at particular time intervals. The combined procedure consists of both the sieve and hydrometer analyses to determine the grain size distribution throughout the full range of particle sizes.

Methods: ASTM D 42263, (reapproved 1972), *Method for Particle-SizeAnalysis of Soils.*

Limitations and Precautions: Because the hydrometer method is extremely sensitive to a number of variables, the accuracy of fine-grained soils distribution is more questionable than that of the coarser-grained soils. The hydrometer analysis may be more sensitive to interferences from hazardous materials than the sieve analysis.

Specific Gravity

Purpose: The specific gravity of soil particles is used in determining the phase relationships of air, water, and solids in soils. For example, specific gravity can be used to determine unit weights that are used in pressure, settlement, and stability problems.

Synopsis: The specific gravity of a soil is the ratio of the weight in air of a given volume of soil particles to the weight in air of an equal volume of distilled water at 4^0C. A pycnometer (volumetric bottle) is calibrated, and a known weight of a soil slurry is introduced into the pycnometer. The pycnometer is evacuated of dissolved air. It is then weighed, and the temperature of the slurry is recorded. The specific gravity of the soil particles is calculated using the dry weight of the original soil sample; the weight of the pycnometer, soil, and water and the weight of the pycnometer plus water.

Methods: ASTM D 564-64, Test Method for Specific Gravity of Soils.

Limitations and Precautions: It Is generally recommended that soils containing soluble salts should be slurried using kerosene. This, coupled with any hazardous waste within the soil being tested, may greatly alter the specific gravity as calculated. Also, kerosene and hazardous materials may be susceptible to fire or explosion. This test is susceptible to sources of error in the measurement of weights and temperature because the equation used involves the differences in weights, which are small compared to the weights themselves.

Soil Classification Systems

Purpose: Soil classification systems attempt to group soils having similar engineering behavior (based on index tests). A number of classification systems have been developed, each for a specific application. For example, the U.S. Army Corps of Engineers (COE) has a classification system based on the frost susceptibility of soils. The Bureau of Public Roads has a classification based on the applicability of soils to highway construction. The Federal Aviation Administration (FM) and the COE have developed a classification system for soils used in airfield construction. The Bureau of Reclamation and the COE have developed a classification system intended for use in all types of engineering problems that involve soils. The system most generally accepted for a wide range of engineering applications is the Unified Soil Classification System (USCS).

Synopsis: Soil classification systems generally use index test methods to permit rational grouping of soils. Some of the specific index test methods that are applicable to soil classification are discussed elsewhere in this section (see index Property lasts, Subsection 9.6.3.1.1).

Methods: ASTM D 2487-85, Test Method for Classification of Soils for Engineering Purposes. Additional methods are forthcoming.

Limitations and Precautions: Caution must be used in salving problems of flow, strength, compressibility, and stability strictly on the information provided by a soil classification system. Many empirical correlations between indexes and soil properties and behavior have large deviations.

Sand Equivalent

Purpose: A sand equivalent testis performed to allow an estimation of the amount of clay-like or plastic fines in a granular soil. The test takes little time to perform and, therefore, maybe used in either the field or the laboratory as a quick check on the relative amount of fines in a granular soil. The results of the test can be used for controlling types of materials placed in earthworks.

Synopsis: A known volume of granular soil is placed with a flocculating agent into a graduated cylinder and is shaken, which loosens clay-like or plastic fines. The material is then irrigated with more flocculating agent. The granular soil settles, and the clay-like particles are forced into suspension. The height of the granular soil and the flocculated clay-like particles are measured. The sand equivalent is the ratio of the height of sand to the height of clay-like material, times 100.

Methods: ASTM D 2419-74 (reapproved 1979), Test Method for Sand Equivalent Value of Soils and Fine Aggregate.

Limitations and Precautions: The test results should be Interpreted as an empirical value of the relative amount of fine material in the sample tested. Sample selection and variations in segregation as a result of handling may significantly alter test results. Hazardous materials within the sample in combination with the flocculating agent may create unusable results. This test Is not Intended to replace either ASTM D 422 or D1140.

Centrifuge Moisture

Purpose: A centrifuge moisture test is performed to estimate the air-void ratio, the water-holding capacity, or the speific retention of a soil. Test results are used in the phase relationships of soils, which can be used as index properties. The results are also used in estimating the amount of water that can be removed from a soil in the laboratory or in situ, by gravity drainage.

Synopsis: Duplicate soil samples are obtained, prepared, and saturated with distilled water. They are then placed In a centrifuge, held at a constant temperature, and accelerated to a force equal to 1,000 times the force of gravity. The speed of the centrifuge Is held constant for 1 hour; the specimens are removed and the mass of dry soil is obtained.

Methods: ASTM D 425-79, Test Method for Centrifuge Moisture Equivalent of Soils.

Limitations and Precautions The test results are affected by temperature and by the equipment used in the test. Results are for extremely small samples, and extrapolation to in situ soils or consideration of scale effects must be used with proper engineering judgment. .

Capillary-Moisture Relationships

Purpose: The capillary-moisture test Is performed to estimate the specific retention of a soil. Specific retention is also referred to as field capacity or water-holding capacity. The specific retention is used in determining the specific yield of soil, which is the ratio of the drainable volume to the bulk volume of a soil material.

Synopsis: A saturated soil sample Is placed in contact with a saturated porous plate or membrane. A pressure drop is induced across the plate or membrane. The soil samples establish equilibrium with the plate or membrane, and water that is held at a tension less than the pressure drop will flow out of the soil through a drain hose. When equilibrium is reached for a given tension, flow will stop and the moisture content of the sample can be determined. A series of tests is performed at varying tensions, and a curve of moisture content versus tension is prepared.

Methods: ASTM D 2325-88 (reapproved 1981), Test Method for Capillary Moisture Relationships for Coarse and Medium-Textured Soils by Porous-Plate Apparatus; and ASTM D 3152-72 (reapproved 1977), Test Method for Capillary Moisture Relationship for Fine-Textured Soils by Pressure-Membrane Apparatus.

Imitations and Precautions: Results of the test provide only an indication of the capillary-moisture relationship of the soil tested. Extrapolation of laboratory results to field or in situ conditions must be used with proper engineering judgment.

9.6.3.1.2 Density Tests

Undisturbed Samples

Purpose: Undisturbed unit weight or density of undisturbed samples Is used to determine the phase relationships for soils and for correlation to soil properties.

Synopsis: A sample of undisturbed soil Is obtained In conformance with the appropriate sampling standards described below. The sample Is weighed and measured for length, width, and height. The density (unit weight) is calculated as the sample weight divided by sample volume. With the moisture content of the sample, the dry unit can be calculated.

Methods: ASTM D 1587-83, Practice for Thin-Walled Tube Sampilng of Soils; and ASTM D 3550-87, Practice for Ring-Lined Barrel Sampling of Soils.

Imitations and Precautions: The term "undisturbed" is a relative term. Disturbance may occur during sampling, shipment, and sample preparation. This disturbance mayor may not be of consequence in determining the unit weight of the soil. Proper engineering judgment and familiarity with the type of soil sampled will minimize the effects of sample disturbance.

Moisture-Density Relationships

Purpose: Laboratory determinations of moisture-density relationships are used in the phase relationships of soils, in specifying density for other laboratory tests, and for comparing in-place field densities to laboratory standard curves for construction of earthwork control.

Synopsis: A soil sample is obtained and divided into at least four specimens. Each specimen is prepared by adjusting the moisture content and compacting Into a volumetric mold using a specified energy. A relationship is developed between the dry unit weight and the percentage of moisture content for each specimen. The results are generally presented In the form of a curve showing the relationship of dry density versus moisture content.

Methods: ASTM D 698-78, Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb Rammer and 12-in. Drop; and ASTM D 1557-78, Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb Rammer and 18-in. Drop.

Limitation and Precautions: The methods used to determine compaction densities are generally applicable to fine-grained soils or to those that are not free draining. The methods have been used on free-draining soils. However, a well-defined relationship between soil density and moisture may not exist, and engineering judgment is required to interpret the results.

Relative Density

Purpose: The relative density expresses the degree of compactness of a soil with respect to minimum and maximum index densities.

Synopsis: The minimum index density is obtained by pouring the soil as loosely as possible into a volumetric mold. Weight and volume relationships are determined, and a minimum density is obtained. The maximum index density is obtained by placing the soil in a volumetric mold, placing a surcharge weight on top of the soil, and then densifying the soil by vibration using a specified amplitude and frequency.

Methods: ASTM D 4253-83, Test Methods for Maximum Index Density of Soils Using a Vibratory Table; and ASTM D 4254-83, Test Methods for Minimum Index Density of Soils and Calculation of Relative Density.

Limitations and Precautions: The determination of relative density is subject to variations in the vibration apparatus used and in the degree of care used to determine minimum density. Materials with greater than approximately 8 per cent fines (i.e., fines are silts and clays) are generally not appropriate for the relative density determination; other methods of determining density should be used (i.e., laboratory moisture-density relationships).

9.6.3.1.3 Strength Tests

Unconfined Compression

Purpose:: The unconfined compressive strength provides an indication of the strength of the soil in unsaturated, undrained conditions without lateral confinement on the sample. Unconfined compression test results assist in evaluating the consistency of soils and can be used in stability analyses of foundations, excavations, and embankments.

Synopsis: A cylindrical soil sample is prepared and loaded in uniaxial compression to failure. The unconfined compressive strength is determined as the peak uniaxial stress that is twice the maximum shear stress.

Methods: ASTM D 2166-85 (reapproved 1979), Test Methods for Unconfined Compressive Strength of Cohesive Soil.

Limitations and Precautions: Strength estimates based on the unconfined compression test are only approximate estimates of the in situ strength of soil because of effects of disturbance, lack of confinement, and unsaturation in test samples. Strain rates, sample preparation, and sample disturbance may alter the results of the test.

Direct Shear

Purpose: The results of the direct shear test are generally used in stability and strength analyses for foundations, excavations, and embankments.

Synopsis: A soil sample is placed and consolidated within a direct shear box, which allows horizontal loading and differential movement of the top half of the sample. Soil samples are sheared horizontally under different normal loads. A plot of maximum shear stress versus normal stress is presented for each normal load. The resulting relationship of normal stress to maximum shear stress provides the shear stress parameters of cohesion intercept and angle of internal friction.

Methods: ASTM D 3080-72 (reapproved 1979), Method for Direct Shear Test of Soils Under Consolidated Drained Conditions.

Limitations and Precautions: The test is generally performed on granular soils, but it has been used for fine-grained soils. Because the direct shear test does not allow control or measurement of some important factors in the test (e.g., pore pressure, actual state of stress), experienced judgment must be used in interpreting and applying the results. Pore pressure increase or decrease during shear may occur, depending on the rate of shear and soil type.

Triaxial Compression

Purpose: Triaxial compression tests are used to determine the strength of soils; these tests have an advantage in that many of the important factors that control soil strength can be simulated in the test. These factors include preloading conditions of the soil, initial stress state in the soil, drainage conditions during loading, and stress changes during soil loading. Triaxial test results are used for stability analyses of foundations, excavations, and embankments.

Synopsis: A cylindrical soil specimen is prepared and installed within a rubber membrane and is placed within the triaxial testing cell. A predetermined lateral or confining pressure is applied, and the sample is loaded until the maximum stress constituting faliure is reached. The test maybe performed at a controlled strain rate or at a controlled stress rate.

Methods: ASTM D 2850-82, Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression.

Limitations and Precautions: A thorough discussion of triaxial testing is beyond the scope of this subsection. Application of triaxial testing demands careful attention to, and clear specification of, test methods to properly simulate desired conditions; use of “standard” methods can be made only in the most general sense. These tests should be used only under the direct supervision of a Geotechnical engineer.

Vane Shear

Purpose: The vane shear test provides a rapid estimate of the shear strength of a cohesive soil. it is useful for approximating allowable soil pressures, safe slopes, and lateral soil pressures on buried structures. This estimate of shearing resistance may also be compared with empirical results of similar soils with regard to strength properties.

synopsis: The vane shear instrument consists of a bladed vane on the end of a rod. The vane is pushed into the soil sample and rotated. The maximum torque required to turn the vane is measured and the results can be used to compute the shearing resistance of’ the soil. A torvane is a small vane shear instrument that can be pushed into a flat surface of a soil specimen. it gives only a general indication of the shearing resistance of cohesive soils.

Methods: ASTM D 2573-72 (reapproved), Test Method for Field Vane Shear Test in Cohesive Soil.

i-imitations and Precautions: The shearing resistance obtained by the torvane is only an estimate of the actual resistance that may exist in a soil mass. Operator procedure and instrument condition may greatly affect the results of the test. The pocket torvane is useful only as a rough indicator of soil consistency, This test is applicable only to fine-grained soils.

Moisture-Penetration Resistance

Purpose: Moisture-penetration tests are used to develop a correlation between penetration of a standard-size penetrometer needle and the density at a specific moisture content of a soil. The results of the test allow rapid collection of estimates of densities and moisture content for various soils used in earthworks.

Synopsis: The resistance of the soil to penetration is determined on each soil sample by penetration of the sample with a soil penetrometer, which consists of a spring-loaded tube with a graduated pressure scale and a needle of known length and end area. The penetration-pressure reading is divided by the area of the needle and presents values of force per unit area. The results are presented as plot of the penetration resistance values versus moisture content of the samples.

Methods: ASTM D 1558-84, Test Method for Moisture Content Penetration Resistance Relations of Fine-grained Soils.

Limitations and Precautions: Penetration resistance of granular or extremely dry soils is difficult; the results obtained, if any, may not be applicable.

Bearing Ratio

Purpose: This test determines the bearing ratio of a compacted soil by comparison of the penetration load of the compacted soil with that of a standard crushed gravel material. The results of the test are used with empirical relationships in evaluating the relative strength of near surface soils to be used as roadways.

Synopsis: A sample is divided into at least four equal portions, the moisture content is adjusted, and the sample is compacted in accordance with ASTM D 698 or D 1557. The sample is surcharged with a predetermined weight, and a penetration piston is seated on the sample. A load is applied to the sample through the penetration piston at a specified strain rate. Load versus penetration is recorded during the test. A load-versus-penetration curve is prepared. The bearing ratios are then calculated by dividing the loads from the test by standard loads of 1,000 psi and 1,500 psi. The bearing ratio reported for the soil is normally based on 0.1 inch of penetration.

Methods: ASTM D 1883-73 (preapproved 1978), Test Method for Bearing Ratio of Laboratory-Compacted Soils.

Limitations and Precautions: The test is an empirical relationship that compares the penetration of remolded compacted soils to the penetration of uniformly crushed gravel material. Proper engineering judgment must be used in applying the results of this test.

9.6.3.1.4 Deformation Tests

One-Dimensional Consolidation

Purpose: The one-dimensional consolidation test results are used to predict the amount and rate of settlement (or consolidation) of a soil mass subjected to sustained loads.

Synopsis: A soil sample is trimmed and placed in a consolidation ring that restrains it laterally. Porous stones are placed on the top and the bottom of the sample to allow drainage of pore water. The sample is then loaded, and the change in the sample height is recorded with time. Loads are applied in increments, and the test is repeated. The time-rate deformation of the sample is presented as plots of log of time or square root of time versus deformation. Plots of void ratio (or percent compression) versus log of pressure curve are prepared for use in assessing total settlement.

Methods: ASTM D 2435-60, Test Method for One-Dimensional Consolidation Properties of Soils.

Limitations and Precautions: Sample disturbance, scale differences between a laboratory sample and actual conditions, and interpretation of primary and secondary compression are areas. requiring engineering judgment in application of the test results.

Swell Test

Purpose: The swell test is used to determine the percentage of volume change or the maximum swelling pressure of a soil as a result of changes in moisture content. The test results are used to determine the suitability of a soil for use in earthworks and to minimize the impact of swelling soils on engineering projects.

Synopsis: A sample Is prepared and placed in a consolidation ring that provides lateral restraint. The sample is subjected to a small vertical pressure, and water is introduced to the sample; the vertical expansion with time or the force required to prevent expansion is then recorded. A percentage of volume change or swell pressure is presented as the results of the test.

Methods: ASTM D 4546-65, Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils.

Limitations and Precautions: The results of the test will yield information on soils under extreme conditions. Changes in moisture content, soil structure during sampling, sample handling, and preparation will lead to results that are only rough approximations. Proper engineering judgment must be used in applying the test results to actual problems.

9.6.3.l.5 Permeability Tests

: Permeability tests are performed to estimate the ability of a soil to transmit water under saturated conditions. Results of the permeability test are used to estimate the quantity and flowrate of water through the soil.

Synopsis: The sample is trimmed, measured, weighed, placed in the triaxial cell, and back-pressure saturated. The sample can be consolidated to approximate anticipated field conditions. flow across the sample is Induced by application of differential pressure across the sample and is measured until flow reaches steady-state conditions.

Methods: No standard method exists at this time for performing the test. Information concerning the generally accepted test methods is found in the references.

Limitations and Precautions: Test methods, temperature, sample disturbance variability, and sample preparation may affect the test results.

Recompacted Samples (Cohesionless and Cohesive)

Purpose: This permeability test is performed to estimate the permeability of a compacted soil. Permeability is a measure of the ease with which water can move through a compacted soil. Results of the permeability test are used to estimate the quantity and flowrate of water through embankments and liners.

Synopsis: Laboratory determination of permeability (also termed hydraulic conductivity) can be performed as falling-head or constant-head tests. PERMEAMETERS that apply a constant head to the sample are generally used to test noncohesive or granular soils. PERMEAMETERS that apply a falling or varying head are generally used to test cohesive or fine-grained soils. Samples to be tested are prepared and generally compacted to approximate field densities in the proper type of permeameter. The flow through the sample is initiated. For the constant-head PERMEAMETERS, the quantity of flow through the sample versus time is recorded. For the falling-head permeameter, the change in head or pressure across the sample and the change in volume with respect to time are recorded. Hydraulic conductivity is calculated by applying data obtained during the test to Darcy's equation.

Methods: ASTM D 2434-66 (reapproved 1974), Test Method for Permeability of Granular Soils (Constant Head). No standard currently exists for performing the falling-head test. Generally accepted test methods are given in the references.

Limitations and Precautions: Laboratory samples are extremely small when compared to conditions. Disturbance of samples occurs, methods of testing are not universally standardized, and extrapolation to field conditions may be approximate at best. Determinations of the coefficient of permeability are generally considered to be accurate only within an order of magnitude. Therefore, the quantities and the rates of flow must also be considered accurate within an order of magnitude. These factors dictate the use of proper engineering judgment in applying the results of a permeability test.

9.6.3.2 Rock

9.6.3.2.1 Apparent Specific Gravity

Purpose: The apparent specific gravity of rock is determined to obtain the rock unit weight (bulk-density), from which vertical and horizontal loads on subsurface installations can be estimated.

Synopsis: Specimens of regular shape (cylinders or blocks) can be weighed, and the volume can be determined by measurement. The apparent specific gravity is the ratio of the weight of the specimen to the weight of a volume of water having the same volume as the specimen. For Irregularly shaped specimens, each may be weighed In air and again while suspended and submersed in water. A formula can be used to determine the apparent specific gravity.

Methods ASTM C 127-63, Standard Test Methods for Absorption and Bulk Specific Gravity of Natural Building Stones.

Limitations and Precautions: Depending on the character of the rock in its natural deposits, the overall bulk density of the deposits may be less than that estimated on the basis of the specific gravity of the sample. This difference is because joints and cavities and other discontinuities reduce the overall density of the natural deposits.

9.6.3.2.2 Uniaxial Compressive Strength

Purpose: The uniaxial compressive strength of the rock can be used as an indicator of rock quality and can be used informing judgments about the allowable bearing pressure for foundations.

Synopsis: A prismatic or cylindrical sample of rock is loaded to failure In a compression-testing machine. A record of stress versus strain is made to enable determination of the elastic modulus of the rock.

Methods: ASTM C 170-85, Test Method for Compressive Strength of Natural Building Stone.

Limitations and Precautions: The number of factors that can affect the test results significantly includes flatness of the bearing surfaces, specimen size and shape, moisture content in the specimen, effect of friction between the bearing platens and the specimens, alignment of the swivel head, and rate of loading. A standardized procedure to account for most of these factors has been proposed by the U.S. Bureau of Mines. The most significant limitation of the uniaxial compressive strength testis that the strength of an individual specimen of rock in a laboratory will probably not be representative of the strength of a large mass of rock in the field. An exception may be a massive unjointed, unweathered rock deposit. Any discontinuities found in the rock mass (such as fractures, joints, and cavities) will lower the compressive strength of the rock mass.

9.6.3.2.3 Direct Tensile Strength

Purpose: The direct tensile strength of rock is useful in calculating rock stability and strength in situations where the rock is stressed in tension.

Synopsis: A regularly shaped specimen of rock (usually cylindrical) is cemented to grips or loading heads that can be used to pull on the specimen without inducing undue local stress concentrations that would cause premature failure of the specimen. The specimen is then lowered in tension in a testing machine. A record of stress versus strain can be made to compute the elastic modulus in tension.

Methods: ASTM D 2936-84, Test Method for Direct Tensile Strength of Intact Rock Core Specimens.

Limitations and Precautions: The applied tensile load must be uniformly distributed over the end of the specimen. The load must be parallel to the specimen's central axis. The grips used for holding the specimen must not produce significant lateral stresses in the specimen. The end of the specimen must be perpendicular to the specimen's central axis within a very small tolerance. As with other tests on rock specimens, the laboratory properties of an individual specimen may not be representative of the properties of a rock mass. The behavior of a rock mass is primarily controlled by its imperfections, such as joints, bedding planes, fractures, and cavities, rather than by the mechanical properties of the individual particles of rock in the mass.

9.6.3.2.4 Splitting Tensile Strength

Purpose: The direct tensile strength of rock is useful primarily in calculating the permissible span of roofs above openings in rock. It may also be useful in calculating allowable slopes for excavations in rock.

Synopsis: A cylindrical test specimen of the rock is placed in a testing machine so that a load is applied to the sides of the cylinder along two lines 180 degrees apart. The specimen is then loaded to failure. Loading in this manner generally results in a fracture that develops on a plane through the central axis of the specimen and extends from one loading platen to the other.

Methods: ASTM D 3967-81, Test Method for Splitting Tensile Strength of Intact Rock Core Specimens.

Limitations and Precautions: Care must be taken to prevent local stress concentrations at the loading heads. The tensile strength that is determined from a splitting tensile test will generally be greater than that determined from a direct tensile test. This result occurs because the splitting tensile test forces the plane of failure to be near the center of the specimen, whereas in the direct tensile test there is a greater opportunity for the specimen to fail at the weakest plane in the specimen.

9.6.3.2.5 flexural Strength (Modulus of Rupture)

Purpose: The flexural strength or modulus-of-rupture test provides a measure of the tensile strength of the material when loaded as a beam. This result can be used in the stability analysis of conditions involving rock flexural stresses.

Synopsis: A small rectangular specimen is supported on either end on knife edges and is then loaded at midpoint on the opposite side of the specimen until the specimen fails.

Methods: ASTM C 99-85, Test Method for Modulus of Rupture of Natural Building Stone.

Limitations and Precautions: A number of specimens should be tested, since this test will produce variable results even with careful specimen preparation. Tests should be made both parallel to and perpendicular to any naturally occurring planes of weakness in the rock. The tensile strength determined by the flexural test will generally be higher than that determined by the direct tensile test. The properties of the rock mass will probably be less than those computed based on individual laboratory specimens because of defects in the rock mass such as joints, bedding planes, fractures, and cavities.

9.6.3.2.6 Soundness

Purpose: This test furnishes information that aids In judging the resistance of rock to weathering, especially as a result of freezing and thawing.

Synopsis: Rock specimens are repeatedly submerged in saturated solutions of sodium or magnesium sulfate and are oven dried to partially or completely dehydrate the salt-precipitate impermeable pore spaces. When the specimen is reimmersed, the dehydration of the salts creates an internal expansive force that simulates the expansion of water when freezing.

Methods: ASTM C 66-63, Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.

Limitations and Precautions: This test is intended to give only a preliminary indication of the probable weathering resistance of the rock material. A better method for judging the weathering durability of rock material is to observe specimens that are the same material and that have been in service for a number of years.

9.6.3.3 Materials

9.6.3.3.1 Concrete

Compressive Strength

Purpose: The test determines the compressive strength of cylindrical concrete specimens, such as molded cylinders or drilled cores, for conformance to specifications of concrete primarily under compressive loadings.

Synopsis: The test method consists of applying a compressive axial load to cylindrical concrete specimens at a rate within a prescribed range until failure occurs. The compressive strength of the specimen is calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen.

Methods: Refer to ASTM C 39-63b, Test Method for Compressive Strength of Cylindrical Concrete Specimens.

Limitations and Precautions: Special sample handling and curing procedures must be followed. Testing equipment must be in current calibration to a standard load. The test result relates more to the conformance of the concrete batch to the mix design specified than to the actual strength of concrete in place.

Entrained Air

Entrained air in concrete improves resistance to freezing and thawing damage in hardened concrete.

Purpose: The test determines the air content of freshly mixed concrete for conformance to specifications.

Synopsis: Freshly mixed concrete Is placed In a measuring bowl. A cover assembly containing an air pump, gauge, and valves Is sealed to the bowl. The operation employs the principle of Boyle's law to observe the change in volume of the concrete with a change in pressure.

Methods: ASTM C 231-82, Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method; and ASTM C 173-78, Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method.

Limitations and Precautions: Calibration of equipment is essential to achieve accurate test results Start tests within 5 minutes after obtaining the final portion of the composite sample.

Flexural Strength

Concrete specimens are subjected to flexural or tension loadings. The test yields the flexural strength of the concrete.

Purpose: The flexural strength of concrete is determined by the use of a simple beam specimen of concrete with third-pdnt loading.

Synopsis: A rectangular prism of hardened concrete is supported by two load-applying blocks near each end. Two load-applying blocks are located on top of the specimen at third-points. A controlled rate load is applied until failure. The modulus of rupture is calculated for the specimen.

Methods: ASTM C 78-84, Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading); and ASTM C 293-79, Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading) (not an alternative to C 78-84).

Limitations and Precautions: Special handling and curing procedures must be fallowed. Testing equipment must be in current calibration to a standard load.

Specific Gravity and Absorption

Purpose: This test determines the specific gravity, absorption, and voids in hardened concrete. It is useful in developing data required for mass/ volume conversions for concrete, allowing conformance to specifications, and showing variability from place to place within a mass of concrete.

Synopsis: An oven-dried specimen of concrete is weighed in air, submerged for a period of time, weighed under saturated surface dry conditions, and then boiled for 5 hours. After coding and reweighing surface dry, the specimen is immersed and weighed in water. The values of specific gravity, absorption, and voids are calculated from the measurements taken.

Methods: ASTM C 842-82, Test Method for Specific Gravity, Absorption, and Voids in Hardened Concrete.

Limitations and Precautions: Specimens may be pieces of Cylinders, cores, or beams; specimens must be free from observable cracks, fissures, or shattered edges.

Splitting Tensile Strength

Purpose: When tensile strength values are not available from concrete beam specimens or are required from existing structures, compressive strength cylinders or drilled cores may be used. This test method covers the determination of the splitting tensile strength of cylindrical concrete specimens, such as molded cylinders or drilled cores.

Synopsis: The cylindrical specimen is positioned horizontally with a bearing plate or bar that extends the full length of the specimen and that is diametrically opposed on the top and bottom. A constant rate of load is applied until failure of the specimen. The splitting tensile strength is calculated from the maximum applied load and specimen dimensions.

Methods: ASTM C 496-85, Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.

Limitations and Precautions: Special handling and curing procedures must be followed. Testing equipment must be in current calibration to a standard load. Special alignment jigs, bearing strips, and loading apparatus are required.

9.6.3.3.2 Soil-Cement

Purpose: Proportions of soil-cement mixtures are determined by trial batch mix designs. Strength and resistance to degradation of the mixture are evaluated by compressive strength, flexural strength, moisture-density relationship, freezing and thawing, and wetting and drying tests. Soil-cement stabilization may also be considered for solidification of some hazardous wastes.

Synopsis: Various amounts of cement are added to soil. The mixture is moistened to optimum water content and is compacted into specimens. The specimens are cured and removed from the molds for further curing and testing. Samples are tested at various intervals to determine compressive strength development. Other specimens are run through repetitive cycles of freezing, thawing, wetting, and drying to identify the most appropriate proportions for the soil-cement mixture.

Methods: ASTM D 2901-82, Test Method for Cement Content of Freshly Mixed Soil-Cement; ASTM D 806-74 (reapproved 1979), Test Method for Cement Content of Soil-cement Mixtures; ASTM D 163243, (reapproved 1979), Method for Making and Curing Soil-Cement Compression and Flexural Test Specimens in the Laboratory; ASTM D 1633-84, Test Method for Compressive. Strength of Molded Soil-Cement Cylinders; ASTM D 1634-63 (reapproved 1979), Test Method for Compressive Strength of Soil-Cement Using Portions of Beams Broken in flexural (Modified Cube Method); ASTM D 1635-63 (reapproved 1979), Test Method for Flexural Strength of Soil-Cement Using Simple Beam with Third-Point Loading; ASTM D 558-82, Test Methods for Moisture-Density Relations of Soil-Cement Mixtures; ASTM D 559-82, Methods for Wetting-and-Drying Tests of Compacted Soil-Cement Mixtures; and ASTM D 560-82, Methods for Freezing-and Thawing Tests of Compacted Soil-Cement Mixtures.

Limitations and Precautions: Not all soils are appropriate for soil-cement treatment, especially fine-grained or clayed soils. Special equipment and space are required.

9.6.3.3.3 Portland Cement, Blended Hydraulic Cement

Purpose: Several types of Portland cement are used to achieve specific properties when making concrete. Blended hydraulic cements are also available in several types to provide specific properties. It is beyond the scope of these procedures to present the physical property tests used to evaluate Portland cement and blended hydraulic cement. The reader should refer to the methods listed below.

Methods: ASTM C 150-85a, Specifications for Portland Cement; and ASTM C 595-86, Specification for Blended Hydraulic Cements.

9.6.3.3.4 Asphalt Cement

Purpose: Several grades of asphalt cement are available for paving and using hydraulic mixtures with aggregates. It is beyond the scope of these procedures to present the physical property tests used to evaluate asphalt cements. The reader should refer to the methods listed in ASTM Volumes 04.03, 04.04, and 04.08.

9.6.3.3.5 Asphalt-Stabilized Soils

Purpose: Emulsified or cutback asphalt may be blended with soil to increase strength and reduce permeability to water. Asphalt stabilized soils may also be considered for solidification of some hazardous waste materials.

Synopsis: Specimens of soil-asphalt mixtures are prepared and tested for strength, specific gravity, permeability, and stability to determine the most appropriate proportions of the soil-asphalt mixture.

Methods: ASTM D 4223-63, Practice for Preparation of Test Specimens of Asphalt-Stabilized Soils.

l-imitations and Precautions: Special equipment and space are required. Special handling of asphalt materials and associated solvents is necessary.

9.6.3,3.6 Geotextiles

Fabric Weight

Purpose The fabric weight is directly related to the fabric tensile strength and, therefore, provides an index of strength.

Synopsis: The fabric weight test is conducted by cutting a sample of fabric and measuring its dimensions and weight. The fabric weight is calculated as the total weight of the sample divided by its area.

Methods: ASTM D 3773-84, Test Method for Length of Woven Fabric, 07.01; ASTM D 3774-64: Test Method for Width of Woven Fabric, 07.01; ASTM D 3775-85, Test Method for Fabric Count of Woven Fabric, 07.01; and ASTM D 3776-85, Test Methods for Mass per Unit Area (weight) of Woven Fabric, 07.01.

Limitations and Precautions: Potential error is reduced by using as large a sample as possible.

Fabric Thickness

Purpose: The thickness of a geotextile is an index to its ability to absorb impacts and transport water (for constant density).

Synopsis: A sample of fabric is placed on an anvil, and gradual pressure is applied by means of a fixed-weighted, mechanical foot. The thickness (distance between the anvil and foot) is measured.

Methods: ASTM D 1777-64 (reapproved 1975), Method for Measuring Thickness of Textile Materials, 07.01.

Limitations and Precautions: Different methods of finishing geotextiles (e.g., spun-bonding, needle punching, heat bonding) may alter the deformation properties of the material, thus affecting the thickness measurement.

Grab Tensile Strength and Elongation

Purpose: The grab tensile test is the most commonly used strength and elongation index for woven fabrics. The test provides a good indication of strength and deformation during installation.

Synopsis: The grab tensile test involves using a specified size sample of fabric loaded in tension between two clamps. The clamps are moved apart at a constant rate until failure of the fabric is achieved. The load at failure is the ultimate grab tensile strength; the deformation at failure is the elongation.

Methods: ASTM D 1682-64 (1975), Test Methods for Breaking Load and Elongation of Textile Fabrics, 07.01.

Limitations and Precautions: Because fabrics are often subjected to multidirectional stresses in actual use, this method may not provide a good indication of the strength or deformations after placement.

Creep

Purpose: Creep tests of fabrics are used to assess potential loss of a reinforcing capability because of time-dependent fabric deformation.

Synopsis: Creep tests are conducted by hanging a constant weight on a strip of fabric and measuring the deformation (elongation) of the fabric over a period of time.

Methods: Standard methods are not currently available. Creep tests must be carefully designed on a case-by-case basis considering the specific loading conditions anticipated. Proprietary methods developed by manufacturers are availabie.

Limitations and Precautions: Creep tests that apply loads and measure deformation in only one direction have limited application to actual field conditions.

Abrasion Resistance

Purpose: Abrasion tests are used to assess the resistance of a fabric to wear by friction. Abrasion may be a concern in applications where relative movement occurs frequently (perhaps cyclically) between the fabric and adjacent soils or materials (e.g., under riprap at shoreline or under heavily loaded road or rail beds).

Synopsis: Not applicable.

Methods: No standards are currently available. The reader should refer to manufacturers for information and methods.

Limitations and Precautions: Current test methods may not be relevant to most hazardous waste applications.

Puncture Resistance

Purpose: The puncture resistance Is important in assessing the ability of a fabric to resist abuse during installation (e.g., compaction of gravels on top of or around a fabric).

Synopsis: A sample of fabric is placed in a ring clamp, and the fabric is penetrated by a hemispherically tipped steel cylinder advanced at a specified rate. The load required to penetrate the fabric is the puncture strength.

Methods: ASTM D 751-79, Method of Testing Coated Fabrics, 09.02.

Limitations and Precautions: The reader should refer to the standard method.

Mullen Burst Strength

Purpose: The Mullen Burst Test is used to assess fabric strength when fabric is subjected to multidimensional loads that may be more representative of actual field loads after placement.

Synopsis: A sample of fabric is placed in a circular clamp and loaded hydrostatically at a constant rate through an Inflatable membrane. The pressure required to rupture the fabric is the burst point.

Methods: ASTM D 3786-80a, Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method, 07.01.'

Limitations and Precautions: The test results must be carefully interpreted because of the small sample size and potential edge effects of the clamp.

Trapezoid Tearing Strength

Purpose: The trapezoid tearing strength test is useful in assessing the tendency of a fabric to continue to tear when tearing is initiated.

Synopsis: A sample of the fabric is marked with an outline of a trapezoid, and the nonparallel sides are clamped in parallel jaws of the testing machine. The jaws are separated at a constant rate, and a continuously increasing load is applied to continue tearing the sample. The load versus deformation curve is recorded, and the maximum (peak) load determined is the tearing strength.

Methods: ASTM D 1117-80, Methods of Testing Nonwoven Fabrics, 07.01.

Limitations and Precautions: The reader should refer to the standard method.

Equivalent Opening Size (EOS)

Purpose: The equivalent opening size test compares opening size in fabrics to U.S. standard sieve sizes to help evaluate the performance of filter fabric.

Synopsis: A sample of filter fabric is attached to a U.S. standard sieve with openings larger than the largest beads to be used. The beads are placed in the sieve and shaken for a fixed period. The size of beads, of which 5 percent or less (by weight) pass through the fabric, is determined by sieving. The EOS of the fabric is the U.S. standard sieve number which retains this fraction of the glass beads.

Methods: U.S. Army Corps of Engineers' Guidelines.

Limitations and Precautions: The reader should refer to the standard method.

Planar Flow

Purpose: Planar flow test results are used to help evaluate the capacity of a fabric to transmit fluid In the plane of the fabric.

Synopsis: Circular fabric samples are placed between flat plates and compressed at a set pressure. Fluid flow is induced under constant hydraulic head from the middle of the sample to the edges. The transmissibility is used as a measure of flow capacity because it includes both permeability and thickness.

Methods: No standard methods are availabie.

Limitations and Precautions: The reader should refer to the manufacturer.

Normal Permeability

Purpose: Normal permeability test results are used to evaluate the capacity of a fabric to transmit fluid perpendicular to the plane of the fabric. The test helps evaluate infiltration and evaporation rates across fabrics and is important in evacuating fabrics for drainage applications.

Synopsis: Normal permeability tests can be conducted by clamping a sample of fabric across the base of cylinder, filling the cylinder with fluid, and measuring the rate of fluid flow through the sample as in a failling-head test.

Methods: No standard methods are availabie.

Limitations and Precautions: The reader should refer to the manufacturer.

Coefficient of Friction (Soil to Fabric)

Purpose: Determining the coefficient of friction between a fabric and soil is essential in evacuating the ability of the fabric to provide lateral reinforcement of the soil. The coefficient of friction provides a measure of the ability to transfer stresses to the fabric, which may affect the thickness of cover required to prevent shifting of the fabric.

Synopsis: Samples of fabric are placed on a horizontal surface, and a sample of soil is placed at one end. The end is raised and the angle of the incline at which the soil starts to slide is measured. The coefficient of friction is the trigonometric tangent of the angle of inclination at incipient sliding.

Methods: No standard methods are available.

Limitations and Precautions: The reader should refer to the manufacturer.

Coefficient of Friction (Fabric to Fabric)

Purpose: The coefficient of friction between two fabrics is essential for evaluating the required overlap needed to keep fabrics in place (unbended seams) and to evaluate the ability of layered fabric systems to transmit lateral stresses or to resist sliding.

Synopsis: Samples of fabric are overlapped and clamped together at fixed pressures. The fabrics are pulled at a constant rate to cause differential movement between the fabric samples, and the force is measured. The first peak load corresponds to the static friction load.

Methods: No standard methods are available.

Limitations and Precautions: The reader should refer to the manufacturer.

Alkali or Acid Stability

Purpose: Alkali or acid stability tests are used to assess potential fabric deterioration caused by exposure to or contact with acidic or basic solutions. Potential deterioration may affect the performance and effective service life of fabrics in drains, liners, and covers.

Synopsis: Fabric samples are attached to frames and placed in alkali or acid baths at constant pH. Samples are periodically removed from the baths, dried, and tested (e.g., grab tensile test). The changes in tensile strength with prolonged bath exposure provide information on the rates of deterioration.

Methods: No standards currently exist.

Limitations and Precautions Within practical limits, the duration of bath exposure may not be representative of field conditions. Extrapolations to estimate actual field service life may be questionable.

Thermal Shrinkage

Purpose: The results of thermal shrinkage tests can be used to evaluate potential deformations of fabric in hot environment applications (e.g., contact with hot asphalts or exothermic chemical reactions).

Synopsis: Samples of fabric are placed in ovens at various temperatures and are periodically measured for unrestrained deformation.

Methods: The reader should see ASTM met hods for width and length measurements that are listed earlier in this compendium under “Fabric Weight.”

Limitations and Precautions: Because measurements are made on unrestrained fabric samples, the test may not be representative of field conditions. Since thermally induced stresses are not measured. the results cannot be used to assess these potential effects.

Ultraviolet Stability

Purpose: The results of ultraviolet stability tests allow assessment of potential deterioration of fabrics that are subjected to sunlight. These assessments can be used to evaluate changes in effectiveness and to predict the service life of the fabrics.

Synopsis: Fabric samples are exposed to ultraviolet light (either artificial or natural sunlight) and are periodically tested (e.g., grab tensile test). The changes in tensile strength indicate the rate of fabric deterioration.

Methods: The reader should see the ASTM method listed earlier in this compendium under "Grab Tensile Strength and Elongation Tests" in this subsection.

Limitations and Precautions: Practical limits on the duration of testing may not represent actual field conditions. Extrapolations of test results to assess long-term effects maybe questionable.

9.6.3.3.7 Geomembranes

Polymeric flexible membranes are available supported (reinforced) or unsupported (nonreinforced). The general types of materials used are elastomeric (rubber), thermoplastic, semicrystalline, or alloys of the various polymers. The physical test specifications to be used depend on the polymer and whether it is supported or not. Many of the test specifications used by manufacturers and listed in National Sanitation Foundation Standard 54 were developed for other purposes and are being used since specifications for specific geomembrane materials and properties are unavailable at this time.

Thickness

Purpose: The thickness of a geomembrane is proportional to the strength and elongation properties.

Synopsis: Three methods for measurement of thickness are presented below. The method selected will depend on the specification for the particular geomembrane.

Methods: ASTM D 1593-8, Specification for Nonrigid Vinyl Chloride Plastic Sheeting; ASTM D 751-79, Method of Testing Coasted Fabrics; and ASTM D 412-83, Test Methods for Rubber Properties in Tension.

Limitations and Precautions: A special apparatus Is required to make measurements.

Specific Gravity

Purpose: The specific gravity measurement of a geomembrane is useful in determining the unit weight of materials.

Synopsis: The test method covers the determination of specific gravity and density of solid plastics by displacement of liquid and the determination of change in weight.

Methods: ASTM D 792-6, Test Methods for Specific Gravity and Density of Plastics by Displacement.

Limitations and Precautions: Special equipment may be required.

Tensile Strength

Purpose: The tensile strength of a geomembrane is an important design parameter related to the ability to withstand the movement of the geomembrane into place, to support itself on slopes, and to withstand operational stress.

Synopsis: There are four methods for determining the tensile strength of geomembranes. The appropriate method will depend on the type of polymeric geomembrane being tested.

Methods: ASTM D 882-83, Test Methods for Tensile Properties of Thin Plastic Sheeting; ASTM D 751-79, Method for Testing Coated Fabric; ASTM D 412-83, Test Method for Rubber Properties in Tension; and ASTM D 638-84, Test Method for Tensile Properties of Plastics.

Limitations and Precautions: The reader should refer to test methods listed above.

Elongation

Purpose: The elongation of a geomembrane is an extension produced by tensile stress. Elongation provides some measure of the material's ability to accommodate minor deformation.

Synopsis: There are four methods for determining the elongation of geomembranes. The measurement is usually an adjunct to the tensile strength test. The appropriate method will depend on the polymeric geomembrane being tested.

Methods: The reader should see the methods that are listed earlier in this compendium under ‘Tensile Strength.”

Limitations and Precautions: Refer to the test methods listed above.

Tear Resistance

Purpose: The tear resistance is a measure of the strength of the geomembrane at a point of stress. The tear resistance of a geomembrane is the stress required to propagate a cut or silt at the edge of a membrane specimen under strain.

Synopsis: There are three methods for determining the tear resistance of geomembranes. The appropriate method will depend on the polymeric geomembrane being tested.

Methods: ASTM D 1004456(1981), Test Method for Initial Tear Resistance of Plastic Film and Sheeting; ASTM D 31-79, Method of Testing Coated Fabrics; and ASTM D 624-66, Test Method for Rubber Property.

Limitations and Precautions: The reader should refer to the test methods listed above.

Dimensional Stability

Purpose: The measurement of linear dimensional changes of geomembranes at elevated temperature suggests the behavior of the materials in the field when exposed to solar heating during placement.

Synopsis: The reader should refer to National Sanitation Foundation Standard 54 for Flexible Membrane Liners, 1983, for details of the test. This method is proposed for all geomembranes listed in Standard 54.

Methods ASTM D 1204-64, Test Method for Linear Dimensional Changes of Nonrigid Thermoplastic Sheeting or Film at Elevated Temperature.

Limitations and Precautions: The reader should refer to the test method listed above.

Bonded Seam Strength

Purpose: The seam strength is the single most important concern for lining integrity, and it applies to both factory made and field-made seams.

Synopsis A tensile strength testis performed on a specimen prepared to have a seam under shearing stress. The specimen is tested to failure to determine the maximum stress. The specimen is examined to determine if the failure was within the seam or in the parent material.

Methods: ASTM D 3063-76(1960), Specification for Flexible Poly (Vinyl Chloride) Plastic Sheeting for Pond, Canal, and Reservoir Lining; and ASTM D 751-79, Testing Coated Fabrics.

Limitations and Precautions: Specimens require special handling and curing before testing. The testing machine must be currently calibrated to a standard. A special testing apparatus is required.

Peel Adhesion

Purpose: The tensile strength of geomembrane seams by 160 degree peel is the definitive test of the bond strength.

Synopsis: The tensile stress is applied to material on adjacent sides of the seam to create a 160 degree strain on the bonded seam. The sample is tested to failure, and the failure location is noted as being in the seam or in the parent material.

Methods: ASTM D 413-62, Test Methods for Rubber Property-Adhesion to Flexible Substrate.

Limitations and Precautions: Specimens require special handling and curing prior to testing. The testing machine must be currently calibrated to a standard. A special testing apparatus is required.

9.6.4 Chemical Properties of Soil and Rock

9.6.4.1 Waste Evacuation Procedures

Section 262.11 of the Resource Conservation and Recovery Act (RCRA) regulations requires that a generator of a “solid waste” – i.e., any garbage, refuse, sludge, or other waste that is not excluded under Section 261.4(a) - must do the following:

1. Determine if the waste is excluded.

2. if the waste is not excluded, determine whether the waste is listed as a hazardous waste.

3. If the waste is not excluded and not listed, then evaluate the waste in terms of the four hazardous characteristics – ignitability, corrosivity, reactivity, and extraction procedure toxicity– unless the generator can properly evaluate the waste based upon previous experience (e.g., corrosivity testing may not be required If the generator has a long history of running the waste through steal pipes without any evidence of corrosion).

9.6.4.1.1 Ignitability (RCRA Requirement)

Purpose: The ignitability test identifies wastes that either present fire hazards under routine storage, disposal, and transposition, or are capable of severely exacerbating a fire once it has started.

Synopsis: The following two methods are approved by the EPA:

1. The Pensky-Martens dosed-cup method uses the dosed-cup tester to determine the flash point of fuel oils, lubrication oils, suspension solids, liquids that tend to form a surface film under test conditions, and other liquids.

The sample is heated at a slow, constant rate and is continually stirred. A small flame is directed into the cup at regular intervals while simultaneously interrupting the stirring. The flash point is the lowest temperature at which application of the test flame ignited the vapor above the sample.

2. The Setaflash closed-cup method uses the Setaflash closed Tester to determine the flash point of paints, enamels, lacquers, varnishes, and related products and their components that have flash points between O°C and 110% (32°F and 230°F) and viscosity lower than 150 stokes at 25°C. Tests at higher or lower temperatures are possible.

The procedures may be used to determine whether a material will or will not flash at a specified temperature, or to determine the finite temperature at which a material will flash.

Methods: EPA SW-846, Test Methods for Evaluating Solid Waste, Methods 1010 and 1020

Limitations and Precautions: Ambient pressure, sample homogeneity, drafts, and operator bias can affect flash point values. Quality control data as specified under Method 1010 and Method 1020 should be available for review.

9.6.4.1.2 Corrosivity (RCRA Requirement)

Purpose: The corrosivity test Identifies wastes that might pose a hazard to human health or the environment because of their ability to do the fallowing:

- Mobilize toxic metals if discharged into a landfill environment
- Corrode handling, storage, transportation, and management equipment
- Destroy human or animal tissue in the event of inadvertent contact

To identify such potentially hazardous materials, EPA has selected two properties on which to base the definition of a corrosive waste. These properties are Pi-I and corrosivity toward SAE Type 1020 steel. The procedures for pH are described in this Subsection 9.6.4.2.5. Corrosivity toward steel is used for both aqueous and nonaqueous liquid wastes. This test exposes coupons of SAE Type 1020 steel to the liquid waste to be evaluated and, by measuring the degree to which the coupon has dissolved, determines the corrosivity of the waste.

Methods: EPA SW-646, Test Methods for Evaluating Solid Waste, Method 1110. Corrosivity of Steel.

Limitations and Precautions: in laboratory tests, such as Method 1110, corrosion of duplicate coupons is usually reproducible to within 10 percent. However, large differences in corrosion rates may occasionally occur under conditions in which the metal surfaces have become passivated. Therefore, at least duplicate determinations of the corrosion rate should be made. Exact requirements are to be included in the QA plan and specified in the laboratory.

9.6.4.1.3 Reactivity (RCRA Requirement)

Purpose: The reactivity test identifies wastes that, because of their extreme instability and their tendency to react violently or explode, pose a problem at all stages of the waste management process.

Synopsis: The EPA gives a descriptive definition of reactivity, because the available tests for measuring the variegated class of effects embraced by the reactivity definition suffer from a number of deficiencies.

Methods: See regulatory definition in EPA SW-646, Test Methods for Evaluating Solid Waste, Section 2.1.3- Reactivity.

Limitations and Precautions: The reader should refer to Subsection 2.1.3 in EPA SW-646.

9.6.4.1.4 Extraction Procedure (EP) Toxicity Test Method and ‘Structural integrity Test

Purpose: This test is used to simulate the leaching a waste may undergo if it is disposed of in a landfill. The testis applicable to liquid, solid, and multiphasic samples.

Synopsis: if a representative sample of waste contains more than 0.5 percent solids, the solid phase of the sample is extracted with deionized water that is maintained at a pH of 5 ± 0.2 using acetic acid. The extract is analyzed for the specified priority pollutants (As, Ba, Cd, Cr, Pb, Hg, Se, Ag, endrin, lindane, methoxychlor, toxaphene, 2,4 D, 2,4,5-TP Silvex]) by the appropriate tests as described under organic and inorganic priority pollutant analyses. Wastes that contain less than 0.5 percent are not subjected to extraction, but they are directly analyzed and evaluated in a manner identical to that for extracts.

Methods: EPA SW-646, Test Methods for Evacuating Soild Waste, Method 1310.

Limitations and Precautions: Potential interferences that may be encountered during analyses pertain to the individual analytical methods.

6.4.1.5 Mobility

Purpose: This test is used to determine the mobility of various components in a waste to evaluate contaminant transport.

Synopsis: A multiple extraction procedure currently is being developed by the EPA. (Method 141 O) Although these procedures are used to evaluate a waste, they are not to be confused with a hazardous characteristic as defined by the RCRA regulations.

Methods: EPA SW-646, Test Methods for Evaluating Solid Waste, Method 1410.

Limitations and Precautions: The reader should see the test method.

9.6.4.1.6 Acid-Base Potential (Potential Acidity With Peroxide, Neutralization Potential, Mine Spoil Potentials)

Purpose: Within impounded mine tailings, the potential for in situ acid formation may exist whenever pyritic sulfide is present in the waste material. If acid were to be formed by the oxidation of pyritic sulfur; the acid theoretically could dissolve and mobilize transition metals. The possibility that acid formation will occur is evaluated by measuring the acid-base potential.

Synopsis: Determination of the acid-base potential is the result of two independent analyses: one is an acidometric measure of the base equivalent (as calcium carbonate) of the tailings solids, and the other is a measure of the hydrogen peroxide-oxidizable sulfur that could produce sulfuric acid. The acid-base potential is the base content minus the acid content.

Methods: Report No. EPA-70/2-74-070, Mine Spoil Potentials for Soil and Water Quality.

Limitations and Precautlons: The reader should seethe test method.

9.6.4.2 Pollutant Analysis

9.6.4.2.1 Organics

Purpose Organics tests are used to identify and quantify the organic contaminants of the soil.

Synopsis The EPA has a list of organic priority pollutants for which well-defined analytical and quality control procedures have been developed. These pollutants are classified in four groups based on the extraction procedures employed before analysis: volatiles, acid extractable, base or neutral extractable, and pesticides. The major analytical procedures employed are gas chromatography and mass spectrocope. For organics other than the priority pollutants, procedures need to be obtained from literature. Appropriate descriptions should be presented to the laboratory on a special analytical services (SAS) form.

Methods: EPA W-646, Test Methods for Evaluating Solid Waste, Methods 6010-6310,3510-3550.

Limitations and Precautions The reader should see the test methods and the literature.

9.6.4.2.2 Metals

Purpose: Metals tests are used to identify and quantify the metal contaminants in the soil,

Synopsis: The EPA has a list of metal priority pollutants for which well-defined analytical and quality control procedures have been developed. In analysis requests, distinctions need to be made in total metal or extractable metal analysis. The soil is digested with a strong acid to dissolve all metals in the first, whereas an appropriate extraction method is employed in the second. The analysis methods are mainly atomic absorption and inductively coupled plasma emission. For metals that are not on the priority pollutant list, procedures need to be obtained from literature and appropriate descriptions given on the SAS form.

Methods EPA SW-646, Test Methods for Evaluating Solid Waste, Methods 7040-7951,3010-3060.

Limitations and Precautions: The reader should sw the test methods and the literature.

9.6.4.2.3 Total and Amenable Cyanide

Purpose: This test is used to determine the concentration of inorganic cyanide. The method detects inorganic cyanides that are present as either simple soluble salts or complex radicals. The test is used to determine values for both total cyanide and cyanide amenable to chlorination. It does not determine the "reactive" cyanide content of wastes containing iron-cyanide complexes.

Synopsis: The waste Is divided into two parts. One is chlorinated to destroy susceptible complexes. Each part Is distilled to remove interferences and Is analyzed for cyanide. The fraction amenable to chlorination is determined by the difference in values.

During the distillation, cyanide is converted to hydrogen cyanide vapor, which is trapped in a scrubber containing sodium hydroxide solution. This solution is titrate with standard silver nitrate.

Methods: EPA SW-646, Test Methods for Evaluating Solid Waste, Method 9010.

Limitations and Precautions: Sulfides interfere with the titration, but they can be precipitated with cadmium. Fatty acids form soaps under alkaline titration conditions and interfere. The fatty acids can be extracted with a suitable solvent. Oxidizing agents can decompose the cyanide; the oxidizing agents can be treated with ascorbic acid. Thiocyanate presence will interfere by distilling over in the procedure. This situation can be prevented by adding magnesium chloride. Aldehydes and ketones can convert cyanide to cyanohydrin under the acid distillation conditions.

9.6.4.2.4 Total Organic Halides (TOX)

Purpose: This test is used to determine the total organic halides (TOX) as Cl extract.

Synopsis: A sample of water that has been protected against the loss of volatiles by the elimination of headspace in the sampling container is passed through a column containing activated carbon. The column is washed to remove any trapped inorganic halides and is analyzed to convert the adsorbed organohalides to a titratable species that can be measured by a microcoulometric detector.

Methods: The reader should see the test methods. EPA SW-946, Test Methods for Evaluating Solid Waste, Method 9020, Total Organic Halides (TOX).

Limitations and Precautions: All samples must be run in duplicate. Under conditions of duplicate analysis, the reliabie limit of sensitivity is 5 u1 per liter.

The method detects ail organic halides containing chlorine, bromine, and iodine that are adsorbed by granular-activated carbon under conditions of the method. Fluorine species are not determined by this method.

The method is applicable to samples whose inorganic-halide concentration does not exceed the organic-halide concentration, by more than 20,000 times.

9.6.4.2.5 pH

Purpose: This test is used to measure the pH of the soil.

Synopsis: The soil is stirred with water and, after equilibration, the pH of the supernatant solution is measured with a glass electrode pH meter.

Methods: The EPA is currently developing a method, EPA SW-846, Test Methods for Evaluating Solid Waste, Method 9045.

Limitations and Precautions: The measured pH value may shift slightly with each change in the soil-to-water ratio used in the preparation of the soil samples, and seasonal fluctuations in pH may also be anticipated.

9.6.4.2.6 Lime Requirement

Purpose: This test is used to determine the pH of acidic soils for estimating the amounts of lime needed to neutralize the soil.

Synopsis: The dried soil is mixed with a buffer solution and allowed to equilibrate, and the pH is measured with glass electrodes and a pH meter. The amount' of lime needed can be estimated from experimental lime versus pH correlation curves specific to the region.

Methods: Methods of Soil Analysis Used in the Soil Testing Laboratory at Oregon State University, Special Report 321, Agricultural Experiment Station, Oregon State University, Corvallis, revised September 1978.

Limitations and Precautions: Electrodes should be rinsed very well between samples to eliminate a constant increase in the pH measured, because of electrode contamination.

9.6.4.3 Other Tests

9.6.4.3.1 Cation Exchange Capacity

Purpose: This test is used to determine the exchangeable cation content of the soil. Many of the assimilative capacity determinations for constituents in industrial waste are based on cation exchange capacity measurement.

Synopsis: Determination of soil cation exchange capacity involves removal of all exchangeable cations by leaching the soil with an excess of neutral ammonium acetate solution and saturating the exchange material with ammonium. This procedure is followed by leaching with Na4Cl. The soil is then washed with isopropyl alcohol until all chloride is removed. The ammonium adsorbed on the exchange complex is displaced by treating the soil with acidified NaCl. The displaced solution is distilled and then titrated to calculate the cation exchange capacity.

Methods: Methods of Soil Analysis Used in the Soil Testing Laboratory at Oregon State University, Special Report 321, Agricultural Experiment Station, Oregon State University, Corvallis, revised September 1978.

The EPA is developing a cation exchange capacity method entitled Test Methods for Evaluating Solid Waste, SW-846, Methods 9080, 9081. This method includes the ammonium acetate and the sodium acetate methods.

9.6.4.3.2 Extractable Cations: K^+, Na^+, Ca^{++}, Mg^{++}

Purpose: Extractable cation content of the soil, along with extractable hydrogen, is used to estimate the cation exchange capacity and the percentage of base saturation required for soil taxonomy.

Synopsis: The ions are extracted from the soil with a neutral ammonium acetate solution. The quantities of the individual ions In the solution are then determined by atomic absorption.

Methods: Methods of Soil Analysis Used in the Soil Testing Laboratory at Oregon State University, Special Report 321, Agricultural Experiment Station, Oregon State University, Corvallis, Method 17, revised September 1978.

Limitations and Precautions: The four cations are determined on the same soil extract but with different dilutions. The single-extraction technique for cations in noncancerous soil gives values that are equivalent to at least 35 percent of the values obtained by multiple extraction. For samples that contain carbonates of Ca^{++} or Mg^{++} the multiple extraction with ammonium acetate may dissolve these carbonates and give higher value: for Ca^{++} and Mg^{++} than are' obtained with a single extraction. For routine testing, there is usually no interest in determining the extractable Ca^{++} and Mg^{++} in alkaline samples that contain free lime.

9.6.4.3.3 Exchangeable Hydrogen

Purpose: To determine the amount of acidic hydrogen that can be removed from the soil by a buffer solution. The extractable hydrogen content, along with the extractable cations, is used to estimate the cation exchange capacity, as well as the percentage of base saturation required for soil taxonomy.

Synopsis: The soil is mixed with a buffer solution and kept for 30 minutes while being shaken to dissolve the acidic hydrogens. The soil is then filtered. This process is repeated two more times; then the filtrate is titrated to determine the acid content.

Methods Methods of Soil Analysis Used In the Soil Testing Laboratory at Oregon State University, Special Report 321, Agricultural Experiment Station, Oregon State University, Corvallis, revised September 1978.

Limitations and Precautions: The reader should seethe test method.

.

9.6.4.3.4 Total Soluble Salts-Electrical Conductivity

Purpose: This test is used to measure the electrical conductivity of the soil extract as an indication of its ionic content (soluble salts).

Synopsis: Water is added to the soil to prepare a saturated soil paste. This paste Is then filtered, and the conductivity of the filtrate is measured.

Methods: Methods of Soil Analysis Used in the Soil Testing Minatory at Oregon State University, Special Report 321, Method 1, revised September 1978.

Limitations and Precautions: The reader should see the literature.

9.6.4.3.5 Carbon, Total Organic and inorganic

Purpose: This test is used to determine the total organic carbon and/or the total inorganic carbon content of the soil. Carbon may exist in sediment and water samples as either inorganic or organic compounds. inorganic carbon is present as carbonates and bicarbonates and possibly as free carbon dioxide. Specific types of organic carbon compounds are nonvolatile organic compounds (sugars), volatile organic compounds (mercaptans), partially volatile compounds (oils), and particulate carbonaceous materials (cellulose).

Synopsis: The basis of the method Is the catalytic or chemical oxidation of carbon in carbon-containing compounds to carbon dioxide, followed by the quantification of the carbon dioxide produced. Alternately, the carbon may be reduced to methane and appropriately quantified. it then follows that the distinction between inorganic carbon and organic carbon Is the method of sample pretreatment. There are presently two procedures for defining this separation. One method Is based on sample treatment with a strong acid. Analysis of an untreated sample is a measure of, total carbon, while analysis of the acid-treated fraction is a measure of organic carbon. Inorganic carbon is calculated by subtraction. The second method of separation Is based on differential thermal combustion with organic compounds being converted to carbon dioxide at 500% to 650°C, and inorganic carbon being converted to carbon dioxide at 950°C to 1,300%.

Methods: Procedures for Handling and Chemical Analysis of Sediment and Water Samples, Russell H. Plumb, U.S. EPA and Army Corps of Engineers' Technical Committee on Criteria for Dredged and Fill Material, Contract EPA-4805572010.

9.6.4.3.6 sulfides

Purpose: This test is used to measure the concentration of total and dissolved sulfides.

Synopsis: Excess iodine is added to a sample, which may or may not have been treated with Zinc acetate, to produce zinc sulfide. The iodine oxidizes the sulfide to sulfur under acidic conditions. The excess iodine is back-titrated with Sodium thiosulfate or phenylarsine oxide.

Methods: EPA SW-646, Test Methods for Evacuating Solid Waste, Method 9030; EPA Method 376(1979).

Limitations and Precautions: The method does not measure acid insoluble sulfides; copper sulfied is the only common acid-insoluble sulfide.

The method Is suitable for measuring sulfide in concentrations above 1 mg per liter. Reduced sulfur compounds that decompose in acid, such as sulfite, thiosulfate, and hydrosulfite, may yield erratic results. Also, volatile iodine-consuming substances will give high results. Samples must be taken with a minimum of aeration to avoid volatilization of sulfides and reaction with oxygen that may convert sulfide to unmeasurable forms. If the sample is not preserved with zinc acetate, analysis must start immediately.

9.6.4.3.7 Total Nitrogen

Purpose: This testis used to determine the total nitrogen content of the soil.

Synopsis: in the micro-Kjeldahl method, the nitrogen in different forms is converted to the ammonium ion by digestion in sulfuric acid. The digest is distilled, and the distillate is titrated for the ammonium content from which the nitrogen content can be calculated.

Methods: Methods of Soil Analysis used in the Soil Testing Laboratory at Oregon State University, Special Report 321, Agricultural Experiment Station, Oregon State University, Corvallis, Method 3, revised September 1978.

9.6.4.3.8 Extractable Phosphorus

Purpose: This test is used to determine the amount of phosphorus that can be extracted with a sodium bicarbonate solution from the soil.

Synopsis: The sodium bicarbonate extract of the soil is treated with a completing agent; the phosphorus complex is determined colorimetrically.

Methods: Methods of Soil Analysis Used in the Soil Testing Laboratory at Oregon State University, Special Report 321, Agricultural Experiment Station, Oregon State University, Corvallis, Method 15, revised September 1978.

I-Imitations and Precaution: The pH of the $NaHC0_3$ solution increases overtime when exposed to the atmosphere. When the pH of the extractant exceeds 8.5, a notable increase in extractable soil is anticipated. A thin layer of mineral oil that is spread over the surface of the extracting solution will effectively decrease the rate at which the pH will change. Chemical reactions that tend to decrease the activity or concentration of soluble Ca, Al, and Fe will allow for a potential increase in soluble phosphate. The amount extracted is also dependent on the shaker time and temperature.

9.6.4.3.9 Total Phosphorus

Purpose: This test is used to determine the total phosphorus content of the soil after digestion.

Synopsis: Numerous methods are available for the digestion of sediment samples to be analyzed for phosphate. Most procedures consist of strong acid digestion or treatment with an oxidizing agent and a strong acid. A common feature of the digestion procedures is that the sample treatments are designed to convert all the phosphate compounds to orthophosphate. The orthophosphate is then quantified colorimetrically.

Methods: Procedures for Handling and Chemical Analysis of Sediment and Water Samples, Russell H. Plumb, U.S. EPA and Army Corps of Engineers' Technical Committee on Criteria for Dredged and Fill Material, Contract EPA-4805572010.

Limitations and Precautions: The reader should see the test method.

9.6.4.3.10 Mineralogy

Purpose: This test is used to determine the mineral characteristics of soil.

Synopsis: The most widely used techniques in mineral identification and composition determination are X-ray diffraction and optical techniques; the underlying principles are beyond the scope of this compendium. References are given in Subsection 9.8.

Methods: Ford, W. E. *Dana's Textbook of Mineralogy, Optical Techniques.* 4th ad. New York:- John Wiley and Sons. 1966.

Hurlburt, C. S., Jr. *Manual of Mineralogy,* 19th ad. New York John Wiley and Sons. 1977.

"X-Ray Diffraction Techniques for Mineral Identification and Mineralogical Composition," Method *of* Soil *Analysis, Agronomy Monograph No. 9,* Part 1, American Society of Agronomy, 1965. (The second edition of this reference is soon to be published.) This reference provides qualitative and semiquantitative soil mineralogical analyses.

Limitations and Precautions: The reader should see the methods.

9.6.5 Compatibility Testing

Materials considered for hazardous waste applications should be analyzed for compatibility with the wastes. The analyses should determine the changes in material properties caused by contact or exposure to wastes. Materials of concern for compatibility may include natural materials (e.g., soils and rock) and synthetic materials (e.g., construction materials).

Although analytical methods are being developed, few standards for compatibility testing exist at present. Decision-makers must use their judgment and experience in evaluating the need for, and use of, compatibility test data. Those laboratories conducting the testing must be appropriately staffed and equipped. The test method must clearly document the test scope, limitations, and materials used, and provide quantification of the degree of alteration and projected useful life of the material.

In general, compatibility testing involves rational use of both chemical tests and tests of physical properties (see Subsections 9.6.3 and 9.6.4) to assess the effects of wastes on the materials. Chemical analyses may be used to determine the types and concentrations of wastes to which the material is subjected. The aggressive substance in a hazardous waste may be of low total concentration, but the substance may accumulate in a particular phase or level in the waste. Under such conditions, the concentration level may be high enough to act aggressively. Physical tests provide the basis for measuring resultant changes.

The following discussions are not intended to be all-encompassing, but they should heighten general awareness about potential effects on various materials. Specific needs and details of such testing must be evaluated on a site-specific basis.

9.6.5.1 Soil

The compatibility of soils with wastes is primarily concerned with the effects of the presence of liquid wastes in the pore fluids of the soils. Compatibility effects may include chemical alteration of the soil itself or alteration of soil properties, such as Permeability, compressibility, and strength (since many of the properties of soils depend on the characteristics of the pore fluids).

9.6.5.1.1 Clay

Clay has traditionally been used for water containment because of the low permeability of most clays and clay mixtures. Recent evidence suggests that permeability and other properties are altered by liquid contaminants. Clays are subject to alteration by organic chemicals, pH changes, ion exchange, and so forth.

9.6.5.1.2 Silt

Silt is a major constituent of alluvial soils and usually appears in combination with various amounts of clay and sand. The parent material from which the silt is derived will influence the effects of wastes on the alteration of silts. concern for the alteration of silts relates more to structural and strength property changes, than to chemical changes.

9.6.5.1.3 Sand

Sand used for bedding and drainage media must be evaluated for alterations that may affect its structural and fluid conductivity suitability. Tests using the liquid phase of hazardous wastes on sands to determine leaching, permeability, strength, and particle size changes should be performed.

9.6.5.1.4 Gravels and Aggregates

Gravels used for structural and drainage systems must be evaluated for alterations that may affect their suitability. Aggregates used in Portland cement and asphaltic concrete products should be evaluated in the same manner as the gravels and sands.

9.6.5.2 Rock

m situ properties of rocks underlying or adjacent to hazardous wastes should be evaluated for potential effects of exposure to wastes. Alteration of strength, permeability, competence, and so forth should be considered.

Samples of rock removed from the site will be useful in determining some physical and chemical property changes in contact with wastes. However, the value of that determination is limited. The overriding concern should be with the behavior of the rock mass as a unit.

9.6.5.3 Materials

9.6.5.3.1 Concrete

Cast-in-place and precast concrete products to be used in hazardous waste control systems must be evaluated for effects caused by the waste materials. The effects of some chemicals are known to cause expansion, cracking, spelling, surface deterioration, and dissolution of cement paste or matrix. A few standard methods for resistance of concrete to some chemical and physical stresses may be found in ASTM Vol. 04.02.

9.6.5.3.2 Soil-Cement

Minor amounts of Portland cement may be added to soils to strengthen them and to reduce permeability of soil materials. An evaluation of the soil-cement system, using specimens from the mix-design procedures, must be made using contaminated soils or Involving hazardous waste materials. Cement is often used to solidify contaminated materials. The solidification procedure should be evaluated for properties to remain within an allowable range over the long term.

9.6.5.3.3 Portland Cement

There are many types of Portland cement and blended hydraulic cements. Some have properties that may be more or less resistant to chemical exposure to hazardous wastes. The compatibility of the cement products must be assessed and evaluated to make successful Portland cement concrete.

9.6.5.3.4 Asphalt Cement

Many types of bituminous products or asphalt cement are used to control leakage. The alteration of properties, such as impermeability, by hazardous wastes must be evaluated to determine product suitability. Evaluation may involve visual observation of changes, as well as physical property changes measured according to ASTM procedures.

9.6.5.3.5 Asphalt Stabilized Soils

Asphaltic cement maybe added to soils for strengthening and reducing permeability. The appropriateness of this method must be evaluated by testing with hazardous waste to determine the alteration of the stabilized soil’s properties.

9.6.5.3.6 Metal Products

Metal products are mentioned in this subsection to draw attention to any materials that maybe buried in soil or contaminated soil or exposed to hazardous wastes. Since exposure of metal products to hazardous waste materials is possible, the corrosion, deterioration, and alteration of the product or its function must be evaluated to determine the most suitable material or the need for an alternative.

9.6.5.3.7 Plastic Products

A broad range of material compatibility information for plastics is available from manufacturers. The potential exposure of plastics to hazardous waste must be defined and the most suitable products tested. Adaptations of the U.S. EPA SW-846 Test Methods for Evaluating Soil Waste, Method 9090 for Flexible Membrane Liners, may be considered fortesting plastics:

9.6.5.3.8 Wood Products

Wood products and lumber that may be subjected to hazardous waste should be evaluated before use. Such evaluation is especially important if wood and lumber products are to be used structurally. _

9.6.5.3.9 Geotextiles

The use of woven and nonwoven geotextiles is common in hazardous waste facilities. The functions these synthetic fibrous materials provide may be altered by exposure to wastes. Geotextiles should be tested and evaluated for their continued ability to provide the functions required. The nature of geotextiles presents a challenging task to the development of meaningful test methods. The U.S. EPA, SW-846 Test Methods for Evaluation Solid Waste, Method 9090, may provide some guidance.

9.6.5.3.10 Geomembranes

Flexible membrane liners or geomembranes are 10- to 100-mil thick sheets of polymeric materials. Compatibility test information and results for most polymeric materials are available from the manufacturers and some independent sources. An accepted method of test for geomembranes is the U.S. EPA Method 9090. Properties of membrane specimens are determined before and after soaking in the hazardous waste liquid, extract, or leachate. Another recommended test method for estimating long-term performance of membrane liners in a chemical environment Is provided in Appendix D of National Sanitation Foundation (NSF) Standard 54 for Flexible Membrane Liners.

9.6.5.3.11 Synthetic Drainage Media

In place of sand and gravel drainage systems, synthetic drainage media may be used. The synthetic media may be separated from the soil above and below by a geotextile fabric. The media may be polymeric mesh mat-like material with favorable strength and hydraulic properties. The material should be evaluated using methods similar to those used for geomembranes, since the materials used are similar.

9.6.6 Laboratory and Analyses Records

A general description of the laboratory recording procedures Is presented below. Specific requirements may be established as contractual obligations with the laboratories (e.g., U.S. EPAs CLP). The user should be familiar with the contractual obligations for sample and data recording when using contract laboratories. Review of existing CLP recording requirements is beyond the scope of this subsection.

9.6.6.1 Sample Log

All samples should be recorded upon receipt at the laboratory. The sample should be logged into a bound record book and assigned a sequential identification number. The log should be used to track the sample through the laboratory by recording date received, date and location stored, date tested, and date disposed of. Chain of custody should be maintained on all samples throughout the process (see Sections 4, 5, and 6). The numerical identification should be used on all laboratory record sheets, together with other pertinent information such as project name and number and case number.

9.8.6.2 Data Sheets

The ‘data and analysis results for each sample should be recorded on data sheets as the test is conducted. The format for specific test sheets may fallow those presented in the ASTM standards, as applicable. Data sheets should be developed and consistently used for tests that do not have standards.

At a minimum, the fallowing identifying information should be provided on each data sheet:

- Project name and number
- EPA authorization number or case number
- Sample identifier (number, location, depth, and name of sampler)
- Date of laboratory analysis
- Laboratory and analyst names

In addition to the identifying information, the data sheet should refer to the standard used including a specific statement of any deviations from the standard. Where standards are not available, a detailed description of the test method should be attached with the data sheets.

The data section of the sheet should be legibly completed without erasures. Any changes to the data should be done by crossing out the original entry, writing in the correction, and initialing it.

Calculations should be orderly and should be done on the data sheet or attached separately. Calculations should follow the same guidelines as for data recording (i.e., it should be legible without erasures).

9.6.6.3 Recordkeeping

Originals of all laboratory sheets and records should be retained in a secure file by the analyzing laboratory. Legible copies should be provided to EPA and its contractors, as required.

In addition to data sheets, all pertinent correspondence, chain-of-custody records, quality assurance records, and other records should be retained. Originals should be retained for the duration of the project including completion of any litigation.

9.7 REGION-SPECIFIC VARIANCES

Many of the methods and procedures discussed in this subsection have not been accepted as standard by the EPA CLP. Because information on variances is rapidly dated, users should consult with the laboratory in each EPA region to obtain clarification of specific regional variations. Changes in variances will be included in Revision 01 to this compendium.

9.8 INFORMATION SOURCES

Oregon State University. *Method of Soil Analyis Used in the Soil Testing Laboratory at Oregon State University.* Special Report 321, Agricultural Experiment, Station. Corvallis, Oregon. Revised September 1978.

American Concrete Institute, Chapter 318.

American Society for Testing and Materials. 1984 *Annual Book of ASTM Standards.* Section *4:* Construction. Vol. 04.08, 1964, and Vol. 08.01 and 09.02. 1984.

Bower, C. A., and L V. Wilcox. "Soluble Salts." *Method of Soil Analysis, Part 2,* Chapter 62. American Society of Agronomists. Madison, Wisconsin. 1965. pp. 933-961.

Bremner, J. M. "Total Nitrogen." *Methods of Soil Analysis, Part 2* Chapter 83. American Society of Agronomists. Madison, Wisconsin. 1966. pp. 1143-1176.

Ford, W. E. "Optical Techniques," *Dana's Textbook of Mineralogy.* 4th ed. New York: John Wiley and Sons. 1966.

Grewling, T. and M. Peach. "Chemical Soil Tests." *Cornell University Agricultural Experimental Station Bulletin 960. 1960.*

Hurlburt, C. S., Jr. *Manual of Mineralogy.* 19th ed. New York John Wiley and Sons. 1977.

Jackson, M. L. Soil Chemical Analysis. Englewood Cliffs, New Jersey Prentice Hall. 1958. pp. 151-154.

Lambe, T. W. *Soil Testing for Engineers.* New York John Wiley and Sons. 1951.

Lambe, T. W., and R.V. Whiteman. *Soil Mechanics. New* York: John Wiley and Sons. 1969.

McWhorter, David B. and Daniel K. Sunada. *Groundwater Hydrology and Hydraulics.* Ann Arbor, Michigan: Water Resources Publications. 1977.

National Association of Corrosion Engineers. *Laboratory Corrosion Testing of Metals for the Process Industries.* Houston, Texas: NACE Standard TM-011-69 (1972 Revision).

Natural Sanitation Foundation. Standard *54 for Flexible Membranes. 1983.*

Obert, L, and W.I. Duvall. Rock Mechanics and the Design of Structures in *Rock New* York: John Wiley and Sons. 1967.

Obert, L, S. L Windes, and W. 1. Duvall. “standardized Tests for Determining the Physical Properties of Mine Rock.” U.S. *Bureau of* Mines *Report of Investigations 3891.* U.S. Government Printing Office, Washington, D.C. 1946.

Olsen, S. R., et al. “Estimation of Available Phosphorous in Soils by Extraction with Sodium Bicarbonate.” USDA Circular No. 939. 1954.

Olsen, S. R., et al. “Phosphorous.” Methods of Soil Analysis, *Part 2,* Chapter 73. American Society of Agronomists. Madison, Wisconsin. 1965. pp. 1035-1048.

Peck, R. B., W. E. Hanson, and T. H. Thornbum. *Foundation Engineering. 2nd ed. New* York John Wiley and Sons. *1974.*

Plum, Russell H. Procedures *for Handling and Chemical Analysis of Sediment and Water Samples,* U.S. EPA and Army Corps of Engineers Technical Committee on Criteria for Dredged and Fill Material, Contract EPA-*4805572010.*

Pratt, P. F. “Potassium.” Methods of Soil Analysis, Part *2, Chapter 71.* American Society of Agronomists. Madison, Wisconsin. 1965. pp. 1022-1030.

Richards, L A “Diagnosis and Improvement of saline and Alkali Soils.” USDA *Handbook 60.* U.S. Salinity Laboratory. 1954.

Schollenberger, C. J., et al. “Determination of Exchange Capacity and Exchangeable Bases in Soil-Ammonium Acetate Method.” Soil/Science, Volume 59, 13-24. 1945.

U.S. Army Corps of Engineers. ‘Laboratory Soil Testing.” *Engineer Manual EM 1110-2-1906* Department of the Army, Office of the Chief of Engineers. Washington, D.C. 30 November 1970.

U.S. Bureau of Reclamation. *Earth* Manual. 2nd ed. U.S. Government Printing Office. Washington, D.C. 1974.

Methods and Procedures

ASTM 1635-63 (preapproved 1979), flexural Strength of Soil-cement Using Simple Beam with Third-Point Loading.

ASTM 1682-64 (1975), Test Methods for Breaking Load and Elongation of Textile Fabrics, 07.01.

ASTM C 39-83b, Compressive Strength of cylindrical Concrete Specimens.

ASTM C 78-84, Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading). .

ASTM C 88-83, Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate.

ASTM C 150-84, Portland Cement, and ASTM C 595-83, Blended Hydraulic Cements.

ASTM C 170, compressive Strength of Natural Building Stone.

ASTM C 178-78, Air Content of Freshly Mixed Concrete by the Volumetric Method.

ASTM C 231-82, Air Content of Freshly Mixed Concrete by the Pressure Method.

ASTM C 293-79, Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading) (not an alternative to C 78-84).

ASTM C 496-71 (preapproved 1979), Splitting Tensile Strength of cylindrical Concrete Specimens.

ASTM C 642-82, Specific Gravity, Absorption, and Voids in Hardened Concrete.

ASTM C 9951, Modulus of Rupture of Natural Building Stone.

ASTM C 9783, Standard Test Methods for Absorption and Bulk Specific Gravity of Natural Building Stones.

ASTM D 93-85, Test Methods for Flash Point by Pensky-Martens Closed Tester.

ASTM D 297, D 412, D 624 (for rubber).

ASTM D 422-63 (reapproved 1972), Particle-Size Analysis of Soils.

ASTM D 425-79, Centrifuge Moisture Equivalent of Soils.

ASTM D 558-82, Moisture-Density Relations of Soil-Cement Mixtures.

ASTM D 559-82, Wetting-and-Drying Tests of Compacted Soil-Cement Mixtures.

ASTM D 560-82, Freezing-and-Thawing Tests of Compacted Soil-Cement Mixtures.

ASTM D 584-83, Specific Gravity of Soils.

ASTM D 638, D 972, D 1004, D 1204, D 3083 (for plastics).

ASTM D 853-82, Standard Definitions of Terms and Symbols Relating to Soil and Rock Mechanics.

ASTM D 898-78, Moisture-Density Relations of Soils. ,

ASTM D 898-78, Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb Rammer and 12-in. Drop.

ASTM D 751 (for supported geomembranes).

ASTM D 751-79, Methods of Testing Coated Fabrics, 09.02.

ASTM D 808-74 (reapproved 1979), Cement content of Soil-Cement Mixtures.

ASTM D 882 (for thin plastic).

ASTM D 1117-80, Methods of Testing Nonwoven Fabrics, 07.01.

ASTM D 1557-78, Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb. Rammer and 18-in. Drop.

ASTM 01558-71 (reapproved 1977), Moisture-Penetration Resistance Relations of Fine-Grained Soils.

ASTM D 1587-83, Thin-Walled Tube Sampling of Soils.

ASTM D 1593 (for polyvinyl chloride).

ASTM D 1632-63 (reapproved 1979), Making and Curing Soil-Cement Compression and Flexure Test Specimens in the laboratory.

ASTM D 1633-43 (reapproved 1979), Compressive Strength of Molded Soil-Cement cylinders.

ASTM D 1834-83 (reapproved 1979), Compressive Strength of Soil-Cement Using Portions of Beams Broken in flexure (Modified Cube Method).

ASTM D 1777-64 (reapproved 1975), Method for Measuring Thickness of Textile Materials, 07.01:

ASTM D 1883-73 (reapproved 1978), Bearing Ratio of Laboratory-Compacted Soils.

ASTM D 2188-88 (reapproved 1979), Unconfined Compressive Strength of Cohesive Soil.

ASTM D 2218-80, Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures.

ASTM D 2325-68 (reapproved 1981), Capillary-Moisture Relationships for Coarse and Medium-Textured Soils by Porous-Plate Apparatus.

ASTM D 241974 (reapproved 1979), Sand Equivalent Value of Soils and Fine Aggregate.

ASTM D 2434-58 (reapproved 1974), Permeability of Granular Soils (Constant Head).

ASTM D 2435-80, One-Dimensional Consolidation Properties of Soils.

ASTM D 2487-83, Classification of Soils for Engineering Purposes.

ASTM D 2488-69 (reapproved 1975), Description of Soils (Visual-Manual Procedure).

ASTM D 2850-82, Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression.

ASTM D 2901-82, Cement Content of Freshly Mixed Soil-Cement.

ASTM D 2936-78, Direct Tensile Strength of intact Rock- Core Specimens.

ASTM D 3080-72 (reapproved 1979), Direct Shear Test of Soils Under Consolidated Drained Conditions.

ASTM D 3152-72 (reapproved 1977), Capillary-Moisture Relationships for Fine-Textured Soils by Pressure-Membrane Apparatus.

ASTM D 3550-77, Ring-Lined Barrel Sampling of Soils.

ASTM D 3740-80, Standard Practice for the Evaluation of Agencies Engaged in the Testing and/or inspection of Soil and Rock as Used in Engineering Design and Construction.

ASTM D 3775-84, Test Method for Fabric Count of Woven Fabric, 07.01

ASTM D 3773-84, Test Method for Length of Woven Fabric, 09.02.

ASTM D 3774-84, Test Method for Width of Woven Fabric, 07.01.

ASTM D 3776-84, Test Methods for Weight (Mass) per Unit Area of Woven Fabric, 07.01.

ASTM D 3782-80, Test Method for Bow and Skewness (Bias) in Woven and Knitted Fabrics, 07.01.

ASTM D 3783-80, Test Method for Fabric Crimp or Takeup of Woven Fabrics, 07.01.

ASTM D 3786-80a, Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method, 070.

ASTM D 3967-81, Splitting Tensile Strength of intact Rock-Core Specimens.

ASTM D 4223-83, Preparation of Test Specimens of Asphalt-Stabilized Soils.

ASTM D 4253-83, Maximum Index Density of Soils Using a vibratory Table

ASTM D 4254-83, Minimum Index Density of Soils and calculations of Relative Density.

ASTM D 4318-83, Liquid Limit, Plastic Limit, and Plasticity Index of Soils.

ASTM E 329-77, Standard Recommended Practice for Inspection and Testing Agencies for Concrete, Steel, and Bituminous Materials as Used in construction.

Anderson, C. H., et al. Preliminary Interim Procedure for Fibrous Asbestos. U.S. EPA Analytical Chemistry Branch, Athens, Georgia. July 1976.

Plumb, Russell H. Procedures for Handling and Chemical Analysis of Sediment and Water Samples. U.S. EPA and Army Corps of Engineers' Technical Committee on Criteria for Dredged and Fill Material, Contract EPA-4805572O1O.

Shrestra, Sharad, and J.R. Bell. "Tensile and Creep Behavior of Geotextiles." Transportation Research Report 81-30. Oregon State University. January 1981.

U.S. Department of the Army, Corps of Engineers. Plastic Filter Fabric. CW 02215. November 1977.

U.S. Environmental Protection Agency. The Interim Method for Determination of Asbestiform Minerals in Bulk Insulation Samples. 1 June 1980. "

U.S. Environmental Protection Agency. "Test Methods for Evaluating Solid Waste." Methods 9030, 9045,9010, 7040-7951,3010-3080, 8010-8310,3510,3550, 1310, 1110, 1010, 1020, and Section 21.3. EPA SW-848.

SECTION 10

SURFACE HYDROLOGY

Note: This section is organized by the topics "Flow Measurement" and "Sampling" for greater usefulness.

10.1 FLOW MEASUREMENT

10.1.1 Scope and Purpose

This subsection provides general guidance for the planning, method selection, and implementation of surface flow measurements for hazardous waste site field investigations that require information on flows for streams, rivers, or surface impoundments.

10.1.2 Definitions

Flow (or Volumetric Flowrate)

‘ That volume of water which passes through a cross-sectional plane of a channel in some unit of time.

Flow Measurement

The act or process of quantifying a flowrate.

Site Manager (SM)

The individual responsible for the successful completion’ of a work assignment within budget and schedule. This person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

10.1.3 Applicability

This subsection discusses general and special flow-measurement techniques that may be applied to the majority of site field investigations. There is no universally applicable procedure, because flows must be measured under a variety of conditions. For any given site, the technique selected must be appropriate for that site's specific conditions. For example, the choice of flow-measurement device can depend on the following criteria:

- Is the flow continuous or intermittent?
- Is the flow channel open or closed?
- What is the channel geometry
- Are there hydraulic discontinuities in the channel (standing waves, hydraulic jumps, dams, etc.)?
- Is there access to the channel at a suitable point for measuring flow?

- How often will flow measurements need to be made?

- Will the flow-measuring device require freeze protection or shelter?

- What water constituents may affect the reliability of the. flow-measuring device? For example, will sediment in the stream clog flow tubes?

- Would there be a need for installing a more permanent flow measuring device for long-term surveys?

- Are utilities (electrical, air, or clean water) available onsite?

The following discussions apply only to water moving from one point to another, not to surface water lying still in an impoundment or liquid waste pond. Such-water does" not fit the flow definition cited above. Flowing water moves because it has a sloping surface that is subject to the pull of gravity and/or a pressure head. This movement from point to point is opposed by frictional forces between the water and the sides of the channel. This friction leads to wide variations in velocity over the cross-sectional plane of the channel. No matter which flow-measurement technique or device is chosen, it will have to accurately account for these variations. Field crews conducting flow measurements must be made aware of the strengths and limitations that apply to any flow-measurement technique.

Another type of "flow" not covered by the following discussion may be tailed "overland flow" or "emergent subsurface flow," wherein water moves across a land surface without being constrained by definable, continuous channel boundaries. Examples of this type of flow occur during floods or heavy storm runoffs. **Such flows** are **mostly ephemeral, nonuniform, and very shallow. Since there is no definite cross-sectional measurement available, flow measurement** by any of the following methods is not practical. Problems related to quantification of such flows are discussed in the ***National Handbook of Recommended Methods for Water Data Acquisition*** compiled by the Department of interior's U.S. Geological Survey (USGS) staff.

10.1.4 Responsibilities

The SM is responsible for obtaining proper flow measurements. The most important tool in carrying out this responsibility is the site operations sampling plan. Details of this plan are site-specific, usually following a site reconnaissance by the site or field team leader.

The field team leader is responsible for implementing the requirements of the site operations sampling plan and for reporting any unusual conditions to the SM as soon as it becomes apparent that plan modifications may be needed. The field team leader must also make "certain that all required documentation is properly originated, maintained, completed, and forwarded to the proper authorities.

The field investigation team is responsible for the actual installation of the proper equipment and the performance of flow measurements. Selected members of the work crew must be familiar with the objectives, the site operations plan, the equipment designated for use, the Recordkeeping requirements, the appropriate safety measures, and the importance of accurate measurements.

10.1.5 Procedures

10.1.5.1 General Considerations

The planning, selection, and implementation of any flow-measurement program require careful consideration by qualified, experienced personnel. A preliminary site visit should be made to review actual conditions and to confirm or correct site plans, diagrams, or layouts.

The purpose of making flow measurements should be clearly defined before commencing this activity. Some common reasons for measuring flowrates include the following:

- Assessing impacts on receiving streams
- Acquiring data on flow volume, variability, and average rate to design and operate wastewater treatment facilities
- Determining compliance with load limitations placed on selected pollutants
- Flow-proportioning composites to comply with permit requirements that govern composite sampling
- Estimating chemical addition requirements or treatment coats for effective wastewater treatment
- Establishing the requirements for sampling frequency or the need for continuous monitoring of flowing streams

Whatever the reason for conducting flow measurements, the parties involved in such work must be made aware of the purpose, so that their contribution to this effort will be better defined. Moat of the techniques described below depend on two critical measurements:

- The geometry of the cross-sectional plane through which the water is passing
- The velocity at which the water is moving, typically expressed In terms of length per unit of time (e.g., meters per second, feet per second)

At times, the velocity may drop to zero and the water may stand still. This phenomenon further divides surface flows into two distinct types: intermittent and continuous. The flow-measurement method chosen must be able to account for periods of zero flow whenever they occur. The measurements themselves may be made continuously using automatic instruments or intermittently by manual methods. Human observers must be aware of flow variations including periods of no flow. But other factors, such as the cost, accessibility, climate, available time for measurements, and the relative accuracy of measurement desired, will also contribute heavily to the choice of method used. The type of measurement technique used will ultimately depend on conditions encountered at each location.

10.1.5.2 Methods and Applications: General

Selection and implementation of flow-measurement practices require that consideration be given to the following Issues that are common to all surface flow measurements at or near hazardous waste sites:

- Preventing the spread of contamination
- Minimizing the risk to health and safety
- Maintaining a high level of accuracy in measuring flows
- Causing the least possible disruption to onsite activities
- Reporting all readings In an organized fashion as required by the sampling plan
- Reducing, where possible, any additional long and short-term impacts

For most sites, flow measurements are made in open channels that consist of a bed, two banks or sides, and a free or open water surface. The term also may apply to water movement through closed conduits or sewers that are flowing only partially full. The most typical cross-sectional shape encountered is either circular or rectangular. On occasion, measurements are taken in pressurized closed channels that are completely full of water at a pressure greater than atmospheric, either because of gravity or the use of pumps. Some of the measurement techniques described in the following discussion, are applicable only to open channels, while others work only In closed channels. Some may be used in either type of channel. Also, some methods are best suited for making single measurements, while others work best on a continuous basis. Individual site conditions will determine the user's options. The most appropriate option is selected and incorporated Into the site sampling plan. ,

Most flow measurements are based on determining two key variables cited in Subsection 10.1.5.1: cross-sectional area and velocity across that area. For open channels, especially the smaller ones, the cross section is often best measured directly using a meter or yardstick and weighted chains or lines. Care must be taken to find a location where the dimensions are not likely to change during the time period in which flow measurements will be taken. Width and depth are expressed in terms of meters or feet, and the cross-sectional area is expressed as square meters or square feet.

Velocity is determined using one of the methods that follow, either directly or by calculation, from head differential or pressure differential relationships. Units are commonly given in meters/see or feet/sec for most flow velocities. When cross-sectional area and flow velocity are multiplied, their product is the volumetric flowrate, expressed as cubic meters/see or cubic feet/see for large flows and as liters/see or gallons/mil for small flows.

At times. the entire flow from a discharge pipe or a notched weir or dam can be caught In a collector of known volume, such as a 5-gallon can or 55-gallon drum. By clocking the amount of time needed to fill the vessel, one may obtain a direct measurement of volumetric flowrate without resorting to cross-sectional area and velocity measurements. A minimum of 10 seconds to fill the container is recommended. Several fill-ups should be timed, and the results should be averaged to improve the quality of this measurement. But other means of flow measurement will be used more often than this direct estimate, which is valid only for flows between 0.06 liter/see (1 gallon per minute (gpm)) and about 6.3 liter/see(100 gpm).

The equipment listed in this subsection is the most commonly used at hazardous waste sites. For selected special applications, the reader should refer to Subsection 10.1.5.3.

Current Meter A current meter can be a mechanical device with a rotating element that, when submerged in a flowing stream, rotates at a speed proportional to the velocity of the flow at that point below the surface. The rotating element may be either a vertical shaft or a horizontal shaft type. Meter manufacturers usually provide the **user with calibration tables to translate rotation into linear speed in meters/see or** feet/sec (Price, undated).

Current meters can also be electromagnetic sensors where the passage of fluids between two electrodes in a bulb-shaped probe causes a disturbance of the electromagnetic field surrounding the electrodes. This disturbance generates a small voltage that can be made proportional to fluid velocity by internal electronic circuitry. A direct readout of velocity in meters/see or feet/see is provided for the user (Marsh-McBirney, undated).

Applicability: Vertical axis meters are more commonly used because they are simpler, more rugged, and easier to maintain than horizontal shaft meters. They also have a lower threshold velocity, on the order of 0.03 meters/see (O. 1 feet/sec). The electromagnetic current meters can be used In making measurements in situations where mechanical meters cannot function, such as weedy streams where mechaical rotating elements would foul. However, the electromagnetic meters must always be carefully aligned to be normal to the stream cross section, since the meter measures only one velocity vector (the one parallel to the probe’s longitudinal axis). Current meters will operate at depths ranging from 0.1 meter (0.3 feet) to any depth where the meter can be held rigidly in place using cables or extension poles. For most hazardous site investigations, depths rarely exceed 2 or 3 meters (6.5 to 10 feet). Since current meters provide readings at a single point, the mean velocity must be based on multiple readings along a vertical line, or on a single reading that can be converted to an estimated mean velocity using standard coefficients. Methods for estimating mean velocity include the following:

- Six-tenths depth method-Uses **the observed velocity at a** point 0.6 of the total depth below the surface as the mean velocity for the vertical. Flow is calculated **for each subsection** defined by the verticals and is the product of the depth times the mean velocity for that subsection. Total discharge flow is the sum of all individual subsection flows, while the average stream velocity is that sum (total discharge) divided by the total cross-sectional area. The number of readings to be taken to increase accuracy will depend on the width of the’ stream, from 2 or 3 for streams less than 5 feet across to 15 to 25 for streams wider than 50 feet across. ideally, the stream should be partitioned into sections small enough that less than 10 percent of the total stream flow passes through each section. In this manner, individual measurements that may be in error will have less Impact on the overall average velocity determination. However, practical consideration, such as a rapidly changing stage or limited time available to conduct measurements, often may preclude the use of the ideal **number of partial sections. Users must** recognize the potential impact on the overall accuracy of velocity measurements from an inadequate number of verticals within a given cross section. This method works best at depths between 0.09 and 0.16 meters (0.3 to 2.5 feet) and is the method of choice when measurements must be made quickly.

- Two-point method – Measures velocities at 0.2 and 0.8 of the total depth below the surface. The average of the two readings is considered to be the average for the vertical. Several different verticals are averaged across the cross section. This method is more accurate than the six-tenths depth method, but it cannot be used at depths less than 0.76 meters (2.5 feet) because the observation points would be too near the surface and the streambed.

- Three-point method – Measures velocities at 0.2, 0.6, and 0.8 of the total depth below the surface. Readings at 0,2 and 0.8 are averaged; then that result is averaged with the reading at 0.6. This method provides a better mean value when velocities in the vertical are abnormally distributed, but it should not abnormally be used at depths less than 0.76 meters (2.5 feet).

- Vertical-velocity method - Primarily for deep channels, this method measures velocities at 0.1 depth increments between 0.1 and 0.9 of the total depth for several verticals. Because of the multiplicity of readings, this method is rarely used.

A step-by-step summary of a typical flow or discharge measurement is as follows:

- Assemble current meter and test for proper operation in accordance with the manufacturer's instructions. Collect data form or notebook, pencil, stopwatch, 50-foot tape, etc.

- Partition stream Into sections (with tag-line or bridge railing), visually observing the velocity and general flow of the stream. Enough stations should be established to prevent more than 10 per cent of the total discharge from passing through any individual partial section. Remember, the partial section in question is <u>not</u> the same as the interval between two successive stations. Mark stations appropriately. A check of measurements may Indicate the need for readjustment of the partitioned sections to upgrade the quality of the readings.

- Record stream stage as indicated by one of the staff gauges, and record this value on the water level recorder chart at the point of pen contact.

- Record a minimum of the following items on the data form or in the notebook:

    Project
    - Site
    Date
    Time at start of measurements
    - Stream stage at start of measurements
    Approximate wind direction and speed
    - General stream condition (e.g., turbid, clear, low level, floating debris, water temperature, type of streambed material, etc.)
    Other factors having a bearing on discharge measurements
    - Location of initial point
    Total width of stream to be measured
    Type of current meter and conversion factor, if applicable
    Name of investigator taking the above reading

- Determine the depth and mean velocity at the first station or "initial point" if the situation allows; record this information.

- Measure depth at the second station from initial point and record. Determine whether the velocity should be measured at the 0.6 depth from the surface (six-tenths depth method), at the 0.2 and 0.8 depths (two-point method), or by either of the other methods available. Calculate respective depths from the surface, measure the velocity at each point, and record these values.

- Continue to each successive station as rapidly as possible, following the same procedure,

- Determine the depth and mean velocity at the last station, or endpoint, and record.

- Record on the data form the ending time of this series of measurements and the stage, since the stage may have been changing during the measurements.

- Enter the ending stage value on the recorder chart at the point of pen contact. This information will illustrate the interval of time and stage variations during the cross-sectional measurements. Also enter the date and indicate that a calibration has taken place over this interval.

- Remove the tag-line (if used); rinse the current meter in clean water, if necessary allow the current meter to dry; then pack it away in its carrying case.

There are a few other comments regarding stream discharge calibrations that should be mentioned:

- Where practical, make the measurements with the investigator standing behind and well to the side of the meter.
- Avoid disturbing or standing along the streambed beneath the cross-sectional measuring points. This location is part of the control area and should remain constant, if possible, from calibration to calibration of the stream. This step is especially important if soft, mucky sediment is encountered somewhere along the cross section.
- Where possible, try to use the same cross section throughout the study period and during all of the stream calibrations. However, the number and position of statiors within the cross section may be changed, if necessary, to accommodate changing flow conditions.
- Always hold the wading rod vertical, and be aware of how V_{NORM} Is determined with each of the various types of meters, if it becomes necessary to switch meters during a calibration.
- Repeat the stream calibration at regular intervals throughout the study period to account for seasonal changes in streambank vegetation and streambed alterations that may affect measurements.

Once the mean velocity for each stream subsection is determined, that value is multiplied by the area of the subsection; the product is the volumetric flow through the subsection per unit of time. The total discharge rate is the **sum of all volumetric flows** for each subsection across the entire cross section of the stream. The reader should refer to USGS Water Supply Paper 2175 for additional information. (USGS, 1982). Customary **units are cubic meters/see** (cm ft/see) for large flows and liters/see (gal/roil) for small flows.

Current Meters **and Stage Gauges:** Where repeated measurements of a volumetric flowrate at a certain cross-sectional area are required, it is best to install a permanent stage gauge along the stream's back or side wall to facilitate measurement of the depth. The gauge should be a rigid rod or board, precisely graduated and firmly mounted with the streambed serving as a possible reference point. Where stream characteristics are such that significant bed erosion from scouring may be expected, it is best not to set the streambed as a zero point, because this could lead to confusion from generation of negative numbers for gauge height readings. An arbitrary datum plume should be selected that is below the elevation of zero flow expected for the stream site. Gauges may be mounted vertically (perpendicular to the stream surface) or may incline along the slope of the stream bank. Vertical gauges are simpler to construct and calibrate, while inclined gauges provide more accurate readings and are less likely to be damaged by material floating by. The gauge provides one of the measurements needed to estimate area. Width is fixed for channels with vertical sides and can be readily determined for other configurations. Velocity is determined using a current meter as described above.

Discharge rating curves can be used to define the. relationship between stage and stream discharge, and to allow conversion of stage hydrography to discharge hydrographs. The discharge calibration points are hand or machine plotted onto a log-log paper graph of stage versus stream discharge. Stream stage is plotted on the vertical Y axis, and stream discharge is plotted on the horizontal X axis. Ideally, enough calibrations are conducted over the full range of stage variations to allow a smooth hand-drawn curve to be drawn through these points on the graph. “

The slope and rate of change of slope may vary significantly over the length of this curve. At certain gauging stations, the slope of this curve may break sharply, or the distribution of points may require the construction of two partial curves rather than one continuous curve. These latter two situations would apply to more complex stage discharge relationships. It is the task of the investigator to derive a mathematical relationship that describes this curve as closely as possible (i.e., an equation). The development of an equation would allow calculation of discharge flow by simply plugging in the stream elevation. This equation will allow computerization of the process of converting stage records into discharge and will eventually allow conversion to volume by noting the time interval on the recorder chart at which this rate of flow applies.

More complicated rating relationships may be required at a particular gauging station. Discharge may be not only a function of stage but also a function of slope, rate of change of stage, or other variables specific to each site. Additionally, stage-discharge relationships are rarely permanent, and discharge calibrations should be carried out at periodic intervals to define the effects of various factors including the following:

- Scouring and deposition of sediment
- Alteration of streambed roughness as a result of the creation and dissemination of dunes, anti-dunes, ripples, and standing-wave features in sandy bottoms; the deposition of leaves and other debris during different seasons; and the seasonal variation in the growth of macrophytes
- Ice effects that may cause additional resistance to flow (If monitoring is carried out during the colder months, a complete ice-over and additional freeze will tend to constrict the stream channel with time and may increase the stage, when in fact the flow may not be increasing at all.)
- Human-related activities, such as upstream construction, recreation, etc.

Applicability: This method applies to sites where many flow measurements will be made over a long period of time. Care must be taken to maintain a known zero reference point elevation. The point does not have to be the stream's bottom. Where bed erosion over the course of flow measurements may become a problem, provisions must be made to recalibrate the gauge at regular intervals (e.g., weekly). The gauge is lowered or raised as necessary to conform with changing bed conditions, Calculation of flow rate is the same as in the preceding subsection for current meters alone.

Weirs: Weirs are commonly used flow measurement devices. They are relatively easy to install and inexpensive to construct. All weirs are deliberate restrictions inserted into an open channel or a partially full pipe to obstruct flow by forcing the weir through a calibrated cross section. The weir causes water to back up and create a higher level (head) than the level below the barrier. The height of that head is a function of the velocity of the flow. Standard tables and nomography are available for many different types of weirs, based on different general equations for each type. The reader should refer to Exhibit 10-1 for a typical profile of an installed weir.

The three most common weir configurations are triangular (or V-notch), rectangular, and Cipolletti (or trapezoidal). The reader should refer to Exhibit 10-2 for examples. Triangular weirs can have submerged angles of any size, but the most common angles are 22-1/2:, 30:, 45:, 60:, and 90:. Rectangular weirs may be designed with no end contractions (the water flows over the full width of the weir) or with contractions on one or both ends (water flows over a notch in the weir). The former case is referred to as a suppressed weir, but this type is often subject to problems when a vacuum develops under the nappe (the sheet of water breaking free from the crest of the weir). The most common type of rectangular weir is the contracted or notched weir with end contractions. Standard contracted weirs have two end contractions whose width is at least twice the maximum head expected above the weir crest. The Cipolletti weir has standardized end slopes of one horizontal to four vertical, which provide a correction for the contraction of the nappe over the crest. Other weir profiles exist, but they are much less common. The reader should refer to the flow-measurement references in U. S. Department of Interior (USDA), 1974; Instrument Specialists Company (ISCO), 1985; and USGS, 1982, for information on other types of weirs.

Exhibit 10-1
PROFILE OF SHARP-CRESTED WEIR

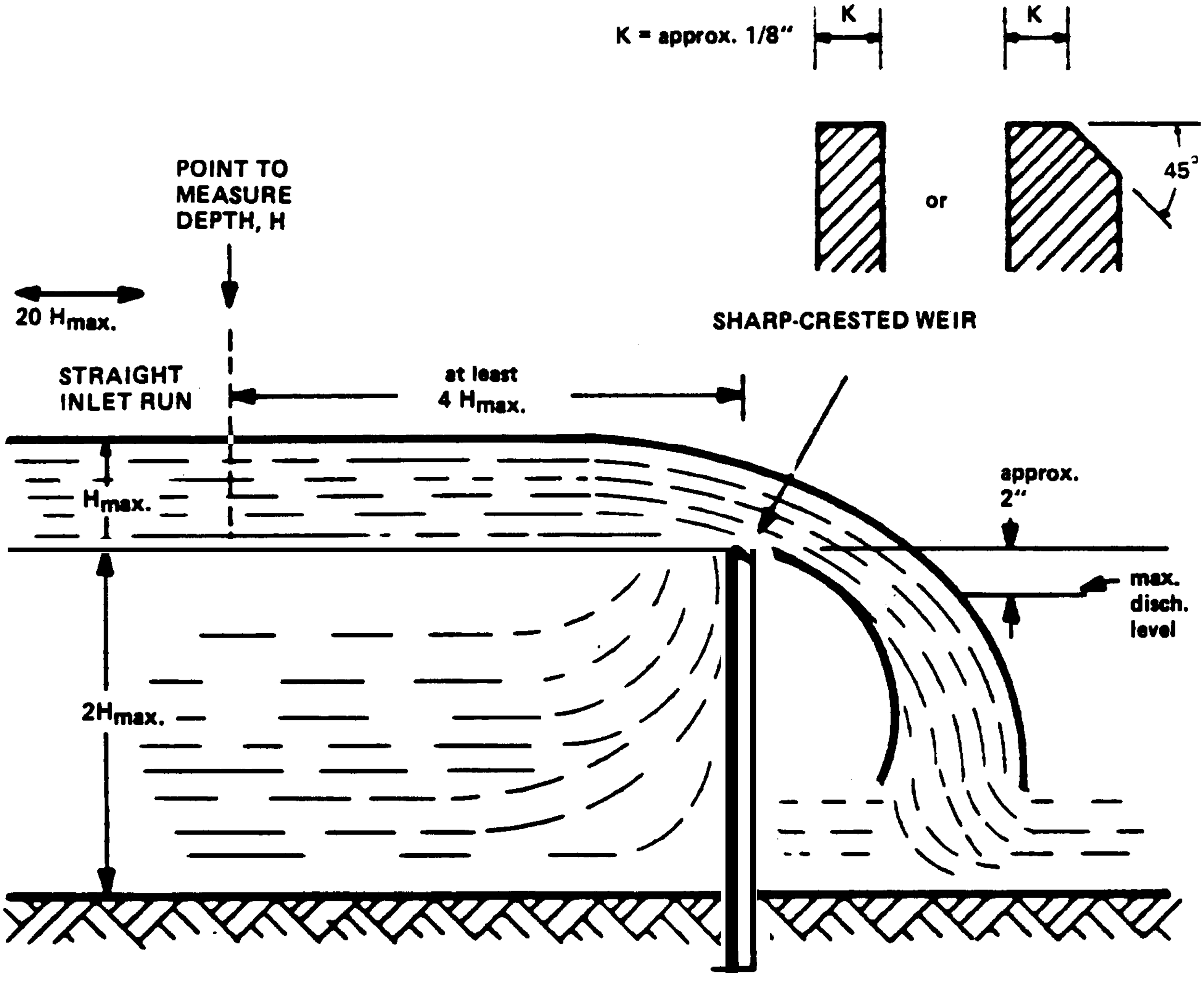
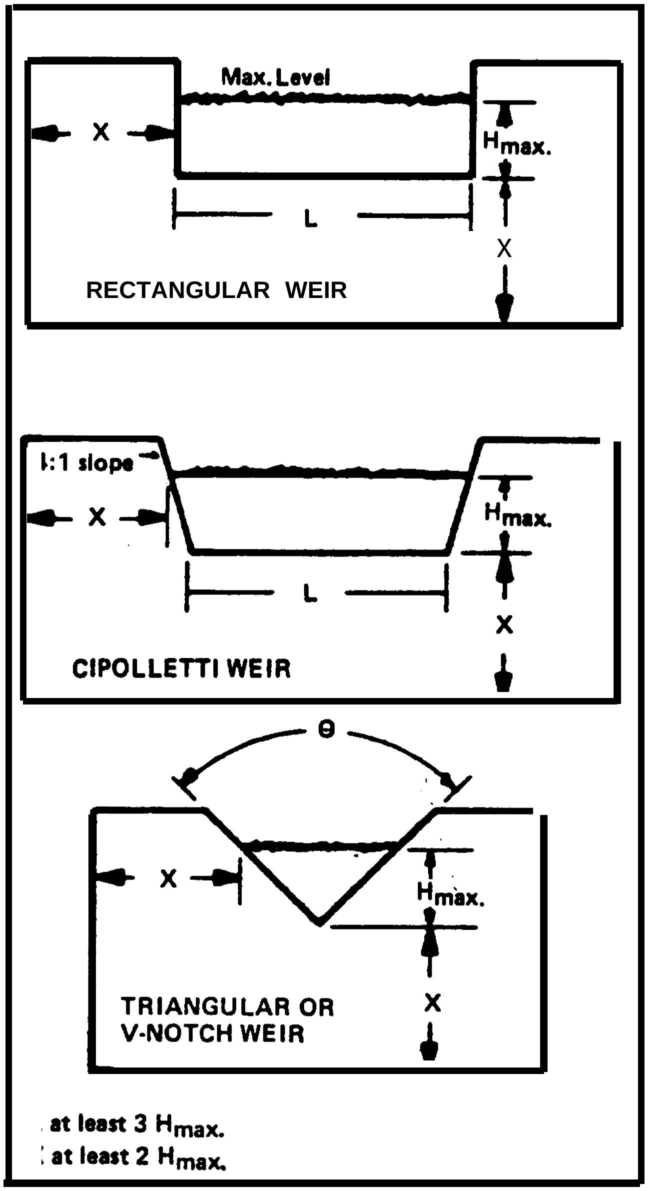


Exhibit 10-2

THREE COMMON TYPES OF SHARP-CRESTED WEIRS



Flumes: flumes are specially shaped open-channel flow sections with a restriction in channel area and, in most examples, with a change in channel slope. Either or both of these shape changes cause velocities to increase and water levels to change while passing through the flume. Typical flumes consist of three sections:

- A converging section to accelerate the approaching flow
- A throat section, whose width is used to designate flume size
- A diverging section, designed to ensure that the level downstream is lower than the level in the converging section

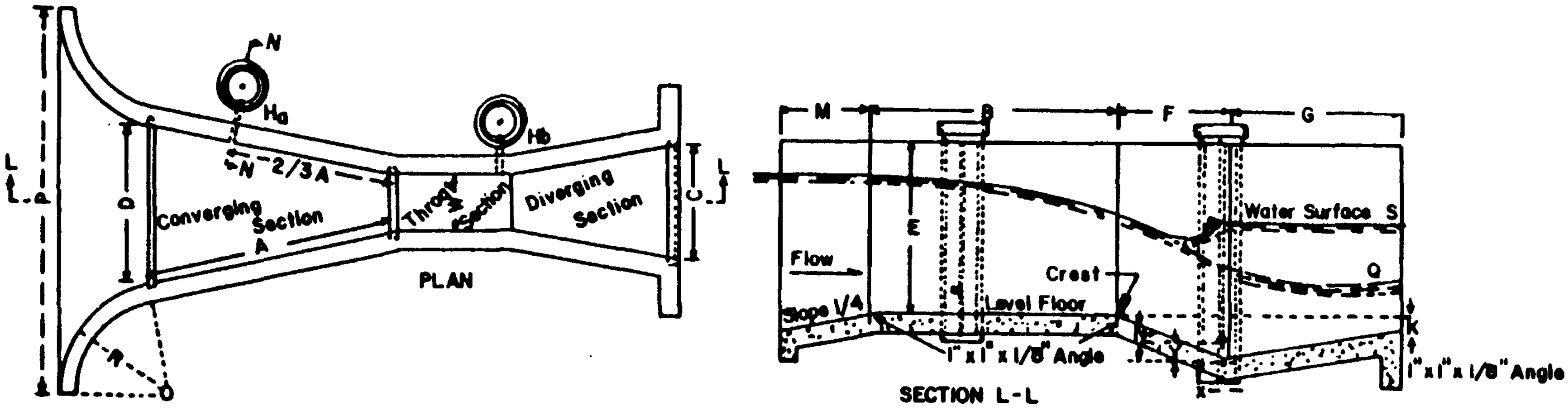
Ideally, flowrate through a flume maybe determined by measurements at a single point some distance downstream from the inlet and above the throat. This single measurement indicates the discharge rate only if critical or supercritical flow is achieved in the flume. By definition, critical flow is that for which the Froude number (the ratio of force due to inertia to the force due to gravity) is unity. Supercritical flow occurs when the Froude number exceeds unity. If the Froude number Is less than one, subcritical flow occurs; a second depth reading must be taken in the throat section to determine the true discharge rate. Refer to USGS Water Supply Paper 2175, Volume 2, Chapter 10, for discussion of flumes and weirs under all flow conditions, including submergence.

The most widely used flume type is the Parshall flume. These flumes may be constructed of wood, fiberglass, concrete, plastic, or metal. The dimensions and capacities for 12 different standard Parshall flumes are given in Exhibit 10-3. The reader should note that considerable overlap exists in capacities, indicating that several different sizes can apply to most flow measurement requirements. Flow curves for free-flow conditions are shown in Exhibit 10-4 for 17 Parshall flumes, ranging in size from 3 Inches to 50 feet.

Another useful, more portable flume Is the Palmer-Bowlus type, which uses the existing channel configuration, but provides a level section of floor and some side contraction to produce supercritical flow. Four commonly used shapes of Palmer-Bowlus flumes are illustrated in Exhibit 10-5. Note that in each case, the floor length is approximately the same as the channel width. Materials of construction include fiberglass, stainless steel, cast iron, or, for permanent installations, concrete. The principal advantage of Palmer-Bowlus flumes is their ease of installation, while the main disadvantage is their smaller useful flow range.

For measurement of low flowrates (less than 2.8 m^3/sec or 100 cfs), one of the H-type flumes maybe used. These flumes are more nearly weirs than flumes or are more properly called open-channel flow nozzles, but they are included with flumes because of historical precedence. Because of their configuration, design of these flumes combined the accuracy of a weir with the self-cleaning feature of a flume. H-type flumes have the advantage of simple construction and can monitor flow over a wide range. They have flat, unobstructed bottoms, sloping side contractions (much like the converging section of a flume), and a trapezoid-shaped opening that tilts backwards toward the approaching flow. This opening is the flow control section; the flowrate Isa function of the convergence angle, the side wall top slope, and the width of the opening. H-type flume size Is designated by the depth, *D,* of the flume at its entrance. There are three basic configurations of H-type flumes, ranging from H flumes for low flows, through H flumes for medium flows, to H flumes for high flows. Dimensions and capacities for H flumes are given In Exhibit 10-6. The reader should consult standard flow references or manufacturers' published data for information on other H-type flumes.

Exhibit 10-3
DIMENSIONS AND CAPACITIES OF THE PARSHALL MEASURING FLUME, FOR VARIOUS THROAT WIDTHS, *W*



W		*A*		⅔ *A*		*B*		*C*		*D*		*E*		*F*		*G*		*K*	*N*	*R*		*M*		*P*		*X*	*Y*	Free-Flow Capacity (Second-Foot *)	
Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	Ft	In.	In.	In.	Ft	In.	Ft	In.	Ft	In.	In.	In.	Minimum	Maximum
0	3	1	6 3/8	1	1/4	1	6	0	7	0	10 3/16	2	0	0	6	1	0	1	2 1/4	1	4	1	0	2	6 1/4	1	1 1/2	0.03	1.9
0	6	2	7/16	1	4 5/16	2	0	1	3 1/2	1	3 5/8	2	0	1	0	2	0	3	4 1/2	1	4	1	0	2	11 1/2	2	3	0.05	3.9
0	9	2	10 5/8	1	11 1/8	2	10	1	3	1	10 5/8	2	6	1	0	1	6	3	4 1/2	1	4	1	0	3	6 1/2	2	3	0.09	8.9
1	0	4	6	3	0	4	4 7/8	2	0	2	9 1/4	3	0	2	0	3	0	3	9	1	8	1	3	4	10 3/4	2	3	0.11	16.1
1	6	4	9	3	2	4	7 7/8	2	6	3	4 3/8	3	0	2	0	3	0	3	9	1	8	1	3	5	6	2	3	0.15	24.6
2	0	5	0	3	4	4	10 7/8	3	0	3	11 1/2	3	0	2	0	3	0	3	9	1	8	1	3	6	1	2	3	0.42	33.1
3	0	5	6	3	8	5	4 3/4	4	0	5	1 7/8	3	0	2	0	3	0	3	9	1	8	1	3	7	3 1/2	2	3	0.61	50.4
4	0	6	0	4	0	5	10 5/8	5	0	6	4 1/4	3	0	2	0	3	0	3	9	2	0	1	6	8	10 3/4	2	3	1.3	67.9
5	0	6	6	4	4	6	4 1/2	6	0	7	6 5/8	3	0	2	0	3	0	3	9	2	0	1	6	10	1 1/4	2	3	1.6	85.6
6	0	7	0	4	8	6	10 3/8	7	0	8	9	3	0	2	0	3	0	3	9	2	0	1	6	11	3 1/2	2	3	2.6	103.5
7	0	7	6	5	0	7	4 1/4	8	0	9	11 3/8	3	0	2	0	3	0	3	9	2	0	1	6	12	6	2	3	3.0	121.4
8	0	8	0	5	4	7	10 1/8	9	0	11	1 3/4	3	0	2	0	3	0	3	9	2	0	1	6	13	8 1/4	2	3	3.5	139.5

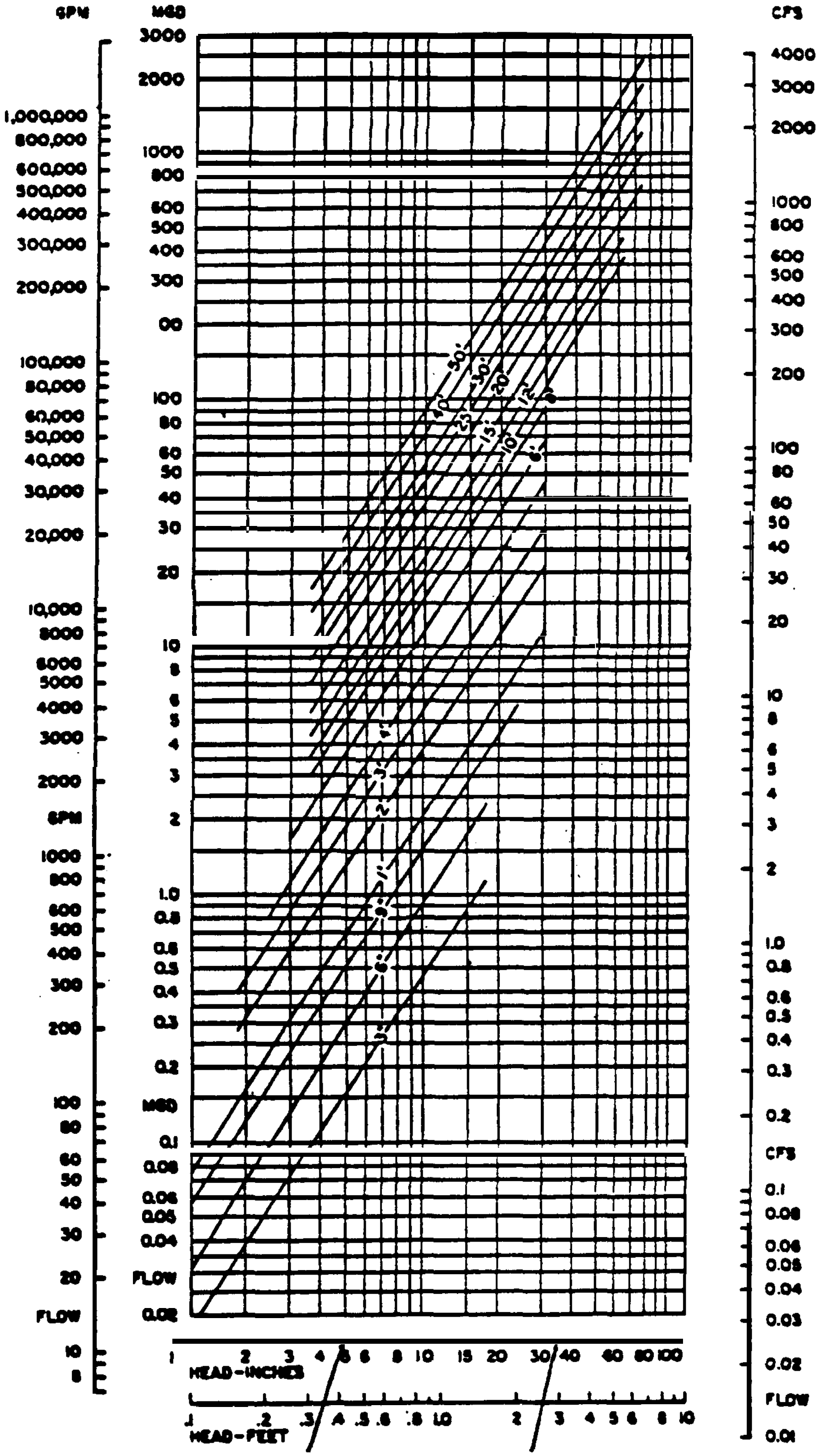
* Equals 1 cu ft per sec.

Legend:

W	Size of flume, in inches or feet.
A	Length of side wall of converging section.
⅔ *A*	Distance back from end of crest to gage point.
B	Axial length of converging section.
C	Width of downstream end of flume.
D	Width of upstream end of flume.
E	Depth of flume.
F	Length of throat.
G	Length of diverging section.
K	Difference in elevation between lower end of flume and crest.
N	Depth of depression in throat below crest.
R	Radius of curved wing wall.
M	Length of approach floor.
P	Width between ends of curved wing walls.
X	Horizontal distance to H_b gage point from low point in throat.
Y	Vertical distance to H_b gage point from low point in throat.

Source: *ORSANCO* (1952).

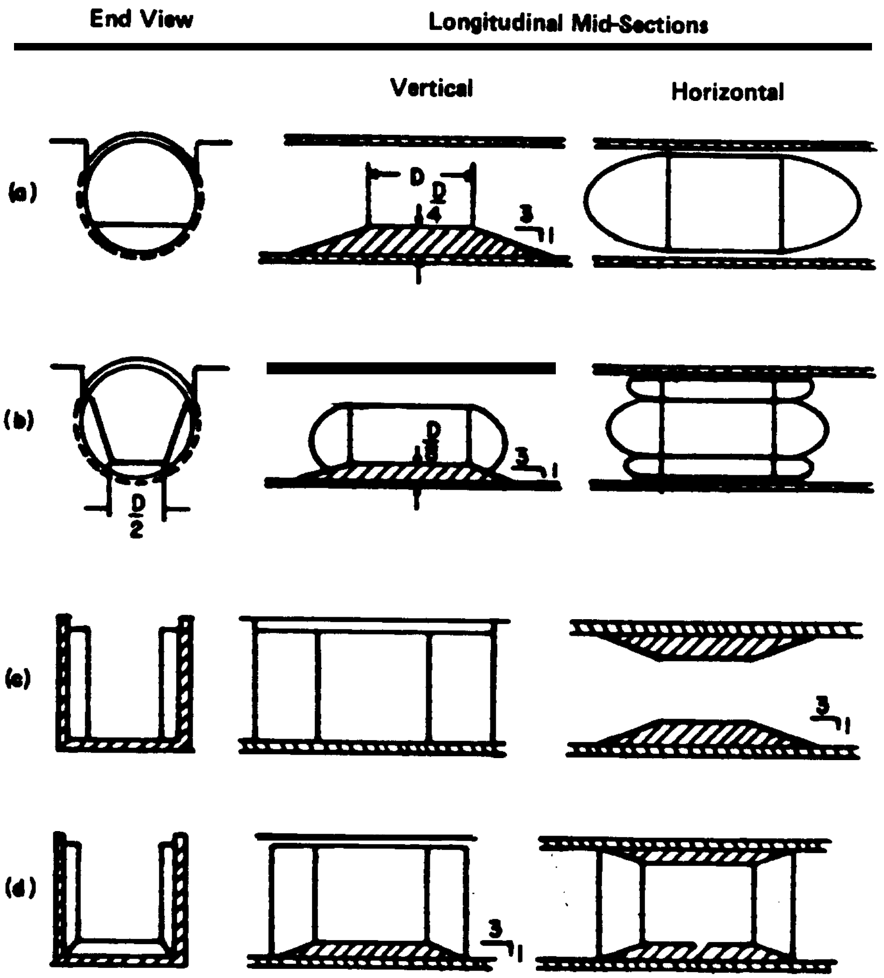
Exhibit 10-4
FLOW CURVES FOR PARSHALL FLUMES



FIVE INCHES IS MINIMUM FULL SCALE HEAD WITH FOXBORO FLOAT AND CABLE METER.

THIRTY-SIX INCHES IS MAXIMUM FULL SCALE HEAD WITH FOXBORO FLOAT AND CABLE METER.

Exhibit 10-5
VARIOUS SHAPES OF PALMER-BOWLUS FLUMES



Applicability Flumes are more versatile than weirs, in that they can be used to measure higher flowrates than comparably sized weirs; they are, to a large extent, self-cleaning because of higher velocities through the throat section. They also operate with much smaller head losses than Weirs. Their major disadvantage Is the cost of construction and installation. As a result, flumes tend to be used only where many measurements over a long period of time are contemplated. Another disadvantage is their insensitivity at low flows because of the rectangular section.

in most cases, the smallest flume that can handle the maximum expected flow is chosen, but the channel width should also be considered when selecting a flume size. Generally, the flume's width should be one-third to one-half of the channel width.

Paimer-Bowlus flume flowrates are best estimated from discharge tables published by the flume manufacturers. The reader should note that tables covering flumes made by one manufacturer may not apply to those of another manufacturer because of subtle discrepancies in shape or physical dimensions. Also, field calibrated tests of flumes have indicated up to a 7 percent difference at low heads between actual and theoretical discharge rates. For Paimer-Bowlus flumes In general, the following equations state some of the applicable relationships:

$$\frac{Q^2}{g} = \frac{Ac^3}{b} \quad \text{and} \quad \frac{Vc^2}{2g} = \frac{Ac}{2b} = \frac{dc}{2}$$

Where

Ac = area at the critical depth in ft^2
Q = discharge flow in cfs
g = 32.2 ft/sec^2 (acceleration because of gravity)
b = width of the flume in ft
Vc = critical velocity in ft/sec
dc = critical depth in ft

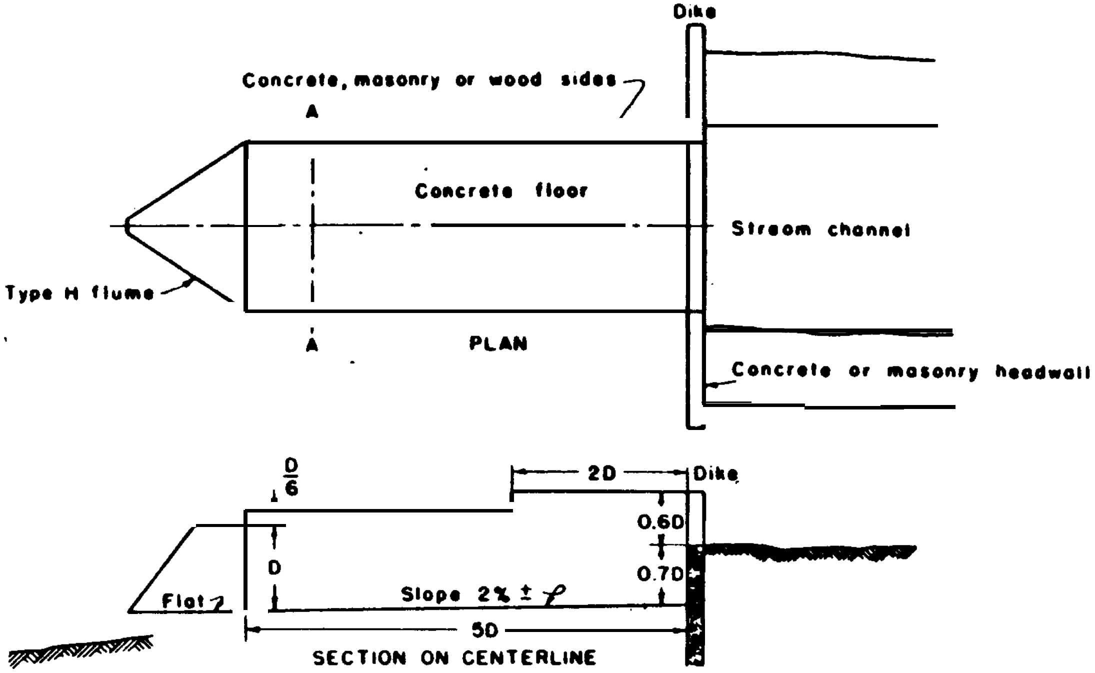
Discharge equations have been developed for various H-type flumes by Gwinn and Parsons. These are quite complex and are not listed here. For further details on HS, H, and HL flumes, the reader should refer to Subsection 10.1.7.

Submerged Orifices: An orifice flow-measuring device consists of a well-defined, typically circular or rectangular hole that is designed to restrict flow when installed in a pipe or on a wall or bulkhead through which flow can occur. Orifices may discharge freely into air or into water as a submerged flow. The submerged orifice is more likely to be used In field investigations, especially where there Is insufficient fail for a weir, and a flume cannot be justified. As in the case of weirs, installation of thin plate orifices is relatively inexpensive and simple, and variations in flowrate are easily accommodated by varying the size or shape of the orifice. Exhibit 10-7 illustrates four common types of orifices: the sharp-edged, the rounded, the short tube, and the Borda-type orifices. The reader should note that each offers different resistances to flow even though the diameters are identical. The coefficient, C, shown for each type is used in calculations to account for the different resistances.

Applicability Submerged orifices may be used to measure flows where the opening can be kept full of water and where the pressure head upstream and downstream of the orifice can be measured. if the upstream water surface drops below the top of the orifice, flow will cease to follow the laws of orifice flow. instead, the partly submerged orifice will begin to function more like a weir. Orifices should be installed in straight sections of the channel or pipe. Orifice diameter (or area for noncircular orifices) is a function of the expected flow and may range in size from 10 percent to 90 percent of the cross sectional area. flows are estimated by measuring the pressure differential upstream and downstream, then relating this dif-

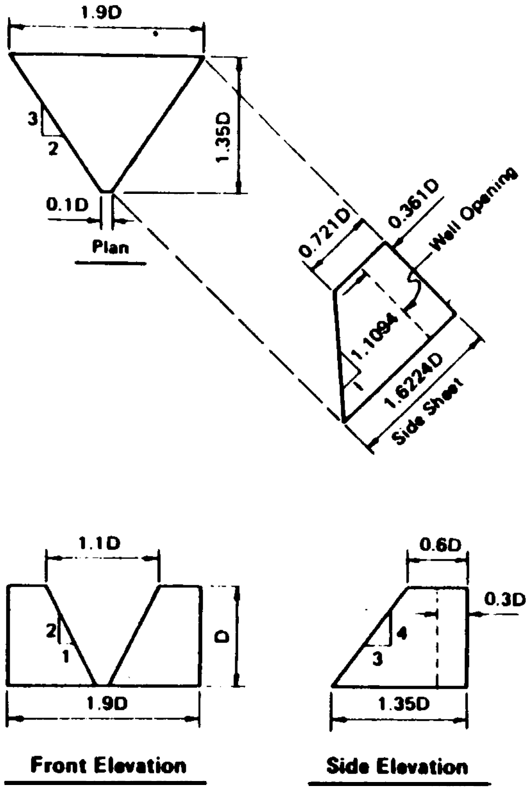
Exhibit 10-6

DIMENSIONS AND CAPACITIES OF H-TYPE FLUMES



STRAIGHT HEADWALL INSTALLATION

or use when flume is to be installed in a well-defined natural channel



Proportions of the Type H Flume

Approximate Capacities	
Depth-D Feet	Capacity $FT.^3/s$
0.5	0.3+
0.75	1-
1.0	2
1.5	5+
2.0	11
2.5	19
3.0	30+

For flumes less than 1 foot deep, the length of flume is made greater than 1.35D so that the float may be attached.

ference to the geometry of the orifice and channel cross section. For most applications the general equation is $Q = CAK(H_1 - H_2)^{0.5}$, where Q is the discharge rate in cfs, A is the orifice area in ft^2, H_1 is the pressure head at the center of the inlet to the orifice (in feet), H_2 is the pressure head downstream of the orifice (in feet), and C and K are constants derived from orifice shape and geometry. Values of K may be calculated from the equation

$$K = \left[\frac{2g}{1 - \left(\frac{d_2}{d_1}\right)^{4}} \right]^{0.5},$$

where $g = 32.2$ ft/sec^2 (acceleration as a result of gravity), d_2 is the orifice area in square feet and d_1 is the channel cross-sectional area in square feet. Alternatively, K may be approximated from the curve shown as Exhibit 10-8 for known values of d_1 and d_2. The coefficient C will be relatively constant for most d_2/d_1 ratios, but it will tend to increase for d_2/d_1 ratios greater than 0.7. For example, the 0.61 coefficient used with sharp-edged orifices covers all d_2/d_1 ratios from 0.2 through 0.7, but it increases to 0.64 for the case where $d_2/d_1 = 0.8$, and to 0.71 when $d_2/d_1 = 0.9$. In most cases, the orifice-to-channel ratio will be less than 0.5, so the coefficient shown in Exhibit 10-8 will apply.

Water Stage Gauges, Recorders and Stilling Wells: in those instances where many repeated flow measurements **are to be made over a period** of time, or where continuous flow readings are desired, it becomes necessary to provide a means for measuring surface elevation more efficiently. Water surface elevation is the variable parameter for most applications, because the channel cross-sectional area at a given point is usually fixed. Three ways of simplifying the measurement of surface water elevation are as follows:

- installation of permanent water stage gauges at points where surface elevation readings are necessary
- Provision for automatic recorders that can track changes in elevation on a continuous basis
- installation of stilling wells for improving the reliability of surface-level measurements

Water stage gauges were discussed previously as an adjunct to the use of current meters, but they are readily adapted to weirs and flumes as well. The graduated face of the gauge must be kept clean to observe the readings accurately. In addition to permanently mounted staff gauges, other types of calibrated gages may be used (e.g., hook gauges, wire-weight gauges with graduated disk readouts, wire-tape gauges, and chain gauges). All are designed to provide reference points so that surface elevations can be more easily measured, but none allows for continuous measurements, because they are all dependent on human observers.

Automatic recording devices can provide continuous readings of surface elevation by using graphic, punched tape, or printed records of the rise and fall of the water surface. A common type of graphic recorder uses a weighted float and cable to rotate a float pulley, which in turn is linked to a flow cam and base plate that cause a pen to move up or down the face of a recorder chart (Stevens, 1976). The reader should refer to Exhibit 10-9 for a simplified sketch of this device. USGS prefers a digital punch-tape recorder because of its greater economy and flexibility and its compatibility with the use of computers to calculate discharge records. The stages are recorded in increments of 0.01 feet and are transmitted to the recorder by rotation of an input shaft. Shaft rotation is converted by the instrument into a coded punch-tape record. For details, the reader should refer to USGS Water Supply Paper 2175 (USGS, 1982). Other similar

Exhibit 10-7
COEFFICIENTS OF FOUR TYPES OF ORIFICES

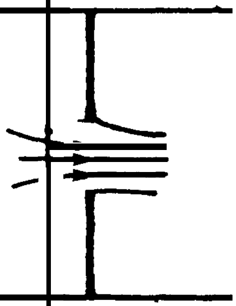
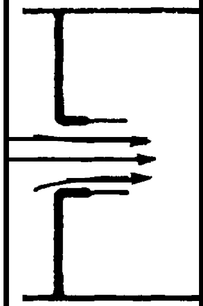
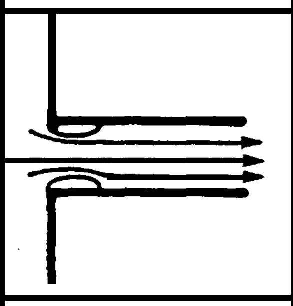
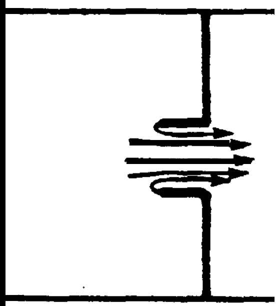
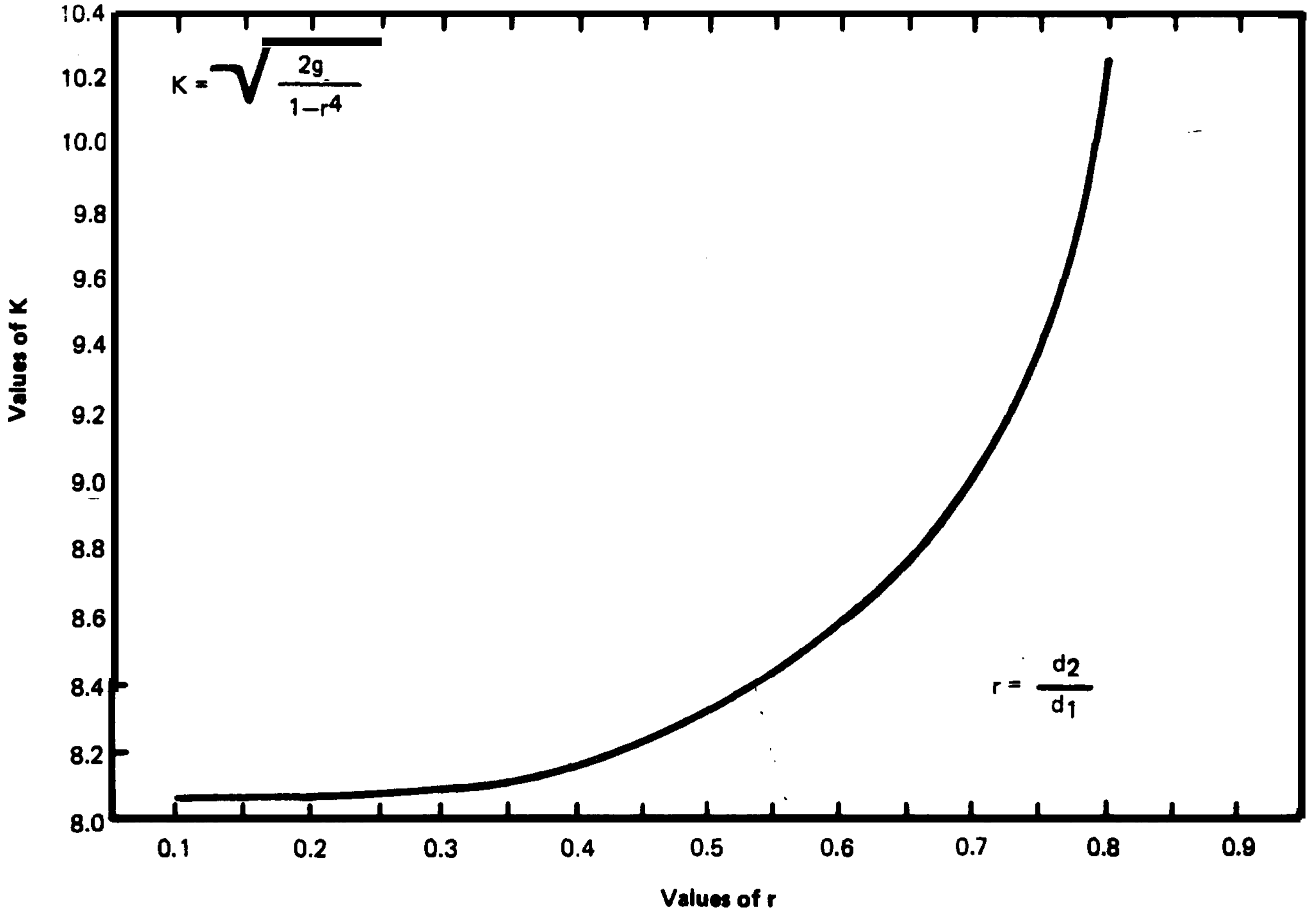
ORIFICES AND THEIR NOMINAL COEFFICIENTS				
	Sharp-Edged	Rounded	Short-Tuba	**Borda**
				
C	0.61	0.98	0.80	0.51

Exhibit 10-8

CURVE FOR DETERMINING THE VALUES OF *K* USED IN THE ORIFICE, VENTURI, AND FLOW NOZZLE EQUATIONS



recorders sense changes in pressure at the water surface. A box containing a flexible diaphragm is mounted at the water surface so that the rise and fall of the surface will increase or decrease the pressure on the diaphragm. These changes in pressure are continuously recorded. The reader should refer to Exhibit 10-10 for an example of this type of recorder mounted in a weir system. Another pressure-based recorder is shown in Exhibit 10-11; it Is based on the fact that changes in water surface elevation will cause increased or decreased resistance to air escaping from an immersed bubbler tube. A pressure-sensitive translator drives the recording chart.

Stilling wells are specially designed reservoirs used to dampen the effects from surface variations or ripples in the main channel, thus allowing for a more stable and steady surface-level measurement. Such wells are especially desirable if float-type water level recorders are used. Several requirements must be met when stilling wells are used:

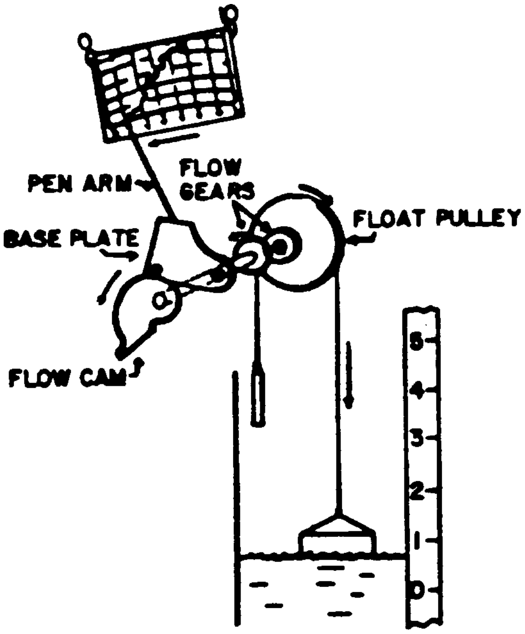
- They must be high enough to cover the entire expected range of surface levels. The well should be long enough that its bottom is at least 0.3 m (1.0 feet) below the minimum stage expected.
- They should be as vertical as possible, so that the float wire or tape can move vertically with no drag or interference.
- Intake pipes or holes should be large enough to make sure that water levels in the well do not lag the rise or fall of levels in the stream.
- They must have provisions to clean out and remove silt.
- If used in freezing weather, they should be provided with a means for heating the devices unless wells can be protected by surrounding ground and a subfloor.
- Stilling wells should have sealed bottoms to avoid seepage if they are installed into streambanks.

Applicability Calibrated water stage gauges are widely applicable to almost any flow measurement problem. Custom-made gauges can even be calibrated to read cfs or m^3/sec directly if all other conditions besides surface elevation can be kept constant. This calibration is especially true for flumes and weirs where cross-sectional areas are fixed.

Automatic recorders find their widest use where readings must be made continuously and where staffing is not available around the clock. These recorders are relatively uncommon in site survey work because there are few occasions where continuous measurements are essential. Even flow readings for nearby streams or rivers are rarely made on a continuous basis. However, the need may arise for special application at certain sites, especially if ongoing remedial work is being done.

Stilling wells are beneficial for ail flow measuring stations where multiple readings at a weir or flume must be made. These wells are essential at any site where continuous recorders are installed. Because stilling wells are isolated from the main flow by a small-diameter inlet, waves and surges in the main flow will not appear in the well. But the well must be able to accurately reflect all steady fluctuations in the main channel. The well may be made of concrete, wood, ceramic pipe, or metal pipe; it must have a solid bottom; and, except for the inlet, it must be water tight. The stilling well inlet should be located at the desired head measuring point in the primary flow measurement device (weir, flume, orifice). The inlet area should be large enough to quickly reflect changes in the stream, but small enough to provide effective damping of surges. Suggested sizes are as follows:

Exhibit 10-9
FLOATING WATER ELEVATION MEASURING DEVICE



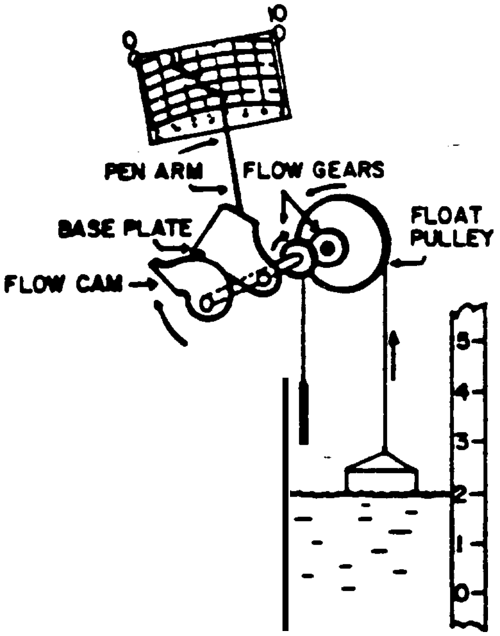


Exhibit 10-10
PRESSURE SENSOR

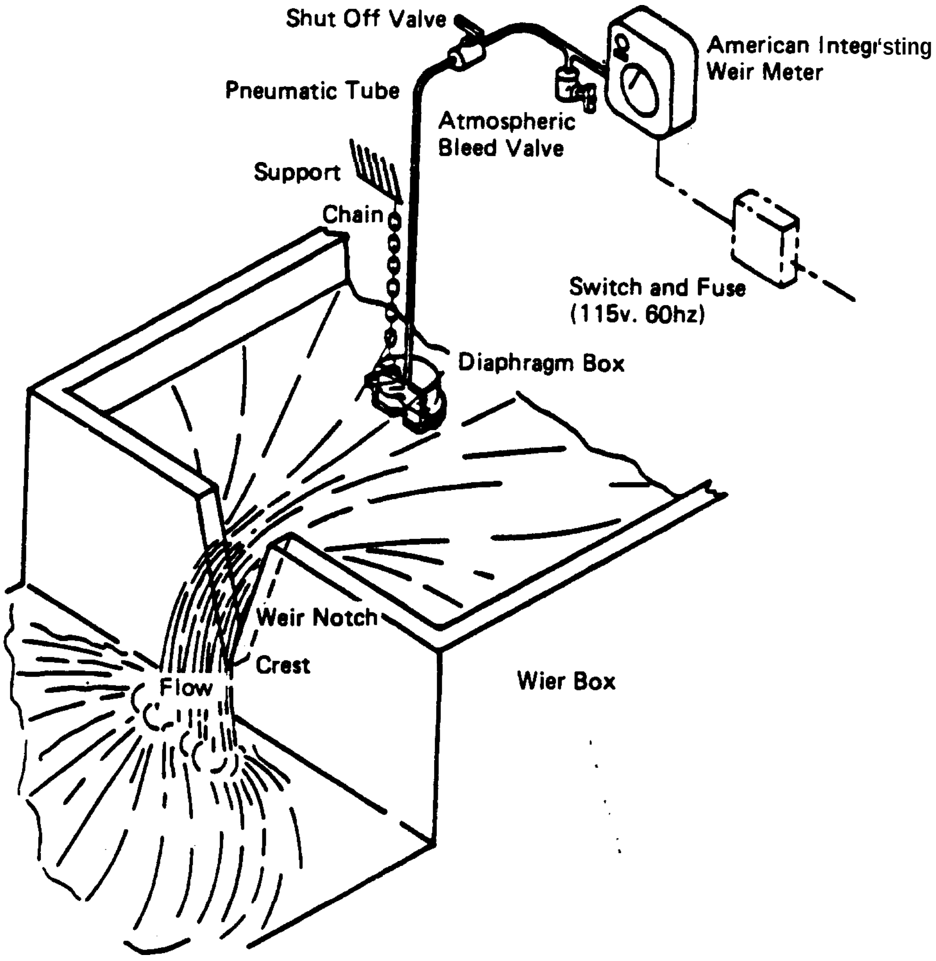
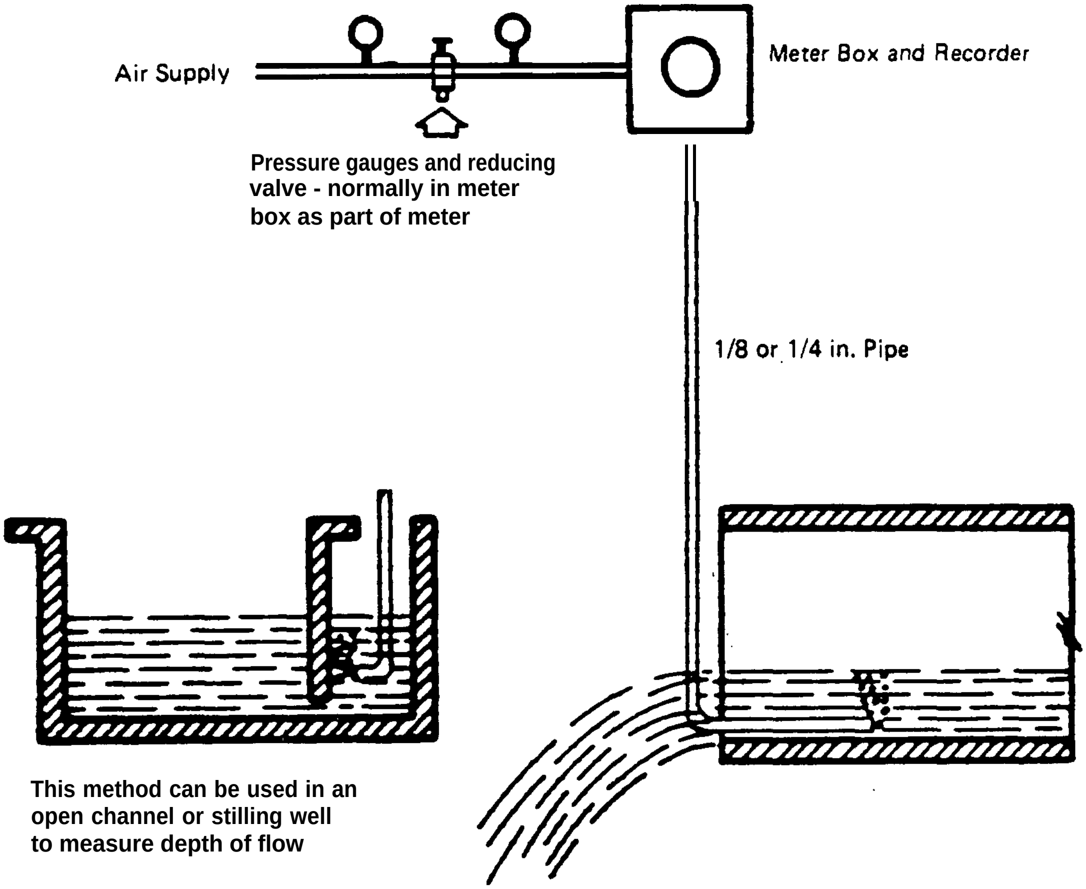


Exhibit 10-11
AIR BUBBLER FOR MEASURING WATER DEPTH

An air bubbler will measure water depth in pipes and channels. The recorder gauges for the bubbler must be selected for the depth of flow because of low air back-pressure.



This method can be used in an open channel or stilling well to measure depth of flow

If the well is of 6-inch diameter, the inlet should be 3/8-inch diameter.

If the well is of 12-inch diameter, the inlet should be l/2-inch diameter.

If the well is of 24-inch diameter, the inlet should be 3/4-inch diameter

If the well if of 30-inch diameter, the inlet should be 1-inch diameter.

If the well is of 36-inch diameter, the inlet should be 1-1/4-inch diameter.

USGS recommends at least 18-inch diameters for stilling wells, and prefers to use a 2- to 4-inch intake line.

Selecting a site for the stilling well partially depends on locating an area where stream velocity cross-sectional measurements can be carried out accurately under **all** variations of stage. The following criteria are generally used, at least in part, for selecting a site for a stilling well.

- A fairly straight section of stream length should be chosen where turbulence Is minimal and flow maintains, as much as possible, a uniform flow under varying stages.
- This section should be accessible to a stable channel or control and should be where a stage discharge relationship can be determined.
- An area should be selected that Is proximate to where the cross-sectional measurements will be made, possibly at some sort of permanent control structure (e.g., either a bridge where abutments contain the stream width with increasing stages or an underwater rocky ledge). To be avoided are undercut banks or areas where overland flooding will occur easily, or where streambed scour or streambank erosion may occur over the study period.
- The site should be a position in the stream that is away from strong current areas, but where water will be available to the stilling well under low flow conditions. A location should be chosen that will also afford some protection to the installation from strong currents during flood events.
- The site should beat a location where the type of sediment is sand, gravel, consolidated clay, or a mixture of these materials, since the substrate may be required to partially support the installation and to resist settling or tilting of the structure.
- An area of low susceptibility to vandalism should be chosen.

For details on installation and maintenance of stilling wells, the reader should refer to USDI, 1965 and 1974; USGS, 1982; ISCO, 1985; and Stevens, 1978.

10.1.5,3 Methods **and Applications: Alternative Flow Measurements**

At times none of the foregoing flow measurements are applicable to the site-specific problem, so other methods must be investigated. Some of the possibilities are briefly discussed below, but readers will need to refer to other publications or manufacturers' instruction manuals for more details.

Pitot Tubes: Although Pitot tubes are usually associated with flow measurements in closed pipes, they can also be used to measure flow velocities in open channels. The principle is illustrated in Exhibit 10-12, where the difference in pressure between an upstream reading and a downstream reading is directly related to flow velocity, at the point of measurement. Pitot tubes are available commercially, and manufacturer's specifications should be consulted before use.

Applicability Pitot tubes should be used where velocities are high enough to generate readable differences in pressure. They are very Inaccurate at low velocities, less than 1 fps. Measurements are best made when the upstream straight section is 15 to 20 times the channel width. Pitot tubes are not reliable for streams carrying high concentrations of suspended matter because the tube inlet plugs easily, giving inaccurate pressure readings. The general formula for calculating discharge rates using Pitot tubes is $Q = AV$ where Q is flow in cfs, A is cross-sectional area of separate subsections of the channel in ft^2, and V is flow velocity in ft/sec. Further, V is calculated from

$$V = \left[\frac{2g\,(P_2-P_1)}{d} \right]^{0.5}$$

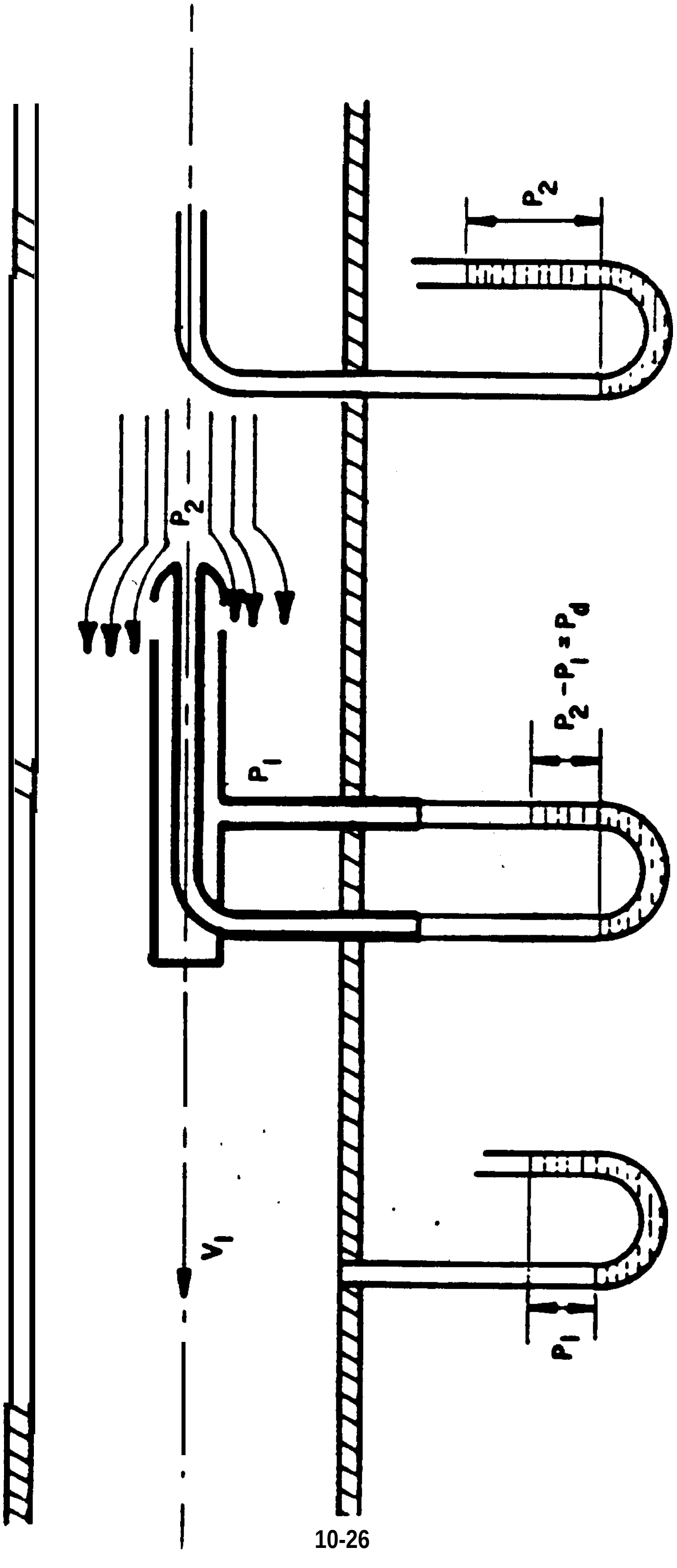
, where $g = 32.2$ ft/sec, P_2-P_1 is the change in pressure in lb/ft^2, and d is 62.4, the density of water in lb/ft^3. Substituting values for the two constants gives $V = 1.02\,(P_2-P_1)^{0.5}$. The reader should note that P_2-P_1 is a pressure difference, and not a measure of depth or head. For very small differences in P, the equation becomes meaningless. The individual subsections' discharge rates are added together to define the total discharge rate for the entire cross-sectional area.

Salt and Dye Solutions: The addition of salt or dye solutions provides a means for estimating volumetric flow rates where channel geometry or inaccessibility render other methods useless. These techniques depend on determining the amount of dilution that a known concentration of a salt or dye receives as it mixes with a much larger volume of salt-free or dye-free water. As a result, the method does not rely on accurate measurements of channel cross sections, water levels, or even velocity. The following general conditions are relevant to successful use of this technique.

(The reader should refer to USDA 1965; USGS, 1962; and Turner, 1976, for detailed information on salt or dye dilution techniques.)

- The salt or dye used as a tracer should be absent in the original discharge flow, or, if salt or dye is present, it must be of low enough concentration that additional salt or dye will yield a mixed concentration at least five times higher.
- The concentration and the injection rate of the tracer being added must be known. There are two ways to add the tracer.
    At a constant rate so that downstream concentrations will eventuality become constant (best for low flows and inexpensive tracers; has long injection time).
    As a sudden Injection or slug of tracer so that a relatively sharp peak concentration can be detected downstream (best for higher flows; requires long sampling time and many individual measurements to make certain peak is detected and quantified).
- The tracer must be stable both in solution and upon mixing with the discharge. It must not react with any chemicals in the discharge.

Exhibit 10-12
PITOT TUBE MEASURES VELOCITY HEAD



- There must be sufficient mixing in the fallowing stream to ensure that the tracer is evenly distributed on addition. The injection point should be far enough upstream to allow for turbulent mixing before the first measuring point.

- Sufficient injection time must be provided to allow downstream samples to reach a concentration plateau or reach a peak concentration, depending on which injection method is used.

Suitable tracers include sodium, potassium or lithium chloride, fluorescein, and Rhodamine WT dyes ideally, concentrations are determined in the field to assure that the downstream concentration plateau was reached and sustained.

Applicability Salt and dye tracer methods have wide application since they do not rely on channel geometry or the ability to measure velocities accurately. These methods do rely heavily on analyzing chemicals, careful metering of concentrated salt and dye solutions, and being able to accurately determine when tracers have reached a point far enough downstream to ensure complete mixing. Wide streams will necessitate the collection of lateral samples for inclusion in the calculations. To guarantee low backgrounds and the absence of materials that may react with the added salt or absorb the dyes, the natural discharge must be analyzed before choice of salt or dye can be made.

Radioisotopes: Radioisotopes may be used as tracers instead of the salts and dyes discussed above. Geiger or scintillation counters are used to determine background, concentrated injection solution, and downstream levels of the radioisotopes added. Since radioactivity measurements are made on other samples from hazardous waste sites, this flow measurement technique can be more easily practiced than standard salt / dye tracer methods. The principles, procedures, and methods of calculating flowrates are the same as for other tracers. The radioisotopes will give positive indications when downstream sampling should commence, simplifying the sample collection task. Results are obtained in short order, since analytical equipment and procedures need not be used. The major problem is the necessity for special handling of the radioactive material to prevent exposure to the users and others at the site. Special licenses are required prior to use, and considerable Recordkeeping and documentation must be maintained.

Applicability This procedure applies to all situations where salt and dye tracer methods apply. The only exception that could occur would involve a site where background radioactivity is high enough to affect the accuracy of the count. The radioisotopes chosen must have a high detectability range and a low decay rate. The discharge formula for this method is $Q = FA/N$ where Q is the flowrate, F is a calibration factor for the probe and the counting system (see the manufacturer's instructions), A is the total amount of radioactivity injected, and N is the total count downstream.

Acoustic Flow Meters: Portable velocity meters, operating on the Doppler principle, have been successfully used to measure flow passing through dosed pipes. Use had been limited to situations where bubbles or particles were evenly distributed through the flowing stream, since the meter transmits an ultrasonic pulse that is reflected by the bubbles or particles. Under ideal conditions, a Doppler shift occurs and is directly related to the flow velocity. The meter translates this reading directly into velocity in feet/sec. The pipe cross-sectional area is then multipiled by velocity to obtain discharge rate (U.S. EPA, 1984). Recently, more sensitive meters have been developed for use in situations where the water is relatively free of particles.

Applicability: in theory, this Instrument is applicable to flow measurements in closed pipe, but in practice many conditions have to be met to ensure reliable readings. The user must be careful to follow all instructions for the particular instrument. All conditions specified for use must be met. Generally, all measurements depend on the flowing stream's ability to transmit sound, on the presence of evenly distributed bubbles or small particles, and on the nonlaminar, turbulent flow of the water at the point of measurement. The user should refer to the instruction manual for the selected instrument before committing it to service.

Slope-Ares Methods: In situations where installation of a weir or flume is impractical, but the cross-sectional area and approximate slope of the channel are known, the Manning formula provides reasonable estimates of flow velocity. Then the discharge flow rate is readily obtained by multiplying that velocity by the cross-sectional area of the channel at the appropriate water level. No equipment or measuring device is necessary other than a means for estimating water surface level in the channel. Tables are used to simplify the calculation, or the basic Manning equation may be solved directly (USGS, 1982; USDA, 1974; King, 1976; and Davis and Sorenson, 1969).

Applicability The slope-area method is most useful when relatively few measurements are to be made –too few to justify installation of permanent measurement equipment. The primary weakness in the method is the fact that the slope of the hydraulic gradient is not always known, nor is it easy to estimate. Another factor that seriously reduces the accuracy of the method is the need to estimate a roughness coefficient for the channel surface. Because of the difficulties in assigning values to these two factors, the slope-area method is subject to a 20 percent error rate, even when carefully practiced, and a much wider potential error if estimated slopes or roughness coefficients are estimated inaccurately. The basic Manning formula expresses velocity as

$$V = \left[\frac{1.486}{n}\right] R^{2/3} S^{1/2}$$

, **where**

V is average velocity in feet/sec, n is the roughness coefficient, S is the slope of the hydraulic gradient, and R is the hydraulic radius in feet. R, in turn, is calculated by dividing A, the cross-sectional area by P, the wetted perimeter (that portion of the channel boundary that is under water).

Roughness coefficients, ***n,*** are listed in ***Wafer Measurement Manual*** by the Bureau of Reclamation for most materials of channel construction. Ranges are given because the coefficients tend to increase with time as a result of erosion, deposition of solids, and corrosion. For additional information on assessing appropriate roughness coefficients, the reader should refer to USGS Water Supply Paper 1849.

10.1.6 Region-Specific Variances

in general, site-specific conditions and project requirements will strongly influence the selection of flow-measurement methods. However, regional preferences may occur in method selection when past experience levels are considered. Region IV requires that all sampling and flow measurement events comply with the procedures described in the “Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual” (ESBSOPQAM) dated 2 April 1986 and prepared by the Environmental Services Division of Region IV. Other similar region-specific variances may evolve as site work progresses and methods are revised or newly published. The reader should contact the EPA RPM for the most up-to-date information on revised methods or variances. Changes in variances will be included in Revision 01 of this compendium,

10.1.7 Information Sources

American Society for Testing and Materials. Manual on *Water.* 4th ad. Special Technical Publication 442A. Philadelphia, Pennsylvania: ASTM. 1978.

Davis, C.V., and K.E. Sorenson. *Handbook* of *Applied H'lies. 3rd ad. New York, New* York: McGraw-Hill. 1969.

Fair, G. M., et al. Water *Supply and Wastewater Removal. New York, New* York: John Wiley and Sons, Inc. 1966.

Instrumentation Speciailists Company. ISCO Open *Chamnel Flow Measurement Handbook.* 2nd ad. Lincoln, Nebraska: ISCO. 1986.

King, H.W., and E.F. Brater. *Handbook of Hydraulics.* 6th ad. New York, New York McGraw-Hill. 1976.

Lythin, J.N. Drainage *Engineering.* Huntington, New York R.E. Krieger Publishing Co. 1973.

Marsh-McBimey, Inc. Instruction"on *Manual Model 201 Portable Water Current Meter.* Gaithersburg, Maryland: Marsh- McBimey, Inc. Undated.

Ohio River Valley Water Sanitation Commission. *Planning and Making Industrial Waste Surveys.* Cincinnati, Ohio: ORSANCO. 1952.

Stevens. *Stevens Water Resource Data Book 3rd ad.* Beaverton, Oregon: Lenpold-Stevens, I no. 1978.

Turner. "Fluorometric Facts, flow Measurements." Monograph. Mountain View, California: Turner Designs Company. 1976.

U.S. Department of Interior, 1965a. "Discharge Measurements at Gaging Stations." *Hydraulic Meaurement and Computations.* Book 1, Chapter 11. Washington, D. C.: USDA, Geological Survey. 1965.

U.S. Department of Interior, 1965b. "Measurement of Discharge by Dye Dilution Methods." *Hydraulic Measurement and Computations.* Book 1, Chapter *14.* Washington, D.C.: Geological Survey. 1965.

U.S. Department of Interior. *Water Measurement Manual 2nd ad.* Revised. Washington, D. C.: USDA. 1974.

U.S. Department of interior. *National Handbook of Recommended Methods for Water-Data Acquisition.* Reston, Virginia: USDA OWDC, Geological Survey. 1977.

U.S. Department of Interior. *Measurement and Computations of Streamflow: Volumes 1 and 2.* Geological Survey Water- Supply Paper 2175. Washington, D. C.: USDA. 1982.

U.S. Environmental Protection Agency. *ESB Standard Operating Procedures Quality Assurance Manual.* 1986.

U.S. Environmental Protection Agency. *Handbook for Monitoring Industrial Wastewater.* Washington, D. C.: U.S. EPA. 1979.

U.S. Environmental Protection Agency. NPDES *Compliance Inspection Manual.* Washington, D. C.: U.S. EPA. 1984.

10.2 SAMPLING TECHNIQUES

10.2.1 Scope and Purpose

This subsection provides general guidance for the collection of surface water, sediment samples, and sludge at hazardous waste sites. The' primary objective of any sampling program is the acquisition of samples representative of the source under investigation. Such samples must be suitable for subsequent analysis to enable identification of the types and amounts of pollutants present. Information derived from sampling often forms the basis for litigation and development of remedial action, so all sampling programs must be conducted in a manner that will stand the scrutiny of the court and the public.

10.2.2 Definitions

Sampling
The physical collection of a representative portion of the population, universe, or environment.

Environmental Samples
Usually offsite samples with mid-or low-contaminant concentrations, such as streams, ditches, ponds, soils, and sediments, that are collected at some distance from direct sources of contaminants. Most surface waters are environmental samples.

Grab Samples
Discrete aliquots representing a specific location at a given point in time. The sample is collected all at once and at only one particular point in the sample medium.

Composite Samples
Nondiscrete samples composed of more than one specific aliquot collected at various locations or at different points in time. Analyzing this type of sample produces an average value for the locations or time period covered by sampling.

Surface Water Samples
Samples of water collected from streams, ponds, rivers, lakes, or other impoundments open to the atmosphere. Surface waters flow over or rest on the land.

Sample Blanks
Samples of deionized or distilled water, rinsed collection devices or containers, sampling media, etc., that are handled in the same manner as the unknown sample and are subsequently analyzed to identify possible sources of contamination during collection, preservation, shipping, or handling.

Sediments
Particles derived from rocks or biological materials that have been transported by a fluid. Sediments include solid matter (sludges) suspended in or settled from water.

SamplingPlan

A detailed, site-specific plan that covers all sampling objectives and strategy for a given site. The plan describes methods and equipment used, locations, number and type of samples, safety requirements, transportation and shipping instructions, scheduling, and any other site-related sampling requirements. The reader should refer to Section 4 for details.

10.2.3 Applicability

This subsection describes general methods for the physical sampling of surface waters, sludge, and sediments. In most cases, such samples will be low- or medium-hazard wastes, rather than the more concentrated high-hazard wastes collected from drums or storage facilities. The individual site sampling plan will always define the requirements for each sampling program. The reader should refer to Section 4 for details.

The following procedures apply to surface water (streams, rivers, surface impoundments) and sediments (sludges, stream bottoms, solids settled out of water).

10.2.4 Responsibilities

Site Managers are responsible for identifying sampling team personnel, assuring that each team member's responsibilities are assigned and understood, ensuring that the project-specific sampling procedures are followed, maintaining chain-of-custody records, and determining that all sampling documents have been completed properly and are accounted for.

Field personnel performing sampling are responsible for properly collecting samples, initiating chain-of-custody forms (see Section 4), monitoring traffic reports, and over seeing the necessary sample documents, as required.

The sampling and analysis coordinator, equipment manager, or the EPA's Sample Management Office authorized requester is responsible for arranging the sample bottle deliveries and coordinating theactivities of the field personnel and the Sample Management Office.

10.2.5 Records

The various documents, forms, labels, and tags that sampling teams will use in the field have been standardized and are described in detail in Sections 4 and 17. These include field logbooks, sample log sheets, sample labels, sample identification tags, traffic reports (organic, inorganic, and high hazard), custody seals, and chain-of-custody forms. Other forms are not usually standardized (e.g., sample shipping documents that may vary according to the shipping company's requirements or photographic records that necessarily must vary from site to site).

10.2.6 Sampling Procedures

10.2.6.1 General Considerations

Regardless of the sampling methods or equipment selected, there are several general procedures that are applicable to the collection of all surface water, sludge, or sediment samples. These procedures include the following:

- Before commencing collection of samples, thoroughly evaluate the site. Observe the number and location of sample points, landmarks, references, and routes of access or escape.
- Record pertinent observations. Include a sketch, where appropriate, Identifying sample locations.
- Prepare all sampling equipment and sample containers prior to entering site. Provide protective wrapping to minimize contamination.
- Place sample containers on flat, stable surfaces for receiving samples. Use sorbent materials to control spills, if any.
- Plan to collect samples first from those areas that are suspected of being the least contaminated so that areas of suspected contamination are collected last thus minimizing the risk of cross contamination.
- Collect samples and securely close containers as quickly as feasible. Where possible, make field observations (pH, temperature, conductivity) at the source rather than in containers.
- Follow the sampling plan in every detail. Document all steps In the sampling procedures.
- For potentially hazardous samples, dispose of sampling gear as determined in the sampling plan, or carry it back to the contamination reduction corridor for decontamination and cleaning in a plastic bag.
- For potentially hazardous samples, deliver the sample containers and equipment to the decontamination station for cleaning prior to further handling.
- Always be attentive to the potential hazards posed by the sampling procedures and the material sampled.

Sampling in the Superfund program is closely guided by many EPA documents that originate in several offices. Guidance documents are listed in the subsection on information sources.

10.2.6.2 Methods and Applications: Surface Water

Because each hazardous waste site will contain a variety of waste substances, a variety of sampling equipment and techniques will be necessary. By following the procedures out lined in this compendium, the degree of uniformity necessary for defining characteristics of hazardous waste sites can be obtained.

Surface Water Sampling: Samples from shallow depths can be readily collected by merely submerging the sample container. The container's mouth should be positioned so that it faces upstream, while the sampling personnel are standing down stream so as not to stir up any sediment to contaminate. the sample. The method is advantageous when the sample might be significantly altered during transfer from a collection vessel into another container. This is the case with samples collected for oil and grease analysis, since considerable material may adhere to the sample transfer container and, as a result, produce inaccurately low analytical results. Similarly, the transfer of a liquid into a small sample contained for volatile organic analysis, if not done carefully, could result in significant aeration and resultant loss of volatile species. Though simple, representative, and generally free from substantial material disturbances, the act of transferring has significant shortcomings when applied to a hazardous waste, since the external surface of each container would then need to be decontaminated.

In general, the use of a sampling device, either disposable or constructed of a nonreactive material such as glass, stainless steel, or Teflon, is the most prudent method. The device should have a capacity of at least 500 ml, if possibly, to minimize the number of times the liquid must be disturbed, thus reducing agitation of any sediment layers. A 1-liter polypropylene or stainless steel beaker with pour Spout and handle works well. Any sampling device may contribute contaminants to a sample. The sampling devices that should be selected are those that will not compromise sample Integrity and will give the desired analytical results.

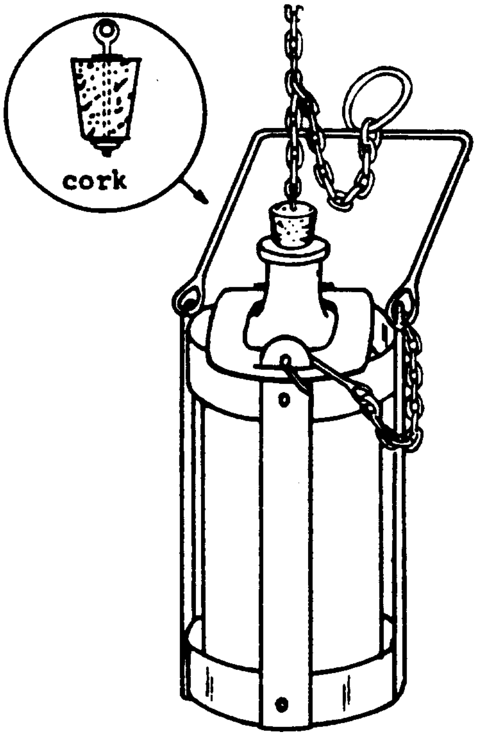
Collecting a representative sample from a larger body of surface water is difficult but not impossible. Samples should be collected near the shore unless boats are feasible and permitted. If boats are used, the body of water should be cross sectioned, and samples should be collected at various depths across the water in accordance with the specified sampling plan. For this type of sampling, a weighted-bottle sampler Is used to collect samples at any predetermined depth. The sampler (Exhibit 10-13) consists of a glass bottle, a weighted sinker, a bottle stopper, and a line that Is used to open the bottle and to lower and raise the sampler during sampling. There are variations of this sampler, as illustrated in ASTM methods D 270 and E 300. This sampler can be either fabricated or purchased. The procedure for use is as follows

- Assemble the weighted bottle sampler as shown In Exhibit 10-13.
- Gently lower the sampler to the desired depth so as not to remove the stopper prematurely.
- Pull out the stopper with a sharp jerk of the sampler line.
- Allow the bottle to fill completely, as evidenced by the cessation of air bubbles.
- Raise the sampler and cap the bottle.
- Wipe the bottle dean. The bottle can be also be used as the sample container.

Teflon bailers have also been used while feasible for collecting samples in deep bodies of water. Where cross-sectional sampling is not appropriate, near-shore sampling may be done using a pond sampler (refer to Exhibit 10-14).

In this instance, a modification that extends the reach of the sampling technician is most practical. The modification incorporates a telescoping heavy-duty aluminum pole with an adjustable beaker clamp attached to the end. A disposable glass, plastic container, or the actual sample container itself can be fitted into the clamp. In situations where cross contamination is of concern, use of a disposable contained or the actual sample container is always advantageous. The cost of properly cleaning usually outweighs the cost of disposal of otherwise reusable glassware or bottles, especially when the cleanup must be done in the field. The potential contamination of samples for volatile organic analysis by the mere presence of organic solvents necessary for proper field cleaning is usually too great to risk.

Exhibit 10-13
WEIGHTED-BOTTLE SAMPLER



1000-ml (1-quart) weighted-bottle catcher

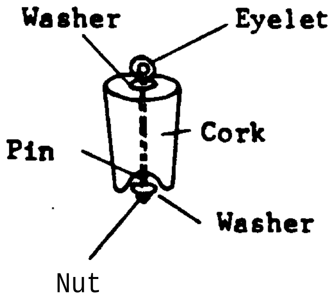


Exhibit 10-14
POND SAMPLER

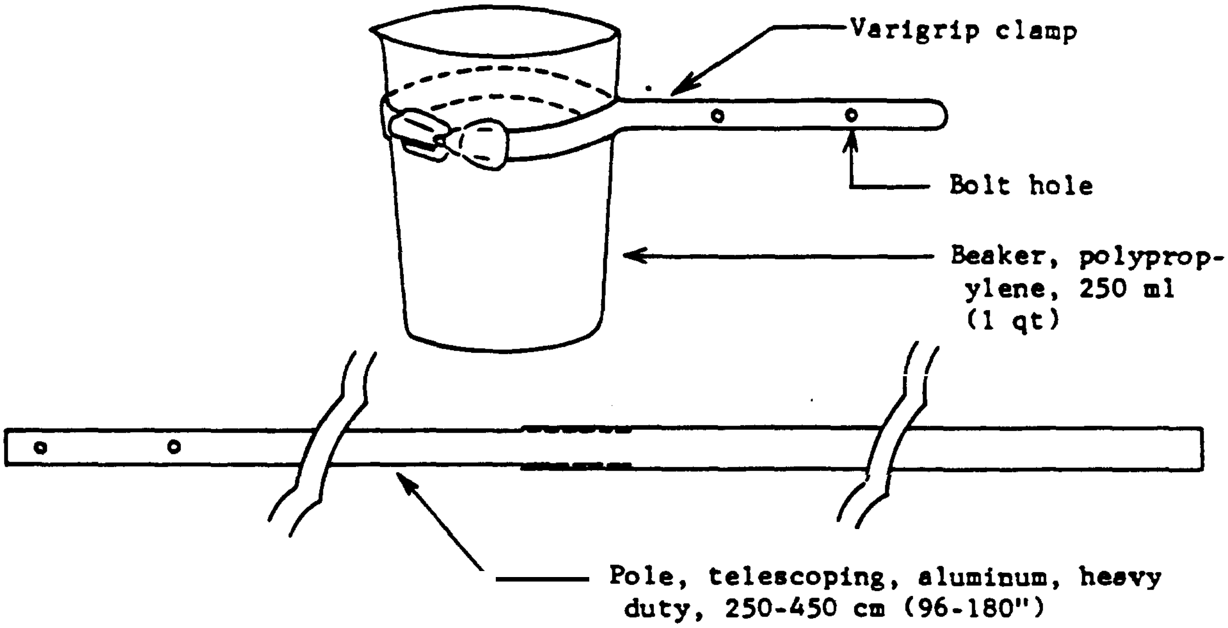
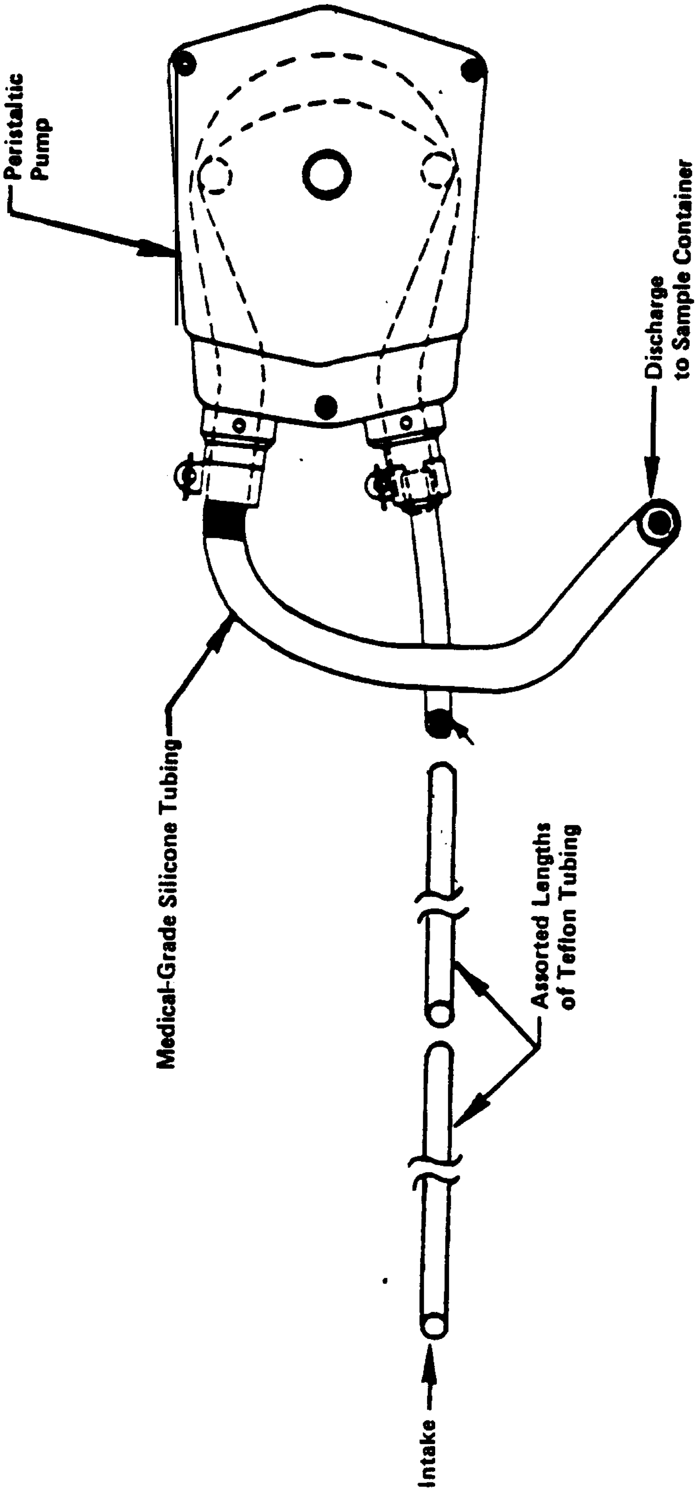


Exhibit 10-15
Peristaltic PUMP SAMPLER



Another method of extending the reach of sampling efforts is the use of a small peristaltic pump (see Exhibit 10-15). In this method the sample is drawn through heavy-wall Teflon tubing and pumped directly into the sample container. This system allows the operator to reach into the liquid body, sample from depth, or sweep the width of narrow streams.

If medical-grade silicon tubing is used in the peristaltic pump, the system is suitable for sampling almost any parameter including most organics. Some volatile stripping, however, may occurr though the system may have a high flow rate, some material may be lost on the tubing. Therefore, pumping methods should be avoided for sampling volatile organics or oil and grease. Battery-operated pumps of this type are available and can be easily carried by hand or with a shoulder sling. It is necessary in most situations to change both the Teflon suction line and the silicon pump tubing between sample locations to avoid cross contamination. This action requires maintaining a sufficiently large stock of material to avoid having to clean the tubing in the field.

When medical-grade silicon tubing is not available or the analytical requirements are particularly strict, the system can be altered as illustrated in Exhibit 10-16. In this configuration, the sample volume accumulates in the vacuum flask and does not enter the pump. The integrity of the collection system can now be maintained with only the most nonreactive material contacting the sample. Some loss in lift ability will result since the pump Is now moving air, a compressible gas rather than an essentially noncompressible liquid. Also, this system cannot be used if volatile compounds are to analyzed. The potential for losing volatile fractions because of reduced pressure in the vacuum flask renders this method unacceptable for use.

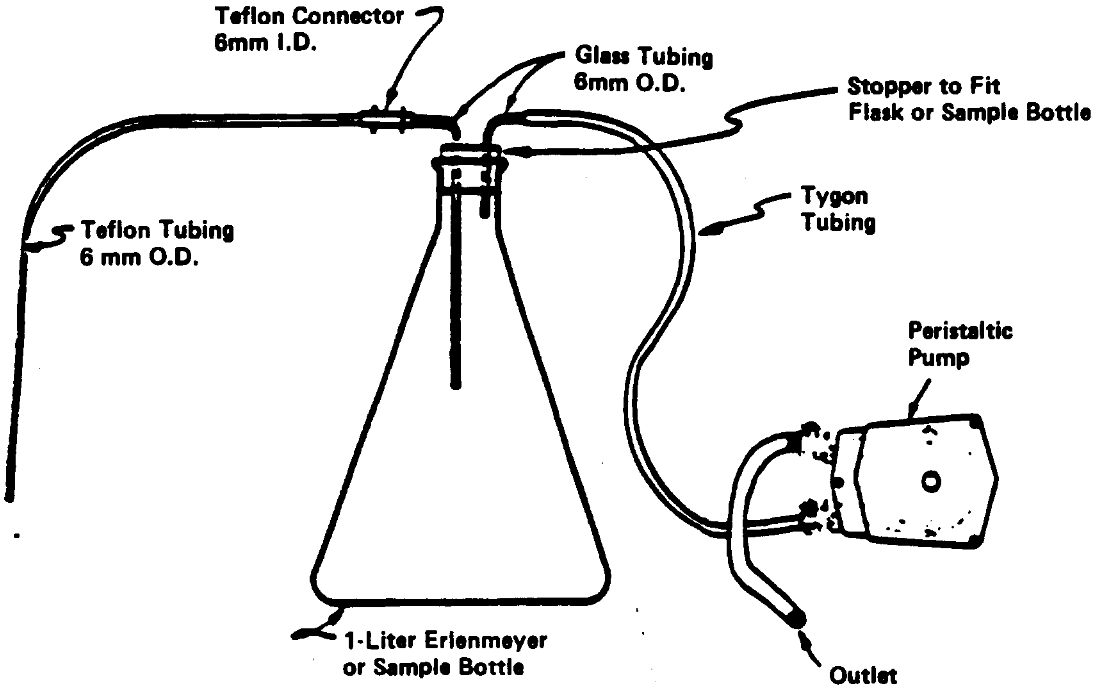
It may sometimes be necessary to sample large bodies of water where a near-surface sample wiLl not sufficiently characterize the body as a whole. In this instance, the above-mentioned pump Is quite serviceable. It is capable of lifting water from depths in excess (but not much in excess) of 6 meters. It should be noted that this lift ability decreases somewhat with higher density fluids and with increased wear on the silicone pump tubing. Similarly, Increases in altitude will decrease the pump's ability to lift from depth. When sampling a liquid stream that exhibits a considerable flowrate, it may be necessary to weight the bottom of the suction line.

Samples from various locations and depths can be composite where investigative goals Indicate that it is appropriate; otherwise, separate samples will have to be collected. Approximate sampling points should be identified on a sketch of the water body. The following procedures are used for samples collected using transfer devices:

- Submerge a stainless steel dipper or other suitable device with minimal surface disturbance. Note the approximate depth and location of the sample source (for example, 1 foot up from bottom or just below the surface).
- Allow the device to fill slowly and continuously.
- Retrieve the dipper or device from the surface water with minimal disturbance.
- Remove the cap from the sample bottle and slightly tilt the mouth of the bottle below the dipper or device edge.
- Empty the dipper or device slowly, allowing the sample stream to flow gently down the side of the bottle with minimal entry turbulence.
- Continue delivery of the sample until the bottle is almost completely filled. Check all procedures. for recommended headspace for expansion.

Exhibit 10-16

MODIFIED PERISTALTIC PUMP SAMPLER



- Preserve the sample, if necessary, as per guidelines in sampling plan. In most cases, preservatives should be placed in sample containers before sample collection to avoid over exposure of samples and overfilling of bottles during collection.

- Check that a Teflon liner is present in the cap if required. Secure the cap tightly. Tape cap to bottle; then date and initial the tape.

- Label the sample bottle with an appropriate sample tag. Be sure to label the tag carefully and clearly, addressing all the categories or parameters. Record the information in the field logbook and complete the chain-of-custody form.

- Place the properly labeled sample bottle in an appropriate carrying container. Water samples for low- or medium-level organics analysis and low-level inorganics <u>must</u> be shipped cooled to 4°C with ice. <u>No ice</u> is to be used in shipping inorganic low-level soil samples; medium / high-level water samples, organic high-level water or soil samples, or dioxin samples. Ice is not required in shipping soil samples, but ice may be used at the option of the sampler. All cyanide samples, however, must be shipped cooled to 4°C. Use a custody seal on the shipping package and make certain that traffic report forms are properly filled out.

- Dismantle the sampler, wipe the parts with terry towels or rags, and store them in plastic bags for subsequent disposal. Follow all instructions for proper decontamination of equipment and personnel.

The reader should refer to Sections 4, 5, and 6 for additional details.

For samples collected using peristaltic pumps:

- Install clean, medical-grade silicone tubing in the pump head, as per the manufacturer's instructions. Allow sufficient tubing on the discharge side to facilitate convenient dispensation of liquid into sample bottles but only enough on the suction end for attachment to the intake line. This practice will minimize sample contact with the silicone pump tubing. (Some types of thinner Teflon tubing may be used.)

- Select the length of suction intake tubing necessary to reach the required sample depth and attach the tubing to intake side of pump tubing. Heavy-wall Teflon of a diameter equal to the required pump tubing will suit most applications. (A heavier wall will allow for a slightly greater lateral reach.)

- If possible, allow several liters of sample to pass through the system before actual sample collection. Collect this purge volume, and then return it to source after the sample aliquot has been collected.

- Fill necessary sample bottles by allowing pump discharge to flow gently down the side of bottle with minimal entry turbulence. Cap each bottle as filled.

- Preserve the sample, if necessary, as per guidelines in sampling plans. In most cases, preservatives should be placed in sample containers before sample collection to avoid overexposure of samples and overfilling of bottles during collection.

- Check that a Teflon liner is present in the cap, if required. Secure the cap tightly. Tape cap to bottle; then date and initial the tape.

- Label the sample bottle with an appropriate tag. Be sure to complete the tag with all necessary information. Record the information in the field logbook, and complete the chain-of-custody documents,

- Place the properly labeled sample bottle in an appropriate carrying container. Water samples for low- or medium-level organics analysis and low-level inorganic must be shipped cooled to 4°C with ice. <u>No ice</u> is to be used in shipping inorganic low-level soil samples; medium/ high-level water samples, organic high-level water or soil samples, or dioxin samples. Ice is not required in shipping soil samples, but ice may be used at the option of the sampler. All cyanide samples, however, must be shipped cooled to 4°C Use a custody seal on the shipping package and make certain that traffic report forms are properly filled out.

- Allow system to drain thoroughly; then disassemble. Wipe all parts with terry towels or rags, and store them in plastic bags for subsequent cleaning. Store all used towels or rags in garbage bags for subsequent disposal. Follow all instructions for proper decontamination of equipment and personnel.

The reader should refer to Sections 4, 5, and 6 for additional details.

At times it is most convenient to collect surface water samples at the flow measuring device (e.g., a weir, stream, or discharge pipe). Good representative samples can usually be collected because such flows have been mixed well. Sampling personnel have been trained to seek out the best locations for collecting representative samples. Requirements are spelled out in the site sampling plans, and the need for deviation from the plans occurs only rarely. There is no substitute for experience when it comes to locating "ideal" sampling points and collecting good samples.

10.2.6.3 Methods and Applications: Sediments and Sludges

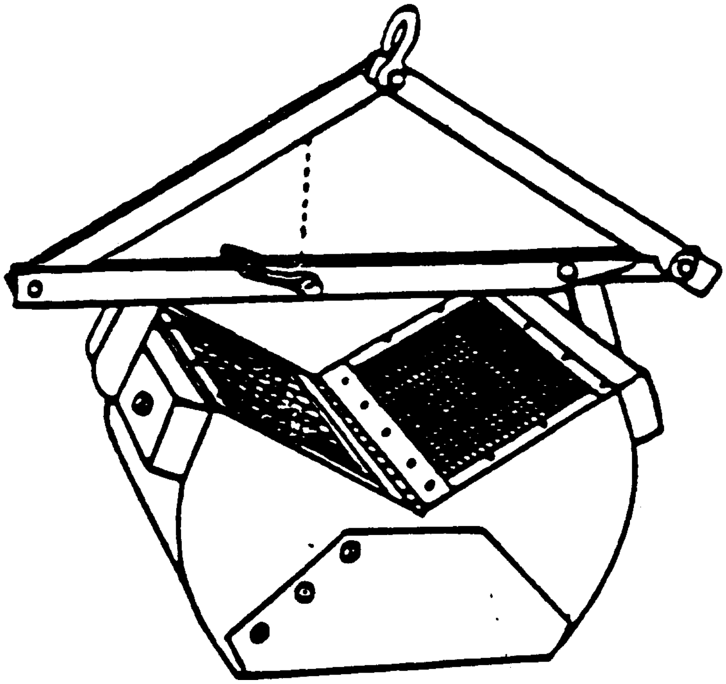
Many of the same constraints that apply to surface water sampling also relate to the collection of sediments and sludges. Sediments are examined to measure whether contaminants are concentrating along stream bottoms, creating hot spots that may have high concentrations of heavy metals, pesticides, or low-solubility organic matter. Sediments may be watery, with relatively little difference in density from water, or they may be compacted semi-solids where water is a minor fraction of the mass. Because of such difference, a variety of sampling methods and equipment maybe necessary.

If the sediment has the potential for being considered a hazardous material, disposable sampling equipment should be considered. For watery sludges from stream bottoms near shore, the pond sampler shown as Exhibit 10-14 can be used, since the plastic beaker can be disposed of, if the sampling plan so ordains. Other devices could include plastic pails or ladles for scooping up sediments from shallow water. The user should allow time for settling to occur, then decant the water off the top of the sediment before transferring samples to their containers. The user should sample only with plastic beakers, pails, or ladles where sample integrity of organics will not be compromised.

The semi-solid sediments near shore or above the water line are most easily collected using simple tools (e.g., polypropylene scoops, trowels, or dippers). Other alternatives for small semi-solid sediments include wooden tongue depressors or stainless steel tablespoons.

If stream-bottom samples of sediment are necessary, vertical-pipe or core samplers are used and can be driven into stream beds to any selected depth. During retrieval, samples are retained inside the cylinder by a partial vacuum formed above the sample and/or by a retainer at the lower end. For compacted sediment, sampling triers or waste pile samplers may be used as long as sample points are above the water

Exhibit 10-17
PONAR GRAB SAMPLER



surface or in very shallow water. If deep water samples from large streams or lakes are specified, specialized samplers (e.g., Eckman or Ponar dredges) are used.

No matter what equipment is used, the following general conditions apply:

- Collect at least three small, equal-sized samples from several points along the sludge or sediment deposition area. If possible, mark the location with a numbered stake, and locate sample points on a sketch of the site. Deposit sample portions in a clean, 1/2-gallon wide-mouth jar. Carefully stir portions together into one composite.
- Sediments from large streams, lakes, and the like may be taken with Eckman or Ponar dredges from a boat. Refer to Exhibit 10-17 for an example of a Ponar grab sampler. Ponar grab samplers are more applicable to a wide range of sediments and sludges because they penetrate deeper and seal better than spring-activated types (e.g., Eckman dredges).
- Streams and lakes will likely demonstrate significant variations in sediment composition with respect to distance from inflows, discharges, or other disturbances. It is important, therefore, to document exact sampling location by means of triangulation with stable references on the banks of the stream or lake. In addition, the presence of rocks, debris, or organic material may complicate sampling and preclude the use of, or require modification to, some devices. Sampling of sediments should, therefore, be conducted to reflect these and other variants.
- Transfer 100 to 200 grams of the composite sludges or sediments from the l/2-gallon jar to a 250-ml sample bottle. Attach identification label number and tag. Record all necessary information in the field logbook and on the sample log sheet. Return unused sample to its source.
- Store the sampler and jars in a plastic bag until decontamination or disposal.
- Tape the lid on the sample bottle securely, and mark the tape with the date and the sample collector's initials.
- Pack the samples for shipping. Attach a custody seal to the shipping package. Make certain that a traffic report and chain-of custody forms are properly filled out and enclosed or attached.

The reader should refer to Sections 4,5, and 6 for additional details.

Specific sampling equipment for collecting sediment and sludge specimens and procedures for their use are as follows:

Scoops and Trowels: This method provides for a simple, quick, and easy means of collecting a disturbed sample of a sludge or sediment.

- Collect the necessary equipment, and clean according to the requirements for the analytical parameters to be measured.
- Sketch the sample area, or note recognizable features for future reference.
- Insert scoop or trowel into material, and remove sample. In the case of sludges exposed to air, it may be desirable to remove the first 1 to 2 cm of material prior to collecting sample.

- If compositing a series of grab samples, use a plastic or stainless steel mixing bowl or Teflon tray for mixing.

- Transfer sample into an appropriate sample bottle with a stainless steel laboratory spoon, scoop, or spatula.

- Check that a Teflon liner is present in cap, if required. Secure the cap tightly. The chemical preservation of solids is generally not recommended. Refrigeration to 4°C is usually the best approach, supplemented by a minimal holding time.

- Label the sample bottle with the appropriate sample tag. Be sure to label the tag carefully and clearly, addressing all the categories or parameters. Complete all chain-of-custody documents, and record in the field logbook.

- Place the properly labeled sample bottle in an appropriate carrying container. Water samples for low- or medium-level organics analysis and low-level inorganics <u>must</u> be shipped cooled to 4°C with ice. <u>No ice</u> is to be used in shipping inorganic low-level soil samples; medium / high-level water samples, organic high-level water or soil samples, or dioxin samples. Ice is not required in shipping soil samples, but ice may be used at the option of the sampler. All cyanide samples, however, must be shipped cooled to 4°C. Use a custody seal on the shipping package and make certain that traffic report forms are properly filled out.

The reader should refer to Sections 4, 5, and 6 for additional details.

Hand Corers: (see Exhibit 10-18) Hand corers are applicable to the same situations and materials as the scoop described above. Corers have the further advantage of collecting an undisturbed sample that can profile any stratification in the sample as a result of changes in the deposition.

Some hand corers can be fitted with extension handles that will allow the collection of samples underlying a shallow layer of liquid. Most corers can also be adapted to hold liners generally available in brass or polycarbonate plastic. Care should be taken to choose a material that will not compromise the intended analytical procedures.

- Inspect the cores for proper precleaning.

- Force cores in with smooth continuous motion.

- Twist cores; then withdraw in a single smooth motion.

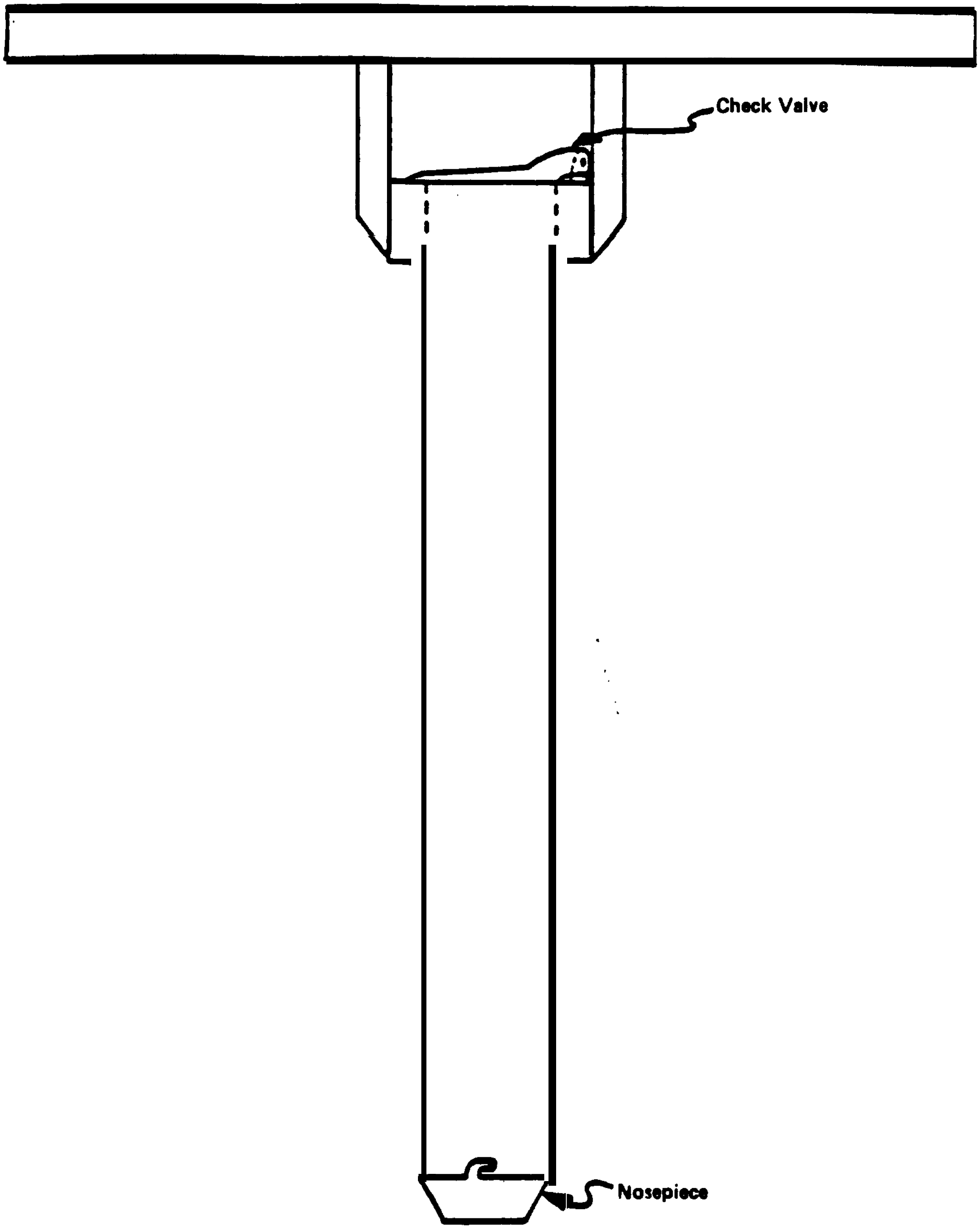
- Remove nosepiece and withdraw sample into a stainless steel or Teflon tray.

- Transfer sample into an appropriate sample bottle with a stainless steel laboratory spoon, scoop, or spatula.

- Label the sample bottle with the appropriate sample tag. Be sure to label the tag carefully and clearly, addressing all the categories or parameters. Complete all chain-of-custody documents, and record in the field logbook.

- Place the properly labeled sample bottle in an appropriate carrying container. Water samples for low- or medium-level organics analysis and low-level inorganics <u>must</u> be shipped cooled to 4°C with ice. <u>No ice</u> is to be used in shipping inorganic low-level soil samples; medium / high-level [illegible] or soil samples, or dioxin samples. Ice is not required in

Exhibit 10-18
HAND CORER



shipping soil samples, but ice may be used at the option of the sampler. All cyanide samples, however, must be shipped cooled to 4°C. Use a custody seal on the shipping package and make certain that traffic report forms are properly filled out.

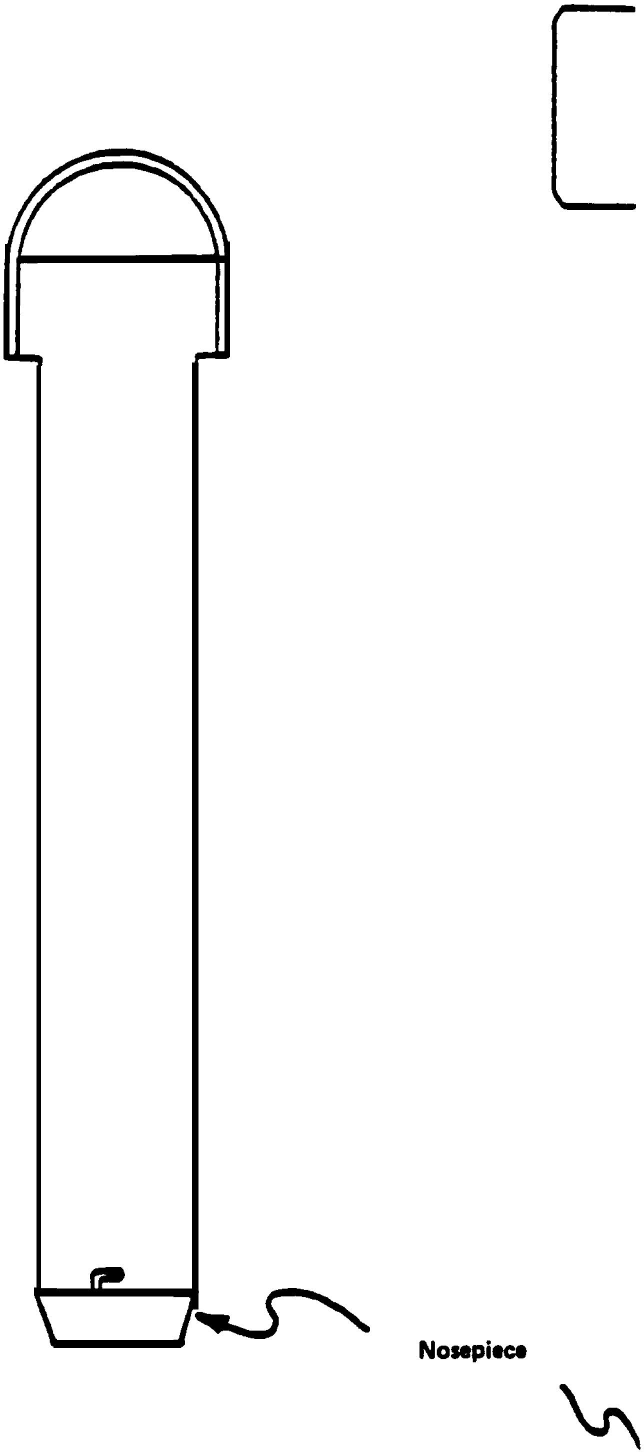
The reader should refer to Sections 4, 5, and 6 for additional details.

Gravity Corers: (see Exhibit 10-19). A gravity corer is a metal tube with a replaceable tapered nosepiece on the bottom and a ball or other type of check valve on the top. The check valve allows water to pass through the corer on descent but prevents washout during recovery. The tapered nosepiece facilitates cutting and reduces core disturbance during penetration. Most corers are constructed of brass or steel, and many can accept plastic liners and additional weights.

Corers are capable of collecting samples of most sludges and sediments. The corers collect essentially undisturbed samples that represent the profile of strata which may develop in sediments and sludges during variations in the deposition process. Depending on the density of the substrate and the weight of the cores, penetration to depths of 75 cm (30 inches) can be attained. Care should be exercised when using gravity corers in vessels or lagoons that have liners, since penetration depths could exceed that of substrate and result in damage to the liner material.

- Attach a precleaned corer to the required length of sample line. Solid braided 5 mm (3/16 inch) nylon line is sufficient; 20 mm (3/4 inch) nylon, however, is easier to grasp during hand hoisting.
- Secure the free end of the line to a fixed support to prevent accidental loss of the corer.
- Measure and mark distance to top of sludge on sampler line to determine depth of sludge or sediment coring.
- Allow corer to free fall through liquid to bottom.
- Determine depth of sludge penetration.
- Retrieve corer with a smooth, continuous lifting motion. Do not bump corer because this may result in some sample loss.
- Remove nosepiece from corer, and slide sample out of corer into stainless steel or Teflon pan.
- Transfer sample into appropriate sample bottle with a stainless steel laboratory spoon, scoop, or spatula.
- Check that a Teflon liner is present in cap, if required. Secure the cap tightly. The chemical preservation of solids is generally not recommended. Refrigeration to 4°C is usually the best approach, supplemented by a minimal holding time.
- Label the sample bottle with the appropriate sample tag. Be sure to label the tag carefully and clearly, addressing all the categories or parameters. Complete all chain-of-custody documents, and record in the field logbook.
- Place the properly labeled sample bottle in an appropriate carrying container. Water samples for low- or medium-level organics analysis and low-level inorganics <u>must</u> be shipped cooled to 4°C with ice. <u>No ice</u> is to be used in shipping-inorganic low-level soil samples; medium / high-level water samples, organic high-level water or soil samples, or dioxin samples. Ice is not required in shipping soil samples, but ice may be used at the option of the sampler. All cyanide samples, however, must be shipped cooled to 4°C. Use a custody seal on the shipping package and make certain that traffic report forms are properly filled out.
  The reader should refer to Sections 4, 5, and 6 for additional details.

Exhibit 10-19
GRAVITY CORER



Ponar Grab Sampler: (see Exhibit 10-1 7) The Ponar grab is a clamshell-type scoop activated by a counter-lever system. The shell Is opened, latched In place, and slowly lowered to the bottom. When tension is released on the lowering cable, the latch releases and the lifting action of the cable on the lever system closes the clamshell.

Ponars are capable of sampling most types of sludges and sediments from silts to granular materials. They are available in a “petite” version with a 232-square-centimeter sample area that is light enough to be operated without a winch or crane. Penetration depths will usuall not exceed several centimeters. Grab samplers are not capable of collections undisturbed samples. As a result, material in the first centimeter of sludge cannot be separated from that at lower depths. The sampling action of these devices causes agitation currents that may temporarily resuspend some settled solids. This disturbance can be minimized by slowly lowering the sampler the last half-meter and by allowing a very slow contact with the bottom.. It is advisable, however, to collect sludge or sediment samples only after all overlying water samples have been obtained. Steps in using Ponar dredges areas follows:

- Attach a precleaned Ponar to the necessary length of sample line. Solid braided 5 mm (3/16 inch) nylon line is usually of sufficient strength; however, 20 mm (3/4 inch) or greater nylon line allows for easier hand hoisting.
- Measure and mark the distance to top of sludge on the sample line. Record depth to top *of sludge* and depth of sludge penetration.
- Open sampler jaws until latched. From this point on, support the sampler by its lift line, or the sampler will be tripped and the jaws will close.
- Tie free end of sample line to fixed support to prevent accidental loss of sampler.
- Begin lowering the sampler until the proximity mark is reached.
- Slow rate of descent through last meter until contact is felt.
- Allow sample line to slack several centimeters. In strong currents, more slack maybe necessary to release mechanism.
- Slowly raise dredge clear of surface.
- Place Ponar into a stainless steel or Teflon tray and open. Lift Ponar clear of the tray, and return Ponar to laboratory for decontamination.
- Collect a suitable aliquot with a stainless steel laboratory spoon or equivalent, and place sample into appropriate sample bottle.
- Label the sample bottle with the appropriate sample tag. Be sure to label the tag carefully and clearly, addressing all the categories or parameters. Complete ail chain-of-custody documents and records in the field logbook.
- Place the properly labeled sample bottle in an appropriate carrying container. Water samples for low- or medium-level organics analysis and low-level inorganic <u>must</u> be shipped cooled to 4°C with ice. <u>No ice</u> is to be used in shipping inorganic low-level soil samples; medium / high-level water samples, organic high-level water or soil samples, or dioxin samples. Ice is not required in shipping soil samples, but ice may be used at the option of the sampler. All cyanide samples, however, must be shipped cooled to 4°C, Use a custody seal on the shipping package and make certain that traffic report forms are properly filled out.

The reader should refer to Sections 4,5, and 6 for additional details.

10.2.7 Region-Specific Variations

The reader should refer to Subsection 10.1.6 for discussion. In addition to examples cited there, certain specific procedures may be subject to continuous revisions, so users should contact the EPA RPM for to the most recent procedures advocated by each region. For example, sediment sampling for possible TCDD contamination contains special precautions as outlined in Section 13. Some regions will incorporate these precautions, whereas others will prohibit use of certain equipment. Such variances change from month to month, so a special effort has to be made by SMs and field team leaders to keep current on the various requirements. Revision 01 to this compendium will include updated variances.

10.2.8 Information Sources

deVera, E.R., B.P. Simmons, R.D. Stephens, and D.L. Storm. "Samplers and Sampling Procedures for Hazardous Waste Streams." EPA 600/2-80-018. January 1980.

Environmental Monitoring System Laboratory (EMSL), ORD, U.S. Environmental Protection Agency. *Characterization of Hazardous Waste Sites--A Method Manual, Volume II--Available Sampling Methods.* Las Vegas, Nevada 89114. 1983.

Lind, Orent. *Handbook of Common Methods of Limnology.* St. Louis, Missouri: C.V. Mosby Co. 1974.

OWDC, U.S. Geological Survey, U.S. Department of the Interior. *National Handbook of Recommended Methods for Water-Data Acquisition.* Prepared cooperatively by agencies of the U.S. Government. Reston, Virginia. 1977.

Smith, R., and G.V. James. *The Sampling of Bulk Materials.* London: The Royal Society of Chemistry. 1981.

SECTION 11

METEOROLOGY AND AIR QUALITY

11.1 SCOPE AND PURPOSE

Section 11 describes the meteorological data that are required to make preliminary (screening) assessments of exposure to hazardous air pollutants before site-specific monitoring data are available. Similarly, the meteorological data requirements for conducting analyses of more refined air quality modeling are described in terms of using both representative offsite and site-specific data. The section also identifies procedures for obtaining the appropriate meteorological information both from existing sources and by conducting site-specific monitoring programs.

11.1.1 Meteorological Parameters for Screening Model Analyses

11.1.1.1 Scope and Purpose

This subsection describes the meteorological data required to make preliminary assessments of exposure to hazardous air pollutants through the use of screening dispersion models. These models are generally used before site-specific monitoring data are available. Screening models purposely over estimate air quality input. This over-estimation is largely a result of the generalization of model inputs and the assumption inherent in the models that certain meteorological conditions, which produce high impacts occur and persist at the site. It is useful to describe the required meteorological parameters, how they are obtained and applied in screening models, and how the results may be used. Such information provides a more complete perspective in determining the possible need for more refined modeling analyses and the associated meteorological data requirements. This subsection provides a general discussion of model selection with more specific guidance provided in the references. Selection of an appropriate model depends on project- and site-specific considerations.

11.1.1.2 Definitions

Specific descriptions of the following generic terms are provided in the text.

Dispersion Model
: A set of algorithms designed to simulate the transport and diffusion of airborne pollutants to obtain estimates of pollutant concentrations at specific receptor locations for specific time periods.

Hazardous Air Pollutant
: An air pollutant to which no ambient air quality standard applies and that, in the judgment of the Administrator of the U.S. EPA, causes, or contribute to, air pollution that may reasonably be anticipated to result in an increase in mortality or an increase in serious irreversible illness or incapacitating reversible illness.

Joint Frequency Distribution
: A statistical distribution that lists the frequency of concurrent wind speed, wind direction, and atmospheric stability data by individual wind speed groups, wind direction sectors, and atmospheric stability classes.

Receptors

The fixed locations relative to modeled sources at which concentration estimates are predicted.

Screening Technique

A relatively simple analysis technique to determine if a given source is likely to pose a threat to air quality. Concentration estimates from screening techniques are conservative.

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. This person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

Source

The point or area of origin of hazardous pollutants emitted into the ambient air.

Source Terms

The set of information that describes the rates, locations, dimensions, and operational and physical release characteristics of hazardous pollutants emitted into the ambient air.

11.1.1.3 Applicability

Screening models are used to provide a conservative estimate of the air quality impact of a specific source or source category (U.S. EPA, 1978, p. 17). Depending on the level of refinement, screening model analyses can also be used to determine: the meteorological conditions that result In maximum short-term and icing-term impacts; the potential for exceeding acceptable ambient concentrations; the receptor locations at which maximum ambient levels are predicted to occur (for use if refined modeling is needed); and impacts on sensitive receptors (State and Territorial Air Pollution Program Administrators / Association of Local Air Pollution Control Officials (STAPPA/ALAPCO), 1984, pp. 135-1 36). The guidance for use of screening models was developed primarily in relation to the evacuation of sources of "criteria" air pollutants (e.g., particulates, sulfur dioxide, and nitrogen dioxide) for which National Ambient Air Quality Standards exist (U.S. EPA, 1981a). The need for equivalent standards for the host of hazardous air pollutants is recognized by federal, state, and local agencies charged with protecting the air quality in their jurisdictions (STAPPA/ALAPCO, 1984).

These currently evolving standards are expressed in terms of a concentration averaged over some period of time. The averging time depends on the specific health impacts known to be associated with a hazardous substance. The ability of these substances to have an impact on health over the short term (e.g., a 24-hour average) and the long term (e.g., an annual average) creates the need for screening analyses to be performed over these different time scales (STAPPA/ALAPCO, 1984, pp. 132-134), The meteorological input data requirements differ between screening models that produce short-term and long-term concentration estimates. These requirements are discussed in Subsection 11.1.1.6.2.

11.1.1.4 Responsibilities

Project Meteorologist and Air Quality Analyst: This person is responsible, through coordination with the appropriate regulatory agencies, for selecting appropriate screening methodologies and model(s), selecting representative meteorological data required as model input, performing model calculations, evaluating and reporting results, and maintaining records that document these activities. The execution of air quality models requires the Input of source-term data. If they have the requisite engineering skills, project meteorologist and air quality analysts may develop this information; if they do not have this capability, they will need to work closely with the SM.

Site Manager The SM is responsible for the program design and coordination. The project engineer also Interacts with the project meteorologist in modeling and monitoring applications, such as source term development.

11.1.1.5 Records

Records of the meteorological data selected for use in the screening model analyses must be maintained to validate these data and to evaluate the modeling results. Selection and determination of the representativeness of meteorological parameters should be documented, as well as the selection, application, and results of the model analyses. The level of detail in these records must support the program's quality assurance requirements, which are to be established before making the screening model analyses. -

Quality assurance records include those records that furnish documentary evidence of the quality of items and of activities affecting quality. Examples of such records include, but are not limited to, the following: raw data records (e. g., strip charts), data validation findings, equipment maintenance and calibration records, work instructions, work scopes (design control documents), model inputs and outputs, modeling assumptions, and software documentation and verification.

11.1.1.6 Procedures

11.1 .1.6.1 Screening Model Selection

The screening methodology to be used is selected in coordination with the appropriate federal, state, or local agencies. Technical considerations (based on the level of refinement required) that should be made include the appropriate averaging periods for acceptable ambient concentrations; source release characteristics (e.g., point, area, or line / volume sources; elevated or ground-level releases); the topography of the site and surrounding area; and the availability of ,appropriate meteorological data. As discussed earlier, the averaging period determines the selection of a short- or long-term screening model. Source release characteristics influence the selection process by defining the need for either simplistic models (e.g., one source or source type) or more sophisticated models (e.g., multiple source types and release characteristics), Topography and receptor locations influence the selection process by defining the need for models capable of representing airborne pollutant transport over flat, rolling, or complex terrain. Screening models approved by the U.S. EPA are provided in the *User's Network for App/ied Modeling of Air Pollution (UNAMAP),* Version 6 (U.S. EPA, 1986). U.S. EPA provides guidelines for screening model selection and application (U.S. EPA, 1977, 1981 b, and 1986). The project meteorologist and air quality analyst should be familiar with this guidance and with the available screening models before coordinating with the appropriate regulatory agencies.

11.1 .1.6.2 Meteorological Data Selection

Screening model analyses are generally made before site-specific meteorological data are available. This process requires the selection of a meteorological database that will provide a conservation assessment of the air quality impact at the hazardous waste site and surrounding area. The selection of meteorological data for use in screening assessments depends on the level of refinement of the modeling methodology and the representativeness of the available data. These input data vary from selected 'Worst case" meteorological scenarios to a source of data, such as the National Weather Service (NWS) whose routine observations are archived by the National Climatic Data Center (NCDC) in Asheville, North Carolina. Data from the Federal Aviation Administration (FAA) and military stations (U.S. EPA, 1981 c, p. 5) or from universities, industry, pollution control agencies, and consultants (U.S. EPA, 1980, p. 31) may be used if these data are equivalent in accuracy and detail to the NWS data. The project meteorologist and air quality analyst must determine the representativeness of any offsite data and the validity of their use, along with the screening model, in providing a conservative assessment. The representativeness depends on the proximity of the station to the area under consideration, the complexity of the terrain, and the exposure of the meteorological monitoring equipment at the station. This selection process is also made in consultation with the appropriate regulatory agencies. Model selection governs the specific meteorological data that are required as input. For short-term analysis, screening models employ a "worst case" meteorological scenario. This scenario may consist either of a specific worst-case meteorological condition or a comprehensive set of meteorological conditions that, when evaluated, will determine the worst-cast meteorology.

Long-term models require that hourly meteorological data be summarized over longer periods of time (e.g., months, seasons, years). Hourly wind speed, wind direction, and atmospheric stability are reformatted into a stability array (STAR). If determined to be representative, STAR data sets compiled by the NCDC for NWS stations throughout the United States (U.S. NCDC, 1963) could be used. Otherwise: the assumptions described for long-term screening in U.S. EPA, 1977, should be used. The average temperature and the average morning and afternoon mixing heights are required Inputs of the long-term models. Mixing height data have been summarized on seasonal and annual bases by Hazardous, 1972, for 62 NWS stations in the United States. The NCDC can also compile daily morning and afternoon mixing-height data for NWS stations that routinely make ballmn-home measurements of meteorological conditions in the upper air (above ground). Since the spatial coverage of NWS stations making these measurements is not dense, the project meteorologist and air quality analyst must carefully select the most representative source of the data to be used.

ıI. 1.1.7 Source Term Development

Another concern in modeling releases from a hazardous waste site is the determination of the source configuration (e.g., release type) and source term (Le., emission rates). Source term determination can be complex for many types of sites such as surface impoundments, landfills, and land treatment facilities. The source term can be determined with a specifically designed onsite monitoring program, which is receptor modeling based on near-site monitoring or on air emission modeling. Emission modeling guidance is summarized in U.S. EPA, 1981 b, and in GCA Corporation, 1983. Appropriate, conservative assumptions for emission rates can be applied for screening model analyses. Determination of the source configuration should be accomplished in conjunction with the SM after careful consideration of all possible release scenarios.

11.1.1.8 Region-Specific Variances

Besides the site-specific considerations to be made in selecting the appropriate screening model and meteorological input data, no region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

11.1.2 Meteorological Parameters for Refined Modeling Analyses

11.1.2.1 Scope and Purpose

Refined modeling analysis uses site-representative hourly meteorological data. When such data are unavailable, onsite meteorological monitoring may be necessary. This subsection provides generic guidance for the site-specific measurement of meteorological parameters that may be required to make detailed short-term and long-term assessments of exposure to hazardous air pollutants through the use of refined models for estimating dispersion of gases and particulate. The need for refined model analyses will generally be identified as a result of the preliminary screening model analyses discussed in Subsection

11.1.1. The procedures indicated here are applicable for use for field work at hazardous waste sites. This subsection briefly discusses model selection with more specific guidance cited by reference. Specific models are not recommended since selection of an appropriate model depends on project- and site-specific considerations. Meteorological parameters that can be readily obtained from other data sources are identified, The references listed in Subsection 11.1 .2.8 provide more detailed discussions of field measurement procedures.

11.1.2.2 Definitions

Definitions of key terms as they apply to this procedure are provided below. Subsection 11.1.1.2 contains additional definitions of terms used in Subsection 11.1.2.

Atmospheric Diffusion

The process by which minute particles of a substance that is suspended in the atmosphere are distributed throughout an increasing volume of air. This process, then, reduces the concentration of the substance since the amount of the substance relative to the amount of air is decreased. Atmospheric diffusion is controlled in the atmosphere by wind speed and atmospheric turbulence.

Atmospheric Dispersion

As used in the context of this procedure, atmospheric dispersion combines the effects of atmospheric transport and diffusion on a substance.

Atmospheric Stability

Terms that describe the ability of the atmosphere to diffuse (see “atmospheric diffusion”) a substance. An unstable, turbulent atmosphere provides for more diffusion than a stable atmosphere. For use in dispersion modeling and impact assessment, stability Is represented by Pasquili-Gifford stability Classes A (unstable) through F (stable).

Atmospheric Transport

The process by which a substance Is carried through the atmosphere.

Mixing Height

The height above the surface through which relatively vigorous vertical mixing occurs.

Refined Model

An analytical technique that provides a detailed treatment of physical and chemical atmospheric processes and requires detailed and precise Input data. The estimates are more accurate than those obtained from conservative screening techniques.

Sigma Theta

Terms that describe the measure of variability of the wind direction. Sigma theta is used as an indicator of the diffusion capacity of the atmosphere and can be used to classify atmospheric stability.

11.1.2.3 Applicability

The purpose of conducting refined model analyses is to provide a more accurate and representative estimate of the impacts of a specific source (U.S. EPA, 1978, p. 17). These analyses are conducted when a potential for exceeding an acceptable ambient concentration of a hazardous air pollutant has been determined through screening model analyses (STAPPA/ALAPCO, 1984, p. 136).

As Subsection 11.1 .1.3 indicates, acceptable concentrations of hazardous air pollutants (and standards based on these acceptable levels) are currently evolving. Refined model analyses may also be required in situations in which source and/or receptor characteristics are complicated (see Subsection 11.1.2.6. 1). The meteorological input data requirements differ between models that produce short-term and long-term concentration estimates. These requirements are discussed in Subsection 11.1.2.6.2.

- -

11.1.2.4 Responsibilities

Project Meteorologist: This person is responsible for the collection of site-specific meteorological data and/or selection of other representative meteorological parameters. Using input from project management, technical personnel, and appropriate regulatory agencies, the project meteorologist would design the measurement program; oversee the data collection, validation, and quality assurance procedures; and maintain records that document these activities.

Project Meteorologist and Air Quality Analyst: This person is responsible, through coordination with the appropriate regulatory agencies, for selecting appropriate refined model(s), performing model calculations, evaluating and reporting results, and maintaining records that document these activities.

Site Manager The SM is responsible for the program design and coordination. The project engineer also interacts with the project meteorologist In modeling and monitoring applications including source term development.

Field Maintenance Engineer: This person is responsible for installing, calibrating, maintaining, and decommissioning the designed program, and for maintaining records that document these activities.

11.1.2.5 Records

Maintenance of records of the meteorological data collection program is required for validation purposes and future use in air quality modeling. These records include not only the data themselves (data can be recorded on an analog strip for future data reduction, digitally on hard copy such as a printer, or digitally on a magnetic tape) but also appropriate calibration and operational logs. These logs document activities performed on the instrumentation for future use in validation. Selection and determination of the representativeness of meteorological parameters, if applicable,. should be documented, as well as the selection, application, and results of the refined model analyses.

Depending on the level of validation and quality assurance applied, additional records to be maintained could include system design drawings, data review logs, data correction logs, audit documents, instructions for data handling and use, and so forth. The level of detail in these records must support the quality assurance requirements of the program, which are to be established before collecting data.

11.1.2.6 Procedures

11.1 .2.6.1 Refined Model Selection

The refined dispersion model(s) to be used is selected in cooperation with the appropriate federal, state, and local regulatory agencies. The same technical considerations made during selection of an appropriate screening model apply in selection of refined models (sw Subsection 11.1.1.6.1), although relatively more detailed input is often required because the refined models are more sophisticated.

The nature of atmospheric releases from hazardous waste sites dictates the need for a detailed evaluation of the appropriate model type and methodology to be applied. Depending on the source characteristics, the model may have to account for neutrally buoyant (i.e., approximately the same density as air).

lighter-than-air, or heavier-than-air plumes; continuous or instantaneous (i.e., puff) releases; gases or particulates; a single or many individual point sources or area sources; and an urban or rural environment. Consideration of these source characteristics plus the required application (i.e., short- or long-term assessment) will Influence model selection. In addition, it may be necessary to consider removal and t transformation processes on the pollutant as it is transported downwind, Examples of these processes are gravitational settling, adsorption, and oxidation, Models with appropriate algorithms must be selected to account for these processes.

As with screening models, determination of the appropriate source term is an important factor in refined modeling and In the analysis of the results (see Subsection 11,1.1.7). Since refined modeling attempts to provide a more realistic and accurate assessment, source term and source characteristic assumptions should be representative of expected conditions,

A set of refined models is available through the U.S. EPA Exposure Evaluation Division, Office of Toxic Substances. The modeling system, known as Graphical Exposure Modeling System (GEMS), consists of a series of atmospheric models with various levels of refinement (GSC Corporation, 1984). These models can also be used for screening assessments, In addition to atmospheric models, GEMS includes models capable of assessing contaminant migration in surface water, ground water, and soils. Examples of EPA-approved atmospheric models available for use through GEMS Include CDM, ISCST, and ISCLT. These computer codes can address short-term and/or long-term assessments wit h various ource configurations. Some GEMS models also can account for removal and transformation mechanisms. Based on expected considerations at a hazardous waste site, the ISC computer code will probably be the most applicable model for many evaluations. The previously mentioned EPA-approved computer codes are also available through the UNAMAP on computer tape (U.S. EPA, 1986). UNAMAP also contains many other EPA-approved codes that may apply to some hazardous waste sites. All the UNAMAP models are also available through CEMS.

The GEMS atmospheric models do not account for all types of site-specific source and atmospheric dispersion considerations. The U.S. EPA is formulating guidance for the use of refined models with sources In complex terrain. Appropriate models may Include accurate wind field analysis to account for terrain-Induced variations in plume transport. In lieu of an adequate refined model that appropriately accounts for plume transport, complex terrain screening models (e.g., VALLEY) may need to be used and the results evaluated on a site-specific basis, considering model limitations as related to the intended application. Another consideration is models that can account for nonuniform or instantaneous releases. An example of a model that can address dispersion in complex terrain, as well as instantaneous releases, would be a plume element type such as a three-dimensional puff model, The ERT Model for Pipeline Ruptures (Hanna, 1982), the SPILLS Model (Fleisher, 1980), and the PFPL Model (Garrett and Murphy, 1981) are examples of plume element/ puff models.

Another modeling concern for hazardous waste sites is the transport and diffusion of heavier-than-air gases. Various field measurement programs and analyses of the physical concepts of dense gas dispersion show that standard, Gaussian atmospheric diffusion models (e.g., the EPA-approved models) are inadequate until the plume has been diluted to where its density approximates that of the ambient air. This situation will occur at some distance from the source. The initial dispersion of dense gases is described by low, flat plumes that disperse in part because of their own density. Unless modified, Gaussian models cannot simulate this. Accordingly, if dense gas dispersion must be considered, especially close to the source, an appropriate model must be used. Discussions of dense gas dispersion modeling is provided in Britter and Griffiths (1982).

The project meteorologist and air quality analyst, when selecting the appropriate model for the application, must be familiar with any technical shortcomings of the models. For example, because of concerns over source size versus downwind distance and the applicability of modeling dispersion parameters at close-in distances, EPA-approved models do not calculate concentrations at distances less than 100 meters from the source. Some evaluations at hazardous waste sites may require assessments at these short distances from the source. These special situations may require site-specific analyses and should be discussed with the appropriate regulatory agency for guidance and approval on proposed methodologies.

11.1 .2.6.2 Meteorological Data Collection

Site-specific meteorological data are preferred when conducting screening or refined model analyses (U.S. EPA, 1978, p. 31). An onsite monitoring program is necessary when there is a lack of representative meteorological data. Collection of meteorological data in the field requires the design of a system that provides the necessary model input information and that takes into account the logistics of siting and operation. Some data are best collected from visual observations or other representative sources (e.g., NWS stations) rather than from erected, in situ towers. In practice, acquiring all of the meteorological inputs to the model(s) will often require a combination of all of these collection techniques.

Model selection governs the specific meteorological data that are required as inputs. Appropriate input parameters and averaging times for screening models producing short-term and long-term concentration estimates are described in Subsection 11.1.1.6.2. The averaging time for meteorological data measured onsite should be consistent with the project requirements. For meteorological parameters, a consecutive period of at least 15 minutes can generally be used to represent the 1-hour period (U.S. NRC, 1980, p. 11). These hourly parameters are input directly to the refined models.

The duration of the monitoring program depends on the application of the measurements. If the project requirements are to assess potential Impacts during periods of site activity, then the meteorological data measured during these periods Is directly applicable to modeling analyses. However, if the project requirements are to assess short-term and long-term impacts not specific to any period (which is the scope of Subsection 11.1), then the monitoring program should be of a duration that will include meteorological characteristics representative of conditions that would produce maximum impacts. In practice, it may be feasible to conduct the monitoring program only for less than a year. The EPA has prepared guidance on using data periods of less than 1 year (U.S. EPA, 1980, pp. 9, 39). However, it should be noted that this guidance was developed primarily in relation to the evaluation of “criteria" pollutants. Therefore, in applying this guidance to evaluations of noncriteria hazardous air pollutants, the project meteorologist and air quality analyst must establish the monitoring program requirements in cooperation with the appropriate regulatory agencies.

For data to be collected in the field, a system should be chosen for the required application. The monitoring system should be designed so that the measurements represent the conditions that determine atmospheric dispersion in the area of interest. Since the atmospheric conditions can vary dramatically with the physical characteristics of the surrounding area, the system (equipment and location) should be designed based on specific site characteristics and program objectives.

Discussions concerning the collection of various meteorological parameters are presented below. More specific guidance on siting, equipment specifications and accuracies, and applications has been prepared by the U.S. EPA (U.S. EPA. 1983; U.S. EPA, 1984), the U.S. Nuclear Regulatory Commission (U.S. NRC, 1980), and its successor, the U.S. Department of Energy (1984). In all cases, specifications and accuracies should be based on requirements determined according to the appropriate regulatory agencies.

The following discussions concern measurements to support atmospheric dispersion modeling using most regulatory agency-approved methodology and models for licensing and permitting activities. Some of the more refined models may require input data for meteorological parameters not discussed here. For special cases, the references provided in this compendium or by the appropriate regulatory agency should be consulted for the accepted measurement techniques.

Horizontal Wind Speed

Description: . Horizontal wind speed sensors (anemometers) are available in a number of different designs. The most common types are the rotational cup and the propellor anemometers. The cup sensors are generally more accurate. The design of the anemometer cups dictates the durability, sensitivity, accuracy, and response of the instrument. Three conical cups usually provide the best performance. Propellor anemometers (similar to windmills in design) revolve about a pivoted shaft that is oriented by a vane into the direction from which the wind is Mowing. The number of blades normally varies from three to six. For most atmospheric dispersion studies, anemometers should have a starting threshold of 0.5 meters per second (m/sac) or less and a system (i.e., sensor through readout device) accuracy of ± 0.2 m/sec.

Applicebility Measurement of horizontal wind speed is an important factor for determining the dispersive capability of the atmosphere. The speed of the wind provides an indication of the transport (e.g., travel speed) and diffusion of a pollutant and is a direct input to air quality models. Wind speed is an important parameter in plume rise and is used as a factor in determining an atmospheric stability class for some stability classification schemes.

Horizontal Wind Direction

Description: Most sensors for measuring horizontal wind direction consist of a vane rotating on a fulcrum. The shapes and designs of the vane surface vary but are generally rectangular or curved. The vanes are designed to orient into the direction from which the wind is blowing. For atmospheric dispersion studies, wind vanes should have a starting threshold of less than or equal to 0.5 m/see and a system accuracy of ± 5 degrees.

Applicability: Horizontal wind direction is directly used as an indicator of pollutant transport and is used as a direct input to air quality models.

it is also preferred that the meteorological system be designed to calculate directly and to give the standard deviation of the horizontal wind direction fluctuations (sigma theta). Sigma theta provides an indicator of the atmospheric stability by measuring horizontal turbulence. Some atmospheric diffusion models use sigma theta as a direct input in determining horizontal plume dimensions. Care should be exercised with this method to ensure that the data are representative. It may be desirable, for example, to install the meteorological tower at a complex-terrain site to ensure that the sigma theta data reflect the surface inhomogeneity.

Vertical Wind Speed and Direction

Description: Vertical wind speed and direction can be measured with a vertical propellor anemometer, a UVW anemometer, or a bivane. The vertical propellor anemometer has a propellor-type sensor mounted on a fixed vertical shaft. Since the propellor can reverse its direction, the sensor can indicate whether wind flows are directed upward or downward. A UV anemometer has three fixed propellors. Two, located 90 degrees apart, measure the horizontal wind vector (both magnitude and direction). The third, like the vertical propellor anemometer, is located on a vertical shaft at right angles to the first two. This anemometer will then measure the total (i.e., U, V, and W components) wind vector. The UVW anemometer, when coupled with an onsite microprocessor to reduce the data, can provide real-time displays of wind speed, azimuth (horizontal wind components), and elevation (vertical wind component). The bivane consists of a vane with two flat plates perpendicular to each other, counterbalanced and mounted on a gimbal that allows the vane to rotate horizontally and verticality. Unlike the UVW anemometer, it does not provide the wind speed (and hence all three wind vector components) unless mounted with a propellor anemometer in place on the counter weight. it does provide both the azimuth and elevation components of the wind direction.

Vertical wind measurement systems should have a starting threshold of less than 0.25 m/see and an accuracy of ± 0.2 M/sac for wind speed and ± 5 degrees for wind direction. Because of the sensitivity of these types of {instruments, long-term use In the field or use In harsh environments may necessitate special maintenance activities. Individual manufacturers should be consulted about each application.

Applicability The measurement of vertical wind components may be required as input to certain refined atmospheric dispersion models. Some refined models may use atmospheric turbulence data directly to define vertical and horizontal plume spread instead of Indirectly from stability class. These models use the standard deviation of horizontal and vertical wind direction fluctuations – sigma theta and sigma phi, respectively. Some models also use both sigma theta and sigma phi measurements classified into atmospheric stability class. Vertical wind speeds can be used for plume downwash considerations (e.g., onsite hazardous waste incineration). The reader should refer to the subsection on atmospheric stability for further discussion.

Ambient Temperature

Description: The two most commonly used temperature measurement devices for air quality studies are the resistance temperature detectors (RTDs) and thermistors. Thermistors are electronic semiconductors that are made from certain metallic oxides. The resistance of the thermistor varies inversely with its absolute temperature so the electrical output through the sensor can provide an indication of the ambient temperature. The RTD Is used in a similar manner. These RTD sensors are made of different pure metals such as silver, copper, nickel, or platinum. Normally, platinum provides the best material. The RTD operates on the principle that the electrical resistance of a pure metal increases with temperature.

Care must be taken to avoid solar radiation error in temperature measurements. This error can be avoided by using naturally or mechanically aspirated radiation shields. The radiation shields should face downward when mounted on a tower. Temperature system accuracies should be approximately ± O.5°C.

Applicability The measurement of ambient temperature can be used to determine relative humidity when used with the dew point temperature or to determine source terms for air releases of chemicals when used in the calculation of vaporization or volatization rates. In addition, surface temperature is used to calculate mixing height. Temperature is also put in air quality models to determine plume rise for buoyant (lighter-than-air) atmospheric releases. Variation of ambient temperature helps characterize local meteorological conditions.

Cloud Cover

Description: Cloud cover Is best determined from data collected at a representative NWS station as there are trained observers available to provide this information. If representative NWS cloud cover data are not available, then the total amount of cloudiness above the apparent horizon should be estimated as a fraction (In tenths) by a visual observation (Tumer, 1964).

Applicability Instead of other data, aloud cover is used as one of the indicators of atmospheric stability in the Pasquill-Turner stability classification scheme. In this scheme, aloud cover, ceiling height, wind speed, and solar radiation are used to determine an atmospheric stability class (Turner, 1964).

Ceiling Height

Description: A ceiling is defined as a layer of clouds that covers more than one-half of the sky. The height of a ceiling is best determined by experienced observers at NWS stations. It can be estimated visually at the waste site by determining the height of the lowest layer of clouds that cover more than 50 percent of the sky. it is necessary for the onsite observer to estimate only whether the ceiling is less than 7,000 feet, between 7,000 and 16,000 feet, or more than 16,000 feet, based on the application of this parameter (Turner, 1964). Rough estimates of altitude can be made by noting the types of clouds when the ceiling height observation is made. Cloud forms with bases of less than 7,000 feet generally include fair-weather cumulus, stratus and stratocumulus, and towering cumulus. Cloud forms with bases between 7,000 and 16,000 feet generally include altostratus, altocumulus, towering cumulus, and cumulonimbus. Cloud forms with bases higher than 16,000 feet are usually of the cirrus type. A pocket-sized cloud atlas may be a useful tool for the field observer.

Applicability Ceiling height is used in the Pasquill-Tumer stability classification scheme to determine atmospheric stability class.

Mixing Height

Description: Mixing heights are best determined from representative NWS stations that record upper air (i.e., above the surface) data. instrumentation packages called radiosondes are carried aloft twice daily (7:00 a.m. and 7:00 p.m., EST) throughout the United States by nontethered balloons. These packages measure wind speed and direction, temperature, and humidity as they ascend. Algorithms exist to compute mixing heights from the data collected by the radiosonde. Care should be taken to select data from a representative station and for the appropriate time, as applicable. Subsection 11.1 .1.6.2 discusses the sources of this parameter. Estimates of the mixing height can also be made at the site through the use of balloonsondes (tethered and nontethered balloons) and with remote sensors such as acoustic sounders. This equipment requires special expertise to use, to evaluate, and to apply the collected data.

Applicability: The mixing height is the level of the atmosphere below which pollutants could be mixed. Mixing height indicates the vertical limit of pollutant dispersion. It Is also an important consideration in air quality model in for nonground-level releases, including ground-level sources with high effective-release heights (e.g., a large plume rise because of a fire).

Atmospheric Stability

Atmospheric stability can be determined in the field for air quality modeling applications by using a number of alterative methods. These methods use the applicable meteorological parameters discussed in previous subsections.

The Pasquill-Tumer method of classifying atmospheric stability uses the combination of wind speed, incoming solar radiation, aloud cover, and time of day. This scheme is indicated In Exhibit 11-1.

The neutral Class D is assumed for overcast conditions during day or night.

The incoming solar radiation intensities are determined from the solar attitude (a function of time of day and day of the year) and modified for existing aloud cover and aloud ceiling height (Turner, 1964).

The EPA provides further guidance for adjusting sigma phi to account for increased surface roughness, and for adjusting the stability category to account for wind speed restrictions on the occurrence of unstable and stable conditions (U.S. EPA, 1981 c). If measurements of sigma phi are not available, sigma phi may be determined using the transform:

Exhibit 11
CLASSIFICATION OF ATMOSPHERIC STABILITY BY THE PASQUILL-TURNER METHOD

Surface Wind Speed (at 10m) m/sec	Day			Night	
	Incoming Solar Radiation			Thinly Overcast or ≥ 4/8 Low Cloud	≤ 3/8 Cloud
	Strong	Moderate	Slight		
< 2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

If vertical wind direction fluctuations (sigma phi) or vertical wind speed fluctuations are collected, atmospheric stability may @classified **as** folllows in Exhibit 11-2 (from U.S. EPA 1966):

Exhibit 11-2
CLASSIFICATION OF ATMOSPHERIC STABILITY BY SIGMA PHI

Stability Classification	Stability Categories	Sigma Phi Categories		
Extremely unstable	A		Sigma phi	11.5
Moderately unstable	B	11.5	Sigma phi	10
Slightly unstable	C	10	Sigma phi	7.8
Neutral	D	7.8	Sigma phi	5
Slightly stable	E	5	Sigma phi	2.4
Moderately stable	F	2.4	Sigma phi	

$$_{ns}\ \text{(Radians)} \quad = \quad nw/^{e}$$

Where $_{ns}$ (Sigma phi) = The standard deviation fluctuations over a 1-hour period
nw = The standard deviation of the vertical wind speed fluctuations over a 1-hour averaging period
• = The average horizontal 10-m wind speed for a 1 hour averaging period (U.S. EPA, 1966)

Using the values of sigma theta computed from the meteorological system, atmospheric stability is classified as follows in Exhibit 11-3 (U.S. NRC, 1980):

Exhibit 11-3
CLASSIFICATION OF ATMOSPHERIC STABILITY
BY SIGMA THETA

Stability Classification	Stability Categories	Sigma Theta Categories		
Extremely unstable	A		Sigma theta	22.5
Moderately unstable	B	22.5	Sigma theta	17.5
Slightly unstable	C	17.5	Sigma theta	12.5
Neutral	D	12.5	Sigma theta	7.5
Slightly stable	E	7.5	Sigma theta	3.8
Moderately stable	F	3.8	Sigma theta	2.1
Extremely stable	G	2.1	Sigma theta	

The U.S. EPA provides further guidance for adjusting sigma theta to account for increased surface roughness and for adjusting the stability category to account for low-level wind direction meander at night and wind speed restrictions on the occurrence of unstable and stable conditions (U.S. EPA, 1968).

Current EPA guidance (U.S. EPA 1981 c) recommends that when onsite meteorological data sets are being used, atmospheric stability categories should be determined from one of these schemes, which are listed in the order of preference:

1. Pasquill-Turner method using onsite data, which include cloud cover, ceiling height, and surface winds (appropimately 10-m height)
2. Sigma phi method
3. Sigma theta method
4. Pasquill-Turner method using onsite wind speed with cloud cover and ceilling height from a nearby NWS site

Applicability The use of atmospheric stability is an important consideration In determining the atmospheric diffusion of a pollutant. Excellent diffusion conditions exist for the unstable categories, while poor diffusion occurs during stable conditions. Estimates of downwind pollutant concentrations are not possible unless atmospheric stability conditions are determined.

The EPA-preferred dispersion models used for short-term and long-term analyses are designed to recognize six stability classes, A through F. Stability classes determined by the Turner method and other associated meteorological data are directly applicable to these models. In the case of stability classes determined by the sigma theta method, Classes F and G and other associated meteorological data are combined into one class, which is designated F.

11.1.2.7 Region-Specific Variances

Besides the site-specific considerations to be made In selecting the appropriate refined model and representative meteorological input data, there are no known region-specific variances for collecting meteorological data for use In refined modeling analyses. No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

11.1.3 Information Sources

The following references will be useful In providing additional, detailed information on meteorological monitoring.

Britter, R. E., and R.F. Griffiths. *Dense Gas Dispersion. New York:* Elsevier Scientific Publishing Company. 1982.

Fleisher, M.T. *Mitigation of Chemical Spills An Evaporation I Air Dispersion Model for Critical Spills on Land* Houston, Texas: Shell Development Co. 1980.

Garrett, A.J., and C.E. Murphy, Jr.*A Puff-PlumeAtmosphetic Deposition Model for Use at SRP in Emergency Response Situations.* DP 1595. Alken, South Cerolina: Savannah River Laboratory. 1981.

GCA Corporation. *Evaluation and Selection of Models for Estimating Air Emissions Hazardous Waste Treatment, Storage, and Disposal Facilities.* GCA-TR-82-83-G. May 1983.

GSC corporation. *GEMS User's Guide.* June 1984.

Hanna, S.R. *Diffusion From Sour Gas Pipeline Ruptures.* Report PB-226. Concord, Massachusetts: Environmental Research and Technology, Inc. 1982.

Holzworth, G.C. Mixing *Heights, Wind Speeds, and Potential for Urban Air Pollution Through the Contiguous United States.* Office of Air Programs Publication Number AP-101. U.S. Environmental Protection Agency. January 1972.

National Climatic Data Center. Star *Tabulations, Master List* Prepared by the National Climatic Data Center, National Environmental Satellite, Information, and Data Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. May 1983.

Randerson, D., ed. *Atmospheric Science and Power Production. DOE/llC-2760.* U.S. Department of Energy. July 1984.

STAPPA/ALAPCO. *Toxic Air Pollutant: State and Local Regulatorv Strategies.* A su rvev conducted by the State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control . Officials, Washington, D.C. January 1984.

Turner, D.B. “A Diffusion Model for an Urban Area”, Journal of Applied Meteorology. February 1964. Pp. 83-91.

United States Code Annotated. *Title 42--The Public Health and Welfare, Section 9604.* As amended and enacted through May 15, 1983. Washington, D.C. 1983.

U.S. Congress. *The Hazardous and Solid Waste Amendments of 1984, Section 3019.* Washington, D.C. 1984.

U.S. Environmental Protection Agency, 1977. *Guidelines for Air Quality Maintenance Planning and Analysis, Volume 10 (Revised): Procedures for Evaluating Air Quality Impact of New Stationary Sources.* Research Triangle Park, North Carolina: Office of Air Quality Planning and Standards. October 1977.

U.S. Environmental Protection Agency, 1978. *Guideline on Air Quality Models.* DAQ PS No. 1.2-080. Research Triangle Park, North Carolina: Office of Air Quality Planning and Standards. April 1978.

U.S. Environmental Protection Agency, 1980a. *OAQPS Guideline Series, Guideline on Air Quality Models.* Proposed Revisions. Research Triangle Park, North Carolina: Office of Air Quality Planning and Standards. October. 1980.

U.S. Environmental Protection Agency, 1980b. *Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD).* EPA 450/4 80-012. Research Triangle Park, North Carolina: Office of Air Quality Planning and Standards. November 1980.

U.S. Environmental Protection Agency, 1981a. "National Primary and Secondary Ambient Air Quality Standards." *Code of Federal Regulations* (40 CFR 81.344, amended through October 22, 1981).

U.S. Environmental Protection Agency, 198lb. *Evaluation Guidelines for Toxic Air Emissions from Land Disposal Facilities.* Washington, D.C.: Office of Solid Waste. August 1981.

U.S. Environmental Protection Agency, 1983. *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV Meteorological Measurements* EPA-600/4-82-060. Research Triangle Park, North Carolina: Environmental Montoring Systems Laboratory. February 1983.

U.S. Environmental Protection Agency, 1984a. "Proposed Guidelines for Carcinogen Risk Assessment; Request for Comments (Part VII)." *Federal Register (49 FR 46294-46301),* Number 227. Washington, D.C. 23 November 1984.

U.S. Environmental Protection Agency, 1984b. "Proposed Guidelines for Exposure Assessment; Request for Comments (Part VIII)." *Federal Register (49 FR 46304-46312),* Number 227. Washington, D.C. 23 November 1984.

U.S. Environmental Protection Agency, 1984c. "Proposed Guidelines for Mutagenicity Risk Assessment; Request for Comments (Part IX)." *Federal Register (49 FR 46314-46321),* Number 227. Washington, D.C. 23 November 1984.

U.S. Environmental Protection Agency, 1984d. "Proposed Guidelines for the Health Assessment of Suspect Develop mental Toxicants and Requests for Comments (Part X)." *Federal Register (49 FR 46324 46331).* Number 227. Washington, D.C. 23 November 1984.

U.S. Environmental Protection Agency, 1986. *User's Network for Applied Modeling of Air Pollution (UNAMAP),* Version 6 (Computer Programs on Magnetic Tape). NTIS No. PB 86-22361. Springfield, Virginia: National Technical Information Service. 1983.

U.S. Nuclear Regulatory Commission. *Proposed Revision 1 to Regulatory Guide 1.23, Meteorological Programs in Support of Nuclear Power Plants*. September 1980.

Weinberg, D.B., G.S. Goldman, and S.M. Briggum, 1983. *Hazardous Waste Regulation Handbqok, A Practical Guide to RCRA and Superfund*. New York, New York: Executive Enterprises. 1983. (Authors are members of the law firm of Wald, Harkrader, and Ross, Washington, D.C.)

11.2 OTHER METEOROLOGICAL PARAMETERS

11.2.1 Scope and Purpose

This subsection provides guidance for the site-specific measurement of certain meteorological parameters used in evaluating air releases from a hazardous waste site and In determining the operation of various air sampling instrumentation. These parameters include precipitation, relative humidity / dew point, atmospheric pressure, incoming solar radiation, soil temperature, evaporation, and visibility. The procedures indicated In this subsection are applicable for use during fieldwork at these sites. More detailed discussions are provided in the references listed in Subsection 11.2.8.

11.2.2 Definitions

Definitions of key terms as they apply to this procedure are provided below. Subsection 11.1.1.2 gives generic definitions for this section.

Dew Point Temperature
: The temperature to which a given parcel of air must be coded at constant pressure and constant water vapor content for water saturation to occur.

Incoming Solar Radiation
: Also referred to as "insolation," the total electromagnetic radiation emitted by the sun and falling on the earth.

Relative Humidity
: The ratio (normally expressed in a percentage) of the actual water vapor content of the atmosphere to the amount of water vapor when the atmosphere is saturated.

11.2.3 Applicability

The collection of site-specific meteorological data, other than those parameters required for dispersion model analyses, may be necessary for evaluating air releases from hazardous waste sites and for determining the operation of various air sampling instrumentation. The level of sophistication in the design of the meteorological monitoring program depends on how the particular data are applied. These data primarily support other activities associated with a hazardous waste site investigation (e.g., operating air sampling instruments, interpreting air sampling results, determining volatilization and vaporization rates of hazardous substances into the air). The applicability of each parameter to other activities is discussed in Subsection 11.2.6.1.

11.2.4 Responsibilities

Project Meteorologist: This person is responsible for the collection of site-specific meteorological data and/or selection of representative meteorological parameters from other data sources. The project meteorologist, using input from project management, technical personnel, and appropriate regulatory agencies, will design the measurement program; oversee data collection, validation, and quality assurance procedures; and maintain records that document these activities. In addition, the project meteorologist will provide any meteorological data required by other program personnel involved in the air sampling program or in the analysis of those results.

Field Engineer: This person is responsible for installation, calibration, maintenance, and decommissioning of the designed program, and for maintaining records that document these activities.

11.2.5 Records

Maintenance of records of the meteorological data collection program is required for validation purposes and future use in air quality assessments. These records include not only the data themselves (data can be recorded on an analog strip for future data reduction, digitally on hard copy such as a printer, or digitally on a magnetic tape) but also appropriate calibration and operational logs. These logs document activities that are performed on the instrumentation for future use in validation. Selection and determination of the representativeness of meteorological parameters, if applicable, should be documented.

Depending on the level of validation and quality assurance applied, additional records to be maintained could include system design drawings, data review logs, data correction logs, audit documents, instructions for data handling and use, and so forth. The level of detail in these records must support the quality assurance requirements, which are to be established before making refined model analyses or conducting air sampling programs.

11.2.6 Procedures

11.2.6.1 Meteorological Data Collection

Collecting meteorological data in the field requires the design of a system that addresses the project requirements as well as the logistics regarding siting and operation. Some required data are best collected from visual observations or other representative sources (e.g., NWS stations) rather than from in situ sensors. In practice, acquiring all of the meteorological data to meet program requirements will often require some combination of all of these collection techniques.

For parameters that are to be collected in the field, monitor placement or siting is important. Monitor placement is intended to site the sensors so that the measurements made are representative of the conditions in the area of interest. Depending on the complexity of the terrain in the area of interest and the parameters being measured, more than one measurement location may be required.

Discussions concerning the collection of various meteorological parameters are presented below. Subsection 11.2.8 contains more specific guidance on siting, equipment specifications and accuracies, and applications of the parameters discussed below.

Precipitation

escription: The recording gauge is the primary precipitation monitor for use in air quality assessments. Recording gauges not only provide the total precipitation but measure the time of the beginning and ending of the precipitation and the rate of fall. There are two basic types of recording gauges – the weighing gauge and the tipping bucket gauge. Both can record liquid or frozen precipitation. Frozen precipitation is usually melted by some type of heating device incorporated into the gauge design. The weighing gauge, which is less precise than the tipping bucket type, normally incorporates a collector bucket and a drum-type recorder. As precipitation fills the bucket, the increasing weight moves a pen across the recorder, indicating the total amount. The tipping bucket-type directs the falling precipitation into buckets that tilt with each 0.01 inches of precipitation. The motion of the buckets causes a mercury switch closure. Each closure Is Indicated on a counter or recorder. The selected gauge should record precipitation totals with a resolution of 0.01 inches and an accuracy of ± 10 percent. Measurements should be made near ground level and away from obstacles that could cause a nonrepresentative value.

Applicability Precipitation measurements can be used as input to complex air quality dispersion models that can account for pollutant plume depletion by precipitation scavenging (i.e., pollutant washout). Care must be taken in applying precipitation data In this manner to assure that the measurements are representative of the area of interest. This care Is necessary because precipitation, especially over short periods of time (e.g., 1 hour to 24 hours), tends to be variable over relatively short distances. If such an application is required, the project meteorologist needs to evaluate other available data sources or to expand the monitoring program by establishing a precipitation monitoring network that will satisfy the model input requirements.

Precipitation measurements can also be used as a beefs for examining groundwater and surface water migration of pollutants by leaching through soil and runoff.

Relative Humidity / Dew Point

A wide range of sensors is available to monitor relative humidity or dew point. Instrument types vary from handheld sling psychrometer to sensitive electronic units that use an optical chilled-mirror technique. Some of these monitors provide relative humidity directly, and' others provide dew point directly. For recording systems in the field, relative humidity sensors that incorporate a capacitor (the electrical characteristics of which vary with humidity or hydroscopic materials that undergo dimensional changes from absorption of moisture) have been used. Dew point sensors using the chilled-mirror technique, or sensors that undergo chemical changes because absorption or adsorption of moisture, are commonly used. The dew point sensors are generally more reliable and accurate. Dew point or retative humidity monitoring equipment should be installed with the same considerations given to temperature measurements (see Subsection 11. 1.2.6.2). The height of the measurement should be based on the program requirements, but care should be taken to avoid any nonrepresentative near-ground effects. The accuracy of the selected system should be contingent on the project requirements and applications. The reader should refer to the manufacturer's literature to determine appropriate accuracies and measurement limitations.

Applicability Values of atmospheric humidity (relative humidity can be calculated from the dew point temperature and ambient dry bulb temperature) are used to determine vaporization or evaporation rates of volatile compounds. Relative humidity is also important in an air sampling program, because it can indicate the efficiency of certain filters in collecting various chemical compounds.

Atmospheric Pressure

Description: Atmospheric pressure is measured with barometers that operate with different types of sensors. Analog signal-output barometers that are used in the field sense variations in pressure primarily with aneroid (or bellows) cells that flex as the pressure changes. Other types of barometers use techniques such as capacitors, which change in electrical characteristics as the pressure changes. Most of these barometers can attain a ± 0.5 millibar accuracy or better, which is adequate for hazardous waste site applications.

Atmospheric pressure can also be obtained using handheld aneroid barometers, which use a dial readout or a microbarograph that uses a direct mechanical readout on a chart. Both of these barometers provide sufficient resolution (1.0 millibar graduations or better). Atmospheric pressures for different averaging times are not easily provided with the handheld barometer since these barometers would provide only “instantaneous” values. Since barometric pressure is a conservative parameter (i.e., variations with time are normally small), this pressure may not be a major consideration. Pressure measurements should be made near ground level and should reflect the outside pressure at the measurement location. Another source of atmospheric pressure is from a representative NWS station. The NWS can provide actual station pressure or pressure corrected to sea level for station elevation.

Applicability: Atmospheric pressure is used to calculate vaporization or evaporation rates of chemical compounds. Pressure is also used in an air sampling program to determine flowrates for sampling pumps (see Subsection 11.4.6). Both of these applications require the station pressure, not a value corrected for elevation.

Incoming Solar Radiation

Description: incoming solar radiation (insolation) is measured with instruments known as pyranometers. These instruments measure the solar radiation received from the hemispherical part of the atmosphere it sees. The pyranometer is mounted near ground level facing toward the sun’s zenith. Care should be taken to avoid possible local interference from nearby obstructions that could block the incoming solar radiation (i.e., there should be no shadows). Logistics of the measurements dictate daily inspections and data validation. Accuracy requirements should be based on the final application of the data.

Applicability Normally, solar radiation measurements are secondary to wind and temperature measurements in air quality evaluations. The solar radiation data can be directly related to atmospheric stability. Existing standard air quality models do not currently use measured solar radiation data. Models to compute rates of chemical volatilization or vaporization may use solar radiation data quantitatively.

Soil Temperature

Soil temperatures can be measured with any of the temperature sensors discussed in Subsection 11.1.2.6. A representative surface temperature of the soil into which a contaminant has been deposited should be determined. The depth at which this measurement should be made varies with soil type. Typically, a measurement of 1 to 5 cm depth is used. Care must be exercised to not disturb the soil when making the measurement.

Applicabiiity: Soil temperature measurements are used to determine vaporization rates of chemicals spilled on the ground surface.

Evaporation Data

The measurement of evaporation in the field is a difficult and imperfect procedure. Most measurements involve the same type of instrumentation used by the NWS, a Class A evaporation pan. This pan is mounted near the ground on supports, and measurements of water loss are made routinely. These pans must be carefully maintained and monitored. Instead of obtaining these data onsite, it would be preferable to obtain the information from a representative NWS station that makes these measurements or to calculate climatology.al average values with any of several equations available.

Applicability These data can Indicate evaporation from lagoons or ponds (and hence a source term) although the relationship between the evaporation rate of the liquid with the chemical makeup of the lagoon or pond compared to that of the pan must be considered. In addition, the relationship between the pan evaporation and evaporation over a larger water body must be considered. Long-term evaporation data, along with precipitation data from representative sources, can also Indicate the potential for contaminants to leach to groundwater.

Visibility

Description: A wide variety of instrumentation is available to measure visibility In the field. Some of these instruments were developed for use In aviation while others were developed specifically for air pollution applications. Instruments such as nephelometers and transmissometers are simple to use in the field, but detailed calculations are required to convert their readings to meaningful values for visibility. Other instruments such as telephotometers are more difficult to use and, like nephelometers and transmissometers, require calculations for visibility determinations.

Studies have shown that the more subjective method of observing visibility with the human eye provides results comparable to the field Instruments.

Use of the human eye to determine visibility is based. on observing techniques of the NWS. In its simplest form, the technique for using the human eye is to select markers at various distances in the direction(s) of interest, determine the distance of these markers from the observation point, and then estimate visibility by noting which markers can be seen. The distance at which the markers are placed and the separation distance depend on the project requirements and the availability of objects that can serve as markers. Visibility markers should be at least 1/2 degreein angular size. (The object, when held at arm's length, will fill a 5/l6-inch diameter hale.) Daytime markers should be dark, while nighttime markers should be unfocused lights of moderate intensity.

Applicability Visibility measurements can indicate the relative impact on visual impairment of pollutant releases to the atmosphere.

11.2.7 Region-Specific Variances

No region-specific variances are known to exist for the measurement of the meteorological parameters discussed in this subsection; however, any future variances will be incorporated in subsequent revisions to this compendium. Because information on variances may become dated rapidly, users should contact the regional EPA RPM for full details on current regional practices and requirements.

11.2.8 Information Sources

More detailed information concerning measurements and applications of the meteorological parameters discussed in this subsection are listed below Air Pollution Control Association Proceeding, *View on Visibility-Regulatory and Scientific.* November 1979.

Bruce, J. P., and R.H. Clark. *Introduction* to *Hydrometeorology.* New York: Pergamon Press. 1969.

Fritschen, L.J., and L.W. Gay. *Environmental Instrumentation.* New York Springer-Verlag. 1979.

Thibodeaux, L.J. *Chemodynamics, Environmental Movement of Chemicals in Air, Water, and Soil.* New York: John Wiley and Sons. 1979.

U.S. Environmental Protection Agency. Quality *Assurance Handbook for Air Pollution Measurement Systems: Volume IV* Meteorological Measurements. EPA-600/4-82-060. Research Triangle Park, North Carolina: Environmental Monitoring Systems Laboratory. February 1983.

11.3 AIR QUALITY

Air quality measurements employ a number of instruments and techniques. Section 15 of this compendium discusses a number of the more commonly used direct-reading field instruments. This subsection discusses the general air and gas sampling methods for determining air quality.

11.3.1 Scope and Purpose

This subsection applies to field air quality monitoring and air sampling activities related to site characterization activities. It describes the methods and equipment necessary for real-time air quality monitoring in the field, and for collecting air samples for laboratory analysis. With regard to site characterization activities, real-time monitoring will help in selection of sampling locations and screening of samples (e.g., screening of split-barrel samplers to select samples for laboratory analysis). Real-time monitoring is also used for health and safety purposes. Air samples collected for laboratory analysis can be used for characterizing the atmospheric transport of contaminants and for risk assessment.

11.3.2 Definitions

Continuous Monitoring Instrument

An instrument that gives quantified measurements of the concentration of usually only one specific pollutant (e.g., CO, H_2S, SO_2) on a real-time basis. A variety of instruments can be used for this purpose, including GC, UV, and IR devices.

Detector Tubes

Small glass tubes filled with solid absorbents, such as silica gel, activated alumina, or inert granules, and impregnated with detecting chemicals through which air is aspirated at a controlled rate. The detector chemical undergoes a color change in the presence of the contaminant; the contaminant concentration is proportional to the intensity of color change, or the length of the stain. Detector tubes are also known variously as “colorimetric tubes” or “indicator tubes.”

Direct Reading Instruments (DRIs)
Instrumentation operating on flame-ionization, photoionization, or infrared principles providing real-time readings of ambient contaminant, usually in parts per million in air.

FID Meter
A portable air monitoring instrument (e.g., OVA-128) that operates by flame-ionization detection (see Section 15).

PID Meter
A portable air monitoring instrument (e.g., HNU Pi-I 01) that operates by photoionization detection (see Section 15).

Representative Sampling
Sampling over a fixed period of time, usually 8 to 24 hours, using a sorbent medium (for volatiles) or filter (for particulate material) to determine the representative concentration of a contaminant in the air volume sampled.

Sorbent Sampling Medium
A material that quantitatively adsorbs volatile or semi-volatile organic compounds from air passing through the medium. These compounds are desorbed in the laboratory (using solvents or thermally) and analyzed. Commonly used sorbent media include Tenax XAD resins, and activated carbon.

11.3.3 Responsibilities

Site Manager: The SM is responsible for determining the need for, and scope of, an air monitoring and sampling program.

Field Team Leader This person Is responsible for Implementing the air monitoring program as it is detailed in the work plan and Quality Assurance Project Plan (QAPjP) for the specific site. Air monitoring requirements may be included in both the work plan and the site-specific health and safety plan. In the case of air monitoring for health and safety requirements, the site safety officer has a lead role in evaluating the data and taking required action as detailed in the health and safety plan.

11.3.4 Procedures

11.3.4.1 Introduction

The purpose of air and gas sampling is to define the concentration of airborne contaminants in a discrete air mass. Because of the wide spectrum of measurement technology and expense of instrumentation, it is critical to clearly define the data quality objectives of the air sampling program. Key considerations are pollutant(s) of interest, turnaround time required for results, sampling frequency, degree of measurement accuracy required, and the level of quality assurance/ quality control (QA/QC) documentation required for the Intended use of the data.

An initial screening program should be included during site reconnaissance activities for sites that may have significant onsite levels and/or offsite transport of airborne contaminants. This screening will help to refine or redefine the air monitoring requirements for the remedial response activities. The screening would be accomplished using an FID (e.g., OVA), PID (e.g., HNU), and possibly air sampling pumps and/or detector tubes. The results of the screening will provide input to the site safety plan and help in selecting the proper site and the number of sampling locations.

Continuous air monitoring is performed by drawing air samples continuously from one or more fixed sampling points. The analyzing instrument may be located at or very near the point of air aspiration or may be several hundred feet from the sampling locations.

When long sampling lines are used, transport time to the analyzer must be taken into account when relating the contamination episodes near the sample point to the real-time analytical record reported at the analytical instrument. Similarly, It should be noted that if the analyzer draws samples successively from several sampling points, important contaminant-releasing events. could be missed if sampling was not occurring from the nearest sampling point at the moment of release.

Analytical instrumentation for continuous monitoring may use fixed- or variable-wave-length UV, IR spectrographic, flame-ionization, or electrochemical detection principles. Fixed-site analytical devices for continuous sampling may require AC power, weatherproof housing, climate control, and various laboratory-grade compressed gases.

Fixed-site continuous monitoring is expensive and uses complex analytical equipment. Monitoring may be used to provide the detailed input necessary for atmospheric simulation modeling or may provide an early emergency warning and/or a legal record when extremely toxic contaminants or sensitive community relations are involved at the site.

Representative air sampling is subdivided into two general categories: gaseous and particulate. The two principal methods for gaseous sample collection are adsorption of the compounds of interest onto sorbent media (such as Tenax, activated carbon, or XAD resin) through which a metered volume of gas has been passed, or collection of a gas sample In a bag constructed of nonreactive material such as Mylar. In all cases using sorbent media, two tubes must be linked in series to evaluate breakthrough from the first tube in the series. Tables of breakthrough values for most common volatile organics are available from the sorbent suppliers; if the concentration in the first tube approaches a breakthrough value, the second tube should be analyzed. Alternately, a two-phase tube with tandem sorbent media maybe used.

Use of sorbent media for air sampling is further described below. Particulate (aerosol) sampling is generally performed using a high-flow pump (about 2 liters per minute) to which a filter assembly is attached. Commonly, filters with 0.8 micron average pore size are used. Calibration and use of air sampling pumps are described in Subsection 11.3.4.3.

11.3.4.2 Air Monitoring

Air monitoring is used to help establish criteria for worker safety, to document potential exposures, to determine protective measures for the public, to evaluate the environmental Impact of the site, and to determine mitigation activities. An effective air surveillance program, tailored to meet the conditions found at each work site, must be established to accomplish these tasks.

Air contaminant data, including any changes that occur, are needed during site operations. Surveillance for vapors, gases, and particulate is accomplished using DRIs and air sampling systems. DRIs can be used to detect many organics and a few inorganic and to provide approximate total concentrations. If specific organics (and inorganic) have been identified, then DRIs calibrated to those materials can be used for more accurate onsite assessment.

The most accurate method for evaluating any air contaminant is to collect samples and analyze them at a reliable laboratory. Although accurate this method has two disadvantages: the cost and the time required to obtain results. Analyzing large numbers of samples in laboratories is very expensive, especially if results are wanted quickly. Onsite laboratories tend to reduce the turnaround time, but unless they can analyze other types of samples, they also are costly. In emergencies, time is often not available for laboratory analysis of samples either onsite or offsite.

To obtain air monitoring data rapidly at the site, site operations may include instruments using flame-ionization detectors (FIDs), photoionization detectors (PIDs), and other similar instruments. This equipment may be used as survey instruments (total concentration mode) or operated as gas chromatography (gas chromatography mode). As gas chromatography, these instruments can provide real-time qualitative/quantitative data when calibrated with standards of known air contaminants. Combined with selective laboratory analysis of samples, they provide a tool for evaluating airborne organic hazards on a real-time basis, at a lower cost than analyzing ail samples in a laboratory.

11.3.4.3 Air Sampling

For more complete information about air contaminants, measurements obtained with DRIs must be supplemented by collecting and analyzing air samples. To assess air contaminant more thoroughly, air sampling devices equipped with appropriate collection media are placed at various locations throughout the area. These samples provide air quality information for the period of time they operate; they can indicate contaminant types and concentrations over the entire period of site operations. As data are obtained (from the analysis of samples, DRIs, knowledge about materials involved, site operations, and potential for airborne toxic hazards), adjustments are made in the type of samples, number of samples collected, frequency of sampling, and analysis required. in addition to air samplers, area sampling stations may also include DRIs equipped with recorders and operated as continuous air monitors. Area sampling stations may be located in various places, as dictated by project and site needs:

- **Upwind:** Because many hazardous incidents occur near industries or highways that generate air pollutants, samples may be taken upwind of the site to establish background levels of air contaminants.

- **Support Zone:** samples may be taken near the command post or other support facilities to ensure that they are in fact located in a clean area, and that the area remains clean throughout operations at the site.

- **Contamination Reduction Zone:** Air samples may be collected along the decontamination line to ensure that decontamination workers are properly protected and that onsite workers are not removing their respiratory protective gear in a contaminated area.

- **Exclusion Zone:** The exclusion zone represents the greatest risk of exposure to chemicals and requires the most air sampling. The location of sampling stations should be based upon hot-spots detected by DRIs, types of substances present, and potential for airborne contaminants. The data from these stations, in conjunction with intermittent walk-around surveys with DRIs, are used to verify the selection of proper levels of worker protection and exclusion zone boundaries, as well as to provide a continual record of air contaminants.

- **Downwind:** One or more sampling stations may be located downwind from the site to indicate if any air contaminants are leaving the site. If there are indications of airborne hazards in populated areas, additional samplers should be placed downwind.

11.3.4.4 Media for Collecting Air Samples

Remedial response activities concerning hazardous material, especially those activities conducted on abandoned waste sites, involve thousands of potentially dangerous substances – gases, vapors, and aerosols –that could become air borne. A variety of media – liquids and solids – are used to collect these substances. Sampling systems typically include a calibrated air sampling pump that draws air into selected collection media. Some of the most common types of samples and their collection media are described next.

Organic Vapors: Activated carbon is an excellent adsorbent for most organic vapors. However, other solid absorbents (such as Tenax, silica gel, and Florisil) are routinely used to sample specific organic compounds or classes of compounds that do not adsorb or desorb well on activated carbon. To avoid stocking a large number of sorbents for all substances anticipated, a smaller number – chosen for collecting the widest range of materials or for substances known to be present – is generally used. The vapors are collected using an industrial hygiene personal sampling pump with either one sampling port or a manifold capable of simultaneously collecting samples on several sorbent tubes –for example, a manifold with four sorbent tubes (or individual pumps with varying flowrates). The tubes might contain the following:

- Activated carbon to collect vapors of materials with a boiling point above zero degrees Centigrade (0^oC). These materials include most odorous organic substances (such as advent vapors).
- A porous polymer (such as Tenax or Chromosorb) to collect substances (such as high-molecular-weight hydrocarbons, organophosphorous compounds, and vapors of certain pesticides) that adsorb poorly onto activated carbon. Some of these porous polymers also adsorb organic materials at low ambient temperatures more efficiently than carbon.
- A polar sorbent (such as silica gel) to collect organic vapors (such as aromatic amines) that exhibit a relatively high dipole moment.
- Another speciality adsorbent selected for the specific site. For “example, a Florisil tube could be used if polychlorinated biphenyls are expected.

Inorganic Gases: The inorganic gases present at an incident would primarily be polar compounds such as the haloacid gases. These gases can be adsorbed onto silica gel tubes and analyzed by ion chromatography. Impingers filled with selected liquid reagents can also be used.

Aerosols: Aerosols (solid or liquid particulate) that may be encountered at an incident include contaminated and noncontaminated soil particles, heavy-metal particulate, pesticide dusts, and droplets of organic or inorganic liquids. An effective method for sampling these materials is to collect them on a particulate filter (such as a glass fiber or membrane-type filter). A backup impinger filled with a selected absorbing solution may also be necessary.

Other Methods: Calorimetric detector tubes can also be used with a sampling pump when monitoring for some specific compounds. Passive organic vapor monitors can be substituted for the active system described if passive monitors are available for the types of materials suspected to be present at a given site.

Information Resource: The National institute for Occupational Safety and Health’s (NIOSH) *Manual of Ana/ytical Method,* Volumes 1-7, contains acceptable methods for collecting and analyzing air samples for a variety of chemical substances. The reader should consult it for specific procedures.

11.3.4.5 Collection and Analysis

Samples are analyzed to determine the types and quantities of substances present. The following paragraphs provide additional guidance on sample collection and analysis.

Aerosols: Samples for aerosols should be taken at a relatively high flowrate (generally about 2 liters per minute) using a standard Industrial hygiene pump and filter assembly. To collect particulate, a membrane filter having a 0.8 micrometer pore size is common. The sample can be weighed to determine total particulate, then analyzed destructively or nondestructively for metals. If the metals analysis is done nondestructively or if the filter is sectioned, additional analysis (for example, organics, inorganic, and optical particle sizing) can be performed.

Sorbent Samples: The sorbent material chosen, the amount used, and the sample volume will vary according to the types and concentrations of substances anticipated at a particular site. Polar sorbent material, such as silica gel, will collect polar substances that are not adsorbed well onto activated carbon and some of the porous polymers. The silica gel sample can be split and analyzed for the haloacid gases and aromatic amines.

Activated carbon and porous polymers will collect a wide range of compounds. Exhaustive analysis to identify and quantify all the collected species is prohibitively expensive at any laboratory and technically difficult for a field laboratory. Therefore, samples should be analyzed for principal hazardous constituents (PHCS). The selection of PHCS is based on the types of materials anticipated at a given site, on generator's records, and on information collected during the Initial site survey. To aid in the selection of PHCS, a sample could be collected on activated carbon or porous polymer during the initial site survey and could be exhaustively analyzed offsite to Identify the major peaks within selected categories. This one thorough analysis, along with what is already known about a particular site, could provide enough information to select PHCS. Standards of PHCS could then be prepared and used to calibrate instrument used for field analysis of samples. Subsequent routine offsite analysis could be limited to scanning only for PHCS, thereby saving both time and money. Special absorbents and sampling conditions can be used for specific PHCS, if desired, while continued multimedia sampling will provide a base for analysis of additional PHCS that may be identified during the course of cleanup operations.

Other sample techniques involve the extraction or resorption of various solid sorbents. While many NIOSH analytical methods are available for a variety of individual compounds, the most useful methods in remedial response investigation involve some form of gas chromatography y coupled with mass spectrophotometry identification (GC/MS).

The main advantage to GC/MS is the relatively high qualitative accuracy obtainable when looking for specific compounds. In addition, unexpected compounds can be identified by comparing sample mass chromatograms to the National Bureau of Standards' standard mass chromatograms. While this method is not infallible, it is very useful in identifying organic vapors at hazardous waste sites.

In addition, when using sorbent tubes, it is wise to check a certain number of traps to assure that they are not channeled or plugged, which would affect collection efficiency. This activity is accomplished by checking pressure drop across the trap.

Passive Dosimeters: A less traditional method of sampling is the use of passive dosimeters. The few dosimeters now available are only for gases and vapors. Passive dosimeters are used primarily to monitor personal exposure, but they can be used to monitor areas. Passive monitors are divided into two groups:

- **Diffusion Samplers:** Molecules move across a concentration gradient, usually achieved within a stagnant layer of air, between the contaminated atmosphere and the indicator material.
- **Permeation Devices:** These devices rely on the natural permeation of a contaminant through a membrane. A suitable membrane is selected that is easily permeated by the contaminant of interest and impermeable to all others. Permeation dosimeters are, therefore, useful in picking out a single contaminant from a mixture of possible interfering contaminants.

Some passive dosimeters may be read directly, as are DRIs and colorimetric length-of-stain tubes. Others require laboratory analysis similar to that for solid sorbents.

11.3.4.6 Personnel Monitoring

In addition to area atmosphere sampling, personnel monitoring, both active and passive, can be used to sample for air contaminants. Representative workers are equipped with personal samplers to indicate contaminants at specific locations or for specific work being done. Placed on workers, generally within 1 foot of the mouth and nose (breathing zone), the monitors indicate the potential for the worker to inhale the contaminant.

11.3.4.7 Calibration

As a rule, the total air sampling system should be calibrated, rather than the pump alone. Proper calibration is essential for correct operation and for accurate interpretation of resultant data. As a minimum, the system should be calibrated before and after use. The overall frequency of calibration will depend on the general handling and use of a given sampling system. Pump mechanisms should be recalibrated after repair, when newly purchased, and following suspected abuse.

11.3.4.8 Meteorological Considerations

Meteorological information is an integral part of an air surveillance program. Data concerning wind speed and direction, temperature, barometric pressure, and humidity, singularly or in combination, are needed for the following:

- Selecting air sampling locations
- Calculating air dispersion
- Calibrating instruments
- Determining population at risk or environmental exposure from airborne contaminants

Knowledge of wind speed and direction is necessary to effectively place air samplers. In source-oriented ambient air sampling, samplers need to be located at different distances downwind of the source and other samplers need to be placed to collect background samples. Shifts in wind direction must be known, and samplers must then be relocated or corrections must be made for the shifts. In addition, atmospheric simulation models for predicting contaminant dispersion and concentration need wind speed and direction as inputs for predictive calculations. Information may be needed concerning the frequency and intensity with which winds blow from certain directions (windrose data); consequently, the wind direction must be continually monitored when use of this type of data is contemplated.

Air sampling systems need to be calibrated before use, and corrections in the calibration curves should be made for temperature and pressure. After sampling, sampled air volumes are also corrected for temperature and pressure variations. The requires knowledge of air temperature and pressure.

Air sampling k sometimes designed to assess population exposure (and frequently potential worker exposure). Air samplers are generally located in population centers irrespective of wind direction. Even in these instances, however, meteorological data are needed for air dispersion modeling. Models are then used to predictor verify population oriented sampling results. “

Proper data are collected by having meteorological stations onsite or by contacting one or more of several government or private organizations that routinely collect such data. The choice of an information gathering method depends on the availability of reliable data at the location desired, the resources needed to obtain meteorological equipment, the degreeof accuracy of information needed, and the use of information.

11.3.5 Information Sources

U.S. Environmental Prtection Agency. Standard *Operating Safety Guides.* November 1984.

National Institute for Occupational Safety and Health. *Manual-of Analytical Methods.* Vols. 1-7. April 1977 through August 1981.

SECTION 12

BIOLOGY / ECOLOGY

12.1 SCOPE AND PURPOSE

Section 12 discusses the general types of field and laboratory activities that can be used to assess biological or ecological impacts resulting from remedial response activities at a hazardous waste site.

This section is divided into four basic components: (1) introductory *remarks* about biological and ecological evaluations of hazardous waste sites (Subsections 12.1 through 12.6.2); (2) a summary of the methods and applications that have been used to date, and their limitations; (3) a list of references to lead a user to more details about methods (Subsection 12.8); and (4) Appendix 12A, which shows additional details on methods. The information sources subsection provides a partial list of methods sources that users should refer to if the site conditions or the questions being asked do not appear to be compatible with the methods described herein. The reader may also refer to "Standard Practice for Conducting Acute Toxicity Tests with Fishes, Macroinvertebrates, and Amphibians," ASTM *Designation E* 729-80, pages 285-309, by the American Society for Testing and Materials.

For purposes of this discussion, the greatest emphasis in Section 12 is placed on terrestrial habitats and the lowest emphasis is placed on marine habitats. Aquatic (freshwater) habitats are given intermediate emphasis because of the general pattern of hazardous waste site locations. To date, marine hazardous waste sites or sites associated with marine areas have been near the shore, generally in shallow water areas. Many of the study techniques described for aquatic (freshwater) studies will also work in marine areas.

In summary, this section is a compendium of past biological and limited ecological work that has been requested at hazardous waste sites. It includes other suggested methods that may work in some varying situations.

12.2 DEFINITIONS

Site Manager (SM)

The individual responsible for the successful *completion of* a work assignment within budget and schedule. This person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

Ail other terms in Section 12 are In common use. If a term is unfamiliar, the user should check the glossary.

12.3 APPLICABILITY

The information in this section is applicable to those hazardous waste sites in which the SM determines the need for such studies (see Subsection 12.4). Biological, especially ecological, investigations have not been a major requirement of remedial response activities In the past; however, requirements may change as more sophisticated evaluations of environmental impacts are required at selected sites.

Detailed biological or ecological studies are not always required. if other studies define the onsite and offsite contaminant migration patterns, this information maybe adequate for the analysis and completion of remedial actions. However, the fact that some stated criterion (usually for single parameters) for a contaminant is or is not exceeded does not always result in an obserable impact on biological systems. The biological impact projection process is made complex by contaminants that are often a mix of parameters, which may also vary in space and/or time. Single parameters may not exceed any known criterion; yet an impact may still be possible from such complex mixtures. Biological and ecological site investigations may be triggered in situations where questions exist about the presence or absence of measurable impacts both onsite and offsite.

Biomonitoring can be conducted to better determine whether the substances detected in soil, sediment, air, and water analyses are affecting or could affect natural systems either directly or through food chain accumulation and, if an impact is possible, what risk there might be to humans. There are two major types of biomonitoring: ecological surveys and individual assays. Ecological surveys involve comparing various ecological parameters, such as species diversity or abundance, in a reference or control site with the same parameters in an affected area. individual assays include measuring tissue levels of contaminants in organisms collected on or near the site and from reference areas, as well as performing bioassays using site materials or leachates to test for toxicity and bioconcentration in various standard organisms. The determination of contaminant levels in the tissues of organisms that are consumed by humans can assist in human health risk assessment.

Control or reference areas are not necessarily considered to be free from any type of contamination, but rather these areas provide information on local background or ambient levels of contamination.

Because of project schedule and reference area constraints and because of the importance of immediate public health concerns, detailed ecological surveys have not often been conducted. Some limited ecological surveys, which focused on a segment of the community such as aquatic invertebrates, have been used to examine possible offsite contaminant migration. Biota tissue analysis and bioassays, both in situ and in the laboratory, have been the primary types of biological surveys conducted on hazardous waste sites.

12.4 RESPONSIBILITIES

The SM determines the need for biological and ecological surveys and tasks the necessary personnel to execute the study.

12.5 RECORDS

Field observations are kept in bound notebooks with numbered pages. Entries are initialed by the notetaker. Laboratory data are recorded on the appropriate forms and in logs. Photographs are recorded in the field notebook; the reader should see also Sections 6 and 17 of this compendium.

12.6 PROCEDURES

The following discussions describe the types of biological field sampling techniques and laboratory analyses that have been used or are being used in biological or ecological assessments of hazardous waste sites.

12.6.1 Presence of Toxic Substances

To determine site contaminants of concern, the project staff should review the results of soil, sediment, groundwater, and surface water testing and should list the priority pollutants present In these media. Then they should review data and make a final listing of onsite pollutants. The data should be compared to applicable or relevant and appropriate requirements, such as state and federal drinking water standards, and to ambient water quality criteria that have been established to protect either human health or aquatic systems. The methodology to use in this comparison is described in EPA's *Draft Superfund Public Health Evaluation Manual (1985b),* which focuses on human health protection. However, If the goal of the project is to protect aquatic ecosystems, emphasis should be placed on EPA's ambient water quality criteria as well.

Project personnel need to clearly define the overall objectives of the site sampling program, which includes physical parameter sampling, before designing the overall field sampling program. If a biological or ecological study is made at the site, an environmental scientist must become involved early In the determination of initial physical parameters for the field sampling program and for any subsequent sampling programs. Biological or ecological studies often cannot be redesigned around the physical parameter of sampling programs that are intended for other purposes.

Site Managers should note that an increase in parameter testing or a requirement for lower detection limits to allow comparison to water quality criteria can dramatically Increase study costs. For example, aquatic life criteria for chromium are set separately for the two chromium spades, chromium VI and chromium Ill (EPA, 1980a and 1985a). Data on total chromium are not adequate to determine whether criteria have been exceeded. The cost Increases for additional analyses may have to fit into available budgets. In some cases, added costs for better biological and ecological assessments will be at the expense of other studies. Therefore, biological and ecological studies must be well thought out and must justify the added time and the costs required to complete them. Overall data quality objectives must be able to justify these added costs.

If the decision is made to complete these increased parameter tests, the laboratory that analyzes the samples needs to know the detection levels and the types of test results required for a comparison to standards and criteria.

Possible goals of conducting biological field studies are (1) to detect differences between biological parameters at the site and those at a reference location, (2) to detect biological contamination, or (3) to quantify risks to humans from contamination of an important food web. It Is Important that the goals of the study are clearly identified before developing a sample plan. The location and number of sample collection sites, experimental procedures, and analytical techniques are chosen to achieve the goals of the study plan.

Applicable or relevant and appropriate requirements relate primarily to air quality and water quality (EPA, 1985b). Soil standards or criteria have not been determined, although EPA is developing soil cleanup guidance. The levels of soil contaminants that are of concern to ecological systems can be determined by comparing data to background levels or to state or federal cleanup levels or by using a model to determine potential migration levels of soil contaminants into groundwater. Cleanup levels, too, are often based on protection of groundwater systems. In some cases, this criterion may not be totally appropriate, because direct contact with surface or subsurface soils or volatiles can also have an impact on ecosystems.

12.6.2 Field Collection Techniques - General

12.6.2.1 Field Sampling Program Development

After the pollutants of concern have been Identified, their probable transport routes or possible human or biota exposure routes are determined by studying the chemical and physical properties of the pollutant (e.g., octanol/ water partition coefficient, solubility, volatility) and by identifying site characteristics that assist in the transport of the chemicals (e.g., topography, wind, groundwater aquifers, surface water drainages, stormwater runoff patterns).

Important factors for the analysis of general ecological system impacts are (1) frequency and degree of exposure, (2) persistence of the material, (3) substrate composition, (4) geographic location, and (5) sensitivity of the habitat exposed and species present. Additional factors that are important in the aquatic system are water depth, velocity and discharge rate, and range In natural water quality parameters at the time of exposure. Other factors important in analyzing terrestrial system impacts include the physical and chemical nature of soil and the nature of vegetation, especially plant rooting depth.

Once the nature of the contaminants of concern is better understood, the first step is to develop the field study program. Several prelminary activities are necessary in the evaluation of both the general biological and ecological survey to be conducted onsite and the specific field sampling program. These activities include (1) an information search, (2) a preliminary she survey, and (3) identification of site-specific issues of concern.

An initial information search Is conducted to identify the following types of data:

- Prior uses of the site including a chronology of events
- Date of last activity onsite
- Any biological and ecological surveys available on the study area and the immediate vicinity
- Species used locally for human consumption and the degree of such usage
- Species moat likely present
- The moat appropriate sampling method for the species of interest that is also permitted by law
- Appropriate identification keys for species to be sampled
- Background levels of contaminants of concern in soils, water, and biota
- Research on the contaminants of concern as to known effects on local biota or related species

Additional information is obtained on any nearby habitat or any species of special concern such as rare, threatened, or endangered species (both federal and state lists). Possible sources of the above information include state or local game and fishery agencies; conservation agencies; state or local agricultural agencies; and local college or university departments such as the biology, ecology, forestry, or fishery departments. Ecological organizations, museums, Forest Service representatives, the National Park Service, state and local park officials, and local sportsman's clubs may also prove useful.

The second step is a preliminary site survey, which Identifies habitat types on and near the site, probable pollutant transport routes, and possible indicator species to serve as the focus of the study.

in preparation for the site survey, the study team prepares a checklist of necessary field gear. The following items can be included in this checklist:

- Site health and safety plan
- Site and vicinity topographic base map (Aerial photographs are valuable in identifying habitat types, but a base map is important for use in the field.)
- Field notebooks
- Camera (Telephoto lenses maybe necessary.)
- Collection containers for items such as vegetation or scats
- Appropriate identification keys
- Required personal safety gear
- A summary of important notes collected during the information search

The site survey includes the following types of activities:

- Mapping of vegetation types including areas that are unnaturally denuded
- Mapping of animal tracks, trails, and burrows
- Noting proximity of the site to aquatic or marine habitat
- Noting aquatic habitat type (water temperature, flow, substrate, cover)
- Noting presence of aquatic species (algae, macrophytes, invertebrates, fish)
- Photographing ecological features onsite and in the vicinity

At the completion of these preliminary activities, the project task leader will have sufficient information to determine the type of field sampling program that will most effectively address the site-specific issues of concern. The primary concern is usually possible risk to human health. if human exposure from surface soil contamination is a concern, the staff can conduct a vegetation and small mammal study. Aquatic surveys are important if the site may affect surface waters. Groundwater concerns are generally evaluated through laboratory bioassays, which will be discussed later.

The staff must obtain any collecting permit required by the appropriate regulatory agency before beginning field collection programs.

Field biology and ecology survey data can vary greatly among sites because of differences in species and habitats. Therefore, the U.S. EPA Corvallis Laboratory (Porcella, 1983) is developing a standardized bioassessment protocol for hazardous waste sites. This protocol uses site soils, sediment, and water samples in bioassays on standard organisms such as freshwater fish (fathead minnow), freshwater invertebrates (Daphnids), earthworms *(Eisenia),* freshwater algae *(.Se/enustrum), seed* germination and root elongation tests, and soil respiration tests. The protocol is currently experimental, and interpretation of the results is not well defined.

These tests are summarized briefly in Subsection 12.6.4.3. This type of standardized bioassessment has been suggested to enable setting priorities for cleanup efforts; more importantly, bioassessment can provide a consistent and relatively inexpensive method for monitoring the effectiveness of any cleanup action.

12.6.3 Field Methods -- Specific

12.6.3.1 Introduction

The field methods, their applications, and their limitations are discussed below. The discussions are grouped by terrestrial, aquatic (freshwater), and near-shore marine environments. Near-shore marine methods are quite similar to many of those discussed for aquatic or freshwater systems and are renamed, but those discussions are not repeated in the marine subsection (12.6.3.4). A parallel description of these methods is discussed in more detail in Appendix A..

The people who collect biological samples at a hazardous waste site must be trained and fully certified to be on that site in accordance with the regulations contained in 29 CFR 1910.120, “Hazardous Waste Operations and Emergency Response; Interim Final Rule,” OSHA, December 1966, Depending on the personal protection levels determined for a specific hazardous waste site, the collector may need to modify the field methods to adapt to the dress and equipment requirements of the level of protection. Some per--sonal protective enseembles will limit the field methods that biologist are physically capable of carrying out. The SM must be made aware of these limitations, and their effects on the project schedule. Also, people planning to collect biota from hazardous waste sites need to be aware of any federal and state endangered species that may be present on the site, as well as having appropriate collection permits as required by the state in which the site is located.

Subsection 12.6.3.2 and Appendix 12A discuss how to collect and process plants and animals before transport to the laboratory. Laboratory methods follow in Subsection 12.6.4.

12.5.32 Terrestrial Field Methods summary

VEGETATION

Methods

1. **Collection – General**

   Applications: Collection is useful on any terrestrial site with vegetation; it provides a permanent record of plant species present and any gross morphological abnormalities caused by pollutants. Some perennial woody plants may incorporate a temporal record of polluant impacts in their structural tissues, either as changes in the chemical composition or in the size of growth rings or shoots. These methods may provide a good qualitative estimate of the size and severity of pollutant impact.

Limitations: Collection is not useful on denuded sites; it requires careful comparison against sites that are very similar, but uncontaminated. Finding these “control” sites might be difficult for highly disturbed situations like landfills. Plant stress caused by pollutants at a site might be moderated or aggravated by other site stressors such as low water availability or abnormally high temperature. Variation in response to pollutants between species may require that the response of many species to pollutants be understood if a large number of pollutant sites are to be examined or studied. Unrecognized genetic variation in response to pollutants within a species may cause difficulties. The transitory nature of pollution damage symptoms or of plant species may require multiple site visits at different times of the year to develop a complete picture.

2. visual

Applications: Visiting the site provides a quick, inexpensive assessment of the extent and severity of damage by pollutants. A visit is particularly valuable in scoping out the impacted area when the pollutants are being moved by some physical factor such as wind (downwind) or water (downgradient).

Limitations: Seasonal changes in weather, plant morphology, and plant occurrence may necessitate multiple visits to the site during different seasons for the collector to construct an accurate overview of the site. Nonpollutant factors such as plant diseases and drought stress may produce symptoms similar to or identical to pollutant symptoms, obscuring pollutant impacts. Several different pollutants may produce symptoms that are indistinguishable from each other. Small quantities of different pollutants may combine to produce a single symptom in plant population. Data tend to be very subjective and require comparison to similar, but unpolluted, areas or to the subject site before the presence of pollutants at the site.

3. Remote Sensing

Applications: Color infrared (CIR) aerial photography can be used on vegetated sites to identify (on a broad scale) those areas that are under stress, possibly from pollutants. CIR can be very useful in defining impacted areas in a general way.

Limitations: Many factors other than pollutants can cause stress symptoms in plants (insect infestation, excessively drained pockets of soil, or some diseases), which must be differentiated from pollutant caused symptoms, probably by examination of the area by an experienced person on the ground. Because different species will show different levels of stress from pollutants, interpretation of CIR photos maybe difficult unless the site is covered more or less uniformly by one type of vegetation. Optimum time to perform aerial photography is in late summer or early fall; taking CIR photos at other times of the year maybe useless because abundant moisture will limit stress in plants. Data tend to be subjective, require comparison to similar unpolluted sites, can be used only on vegetated areas, and maybe costly.

4. Ecological Assessments

Applications: An assessment is a good technique to collect quantitative data on the species composition and the percentage of groundcover.

Limitations: An assessment requires the use of an unpolluted (control) area similar to the one suspected of being polluted. This control area may be either an adjacent unpolluted site, or more rarely, data that were collected from the subject site before the first pollutant impact. Sensitivity of technique depends In large part on ‘the control area being very similar to the treated area. The amount of pollutant cannot be quantified satisfactorily using these techniques; it is useful only on vegetated sites.

5. Tissue Analyses

Applications: These analyses are suitable for collecting quantitative data on levels of contaminants in plants growing on polluted sites. The data indicate the extent to which the pollutant maybe moving Into the animal food web.

Limitations: Plants selectively absorb various chemicals or elements from the soil; therefore, plant tissue analysis could give a very poor indication of absolute quantities of a pollutant present on a site. Variation in soil characteristics over a polluted site could markedly affect the quantity of a pollutant present in plant tissues. Normal plant metabolism could chemically alter the pollutant and obscure results of tissue analysis. The amount of pollutant in plant tissue would probably vary among species and possibly among individuals within a species, necessitating the collection of multiple samples per site. Death of pollutant-sensttive species on a site before sampling could result in collection of misleading data. Collections during various seasons may be required for a complete picture.

VERTEBRATES

Methods

1. Collection – General

Applications: Collection of terrestrial vertebrates will document the presence of species. Collection techniques can be used to esthete population sizes. Vertebrate collection can be used to gather tissue for pollutant analysis.

Limitations: Some vertebrate collection techniques are unsuitable for certain sites (for example, shooting animals near residential areas). Vertebrate collection may generate opposition from animal-rights activists. Some sites might not contain enough animals to ensure statistical validity of the study.

2. Live Trapping

Applications: Live trapping can be used for collection of “sensitive species” when lethal traps or hunting would be inappropriate. Population sizes can be estimated using live traps in a “mark-and-recapture” context. A list of species present on the site can be generated. The size of the home range of the species can be estimated either through use of marked and retrapped animals or through radiotelemetry of animals that were trapped alive, marked, and released. Animals can be trapped alive to collect tissue (especially blood) for analysis.

Limitations: Humane live trapping can be a very time consuming activity; trappers can be injured by animals that are trapped alive. Successful live trapping requires experienced personnel for trap placement and rapid field identification of species. Trapping may need to conform to local laws on animal capture. Some species are not very susceptible to live-trapping techniques.

3. Lethal Trapping

Applications: Lethal trapping can be used to establish which species are present on a site and to collect tissue-donor specimens for analysis of pollutants.

Limitations: This method is not suitable for work with “sensitive species” and may agitate animal-rights activists. Lethal traps may cause injury or death to domestic animals on a site and may conflict with local laws or require a special permit. An experienced trapper is required for best results. Proper frequency of checking the traps can make this method extremely time-consuming. Depending on the type of tissue analysis being conducted, tissues of interest may be mangled beyond use during trapping. Some species may not be susceptible to lethal trapping.

4. Hunting

Applications: Hunting allows the documentation of species present on the site and is suitable for collecting tissues for analysis. it is most useful on medium-to large-sized species and may be best for species not susceptible to trapping.

Limitations: Hunting is impractical for smaller species. it may be a dangerous technique in urban areas where people or property are nearby; hunting may also be illegal or may require special permits. Hunting is not suitable for colliecting “sensitive species,” is poorly adapted to collection of nocturnal animals, can be a very time-consuming method for collecting certain species, and may result in damage to the tissues being collected for analysis.

5. Ecological Analysis– Habitat Evaluation Procedure (HEP)

Applications: HEP provides an integrated analysis of the habitat values on a site. The impact of the pollution on the site’s most important habitat values can be assessed by using an uncontaminated comparison area or information on a polluted site before it was polluted.

Limitations: A full HEP analysis is a very time-consuming activity. it provides an assessment of impact but does not identify causes of the impact.

12.6.3.3 Aquatic (Freshwater) Field Methods Summary

Vegetation

Some collection techniques discussedfor the terrestrial environment can be applied to most freshwater systems. Remote sensing techniques are limited to emergent vegetation or other vegetation on or above the water’s surface, which creates a major imitation of this terrestrial technique to freshwater studies. in addition, artificial substrate techniques discussedbelow for freshwater macrovertebrates can also be used to collect or monitor colonization rates of lower forms of aquatic vegetation.

MACROINVERTEBRATES

Methods

1. Sediment Grabs

   Applications: Sediment grabs are used In lakes and slower moving rivers and in softer bottoms with invertebrates either in or associated with the sediments down to shallow depths. The grabs can concurrently collect surface sediment for contaminant analyses and characterization.

   Limitations: Complex gear can be required for deeper water use, and harder sediments require heavier grabs. A boat with a winch maybe required in many applications. The use of a boat on a hazardous water body will need to be assessed for human health risks.

2. Core Samplers

   Applications: Core samplers are used In lakes and slower moving rivers and in softer bottoms where a deeper penetration is required than a grab. Core samplers are needed for bottoms that are harder than a grab can sample and that can be pushed in by hand during shallow water applications. Core samplers can concurrently collect surface and deeper sediments for contaminant analyses and characterization.

   Limitations: As with grabs, the size of target invertebrates must be considered along with inside barrel diameter of the core and retaining devices in the core mouth. Core samplers (including sophisticated vibracores) can require multiple-ton winch capacities on larger ships to retrieve longer cores.

3. Shovel

   Applications: Shovels are used for shallow sediment collection in substrate that will stay on the shovel when lifted through shallow water.

   Limitations: Use of a shovel Is qualitative only very shallow water must be over the sediments. Sediment must be somewhat cohesive to stay on shovel (days, fine sands); porous gravels or cobbles may allow invertebrates to leave the sample.

4. Box Sieves (used in conjunction with grab, core, and shovel sediment samples)

   Applications: Box sieves separate invertebrates of Interest from sediments collected.

   Imitations: The choice of screen size determines the size of retained invertebrates; the smaller the screen size the greater the time and cost to process the invenebrate sampled but the better definition of the invertebrates present.

5. Surber Samplers

   Applications: Surber samplers are used in moving river water to depths less than 12 inches and are best on a bottom that can be disturbed to 2 to 4 inches deep.

Limitations: These samplers cannot be used in waters too deep, too slow, or too swift to deploy the gear; the bottom cannot be a solid substrate (rock or very hard clays).

6. Invertebrate Drift Nets

Applications: These nets are used in river water moving faster than 05 feet per second for invertebrates that migrate or are dislodged from the substrate. The nets can be modified for use in lakes with the net inverted (net opening faces the bottom of lake) to caputre vertically migrating invertebrates.

Limitations: The nets will not sample species that do not migrate or dislodge from the substrate. Currents can be too swift and may either tear the gear or mutilate hate the invertebrates sampled, making it difficult to quantify what the samples represent.

7. Other Trawls (The reader should see the fish methods subsection that follows)

Many larger macroinvertebrates associated with the bottom or near bottom at certain times of the day or night can be collected in conjunction with demersal fish. Applications and limitations discussed in the fish subsection apply.

8. Traps

Applications: Traps are used in river or lake bottoms too rough for trawls and for larger macroinvertebrates (i.e., crayfish) that are attracted to bait.

Limitations: Traps should be used with mobile macroinverbrates only. The collector should consider the contaminant content of the bait used to capture animals in traps if the animals are to be used for tissue analyses close to the digestive process.

9. Artificial Substrates

Applications: This method is good as a quantitative benthic invertebrate colonization tool and is best for smaller attached or less mobile invertebrate species.

Limitations: The method is time consuming; interpretation is more complex if test substrate is not representative of the natural substrate present. This method is not suited to larger, slow-growing, mobile macroinvertebrates.

10. In Situ Bioassays (The reader should see the labroatory tests and analyses in subsection 12.5.4.)

Applications: In situ bioassays are a good toxic: challenge or bioaccurnulation tool for multi-parameter contaminants.

Limitations: This method is time consuming for bioaccumulation and requires healthy test invertebrates (crayfish, mussels, etc.) that occur either naturally in the site area (beyond the site's influence) or from other sources (inclucding artificially reared invertebrates) that could inhabit the site area. A cautious assessment of test animal response is required to be certain that noncontaminant-related site parameters(water temperature, low dissolved oxygen (DO), starvation) are not involved. The method lacks control of dependent variables that exist in laboratory bioassay.

11. **Miscellaneous (hands, hand teds, dip nets, plankton nets)**

Applications: Miscellaneous methods have limited gear needs, if at ail, and are adaptable to shallow water areas. Diving is presumed unsafe for human health reasons.

Limitations: This method is only qualitative, except if fried-opening nets are metered. The collectors must be gloved or otherwise protected as dictated by site personal protection levels.

12. **Tissue Analyses and Species Selection**

These methods do not lend themselves to applications and Limitations The investigators must compare the contaminants expected or known on a hazardous waste site with the macroinvertebrates that are likely to be present to decide which may be the best species and tissues to monitor from that species. Local human consumption and tissues consumed must be considered. In many cases, the available aquatic macroinvertebrates to choose from may be quite limited. The same process must be gone through to select a bioassay or bioaccumulation species that is brought into the site. Many aquatic macroinvertebrates are small in size, and whale body samples may be needed. Since different metals and organic chemicals may accumulate in certain tissues in these invertebrates, tissue selection by organ and by pooled samples (if the quantity permits) may yield a higher resolution of what is being accumulated and of what level of risk the bioaccumulation is to the Invertebrates that are involved.

FISH

Methods

1. **Travels**

Applications: These methods are used in the flatter, smooth-bottom areas of lakes or ponds or in large, slow-moving rivers. The methods are quantitative if net opening, distance traveled, and gear avoidance by the target species is understood. Other trawls can be modified to fish in midwater or in surface areas for nondemersal fish species.

Limitations: The gear can become cumbersome and labor intensive, especially as larger trawls are used and greater boat capacity is required. Gear avoidance in high-visibility water is a problem with larger-sized individuals and with more mobile species. Distance trawled can be difficult to calculate on larger bodies of water; gear is easy to entangle and damage or to lose on bottom obstructions and debris.

2. **Electrofishing**

Applications: This method is quantitative in small confined water bodies that have good in-water visibility. Fish can usually be examined and returned without harm. The method is portable for remote applications, if required, and is boat-deployable for larger river or lake applications. Electrofishing is a good choice where bottom type or stream course precludes trawls or seines.

Limitations: The method has variable efficiency with conductivity in freshwater or in estuarine (saline) areas. Depending on the gear and settings, electro fishing can be very selective for the size of fish taken. In low-visibility water, capturing stunned fish can be difficult. The method is qualitative in larger water bodies and has added risks to investigators. Behavioral and habitat preference differences among species will influence sampling efficiency. Electro fishing is not effective on very small fish that are in large cobble or rock-type bottoms. Gear efficiency declines with depth in larger bodies of water.

3. Seining

Applications: Smoother-bottomed, lower-sloped beaches are suited to this gear. If a person can wade in the area to sample, a seing can be used without a boat, although a boat can be very useful to sample multiple shore areas around some water bodies. Seining gear is compact, easy to store, and easy to use; it is generally reliable (little risk of loss or great damage).

Limitations: Net avoidance can be a problem with some larger individuals and mobile species in higher visibility waters. Seining is semiquantitative in most applications and is difficult to use in faster flowing river areas.

4. Hook and Line

Applications: The hook and line method is a simple method If target fish are suited to it. it is a good approach to collect a few larger individuals for tissue analyses (artificial lures rather than bait are preferred). The method is usually better for larger individual fish than smaller fish and is independent of bottom condition, depth, or water current conditions.

Limitations: This method is very selective to the fish attracted to the lures or bait used. investigators may need a license as well as a collector's permit. The hook and line method is not quantitative.

5. Other Fish Collection Approaches

Additional collection approaches that may be adaptable to hazardous waste sites include gill nets, trammel nets, fyke nets, or rotenone. The reader is referred to Nielsen and Johnson (1963) for a discussion of a large number of collection techniques.

6. in Situ Bioassay (The reader should seethe laboratory tests and analyses in Subsection 12.6.4.)

Applications: In situ bioassay is a good toxic challenge or bioaccumulation tool for multiparameter contaminants that vary in concentration with space and time.

Limitations: The bioaccumulation method is time consuming and requires healthy test fish that occur either naturally in the site area (beyond the site's influence) or that could inhabit the site area. The latter type of fish can be obtained from other sources (including fish that are artificially reared) that could inhabit the site area. A cautious assessment of test animal response is required to be certain that noncontaminant-related site parameters (water temperature, low DO, starvation) are not involved, This method lacks control of dependent variables when compared to laboratory bioassay.

7. Tissue Analyses and Species Selection

These methods do not lend themselves to applications and Limitations The investigators must compare the contaminants expected or known on a hazardous waste site with the fish that are likely to be present before deciding which maybe the best species and tissues of that species to monitor. Local human consumption and tissues consumed must be considered. In some cases, the available fish spades to choose from may be quite limited. The investigators must go through the same process before selecting a bioassay or bioaccumulation species that is brought Into the site. Some aquatic (freshwater) fish are small in size, and whole body samples may be a necessity. Since different metals and organic chemicals may accumulate in certain tissues in these fish, tissue selection by organ and by pooled samples (if the quantity permits) may yield a higher resolution of what Is being accumulated and what degree of risk the bioaccumulation poses to the fish species involved. The collector should avoid the spawning season when sampling fish spades.

The reader should see Appendix 12A for samples of target fish species.

12.6.3.4 Marine Field Methods Summary

For near-shore marine studies anticipated in hazardous waste sites, nearly all of the collection and other practices in Subsection 12.6.3.3, Aquatic (Freshwater) Field Methods Summary, can be applied here. In the interest of conserving space, only those methods that require an approach different from approaches listed in the freshwater section will be discussed in this subsection. The reader should refer to the previous subsection for method applications and Limitations Three gear types discussed in the aquatic (freshwater) subsection are not applied In the marine environment (Surber Sampler, Invertebrate Drift Net, and Electrofishing).

Attached or nonmigratory species are best for the Investigator to assess, if at all possible; these species allow interpretation of plant and animal condition in the zoned Influence of the contaminants reaching the marine environment.

VEGETATION

The reader should see the terrestrial and freshwater discussions (Subsections 12.6.3.2 and 12.6.3.3). In intertidal zones, tidal levels can be used to an advantage in marine vegetation collection and can increase the reliability of remote sensing applications over the limited use of such techniques in freshwater.

MACROINVERTEBRATES

- 1\. Sediment Grabs
- 2\. Core Samplers
- 3\. Shovel
- 4\. Box Sieves

In the near-shore zone, tidal levels can be used to eliminate water over sampling areas in the intertidal zone or to reduce water levels in areas beyond the intertidal zone. The size of larger targeted macroinvertebrates in marine sediments must be considered relative to the opening of grabs, especially core samplers and any core-retaining devices.

- 5\. Otter Trawls
- 6\. Traps
- 7\. Artificial Substrates
- 8\. In Situ Bioassays

Limitations: In addition to limitations for freshwater, fairly protected marine waters would be required-to attempt in situ marine bioassays.

- 9. Miscellaneous (hands, hand tools, dip nets, plankton nets)
- 10. Tissue Analyses and Species Selection

FISH

- 1. Trawls
- 2. Electrofishing (not applicable in marine waters)
- 3. Seining
- 4. Hook and Line
- 5. Other Fish Collection Approaches
- 6. In Situ Bioassays

  Imitations: In addition to imitations for freshwater, fairly protected marine waters would be required to attempt in situ marine bioassays.

- 7. Tissue Analyses / Species Selection

Several of the field techniques described in Appendix 12A can yield subjective evidence of the impact on biotic systems. Examples of this subjective evidence include unnatural vegetation growth (or lack of growth) and tissue result analyses from an affected area only. While helpful in determining relative risk to humans and natural systems, this type of information is not often defensible because it does not define a statistical basis for impact assessment. Such information can, however, provide another measure for ranking sites relative to other sites. Subjective evidence of harm to natural systems can also provide information on areas of interest that should be included in the physical and biological parameter sampling program.

12.6.3.5 Vegetation

Subjective evidence of harm to vegetation (terrestrial, aquatic, and marine) is primarily from visual observation of lack of growth where growth would be expected or of unusual growth of species or specific individuals. For example, *Ulva* is a marine algae susceptible to introduced pollutants. In areas with a high nutrient loading, the *Ulva* can be excessively abundant. In areas where the composition of pollutants includes hazardous materials, areas can be locally devoid of *Ulva* or of any other algae.

The impact on vegetation is obvious in some areas where spills or leaks have discolored the soil and no vegetation is found. Other areas that appear natural but are devoid of vegetation for extended periods of time indicate possible contamination of soils or water sources. In some cases, field botanists and ecologists can determine harm to the community if the species composition favors tolerant species and if more sensitive species are absent or reduced. Some vegetation, trees in particular, can appear to be unhealthy or dying in a contaminated area.

When the area to be inspected is large, remote sensing can be useful in collecting subjective evidence of harm to biotic systems, as discussed in Subsection 12.6.3.2 and in Section 14, Land Surveying, Aerial Photography, and Mapping. Aerial reconnaissance surveys are common tools in evacuating hazardous waste sites.

12.6.3.6 Terrestrial Animals

Compared to vegetation, potential impacts to terrestrial animals resulting from hazardous wastes are much more difficult to subjectively assess in the field. Either a lack of animals and animal tracks in areas expected to support some wildlife or a trapping effort that yields no organisms during the field survey might be indications of an adverse impact. While avoidance behavior in free-ranging populations should not be interpreted without an adequate data base, an absence of wildlife indicates a possible impact on these populations in the vicinity of the site.

Disturbances to wildlife habitats as a result of hazardous waste site operations may suggest impacts to wildlife populations. This disturbance is especially apparent in cases where the waste site is in or adjacent to a sensitive habitat such as a wetland or estuary. in these habitats, there are many opportunities, including high productivity, for wildlife to come in contact wtth contaminants.

Other subjective assessments of harm to biota can result from cases of animal poisoning, abnormal behavior, or other potential toxic responses reported to local authorities that have occurred in either wildlife species or domestic animals (including pets) found near of the she.

As stated in Subsection 12.6.3, wildlife bioaccumulation data can also be considered subjective because of the possible lack of an adequate reference sample, because of low sample size, and because of a general lack of data amenable to statistical analysis.

12.6.3.7 Aquatic Invertebrates

Subjective field assessment of benthic aquatic invertebrate communities can include evidence of poor water quality or visual observations of an extremely low or extremely high abundance of plants in the system. Subjective evidence of possible harm to aquatic invertebrates would include oil sheens on the water; abnormal water color or results of water-quality parameter testing that shows low oxygen content, abnormally high salinity or temperature, or extreme ranges In pH.

12.6.3.8 Fish

The same sources of subjective evidence described for aquatic invertebrates can be used to subjectively determine possible harm to fish populations. Additional subjective evidence of an impact on fish populations would include reported fish kills and observations of abnormal growths or tumors in fish caught near the hazardous waste site.

12.6.4 Laboratory Tests and Analyses

12.6.4.1 Introduction

Laboratory bioassessment analyses and tests are used to obtain more objective and more detailed information regarding the impact of pollutants on natural systems than would be possible from either the initial subjective biotic field surveys or from chemical testing of site-contaminated soil and water. Laboratory bioassessments include determination of levels of contaminants in organisms that were collected from the site vicinity and in bioasaays or toxicity testing using site media, in reference organisms from unaffected areas near the site, or in standard assay organisms.

Bioconcentration and biomagnification tests are conducted when the investigator suspects that an identified food web may be affected by site contaminants. These tests are particularly important if site chemicals are known to bioconcentrate or if the octanol/ water coefficient indicates that a potential for bioconcentration exists. This information is important in the assessment of possible human health risks resulting from the site. Tissues are collected from food web organisms, such as fish or mammals, found on or near the site (Subsection 12.6.2) and analyzed according to laboratory protocol (Subsection 12.6.4.3).

Laboratory bioassays or toxicity tests are used for a variety of reasons including preliminary site screening, monitoring cleanup efforts, or determining the toxicity of complex and/or unusual mixtures of chemicals. An example of a screening test for bioassessment of hazardous waste sites Is the experimental protocol being developed by the EPA research laboratory in Corvallis, Oregon. This protocol is composed of a series of tests that use site soils, ground water, surface water, and extracts of site soils to deter mine their respective toxicities to bacteria, algae, seeds, earthworms, aquatic invertebrates, and fish (Porcella, 1983). EPA is assessing the use of this protocol as a standard screening test to establish priorities for site clean ups and as a monitoring tool for cost-effective site clean up. If the procedures for regular analytical testing of site chemicals of concern are expensive and if turnaround time is extensive, some or all of the proposed bioassessment protocol might be used to yield more cost-effective monitoring data.

Toxicity test methods for hazardous waste sites are in the development stage, with no one set of protocols mandated for use. Until some future date when toxicity tests are better established for these sites, investigators must keep up with the developing protocols as discussed above, and they must use existing methods that were designed for other uses. Since most hazardous waste site waters can be characterized as complex effluents, wastewater bioassays can be adapted for use. These techniques are published by EPA and are required to be used in state and regional National Pollutant Discharge Elimination System (NPDES) procedures. Hazardous waste sites that may have (or had) point or nonpoint discharges may have ongoing (or past) bioassays completed by some of these methods. Two recent publications that characterize the present techniques for effluents can be applied to hazardous waste sites (EPA, 1985c and 1985d).

These manuals and other documents referenced In them provide details on methods beyond the developing protocols (Porcella, 1983) that can also be applied to hazardous waste sites.

The most common bioassay or toxicity test currently used is the static acute bioassay using aquatic invertebrates or fish. This test can be used as a quick toxicity screening twice or can be employed when chemical analyses indicate the presence of a complex mixture of contaminants. There are often synergisms or antagonisms among the site contaminants that are difficult to describe from available literature or from a comparison to criteria. Bioassays can be important tools in identifying actual toxic responses to the unusual combination of contaminants found onsite. Acute bioassays do not address long-term or chronic toxicity concerns. The reader should see EPA (198d) for short-term approaches to chronic toxicity issues. Exhibit 12-1 provides recommended species, test temperatures,’ and life stages for measuring acute toxicity.

Data interpretation of the results of EPA's draft bioassessment protocol can yield an indication of the relative acute toxicity of a specific hazardous waste site based on toxicity criteria (Exhibit 12-2). Low or nondetectable levels of toxicity do not necessarily mean that the site Is “safe.” Long-term or chronic toxicity is not addressed by this protocol.

Theoretically, hazardous waste sites can be compared by this protocol if the study plans are designed to incorporate randomness in sample collection and to minimize the variability of site-specific characteristics. Ultimately, the protocol is aimed at allowing EPA to rank hazardous waste sites for cleanup priority and to monitor the cleanup efforts to more effectively protect human life and natural systems.

12.6.4.2 Test Material Handling Requirements

12.6.4.2.1 Collection Techniques

As described in Subsection 12.6.2, types of biotic test materials collected from sites can include vegetation, aquatic invertebrates, tissues from terrestrial animals, and whole fish or tissues from fish. Approximately 30 grams of vegetative material and 100 grams of animal tissue are needed to run most tissue

Exhibit 12-1
RECOMMENDED SPECIES, TEST TEMPERATURES, AND LIFE STAGES

Species		Test Temperature[a] (°C)	Life Stage[b]
Freshwater			
Vertebrates			
Cold Water			
Brook trout	*Salvelinus fontinalis*	12	30 to 90 days
Coho slamon	*Oncorhynchus kisutch*	12	30 to 90 days
Rainbow trout	*salmo gairdneri*	12	30 to 90 days
Warm Water			
Bluegill	*Lepomis macrochinus*	20	1 to 90 days
Channel catfish	*Ictalurus punctatus*	20	1 to 90 days
Fathead minnow	*pimephales promelas*[c]	20	1 to 90 days
Invertebrates			
Cold Water			
Stoneflies	Pteronarcys *spp.*	12	Larvae
Crayfish	*Pacifastacus leniusculus*	12	Juveniles
Mayflies	*Baetis* spp. or *Ephemerella* spp,	12	Nymphs
Warm Water			
Amphipods	*Hyalella,* spp.,	20	Juveniles
	Gammarus lacustris, G. *fasciatus,*	20	Juveniles
	or G. *pseudolimnaeus*	20	Juveniles
Cladocera	*Daphnia magna* or *D. pulex,*[d]	20	1 to 24 hours
	Ceriodaphnia spp.		1 to 24 hours
Crayfish	*Orconectes* spp., *Cambarus* spp.,	20	Juveniles
	procambarus Spp.,	20	Juveniles
Mayflies	*Hexagenia limbata* or *H. bilineata*	20	Nymphs
Midges	*Chironomus* spp.	20	Larvae
Marine and Estuarine			
Vertebrates			
Cold Water			
English sole	*Parophyrys Vetulus*	12	1 to 90 days
Sanddab	*Citharichthys stigmaeus*	12	1 to 90 days
Winter flounder	*Pseudopleuronectes americanus*	12	Post-metamorphosis

Exhibit 12-1
(continued)

Species		Test Temperature[a] (°C)	Life Stage[b]
Warm Water			
Flounder	*Paralichthys dentatus*	20	1 to 90 days
	P. lethostigma	20	1 to 90 days
Longnose killifish	*Fundulus similis*	20	1 to 90 days
Mummichog	*Fundulus heteroclitus*	20	1 to 90 days
Pinfish	*Lagodon rhomboides*	20	1 to 90 days
Sheepshead minnow	*Cyprinodon variegatus*	20	1 to 90 days
Silverside	*Menidia* spp.	20	1 to 90 days
Spot	*Leiostomus xanthurus*	20	1 to 90 days
Threespine stickleback	*Gasterosteus aculeatus*	20	1 to 90 days
Invertebrates			
Cold Water			
Dungeness crab	*Cancer magister*	12	Juvenile
Oceanic shrimp	*Pandalus jordani*	12	Juvenile
Green sea urchin	*Strongylocentrotus droebachiensis*	12	Gametes/embryo
Purple sea urchin	*S. purpuratus*	12	Gametes/embryo
Sand dollar	*Dendraster excentricus*	12	Gametes/embryo
Warm Water			
Bluecrab	*Callinectes sapidus*	20	Juvenile
Mysid	*Mysidopsis* spp.	20	1 to 5 days
	Neomysis spp.	20	1 to 5 days
Grass shrimp	*Palaemonetes* spp.	20	1 to 10 days
Penaid shrimp	*Penaeus setiferus*	20	Post larval
	P. duorarum	20	Post larval
	P. aztecus	20	Post larval
Sand shrimp	*Crangon* spp.	20	Post larval
Pacific oyster	*Crassostrea gigas*	20	Post larval
American oyster	*Crassostrea virginica*	20	Embryo/larval

---

[a] To avoid unnecessary logistical problems in trying to maintain different test temperatures for each test organism, it would be sufficient to use one temperature (12°C) for cold water organisms and one temperature (20°C) for warm water organisms.

[b] The optimum life stage is now known for all test organisms.

[c] In tests with nine toxicants, Mayes et al. (1983) found no significant difference in the sensitivity of fish ranging in age from 10 to 100 days.

[d] *Daphnia pulex* is recommended over *D. magna* because it is more widely distributed in the United States, test results are less sensitive to feeding during tests, and it is not as easily trapped on the surface film.

Source: EPA (1985c).

Exhibit 12-2
DEFINITION OF TOXICITY CATEGORIES FOR AQUATIC AND TERRESTRIAL ECOLOGICAL ASSAYS

Assay	Activity Measured	Sample Type[a]	MAD[b]	Units	Response Levels for LC_{50} or EC_{50} Concentrations[c]		
					High	Moderate	Low or Not Detectable
Freshwater Fish	96-hr LC_{50} (lethality)	S	1	g/1	<0.01	0.01-0.1	0.1-1
		L	100	percent	<20	20-75	75-100
Freshwater Invertebrate	48-hr EC_{50} (immobilizition)	S	1	g/1	<0.01	0.01-0.1	0.1-1
		L	100	percent	<20	20-75	75-100
Freshwater Algae	96-hr EC_{50} (growth inhibition)	S	1	g/1	<0.01	0.1-0.1	0.1-1
		L	100	percent	<20	20-75	75-100
Seed Germination and Root Elongation	115-hr EC_{50} (inhibited root elongation)	L	100	percent	<20	20-75	75-100
Earthworm Test	336-hr LC_{50}	S	500	g/kg	<50	50-500	500
Soil Respiration Test	336-hr EC_{50}	S	500	g/kg	<50	50-500	500
		L	100	percent	<20	20-75	75-100

[a] S = solid, L = aqueous liquid, includes water samples and elutiate or leachate. Nonaqueous liquids are evaluated on an individual basis because of variations in samples, such as vehicle, percent organic vehicle, and percent solids.

[b] MAD = Maxium applicable dose.

[c] LC_{50} = Calculated concentration expected to kill 50 percent of population within the specified time interval.

EC_{50} = Calculated concentration expected to product effect in 50 percent of population within the specified time interval.

Source: Porcella, 1983

analyses (EPA, 1980b and 1980c). Surface soils, groundwater, sediment, and surface waters are collected to run bioassay types of tests.

Initial screening bioassays are usually performed using site soils collected from three sample sites: one at the point of greatest contamination, one at the boundary of the hazardous waste site, and one from a reference or control area. If the boundary-stie contamination level is found to be higher than the control, additional offsite samples are taken to Identify the contaminant boundary. Additional screening bioassays can be run using onsite or near-site surface water or groundwater.

Surface soils and sediments from the site are collected according to the protocol as described in other sections (Sections 8 and 10) of this compendium. Typically, three subsamples of soil are collected from the top one-half meter of depth in a square meter area at the desired sample location and are thoroughly mixed. The size of the sample depends on the test being performed. Soil and sediment samples are sampled and stored according to procedures described in other sections (Sections 6, 8, and 10) of this compendium.

Groundwater and surface waters are also collected and handled according to procedures described in other sections (Sections 6, 8, and 10) of this compendium. The size of the sample depends on the test being performed.

12.6.4.2.2 Laboratory Techniques

Sample Storage

Biological samples, including fish and mammal tissues frozen in the field, are stored in a designated freezer until extracted. The biological samples should be stored separately from other samples. Water and soils / sediments that were collected from the site and are to be used In bioassays are stored on ice during shipment and are kept at 4°C until testing begins. The temperature of the stored water sample is allowed to equilibrate to that of the bioassay test temperature before being diluted. All samples are labeled and kept in designated storage areas. If sample jars are breakable, outer unbreakable containers are used to transport samples to the test area.

Equipment Cleaning

Test containers are primarily made of glass, No. 316 stainless steel, and perfluorocarbon plastics. Each test container is cleaned as follows:

1. Wash with nonphosphate detergent.
2. Rinse with distilled water.
3. Rinse with 100 percent acetone. If volatile analyses are required, acetone use is discouraged and methanol is often used as a substitute.
4. Rinse with distilled water.
5. Rinse with nitric acid (5 percent).
6. Rinse thoroughly with distilled water.

7. Rinse finally with distilled, deionized, or organic-free water (three times), as appropriate to required analyses.

12.6.4.3 Specific Teats and Analyses

12.6.4.3.1 Vegetation

Tissue Analysis

Before plant tissues are analyzed, samples need to be prepared for the type of analysis being done. If airborne sources of contamination are suspected, it may be necessary to wash all samples before analysis. Washing will remove loose surface contaminants and provide for an analysis of tissue concentrations. If surface contamination data are required, samples are not washed. Roots are thoroughly washed because of the possibility that contaminants could be adsorbed to soil particles and not to root tissue.

Samples are weighed before washing to determine weight gain as a result of water absorption. Plant material to be analyzed is washed slowly in distilled or deionized water. The material is gently moved in the water and is not scrubbed. Detergents are not used. Washed material is placed on clean blotter paper and is not allowed to air dry. Each sample is prepared for analysis immediately following washing.

The laboratory also analyzes a sample of the dean wash water, of the wash water after washing plants, and of a place of the blotter paper.

Vegetative samples are homogenized through mincing, grinding, or blending. For nonvolatile contaminant analyses, these plant tissues can be dried and then processed through a Wiley mill or other tool as appropriate to the analyses planned. For volatile contaminant analyses, these plant tissues need to be processed "Wet" with no drying during the analytical process., In this situation, a separate sample is dried for measurement of wet and dry weight ratios and is not used in the volatile analyses.

The amount and types of planned analyses dictate the required sample size of plant tissue. in most cases, 30 grams (wet weight) will suffice, although many different types of analyses may require a larger amount of plant material. if the investigator anticipates that an organic contaminant is very dilute in plant tissues, large quantities of the plant tissue may have to be collected and subjected to extraction procedures before achieving the required analytical result. For nonvolatile analyses, 1 gram (dry weight) of plant tissue is often used.

For the most part, “standard methodology" does not currently exist for plant (or animal) tissue analyses. Methods originally designed for water or sediment will usually address plant tissue analyses; however, the sample preparation process is not inducted. In some cases, the analytical technique or the interpretation of gained results must be modified because of matrix-related interferences and other tissue problems not encountered In water and sediment testing. Pesticides are well covered in the EPA, 1980d manual. In other cases, modified water or sediment analytical techniques exist in an “interim” or “draft” status that may cover only a subset of the required analyses.

Because of the current lack of a standard methodology for plant tissue analyses, the reader should contact the regional EPA laboratory for the latest available plant tissue processing and analytical chemistry techniques for the contaminants of concern. The Information sources subsection lists several EPA methods manuals that can provide some assistance, including EPA 1980b, 1980c, 1980d, 1982, and 1983.

Seed Germination and Root Elongation Bioassay

Toxic substances that inhibit plant germination or root elongation (often the most sensitive phase in plant growth) can decrease primary productivity, reduce crop yields, and change natural systems by selection for tolerant species. A brief description of this test is provided below. For additional details, the reader should sea Porcella (1963). Although inhibition of both seed germination and root elongation is an observable toxic response, root elongation inhibition is more likely at lower concentrations and is a preferred end point in this bioassay.

Untreated seeds (i.e., seeds not treated with fungicidie, other pesticides, or fertilizers) can be obtained from commercial seed companies, state agricultural experiment stations, and U.S. Department of Agriculture laboratories. Seeds are sized and individually examined, and tests are conducted using the most common size of seed.

Five teat species representing commercially important and different plant families are used in this assay lettuce (butter crunch), *Lactuca sativa L.;* cucumber (hybrid Spartan valor), *Cucumis sativa L.;* red clover (Kenland), *Trifolium praetense L.;* wheat (Stephens), *Triticum aestivum L.;* and radish (Cherry Belle), Raphanus *sativa L.*

Equipment needed to conduct this assay includes one-piece molded glass tanks (6-liter capacity) outfitted with glass pegs or rods to hold at least five glass plates at a 67-degree angle, a spray bottle with a fog or mist nozzle, a metric ruler, forceps, a Soxhlet extraction apparatus, Whatman No. 3 mm chromatography filter paper, single-ply cellulose tissues (e.g., Kimwipes), a triple-beam balance, a pH meter, storage bottles, and plastic bags to enclose the test tanks (described above).

The test medium is an extract of a solid sample and is prepared according to the procedure listed in Exhibit 12-3. Dilutions of the extract should be made with distilled water, which is used as a negative control. The plate is then placed in the test chamber along with enough test medium solution to immerse by 2 to 3 centimeters the bottom of the test plate and filter paper (500 mililiters). This procedure is repeated for each plant species in the test. The whale chamber is enclosed in a plastic bag to maintain a humid atmosphere and is placed in a dark, temperature-controlled area at 252% for 115 hours. Extracts should be tested for pH and salinity. Generally, pH >6.5 and salinity <0.01 N salt will not be toxic. If the medium is outside these ranges, an artificial control should be assayed.

A filter paper is soaked in the test medium, and then 15 seeds are placed on the test paper. A narrow strip of previously cleaned (using the Soxhlet extraction apparatus) cellulose tissue is placed over the seeds and misted to cause the tissue to adhere.

The plate is then placed in the test chamber along with enough test medium solution to immerse by 2 to 3 centimeters the bottom of the test plate and filter paper (500 milliliters). This procedure is repeated for each plant species in the test. The whale chamber is enclosed in a plastic bag to maintain a humid atmosphere and is placed in a dark, temperature-controlled area at 25 ± 2°C for 115 hours.

Each assay is composed of a tank for each test concentration, positive controls, and negative (distilled water) controls. The concentration range of NaF used for the positive control that causes an EC_{50} (effective concentration causing inhibition of 50 percent of growth compared to control) for each seed species is radish, 400 to 500 mg NaF/liter wheat, 300 to 400 mg NaF/liter lettuce, 100 to 200 mg NaF/liter cucumber, 150 to 200 mg NaF/liter; and red clover, 60 to 100 mg NaF/liter.

Seeds and roots must be examined and measured at 30 minutes from the end of the 115 hours to have a valid test. The root length is measured from the transition point between hypocotyl and root to the tips of the root. At the transition between the hypocotyl and the primary root, the axis may be slightly swollen,

Exhibit 12-3
METHODS FOR PREPARING SOIL EXTRACT

Steps

1. Weigh an adequate amount of air-dried soil sample or all desired tests.

2. Add a weight of distilled water equal to four times the soil weight.

3. Shake for 48 hours (150 rpm) at constant temperature (20 ± 2°C) in the dark.

4. Allow to settle, decant, and filter with 0.45 µm membrane to obtain the extract. Soil sample extracts with high day content will have to be centrifuged and decanted before filtration.

5. Relate all extracts to the original weight of soil. Measure volume of extract and relate to initial soil weight. For example, if 3,100 ml of extract Is obtained from 1,000 grams of air-dried soil, there are 3.1 ml/gram of soil. Then, if 25 ml of extract are added to 100 grams of soil for a test, this combination would be equivalent to 8 grams of soil (25/3.1) or a 7.4 percent soil solution (8/108). This soil solution would be the highest concentration. For a geometric series of teats, subsequent samples would be decreased by halves. For example, for 7.4, 3.7, 1.85,... the percent extract plus sample volumes would be 25 + O, 12.5 + 12.5,6.25 + 18.75, ...

6. Do not concentrate extracts; extracts should be prepared within 24 hours of collection. Extracts should be checked for salinity using conductivity.

Source: Porcella, 1983.

may contain a slight crook, or may change noticeable in size for the radish, lettuce, cucumber, and red clover. In wheat, the single longest primary or seminal root is measured from the point of attachment to the root tip.

A range-finding test that consists of one control tank and one test tank each of 100, 10, 1,0.1, and 0.01 percent extract is conducted to see if a definitive test is necessary. If the 100 percent tank has mean root lengths that are 85 percent of control and if at least 10 of the 15 seeds germinate, no further testing, examination, or root measurement is done. No EC_{50} is possible with these results. If a definitive test is called for, at least six extract concentrations must be chosen in geometric series: the highest concentration used will be the next higher concentration than that concentration which reduced the mean root length to less than 50 percent of the control.

Freshwater Algae 96-Hour Test

Unicellular algae are important primary producers in aquatic food webs and are often sensitive to environmental changes. Algal growth can be either inhibited or stimulated in the presence of contaminants. In EPA's Corvallis laboratory, the bioassessment protocol includes a simple screening test to be conducted in 98 hours for freshwater algae. This 96-hour screening test exposes algae to various concentration of test material and growth (measured by cell counts or other methods listed below). Typical results of this test are reported as EC_{90} and EC_{50} if growth is inhibited or as SC_{20} if growth is stimulated. (EC_{50} is the lowest test concentration causing growth inhibition of 50 percent relative to control. SC_{50} is the lowest concentration causing growth stimulation of 20 percent relative to the control.)

The proposed test species is *Selenast.rum capricomutum,* a nonmotile chlorophyte that is easily maintained in laboratory cultures. The test algae is kept in flasks containing standard Algal Assay Medium (AAM) in a constant-temperature room or incubator at 24 $\pm$ 2°C (from Miller et al., 1978, as reported by Porcella, 1983). Exhibit 12-4 lists nutrient components of the AAM. Continuous illumination of 4300&430 lumens/m^2 (400 ft-c) is required, and overhead cod-white fluorescent bulbs are recommended. The algal culture is checked microscopically to ensure that the culture is healthy and is composed only of the test algae. The concentration of cells at the beginning of the test should be approximately 10,000 cells/ ml.

According to Porcella, test material can be aqueous liquids (groundwater, surface water, or soil extracts in water); nonaqueous liquids (aqueous samples with greater than *0.2* percent organics, nonaqueous liquids, solvent exchange samples, and extracts or leachates In a nonaqueous or organic vehicle); or solids. Nonsolid test material should be filtered (preferably onsite) using a 0.45-micrometer cellulose acetate filter to remove indigenous algae. The minimum sample size needed to run the algae test is 1 gram of soil (or solid material), 0.08 liter of aqueous liquid, or 0.05 liter of nonaqueous liquid. Test material is obtained from areas specified in the study plan by using standard collecting methods.

Preliminary tests are run with 100 percent test material with and without nutrients contained In the AAM. If the 100 percent test with nutrients shows a less than 50 percent inhibition compared to a control sample, the material is considered relatively safe and no further testing is done. If there is a greater than 50 percent inhibition, test material should be assayed by either a range-finding test (dilutions of 80 percent, 10 percent, 1 percent, and 0.1 percent using three replicates each) or a definitive test, or both. A definitive test is conducted after a range-finding test by spanning the moderate response concentration using a geometric series. For example, if 1 percent (0.01) and 10 percent (O. 10) gave toxic responses, the definitive test series would include 0.1, 0.05, 0.025, 0.0125, 0.00825, and 0.003125. All tests are conducted with nutrients added essentially equivalent to 100 percent AAM, with AAM used to make dilutions.

Controls include the AAM (negative control) to check standard organism response; the receiving water, if applicable (reference control); and a solvent control, if applicable (dilution water plus solvent). The positive control is applied with $ZnCL_2$ in AAM at a concentration of 80 mg Zn^{++}/1 to give a range of inhibition of 51 to 68 percent (long-term mean = 58.8).

Exhibit 12-4
COMPOSITION OF ALGAL ASSAY MEDIUM (AAM)

Macronutrients
Nutrient Composition

Stock Solutions'		Prepared Medium	
Compound	Concentration (g/l)	Element	Concentration (mg/1)
$NaN0_3$	25.500	N	4.200-
$NaHC0_3$	15.000	Na	11.001
K_2HP0_4	1.044	C	2.143
		P	0.186
$MgSO_4.7H_20$	14.700	S	1.911
$MgCl_2.6H_20$	12.164	Mg	2.904
$CaC1_2.2H_20$	4.410	Ca	1.202

Micronutrients
Nutrient composition

Stock Solutions*		Prepared Medium	
Compound	Concentration (g/1)	Element	Concentration (mg/1)
H_3B0_3	185.520	B	32.460
$MnCl_2.4H_20$	415.610	Mn	115.374
$ZnCl_2$	3.271	Zn	1.570
$COCl_2.6H_20$	1.428	co	0.354
$CuCl_2.2H_20$	0.012	Cu	0.004
$Na_2Mo04 .2H_20$	7.250	Mo	2.878
$FeCl_3.6H_20$	160.000	Fe	33.051
$Na_2EDTA.2H_20$	300.00		

---

* Other forms of the salts may be used as long as the resulting concentrations of elements are the same.

Source: Porcella, 1983, from Miller et al., 1978.

After 96 hours of exposure, algae growth is measured by any one of the following methods: electronic particle counting, biomass (dry weight), absorbance (as measured by a spectrophotometer), or microscopic counting. Electronic particle counting is preferred, but cursory microscopic examination is important to identify abnormal cell shape or condition.

Exhibit 12-5 contains a summary of the possible methods used in counting cells, the equipment used, and the appropriate format used for results.

The investigator must use the definitive test to obtain data to calculate the EC$_{50}$, EC$_{90}$, or SC$_{20}$ and should assay a minimum of four test concentrations. The EC$_{50}$, EC$_{90}$, and SC$_{20}$ are calculated using any of several statistical methods. Exhibit 12-2 lists the toxic categories for results of the freshwater algal 96-hour test (Porcella, 1963)[4]

12.6.4.3.2 Terrestrial Animals

Laboratory tests and analyses pertinent to terrestrial animals include bioaccumulation and biomagnification analyses that are performed on vertebrate tissues taken from animals collected on or near the study site. The anal yeas also include laboratory assays of toxicity of soil and soil extracts to invertebrates (i.e., earthworms).

Bioaccumulation and Food Web Transfer Tests

Laboratory protocols for determining the presence of pesticides and related compounds in tissue and blood samples are contained in the information sources under Sherma (1976). An additional reference containing protocols for determining other contaminants in tissue is EPA 1960d.

In general, tissues to be analyzed are collected and stored in glass jars or vials with foil- or Teflon-lined screw caps and are either refrigerated (if analyses will be conducted within 24 hours) or frozen. The amount of tissue needed depends on the expected degree of contamination and the detection levels required for data interpretation. If low concentrations are expected, more tissue will be needed. If the degree of contamination is unknown, 100 grams of tissue is the typical amount collected. Specific procedures for the extraction of pesticides and their residues will vary. Solvents range from hexane or petroleum ether for nonpolar organochlorine and organophosphorus compounds to methylene chloride for polar carbamates. Some prior knowledge of the pesticides of concern is necessary in determining the laboratory methodology to be used. Details of these methodologies are contained in previously cited references.

Briefly, tissue samples are broken down into small pieces and blended before extraction. In most cases, the Soxhlet extraction method is used. High-performance liquid chromatography is EPA's recommended technique for the separation and analysis of complex mixtures (Sherma, 1976). However, gas or column chromatography is also used. Thin layer chromatography can be used to confirm residues following initial screening and quantification by gas chromatography.

Earthworm Toxicity Test

In EPA’s laboratory in Corvallis, the bioassessment protocol includes a two-phase test involving the earthworm *Eisenia foetida.* The reader should contact the regional EPA laboratory to obtain the current status of this procedure and a source for this earthworm. Although it is not common, this earthworm is regularly used in testing, grows easily in organic soils (commonly found in sewage beds), has a short life cycle, and readily reproduces. The proposed tests closely approximate actual conditions encountered by earthworms and do not require elaborate equipment or extensive personnel training.

Exhibit 12-5
ALGAE ASSAY PROCESSING METHODOLOGIES

Method	Equipment/Procedure	Resulting Data Format
Electronic Particle Counting	Model ZB1 Coulter Counter with Mean Cell Volume (MCV or MHR) computer	mg dry weight *S. Capricomutum*/liter or Number of *S. Capricomutum* cells/liter
Biomass	Measured portion of algal suspension filtered with tared 0.6 micrometer PVC membrane filter-dried for 2 hours at 70°C--cool in desiccator weighed. Test culture volume filtered and handled same. Subtract tare weight and divide by volume of culture filtered	mg/liter dry weight
Absorbance	Spectrophotometer or colorimeter at wave-length of 750 nm with optical density greater than 0.05 and less than 1.0	Absorbance units per mg dry weight per liter
Microscopic Counting	Hemacytometer counting chamber and microscope	cells/liter

The calculations used to interpret data results are as follows:

$$\frac{(T\text{-}IN) - P\,(C\text{-}IN)}{P(C\text{-}IN)} \times 100 = \begin{matrix}(+)\,\% = \text{Stimulation} \\ (-)\,\% = \text{Inhibition}\end{matrix}$$

where:
P = percent volume of AAM used to dilute test sample ($\geq$20 percent)
T = maximum standing crop (mg/l) in test sample
IN = dry weight (mg/l) of inoculum at start of test
C = maximum standing crop (mg/l) in AAM control

Source: Porcella, 1983.

Briefly, the first phase of the test is a simple contact test where individual worms are exposed to various concentrations of soil extracts on filter paper. The second phase exposes earthworms to actual test soils or to extracts in a defined soil medium. The contact test consists of a range-finding and definitive test, while the soil test Is usually just definitive. The end point of these definitive tests is an LC_{50}, with worms classified as dead when they do not respond to a gentle mechanical stimulus to the anterior end.

The first earthworm test Is the range-finding contact test where individual worms are placed in vials lined with filter paper (Whatman Grade 1) soaked in varying concentrations of extracts and a negative control (distilled water). Extracts are prepared as described in Exhibit 12-3. Dilutions used in this preliminary test are 100 percent, 10 percent, and 1 percent. Ten replicate test vials for each dilution are laid on their sides in a dark, temperature-controlled area ($20 \pm 2^{\circ}C$) for 48 hours. The number of dead worms is counted at the end of the test and compared to the control tests.

A geometric dilution series is used in the definitive contact test, with the concentrations used determined by the results of the range-finding test. A positive control is run using 0.354 mg Cu/liter of copper sulfate. This concentration will provide a response range of 0.9 to 1.1 of the LC_{50}. A negative control is also run. Test procedures are the same as for the range-finding tests.

Earthworm toxicity tests using soils are conducted In two ways: one with artificial soil to which test soil extract is added in varying concentrations, and a second in which test soil is used directly and “diluted” with artificial soil. Artificial soil is made of three general constituents: 70 percent industrial sand, 20 percent Kaolinite clay, and 10 percent sphagnum peat. Exhibit 12-6 provides a detailed list of two of these components. Calcium carbonate is used to adjust the pH to 7.0. The moisture content is adjusted to approximately 20 percent of dry weight with either test extract and/or distilled water. Site soil Is prepared using the procedure outlined in Exhibit 12-7.

Test containers are 500-ml crystallizing dishes covered with plastic lids, petri dishes, or plastic film. In each dish, 400 grams of moist test medium are used. For each test, four replicates of each concentration are run on 10 test worms. Four negative controls (distilled water) and one positive control, containing cop per sulfate at a concentration of 800 mg Cu/kg of soil, are also run for each test. Test containers are held at a constant temperature ($20\& 1^{\circ}C$) in a continuously lighted area for 14 days. The average weight of the test and control worms is determined at the beginning and at the end of each test. Again, mortality is determined by sorting the worms from the soil and recording their reaction to mechanical stimulation.

An assessment of mortality at 7 days and continuation of the test to 28 days Is optional. However, soil moisture may need to be adjusted because moisture is lost during sorting.

Test results are plotted on log probit graph paper and the median lethal concentration (LC_{50}) and its confidence limits are estimated. The LC_{50} values are given as percent of test soil sample. Mortality in the negative controls should not exceed 10 percent. If some mortality does occur (<10 per cent), a correction is made using the following formula: Corrected mortality percent = (observed mortality percent - control mortality percent)/100 - control mortality.

Acute Toxicity Test

The acute toxicity test Isa standard test that is commonly used to describe the toxicity of a compound or mixture of compounds to aquatic systems. *Daphnia* is the most common freshwater organism used. However, many crustaceans, mollusks, and fish have been used. The following is a brief description of the acute-static toxicity test used as a part of the EPA's bioassessment protocol.

The daphnid, *Daphnia magna,* was the basis for much of the preliminary work in acute toxicity testing as described by Porcella (1983). EPA (1985c) now recommends *D. pulex* over *D. magna* because the former

Exhibit 12-6
COMPONENTS OF ARTIFICIAL SOIL

General Composition by Weight

1. 70% Industrial Sand
2. 20% Kaolinite Clay
3. 10% Sphagnum Peat

Specific Composition

1. Industrial Sand

Diameter in Microns	Percent
45	1.7
45	9.3
63	29.0
90	34.3
125	20.8
180	4.0
250 & greater	0.8

2 Kaolinite Clay

Composition	Percent
SiO_2	58.5
TiO_2	1.3
AL_2O_3	28.0
Fe_2O_3	1.0
MgO	0.3
CaO	0.2
K_2O	2.0
Na_2O	0.3
loss on ignition	8.4

Source: Porcella, 1983.

Exhibit 12-7

PROCEDURE FOR HOMOGENIZING SOIL SAMPLES

1. Air dry the soil to be tested. (Air drying is considered completed when an aliquot of soil has no more weight loss.)

2. Add 25 burundum cylinders and about 2 liters of air-dried soil to a ball mill.

3. Mill about 5 minutes (until soil is coffeeground size). Then sieve through a 2mm-mesh sieve. .

4. Return larger particles to the ball mill, and repeat steps 2 through 4 until the sample is completely ground with the exception of rocks. Discard rocks.

5. Before use, thoroughly homogenize soil using a laboratory or small cement mixer.

6. Clean the ball mill by adding 1 quart of silica sand and 10 burundum cylinders. Mill for 15 minutes, discard, and then brush out mill.

Sources Lighthart, 1980; unpublished procedures as reported by Porcella, 1983.

species is "more widely distributed in the United States, test results are less sensitive to feeding during tests, and it is not as easily trapped on the surface film." D. *pulex* is, therefore, preferred in these studies, if available. .

EPA's test uses early instars of *Daphnia* in a static type of assay (i.e., the same body of water is used throughout the test as compared to a flow-through test in which the water is replaced). The exposure time is 48 hours, and because death is not always easily determined in *Daphnia,* be test results are given as effective concentration (48-hour EC_{50}). A summary of test conditions for the *Daphnia* acute test is presented in Exhibit 12-8.

It should be noted that static bioassay has a limited application for compounds that become volatile or undergo rapid chemical change in water.

Dilution water can be water from the site (upstream of possible contamination), local dechlorinated tap water, or reconstituted water, as long as it can support healthy organisms for the duration oft he test procedure without having the organism show any sign of stress. The water chosen for dilution water is tested to ascertain that none of the following substances exceeds the maximum allowable concentration as shown:

Pollutants	Maximum Concentration
Suspended solids	20 mg/l
Total organic carbon	10 mg/l
Unionized ammonia	20 µg/l
Residual chlorine	3 µg/l
Total organophosphorus pesticides	50 µg/l
Total organochlorine pesticides plus PCBs	50 µg/l

Other water quality considerations are pH, hardness, temperature, alkalinity, and conductivity.

The test animal, *Daphnia,* was chosen because of its wide geographic distribution, importance in the food web, temperature requirements, wide pH tolerance, ready availability, and ease of culture. *Daphnia* is obtained from laboratory cultures in its early instar stages (less than 24-hour neonites), and each test is conducted using organisms that are from the same source and that are as healthy and uniform in size and age as possible. Care is taken to maintain the cultures in as ideal a situation as possible. Avoidance of stress and disturbances is important.

Unless the approximate toxicity of the sample material is already known, a minimum of six concentrations of test material should be prepared, with the maximum concentration being the maximum applicable dose (MAD) for that sample type (see Exhibit 12-2) Test organisms are placed in test vessels no later than 30 minutes after test solutions are prepared.

12.6.4.3.3 Fish

Fish, especially those species consumed by humans, are common test organisms in acute and bioconcentration tests. Because of the relative difficulty in maintaining saltwater aquariums, most testing is done on freshwater species.

Exhibit 12-8
RECOMMENDED TEST CONDITIONS FOR DAPHNIDS
(*DAPHNIA PULEX*[a] AND *D. MAGNA*)

1. Temperature (°C)	20 ± 2°C
2. Light quality	Ambient laboratory illumination
3. Light intensity	50 to 100 footcandles (ft c)[b] (ambient laboratory levels)
4. Photoperiod	8 to 16 hours light/24 hours
5. Size of test vessel	100 ml beaker
6. Volume of test solution	50 ml
7. Age of test animals	1 to 24 hours (neonates)
8. No. of test animals per test vessel	10
9. No of replicate test vessels per concentration	2
10. Total no. organisms per concentration	20
11. Feeding regime	Feeding not required first 48 hours. For longer tests, feed every other day beginning on the third day (Appendix A).
12. Aeration	None, unless DO concentration falls below 40% of saturation, at which time start gentle, single-bubble aeration.
13. Dilution Water	Receiving water or other surface water, groundwater, or synthetic water: hard water for *Daphnia magna;* moderately hard or soft water for *D. pulex.*
14. Test duration	Screening test--24 hours (static tests) Definitive test--48 hours (static tests)
15. Effect measured	Mortality--no movement of body or appendages on gentle prodding (LC_{50})

---

[a] Use of D. pulex is preferred.

[b] ft c = foot candles

A 96-hour static toxicity test using the freshwater fish species fathead minnow, *Pimephales promelas,* is part of EPA's bioassessment protocol (Porcella, 1983). The fallowing is a brief discussion of that test protocol. Details on test protocols using other species and flow-through systems are contained in Appendix 12B, which is the ASTM Standard Practice for conducting Acute Toxicity Tests with Fishes, Macroinvertebrates, and Amphibians (ASTM Designation: E 729-80).

As with *Daphnia,* the fathead minnow was chosen because of its commonness, range of pH tolerance, temperature requirements, importance in the food web, and ready availability. Fish can be obtained from state, federal, or local hatcheries or from wild populations in relatively unpolluted areas. Fish collected by electroshocking should not be used. The fathead minnows used in testing should weigh between 0.5 and 1.0 gram each, and the standard length (tip of snout to end of caudal peduncle) of the longest fish should be no more than twice that of the shortest fish. Weights and lengths are recorded before and after the test.

The same water-quality considerations discussed for *Daphnia* testing are true for fathead minnow testing. Test procedures are contained in Exhibit 12-9. The test results in the case of minnows is the concentration causing 50 percent lethality (LC_{50}) and is determined using any of the methods mentioned above for determining *Daphnia* test results. The 96-hour LC_{50} are evaluated according to Exhibit 12-2.

12.6.4.3.4 Aquatic Invertebrates

Laboratory tests and analyses using aquatic inverebrates include the classic acute toxicity tests and bioconcentration analyses. The most common acute toxicity test is a static toxicity test using *Daphnia,* a small freshwater crustaceans. Bioconcentration analyses are usually conducted on invertebrates consumed by humans, such as mollusks (e.g., mussels and oysters) and crustaceans (e.g., crabs and crayfish). The U.S. Mussel Watch program is an example of bioconcentration analyses using invertebrates to determine the degree of contamination occurring along the U.S. coasts (Goldberg et al., 1978).

12.6.4.3.5 Bacteria

Bacteria can be used to assay a variety of potential impacts on biotic systems resulting from exposure to a contaminant or chemical compound. The fallowing two types of bacteria assays can be used in study plans for hazardous waste sites.

Soil Respiration and Soil Litter Test

Soil micro-organism are important recyclers of ecosystem nutrients. Their stress levels can be relatively easy to determine by measuring the carbon dioxide ($C0_2$) evolved from their respiration process. The results of this test show the percentage of Inhibition (EC_{50}) or stimulation (SC_{20}) between CO_2 evolved in control and tested microcosms at specified time intervals.

This test used 1-quart (approximately 1 liter) wide-mouth jars with airtight lids and 1-ounce *(30* ml) glass bottles with airtight lids. One hundred grams of air-dried artificial soil (Exhibit 12-6) In combination with test soil or soil extract (prepared as instructed in Exhibits 12-3 and 12-7) at specified concentrations are added to the cleaned wide-mouth jars. Deionized water Is used to adjust the moisture content. A 1-ounce bottle containing $C0_2$ trapping solution is then added, and the whale test container is tightly sealed and placed in a dark, temperature controlled area (20 ± 2°C) for 14 days. Three special blank jars are used to correct for atmospheric $C0_2$ by placing a CO_2 trap in a clean, empty wide-mouth jar and running that jar at the same time as the testjars.

The $C0_2$ is typically measured twice weekly using the procedure for titrating $C0_2$ (Exhibit 12-10). Results are based on the total of ail $C0_2$ measurements taken during the 14-day test. End results are either

Exhibit 12-9
SUMMARY OF TEST CONDITIONS
(from Brusick and Young, 1982)

	Fathead Minnow, *Pimephales promelas*
Temperature °C	22 ± 1
Photoperiod, hours light:dark	16:8
Water quality, hardness* mg/l as $CaCO_3$	100
Container size	20 liters
Test volume	15 liters
Organism per container	10
Replicates	2
Feed	No
Duration, hours	96
Measurements of DO and pH, hours	0, 24, 48, 72, 96

---

*For dilution water only; the investigators add salts as appropriate to obtain 100 µg/l as $CaCO_3$.

Source: Brusick and Young, 1982, as reported by Porcella, 1983.

an EC_{50} (the lowest test concentration causing growth inhibition of 50 percent relative to control) or SC_{20} (the Lowest concentration causing growth stimulation of 20 percent relative to the control).

Microtox System

The Microtox system (from Beckman instruments, Inc., Microbics Operations, Carlsbad, California 92008) measures the mean toxic response of approximately one million bioluminescent organisms to the introduced test medium. The system uses a Microtox analyzer to measure the light output of standardized marine bioluminescent bacteria that are grown and harvested by Beckman Instruments, Inc. The bacteria, called Microtox reagent, are lyophilized (freeze-dried under vacuum) and dehydrated by the user with a Microtox reconstitution solution.

Because of the standardization of all the variables described above, this test can yield results that can be compared from site to site. However, this method should be considered as a rapid screening tool that will lead to other bioassay tests. If the temperature is held constant at the "normal test temperature" of 15°C (analyzer range $10^0 2$ to 25^0C), the primary variable in this system is time. Data results are the determination of the EC_{50} or the effective concentration causing a 50 percent decrease in the Microtox reagent light output under specified time *(t)* and temperature *(T)*. To compare information, the user must know time and temperature data.

The length of time it takes for the reagent to react varies greatly with the test medium. However, the normal reaction will occur after between 5 to 15 minutes have elapsed. Readings at 5 and 15 minutes are recommended, with additional readings if it appears that more time is needed. For example, phenols are a class of toxicants that cause immediate light loss fallowed by either a slight recovery or a stable light output, whereas bivalent metals exhibit slow inhibition reactions and may require longer test times.

The reader should obtain the Microtox manual from Beckman Instruments, Inc., for detailed test procedures.

Because this test is conducted with a single species, the results are primarily indications of relative toxicities of sites and are not indications of the actual toxicity of the hazardous material.

12.7 REGION-SPECIFIC VARIANCES

Regional variances exist. Climatic differences will influence different responses with standardized test organisms. Regional differences also exist in native plants and animals that are on hazardous waste sites. The reader is urged to contact the appropriate EPA RPM for referral to the knowledgeable technical specialists. Regional variances will be updated in Revision 01 to this compendium.

Exhibit 12-10

PROCEDURES OF TITRATING CO_2 IN TRAPS AND METHODS FOR PREPARING REAGENTS

A. CO_2 TITRATION PROCEDURE

1. Replace the CO_2 traps at the designated intervals by opening the microcosm, removing the exposed CO_2 trap, and replacing it with an unexposed one. (At the same time this step is being performed, insert an open vacuum line to aid in properly replenishing the air in the microcosm. Remove at least 3 times the volume of the air space.)

2. As quickly as is practical, place an airtight cap on the exposed CO_2 trap; return the microcosms to the dark 20°C incubator.

3. Add 5 ml of 1.3N of $BaCl_2$ and a stir bar to each exposed CO_2 trap immediately before titration.

4. Titrate excess 0.6N NaOH remaining in the trap to pH 9.0 with a buret and pH meter (or autotitrator) using Trizma standardized 0.6N HCl to measure milligrams of CO_2 produced.

Formula for the Calculation of CO_2 Production

mg of CO_2 = (Blank ml - Sample ml) x 22 mg of CO_2/ml/N x Normality of Acid
e.g., mg of CO_2 = (10.40 ml - 6.93 ml) x 22 mg of CO_2/ml/n x 0.6013 N
= 45.90 mg of CO_2 produced

B. PREPARATION OF REAGENTS

1. 0.6N NaOH
   - a. Rinse 20-liter glass carboy with distilled H_2O.
   - b. Place on a large magnetic stir plate; add degassed distilled H_2O to the 18.9 liter mark.
   - c. Add 454 grams (1 lb) of NaOH pellets.
   - d. Stopper and stir overnight before use. (Maintain the NaOH stock solution in a CO_2-free atmosphere by using ascarite traps.)

2. 0.6N HCl
   - a. Rinse 20-liter glass carboy with distilled H_2O.
   - b. Add 1.0 liter of concentrated HCl.
   - c. Add distilled H_2O until the 20-liter mark.
   - d. Stopper and stir overnight.

Exhibit 12-10
(continued)

e. Titrate 5 "Tris" samples (0.5 to 0.9 grams of "tris" in 10.0 ml of distilled H_2O and 5 ml of 1.2 $BaCl_2$) to pH 5.0 with about 0.7 HCl; calculate mean and standard deviation ("s"). (If "s" is larger than 0.0015, do 5 more samples and combine results.)

$$\text{Normality of HCl} = \frac{(0.1211\ \text{g/meq})\ (\text{ml of HCl used})}{(\text{Weight of Tris in grams})} \qquad \frac{(0.1211\ \text{g/meg})\ (9.69\ \text{ml})}{0.7089\ \text{grams}}$$

e.g., Normality of HCl = 0.6041N

3. 1.3N $BaCl_2$
   a. Weigh 317.56 grams $BaCl_2{:}2H_2O$
   b. Dissolve in degassed distilled H_2O in a 1-liter volumetric flask.

4. Tris

   Aminomethane (hydroxymethyl) tris--Trizma Base (Sigma Chemical Company, St. Louis, Missouri).

Source: Lighthart, 1980; unpublished procedure as reported by Porcella, 1983.

12.8 INFORMATION SOURCES

American Fisheries Society. *A List of Common and Scientific Names of Fishes from the United States and Canada.* 4th ed. Special Publication No. 12. 1980.

American Public Health Association. *Standard Methods for the Examination of Water and Wastewater.* 16th ed. APHA-AWWA-WPCF. Washington, D.C. 1984.

American Society for Testing and Materials. *ASTM Designation* E 729-80. Pp. 285-309.

Brown and Zan. *Field and Laboratory Methods for General Ecology.* 1977.

Cox, George W. *Laboratory Manual of General Ecology.* Dubuque, Iowa: William C. Brown Company. 1967.

FAO. *Manual of Methods in Aquatic Environment Research.* Part 1—Methods for Detection, Measurement, and Monitoring of Water Pollution. Technical Paper No. 137. FIRI/T137. Rome, Italy. 1975.

Freed, J.R., P.R. Abell, D.A. Dixon, and R.E. Huddleston, Jr. *Sampling Protocol For Analysis of Toxic Pollutants in Ambient Water, Bed Sediments, and Fish.* Interim Final Report. Prepared by Versar, Inc., Springfield, Virginia, for EPA Office of Water Planning and Standards, Washington, D.C. 1980.

Goldberg, E.D., V.T. Bowen, J.W. Farrington, G. Harvey, J.H. Martin, P.L. Parker, R.W. Risebrough, W. Robertson, E. Schneider, and E. Gamble. "The Mussel Watch." *Environmental Conservation,* Vol. 5, No. 2, pp. 101-126. 1978.

Mosby, Henry S. *Manual of Game Investigational Techniques.* U.S. Wildlife Society. 1960.

Nielsen, Larry A., and David L. Johnson, eds. *Fisheries Techniques.* Bethesda, Maryland: American Fisheries Society. 1983.

Phillips, E.A. *Methods of Vegetation Study.* New York, New York: Holt, Rinehart and Winston. 1959.

Platts, William S., Walter F. Megahan, and G. Wayne Minshall. *Methods for Evaluating Stream, Riparian, and Biotic Conditions.* Draft. U.S. Department of Agriculture Forest Service General Technical Report. INT--138. Ogden, Utah. May 1983.

Porcella, D. B. *Protocol for Bioassessment of Hazardous Waste Sites.* Prepared by Tetratech, Inc., for U.S. EPA. Corvallis, Oregon. TC 3547-1. 1983.

Reeves, Robert G., Abraham Anson, and David Landen. *Manual of Remote Sensing.* Falls Church, Virginia: American Society of Photogrammetry. 1975.

Schemnitz, S.D., ed. *Wildlife Management Techniques Manual.* 4th ed. Washington, D.C.: The Wildlife Society, 1980.

Sherma, Joseph. *Manual of Analytical Quality Control for Pesticides in Human and Environmental Media.* U.S. EPA-600/1-76-017. 1976.

U.S. Environmental Protection Agency, 1973. *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents*. EPA 670/4-73-001. 1973.

U.S. Environmental Protection Agency, 1980a. *Ambient Water Quality Criteria Documents.* Washington, D.C. 1980.

U.S. Environmental Protection Agency, 1980b. *Manual of Analytical Methods for the Analysis of Pesticides in Human and Environmental Samples.* EPA 600/8-800-038. 1980.

U.S. Environmental Protection Agency, 1980c. *Extraction and Analysis of Priority Pollutants in Biological Tissue*. Method PPB.10/80, EPA, S&A Division Region IV. Athens, Georgia: Laboratory Services Branch. 1980.

U.S. Environmental Protection Agency, 1980d. *Interim Methods for the Sampling and Analysis of Priority Pollutants in Sediments and Fish Tissue.* Cincinnati, Ohio: ESML. October 1980.

U.S. Environmental Protection Agency, 1982. *Test Methods for Evaluating Solid Waste.* Physically Chemical Methods, SW-846. 1982.

U.S. Environmental Protection Agency, 1983a. *Methods for Chemical Analysis of Water and Wastes.* EPA 600/4-79-020. 1983.

U.S. Environmental Protection Agency, 1983b. *Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analysis*. OWRS. November 1983.

U.S. Environmental Protection Agency, 1985a. *Water Quality Criteria; Availability of Documents. Federal Register.* Vol. 50, No. 145. 29 July 1985.

U.S. Environmental Protection Agency, 1985b. *Draft Superfund Public Health Evaluation Manual.* OSWER Directive 9285.4-1. Prepared by ICF, Incorporated, Washington, D.C. 18 December 1985.

U.S. Environmental Protection Agency, 1985c. *Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms.* 3rd ed. EPA 600/4-85/013, ORD. Cincinnati, Ohio. March 1985.

U.S. Environmental Protection Agency, 1985d. *Short-Term Methods for Estimating the Chronic Toxicity of Effluent and Receiving Water for Freshwater Organisms*. EPA 600/4-85/014, ORD. Cincinnati, Ohio. December 1985.

Verschueren, Karel. *Handbook of Environmental Data on Organic Chemicals.* 2nd ed. 1983.

Watts, Randell R. ed. *Analysis of Pesticide Residues in Human and Environmental Samples*. U.S. EPA-600/8-80-038. 1980.

APPENDIX 12A

COLLECTION AND PROCESSING TECHNIQUES

A. VEGETATION COLLECTION TECHNIQUES

Two general types of Information can be used to determine the level of impact of any pollutant on vegetation. First, the general health and stress level of plants on the site should be assessed. This can be done with superficial visual observations, through remote sensing using color infrared photography, and by tissue analysis. Second, the composition of the plant community can be measured through an ecological survey to determine if the stress has been great enough to change the relative abundance of the vegetation.

Assessing the stress level of the plants growing on a site is appropriate for determining subtle environmental effects. By the time an impact is severe enough to change the species composition of a site, it may be pointless to review existing vegetation for stress effects.

important factors to consider in analyzing the effects of pollutants on the terrestrial ecosystem include how the pollutant entered the ecosystem (for example, by a spill on the soil surface, or through contamination of an underground water table); the time of entry of the pollutant in relation to the season of the year and the life-cycle of principal life forms; the physical and chemical nature of the soil, especially infiltration rates, internal drainage, buffering capacity, and soil pH; the nature of the vegetation, especially plant rooting depths, litter quantity, and rate of organic matter turnover; specific types of potential human and animal food produced by the vegetation, such as crops, deer browse, edible nuts; and animal use of the area, including identification of resident and migratory species.

Al. Visual Field Observations

During site surveys, an ecologist should observe the vegetation throughout the vicinity and in downgradient (downwind, downstream, and downhill) areas. it may be desirable to make such observations at different times of the year, especially during the spring growth of the major species, during a period of high heat-and-water stress in the summer, and just before leaf fall in the autumn. These are times when symptoms of stress may be particularly obvious, especially if there is a chance that the pollutant has impaired the function of the root system.

Team personnel should determine the types of vegetation expected to be found and the successional stages common to the area. it is imperative that the length of time since site disturbance or site abandonment be known to interpret properly these visual assessments. Signs of stress that need to be assessed in both the affected and unaffected areas include size of annual or biennial plants, leaf size of perennial plants, leaf and stem necrosis, chlorosis, evidence of changes in levels of disease or insect damage that may be linked to stressed plants, increases in size of seed crops of perennial plants (often association with stress), premature leaf fall, abnormal wilting of succulent plant parts, and abnormal plant coloration.

A2. Remote Sensing

When the site vicinity is large or the possible offsite pollutant pathways are extensive or unknown, aerial photography using color infrared (CIR) film can be used to identify and delineate the extent of vegetational stress. Field checks are necessary to substantiate conclusions made by the examination of CIR photographs. The success of this method depends on the experience and interpretive abilities of the investigator and on the amount of information available about the expected effects of the pollutants on vegetation.

Remote sensing may be applicable only at certain times of the year and is probably most effective during the warmer, drier periods of the growing season. Additional information can be found in the following:

- Reeves, Robert G., Abraham Anson, and David Landen. *Manual of Remote Sensing.* Fails Church, Virginia: American Society of Photogrammetry. 1975.
- Schemnitz, Sanford D., ad. Wildlife *Management Techniques Manual.* Washington, D. C.: The Wildlife Society. 1980.

A3. Ecological Assessments

There are a number of ecological survey techniques available for obtaining quantitative, defensible information about the structure, composition, biomass, and productivity of plant communities. Ecological surveys conducted simultaneously in a (possibly) affected area and a reference area can demonstrate vegetational stress if exposure to site contaminants is the only difference between these two sites. The most common survey techniques include plot sampling, plotless sampling, and line-intercept sampling.

Plot sampling is frequently used to quantify species composition within an area. For this purpose, plots are laid out in the study area on either a random or systematic sampling basis. Plot sizes vary with the size of the vegetation being sampled. (If the composition ofa stand of large plants, such as trees or tall shrubs, is being quantified, the plots may be, for instance, 10 m x 10 m; however, if the composition of a stand of annuals is being measured, plot size may be only 1 m x 1 m.) The size and number of plots sampled is also a function of the uniformity of the plant community. In plant communities with multiple layers – for example, in a temperate forest with an over-story canopy, a shrub layer, and a herbaceous layer– three different plot sizes may be used, each of the smaller plots being a subsample of the next largest plot.

Once the plots are laid out, the scientist estimates the percentage of the plot covered by a projection of the leaves of each species onto the ground. By taking several of these plots within a study area, an average percent-cover is calculated for each plant species.

in a variation of this plot-sampling technique, the scientist harvests all plants growing within a plot, sorts them by species, and weighs them. This technique gives a more precise measure of species composition, but it is more costly. Data gathered from harvested plots can be compared to data gathered from “percent-covet" plots only with a great deal of care.

Plotlesa sampling is an alternative to the establishment of plots when the plants to be sampled are widely spaced, as in arid or otherwise semi-barren areas. There are several plotless sampling procedures. One common procedure involves the selection of random points in a plant community. At each point, four quadrants of 90 degrees each are established. in each quadrant, the distance from the point to the nearest plant is measured. The nearest plants can be measured for whatever parameters are of interest, including the projected area of the leaves of the plant upon the ground. The point-to-plant distance squared is, on the average, the mean area occupied by one plant. The percentage of coverage by species can be calculated from this data. Again, the number of sample points required depends on the accuracy required in the study and the uniformity and distribution of plants within the community.

The line-intercept sampling method is particularly useful in quantifying low-growing vegetation. In this technique, a randomly oriented line is laid out on the ground. The scientist then moves along the line, measuring and recording the length of the line under the projected leaf area of each plant. The length of line covered by each species is divided by the total length of the line to determine a percent-cover for each species. By laying out a number of short lines, or by arbitrarily dividing a long line into segments, species frequency can be determined.

Each of the sampling techniques presented here can be used to gather a variety of information. The examples above primarily illustrate the mechanics of each technique.

Quantitative ecological vegetation assessments are rarely done in hazardous waste site studies because they are labor intensive and because little additional information is gained for use in a human health risk assessment beyond that information available from the visual site investigation. For these reasons, vegetation sampling techniques should be selected on a site-specific basis. Several references are available for use in designing quantitative vegetation study plans, including the following:

Cox, G.W. The *Laboratory Manual of General Ecology.* Dubuque, Iowa: Wm. C. Brown Co. 1967.

Phillips, E.A. *Methods of Vegetation Study.* New York: Holt, Rinehart and Winston. 1959.

Brown and Zan. *Field and Laboratory Methods for General Ecology.* 1977.

A4. Tissue Analyses

Plant tissues can become contaminated by metals, organics, and various other elements of environmental concern. The type of plant and/ or plant tissue collected for analysis will depend on site conditions. Approximately 30 grams (wet) of plant tissue are normally needed for analysis, but the number and type of analyses required will determine how much material must be collected. The laboratory performing the analysis will inform the collector of the amount of material needed and any special handling methods required. Grasses and forbs should be clipped just above ground level using scissors or plant shears. No soil should be included in the material collected. Samples should be placed in clean 1-gallon paper bags as described in Subsection El of this appendix.

Leaves collected for analysis should be clipped at the petiole and allowed to drop directly into the collecting bag. All flowers, leaves, and other plant growth should be removed from plant stems collected. Stems are then cut into 3- to 4-inch lengths and allowed to drop directly into the collecting bag.

All leaf, flower, or cover tissue is removed, if possible, from fruits, nuts, or seeds. If this is not possible in the field, the sample label should indicate what part of the sample is to be analyzed.

Roots, tubers, or other underground plant growth are handled differently than above-ground plant tissue. Underground structures are collected by digging with a trowel or other tool, rather than by pulling the plant out of the ground. The entire root system is carefully collected, and attached soil is gently removed by shaking or striking. (Some soil will remain, but the laboratory will clean the material prior to analysis.) The root should be cut away from the stem at ground level, and each root placed in a separate bag and labeled as described in Subsection El of this appendix.

B. TERRESTRIAL VERTEBRATE FIELD COLLECTION TECHNIQUES

Assessments of effects on terrestrial vertebrates can be accomplished through tissue analysis and through ecological survey techniques. Collection techniques for tissue analyses of terrestrial vertebrates normally involve small to medium-sized animals. The most common techniques are live trapping, lethal trapping, and hunting with a gun. Other assessments used on terrestrial vertebrates include mark and recapture studies and scatological studies. The US. Fish and Wildlife's Habitat Evacuation Procedure (HEP) incorporates vegetation and wildlife survey techniques to estimate natural resource losses expected over time as a result of a specific project. The reader should also refer to Subsection B4 – Habitat Evaluation Procedure of this appendix.

The collection of terrestrial vertebrates at any site can serve a multitude of functions, including identification of species present, estimation of total numbers of each species, and securing of tissue for chemical analysis. Because of the time and expense involved, the collection procedures are usually used only when tissue residue studies are needed.

B1. Live Trapping

Live traps completely. enclose the captured animal. This system normally does not kill the captive; however, some animals may become hurt in their attempts to gain freedom or may die from exposure if the traps are not properly insulated. Death because of exposure occurs most frequently during cold or rainy weather. Live traps should be checked frequently.

Live traps can be used in ecological surveys or, more typically, for capturing specimens for tissue analysis. Live traps allow the collector to be Selective because unwanted species can be released unharmed.

The most commonly used live traps are small, medium, or large Havahart traps or Peterson live traps (Exhibit 12A-1). Havahart traps are used for squirrel-sized or larger mammals, while Peterson traps (with dimensions of 3 x 3 x 9 inches) are used for small, rodent-sized animal. Traps can be baited with a variety of food such as smoked fish, oatmealand peanut butter, birdseed and peanut butter, or other appropriate attractants.

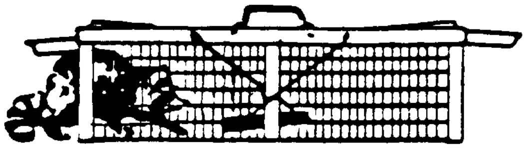
Before it is used for the first time, a trap is specially cleaned with a trap dye to remove the scent accrued during manufacture; it is then treated with sealing wax to reduce rusting. Gloves are used to handle the trap so that human scent is not associated with it.

Trap placement is determined by the species to be captured. Carnivores, omnivores, or herbivores with relatively small home ranges (less than 20 acres) are considered to be the most likely terrestrial vertebrates to have come in contact with site contaminants. Mammals such as opossums, rabbits, woodchucks, mice, moles, shrews, muskrats, and raccoons are the most commonly collected mammals.

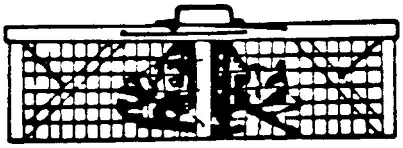
The site vicinity is examined by biologists to identify likely habitats and animal trails. Live traps are baited, wired open, and placed in likely areas for 2 to 3 days to acquaint animals with the foreign object. Following the acquaintance period, the trap is baited and set to close when tripped.

The number of animals needed for tissue analysis depends on the species available, the target tissue (e.g., muscle, liver, brain), the number and types of analyses to be done, and the detection limit required for study objectives. The primary laboratory protocol used (see EPA, 1980c in Subsection 12.8) requires a minimum of 10 grams for base/ neutrals and acids, 10 grams for pesticides and PCBs, 5 grams for volatiles,

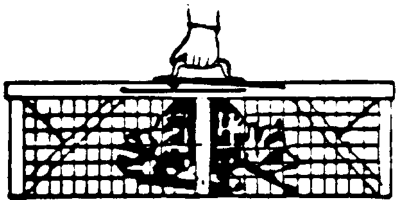
Exhibit 12A-1
LIVE ANIMAL TRAPS



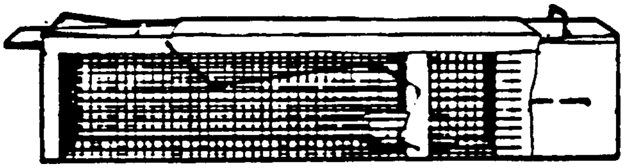
1 **ANIMAL ENTERS.** Lured by bait on bait pan or fooled by trap set on runway, animal enters trap. Animal can see through open ends of trap and enters unsuspectingly.



2 **DOORS SLAM AND LOCK.** Animal trips bait pan and doors slam shut. Door design restricts animal movement to help prevent injury.



3 **READY TO GO.** Pets and non-target wildlife can be released immediately. Pests can be transported in trap for relocation and release. Trap doubles as a handy animal carrier.



For Foxes, Raccoons, Bobcats, Otters
Special single-door trap with compartment for live chicken, rabbit or other bait. Size 55" x 12" x 12".

and 10 grams for metals. Approximately 100 grams of the target tissue is usually required. Trapping an adequate number of a single species may sometimes be difficult within the schedule of the sampling program.

Field notebooks (bound, with numbered pages) are kept to record all field data, including sampling locations, date, weather conditions, species caught, weight, length, sex, and any unusual biotic condition observed. Photographs including a scale object, are made of all specimens retained for sacrifice.

Animals to be used in tissue analyses can be killed with a shot to the head, by suffocation, or by breaking the neck. The animal is dissected according to the procedure described by Henry S. Mosby in *Manual of* Game *Investigational Techniques* (U.S. Wildlife Society, 1960). Another important reference in wildlife collection is the 1980 Wildlife *Management Techniques Manual* (The Wildlife Society, S.D. Schemnitz, cd.). (See Subsection 12.8 for information source.) Additional details on tissues sampled and sample preservation are provided in Subsection E2 of this appendix.

The “mark-and-recapture” system of live trapping is useful for estimating population sizes. in this system, a number of animals of a particular species are trapped alive, marked in some way, and returned to the ecosystem. After allowing a brief interval for the marked animals to meld into the population, a large number of traps are set and animals are captured. The population of animals in the ecosystem can be calculated based on the number of animals marked, the number of marked animals recaptured, and the total number of animals captured in the second trapping. Information on the size of animal populatiions might reveal whether or not the environment has been seriously disturbed by some factor, such as a pollutant, but this technique is not likely to be useful when the polluted area is very small.

B2. Lethal Traps

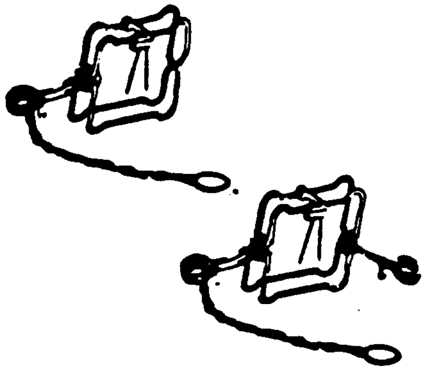
Lethal traps physically grab and retain animals once the trap is tripped. This type of trap is used to collect such animals as muskrats, raccoons, minks, or skunks (which are more easily handled by this method) for tissue analysis. Common traps used include the Victor No. 1 coil spring leg trap, the Conibear No. 1 body trap, and the museum special, Victor rat traps (Exhibit 12A-2). Traps are baited and/or set along identified animal trails, preferably at night. As with live traps, lethal traps are specially cleaned and prepared to reduce human scents and improve the catch.

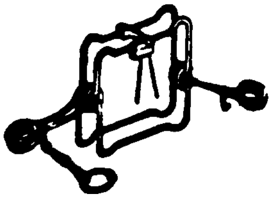
The ambient temperature helps to determine how often a trap should be checked, because heat and low humidity can decay or dessicate samples. The following frequency is recommended:

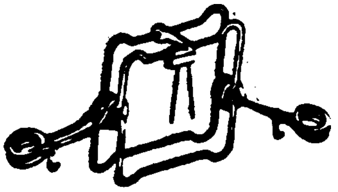
- Below 50°F at night, traps can be left out overnight. .
- Below 50°F during day, traps should be checked every 4 hours.
- Between 50°F and 80°F at night, traps should be checked every 4 hours.
- Between 50°F and 80°F during day, traps should be checked every 2 hours, especially on sunny days.
- Above 80°F at night, traps should be checked every 2 hours,
- Traps should not be set during daylight hours if the temperature is above 80°F unless traps are continuously checked.

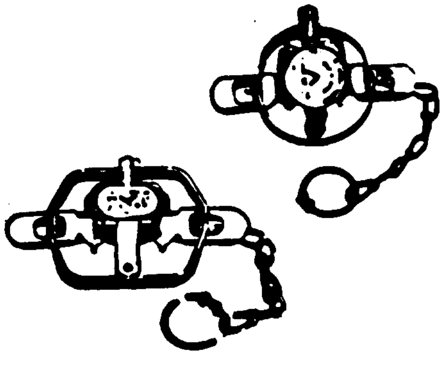
Exhibit 12A-2

LETHAL ANIMAL TRAPS









Captured organisms are killed and processed in the same manner as described in the live trap subsection above.

B3. Hunting

Species not easily captured by trapping methods are occasionally obtained by standard hunting methods using a .22-caliber gun. Large aquatic turtles are an example of such a species. Once the organism is killed, it is processed in the same manner as described in the live trap subsection above. Hunting is used to collect organisms for tissue analysis.

B4. Additional Ecological Assessments

Ecological assessments of hazardous waste sites to date have been very limited. Terrestrial, aquatic, and marine ecological studies may be called for in the future. The fallowing references will provide guidance:

Brown and Zan. *Field and Laboratory Methods for Genenral Ecology.* 1977.

Cox, George, W. *Laboratory Manual of Genenal Ecology.* Dubuque, Iowa.: William C. Brown Co. 1967.

Updates of this compendium will incorporate any ecological techniques applied through the date of preparation. The Habitat Evaluation Procedure (HEP) discussed below is a tool that can be applied to hazardous waste site evaluations.

Habitat Evaluation Procedure (HEP)

The U.S. Fish and Wildlife Services (FWS) HEP is part of the methodology being assessed by the Department of Interior for use in establishing a monetary value for natural resources lost because of hazardous waste sites. This procedure might be used in rural settings where wildlife resources have been lost, but it would have limited use in urban areas.

There are two possible objectives to this type of study. The first is to evaluate the impacts of the site on wildlife, using the HEP methodology. The second is to develop a conceptual mitigation plan describing the possible replacement of wildlife habitat or other mitigation to compensate for the habitat affected by the site. Fallowing is a brief summary of the major tasks involved in conducting the HEP.

Task 1. Literature Review and HEP Evaluation Team Formation

Wildlife biologists meet with personnel from federal and state resource agencies and other appropriate agencies to gather existing published and file data and to identify significant issues or resources related to the site vicinity. Representatives of these entities will form an HEP evacuation team. This team identifies species of interest, clarifies agency concerns, and provides an opportunity for agency input into the design phase of the study. This task also includes a site visit.

Task 2. Study Definition

The results of Task 1 activities are used to determine several elements of the study. The study area is roughly defined, and an initial selection of evacuation species is made. The inclusion of species is determined jointly by representatives of the HEP evaluation team.

Selection of evacuation species is determined by several criteria and may include species of special concern, such as threatened or endangered species, or species of interest to the wildlife resource agencies because of their management significance as game species. Additionally, the list of evacuation species may include representatives of several guilds (that is, species with similar nesting or foraging requirements), to provide an ecologically balanced approach to the study. A maximum of eight evacuation species are usualliy selected. If possible, the study should select only species for which published verified models or habitat suitability index (HSI) curves are available.

An evacuation team meeting is then held to discuss species selection, modify species models as necessary, and clearly establish study goals and objectives.

Task 3. Habitat inventory and Study Site Selection

Aerial photographs taken from before site development to the present are obtained for the study area. These photos, combined with onsite visual verification and any other available data sources (such as timber harvest records, land use maps, or old zoning records) are used to classify the cover types in the area under existing and baseline conditions. Photos are also helpful in determining succession and agricultural or silvicultural practices on lands adjacent to the site.

in evacuating an existing site using the HEP methodology, it is necessary to identify cover types in the study area that can be used to represent uncontaminated baseline conditions. An underlying assumption is that these baseline areas represent conditions at the site before contamination. This assumption is critical because baseline conditions establish the standard against which impacts are measured.

The results of the habitat inventory can be presented in several ways. Each cover type can be described using standard FWS habitat classifications (where appropriate), and can include a description of the dominant species in the tree, shrub, and ground layers as well as estimates of canopy coverage, tree height, and diameter breastheight (d.b.h.), as appropriate. Specific methodologies that can be used are described in *Laboratory Manual of General Ecology.* (See Subsection 12.8 for Cox, G.W. Dubuque, Iowa: Wm. C. Brown Co. 1987.)

A copy of the draft report of the habitat inventory results is to be sent to each HEP evaluation team member along with HEP models for the evacuation species. The evacuation team then meets to select specific sampling locations, develop the sampling design, and make any final modifications to the evaluation species models.

Sampling sites are selected in each of the major plant communities and successional stages, as represented by the cover types described in the habitat inventory Sampling sites are selected by a stratified, random process whereby the number of sampling sites per cover type will be approximate y proportional to the total area and to the amount of variability within each type. Where possible, an equal number of sample sites are selected and evaluated in each of the three major areas of study: baseline, impact, and mitigation sites.

most useful in sampling soft sediments; for clay hardpan and coarse substrates, the heavier grabs such as the orange peel or clam shell type (including the Ponar, Petersen, Shipek, and Smith-McIntyre) are better. Exhibit 12A-3 shows various grab samplers.

Medium-sized boats equipped with winches are normally necessary to deploy and retrieve grab samplers. The substrate collected is funneled into either a box screen or a bucket to await screening. *Standard Methods for the Examination of Water and Wastewater,* 16th ed. (APHA AWWA-WPCF, 1984), contains detailed descriptions of the most popular grab samplers.

Core samplers vary from hand-push types to gravity-operated types. The length of core taken by gravity or by hand will vary with substrate texture and density and the amount of weight or effort expended.

Grabs and corers are operated according to manufacturers' specifications. If the study plan calls for ecological data, invertebrates are collected according to the methodologies described in EPA's *Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents* (Weber, 1973) or in *Standard Methods for the Examination of Water and Wastewater,* 16th ad. (APHA-AWWA-WPCF, 1984). In both tissue analysis and ecological survey studies, samples are collected from both the test or affected area(s) and a reference site. Ecological surveys require replicate sampling, while tissue analysis sampling requires approximately 100 grams of tissue of a single species. As discussed in Subsection B1 of this appendix, the amount of tissue needed can vary.

Sampled organisms are handled and preserved in the field according to the procedures described in Subsection E3 of this appendix.

C2. Sieving Devices

Sieving devices remove aquatic inverebrates from their habitats, either by capturing organisms larger than the sediments in which they live or by capturing organisms, drifting in the water column. In the first case, box-type sieves are used in conjunction with grab-collection methods (Subsection Cl oft his appendix). In the second case, invertebrates are sampled from rubble and gravel riffles in streams using a Surber. type sieving device (Exhibit 12A-4) or from the water column using an invertebrate drift net.

Sieving devices can be used to collect specimens for tissue analysis. These devices are especially useful in collecting sediment-dwelling mollusks, both freshwater and marine species. Sieves can also be used in ecological survey studies when a quantitative sediment sampling method Is employed (Subsection C of this appendix). Surber samplers can be used with relative ease as sampling devices for small streams and are useful for comparative types of ecological studies (i.e., upstream versus downstream). Surber samplers can be used only in flowing water with a depth of less than 12 inches.

Surber samplers are composed of a stainless steel square frame and attached nylon net, typically 0.21-mm mesh. The sampler is placed over the sample site, and ail sediments within the frame are disturbed to loosen attached invertebrates. Larger rocks are lifted, scrubbed, and removed. Remaining sediment is disturbed to a standard depth (usually 2 to 4 inches) by digging and stirring either by hand or using a tool. Net contents are rinsed into the bottom of the net with local water and then carefully removed to the collection container. Stainless steel forceps are often useful in removing small specimens.

Benthos screens used to process grab-type samples are usually about one-half-meter-square, low-sided boxes with bottoms made of 0.25-inch or finer stainless steel or nylon mesh. Sediment samples are placed In the box, and local water is used to wash sediment through the mesh. The washing process is usually performed from the bottom upward so as not to mutilate more delicate organisms of interest. Collected specimens are then removed to collection jars or aluminum foil, depending on the type of study

Exhibit 12A-3

TYPES OF GRAB SAMPLERS

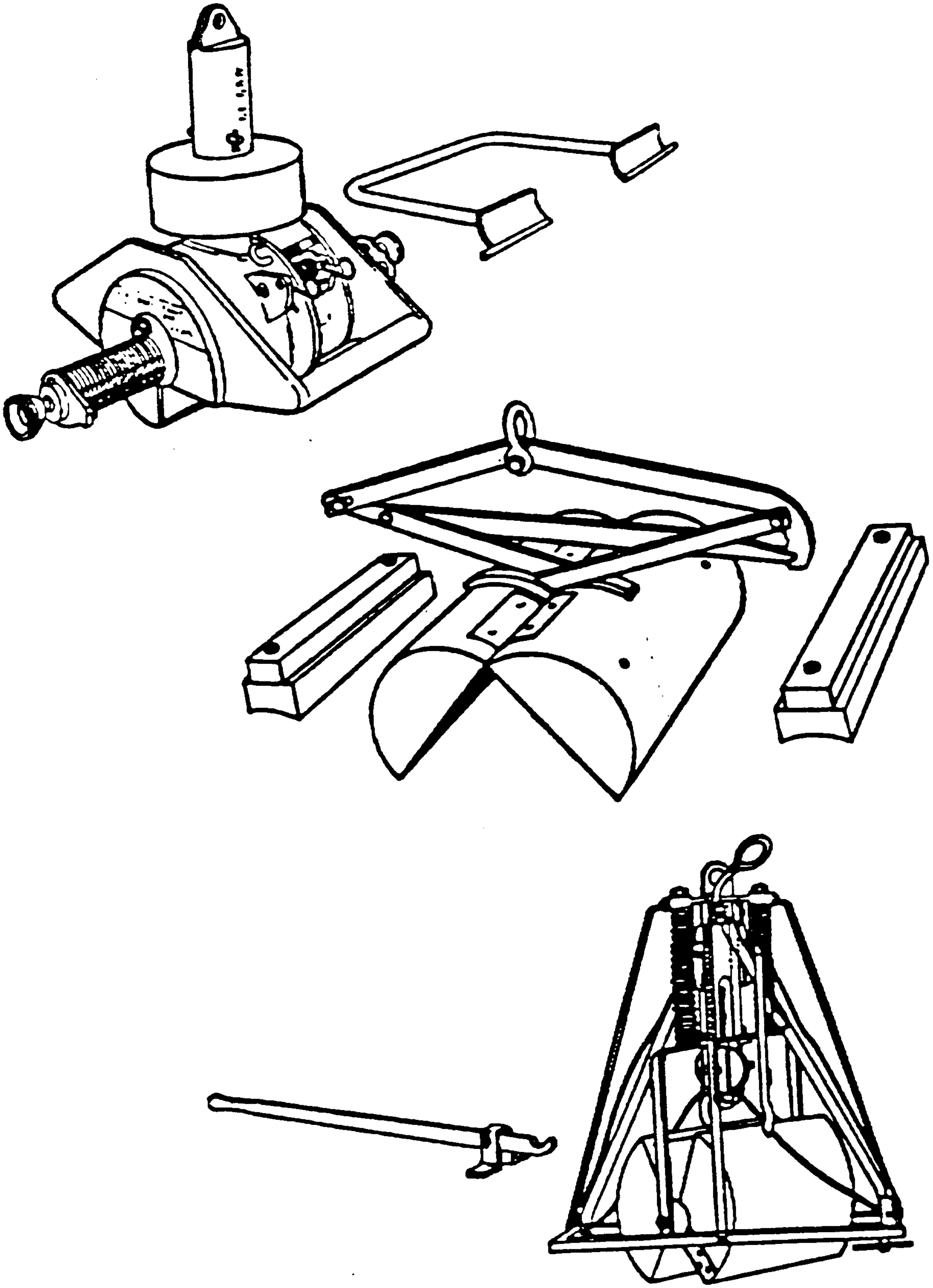
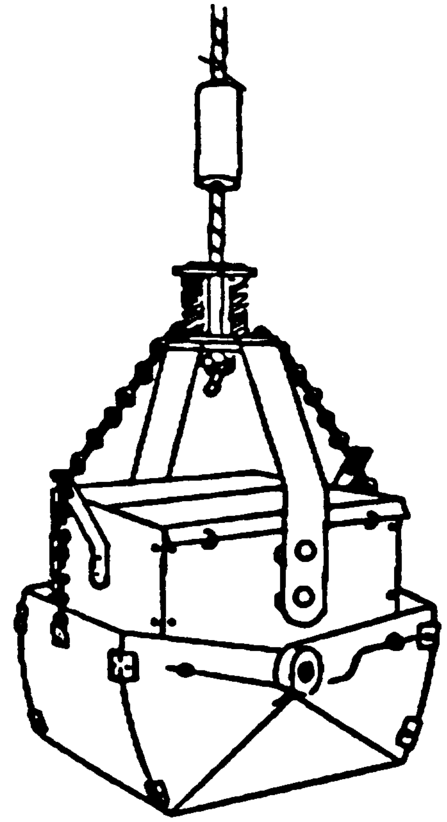
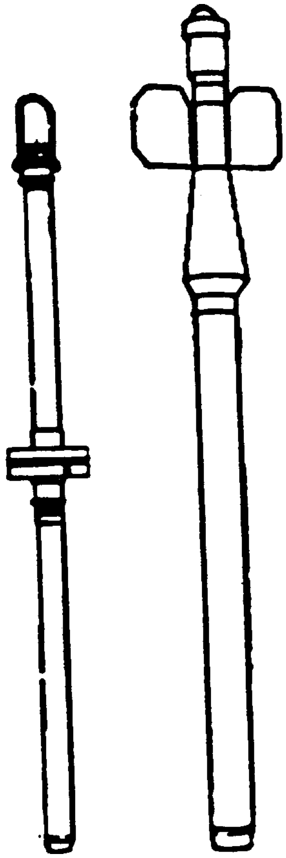
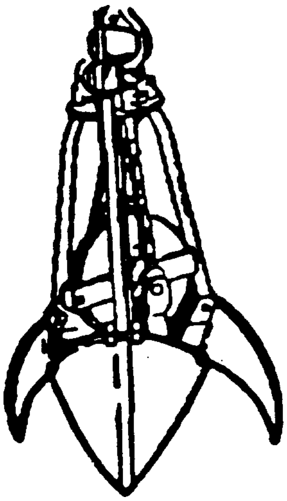


Exhibit 12A-3
(continued)







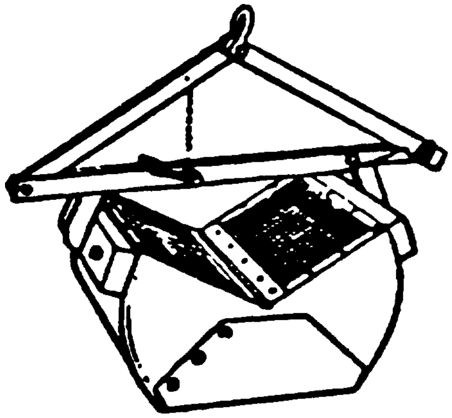
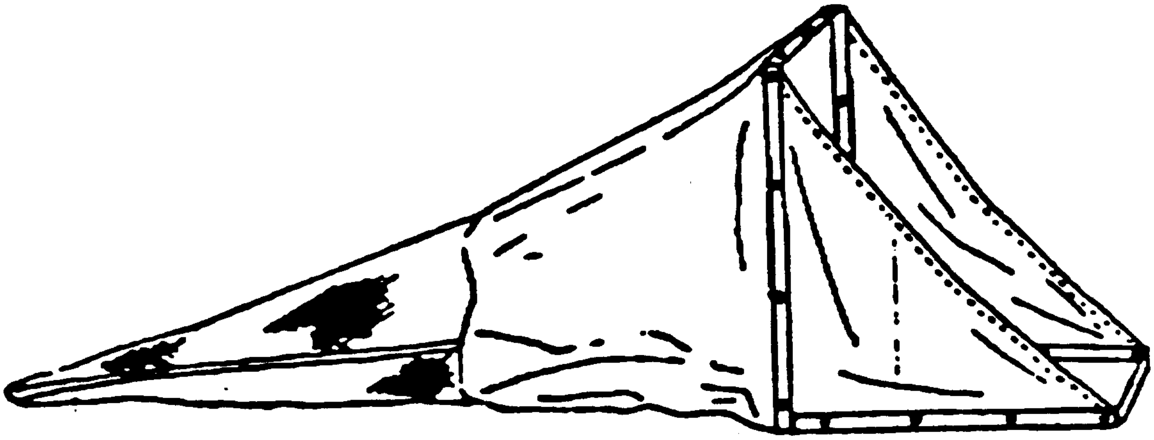


Exhibit 12A-4
SURBER SAMPLER



being conducted. Sample handling techniques and preservation are discussed in Subsection E3 of this appendix

Invertebrate drift nets are small, funnel-shaped, fine-meshed nets with a rectangular opening and a typical bag length of 1.3 meters. These nets are anchored in small, swift streams (minimum current of 0.5 feet per second) above the bottom and slightly below the surface. This type of net is useful for collecting macroinvertebrates that migrate or are dislodged from the substrate.

This sampling methodology can be used to collect organisms for tissue analysis or for ecological surveys. Important factors in obtaining quantitative ecological data are net opening size, duration of operations, stream flow, time of day, and season.

Examination trays, either stainless steel or white enamel, are often used in the field to do the Initial sorting of collected invertebrates. Sample handling techniques and preservation are discussed in detail in Subsection E3 of this appendix.

C3. Otter Trawl

Marine macroinvertebrates associated with the surface sediment are collected In otter trawls along with dernersal fish. This sampling method is described In Subsection D1 of this appendix.

Invertebrates collected by this method are bandied and preserved by the techniques described in Subsection E3 of this appendix

C4. Traps

Minnow or crab traps are screened devices that are baited with an attractant to lure species of interest. These traps are most commonly used to collect organisms such as crayfish or marine crabs to be used in tissue analysis.

Traps are baited with items that will attract the spades of interest. Crayfish, for example, are scavengers and will be attracted to any odorous food item such as fish or cat food. The traps are then set on or near the site and at a reference site and are checked at appropriate time Intervals. Specific trapping methodologies will vary with the organism of interest. Once the organisms are collected (at least 100 grams per sample), they are bandied as described in Subsection E3 of this appendix.

C5. Artificial Substrate

Artificial substrate samplers are devices that are placed in the water for an extended period for colonization by macroinvertebrates. This sampling technique can be used to collect invertebrates (such as small crustaceans, insects, and other arthropods) for tissue analysis. These devices can be used in ecological studies if a standard artificial substrate sampler is used at both the reference and study locations and if care is given to placing the substrates in equal water depth and under equal conditions for equal time periods.

Because artificial substrate sampling methods can take extended amounts of time (4 to 6 weeks), other available methods may be preferable. However, in monitoring studies, artificial substrates can provide information concerning relative environmental conditions. This is one of the only means for obtaining quantitative data relative to benthic colonization in areas where substrate conditions may not allow invertebrate colonization or where organisms are scarce, making other collection efforts difficult.

The most common standard samplers are the multiplate or Hester-Dendy sampler and the basket sampler (Exhibit 12A-5). The multiplate sampler is positioned (preferably) in the top meter of water, using floats and stainless steel cable, for 4 to 6 weeks. For maximum retention of organisms during retrieval, the sampler is placed In a bag or large dip net while still positioned In the water.

A basket sampler is a cylindrical basket containing approximately 30 rocks of equal size. This device is often used In creeks and rivers where rocks are the preferred habitat for most invertebrates. Such samplers are also left In place for 4 to 6 weeks.

Organisms removed from either artificial substrate are processed using techniques described in Subsection E3.

C6. In Situ Bioassays

During this procedure, local invertebrates from" a comparatively clean area or invertebrates raised in laboratories under known conditions are confined in traps and held at the site and at a reference site to determine the acute toxicity of the area of suspected contamiants or to determine whether bioaccumulation is occurring.

Approximately 40 to 50 organisms such as bivalves or crayfish are obtained. Then 10 to 15 organisms are placed in two cages – one for the test area and one for the reference area. If the purpose of the study Is to determine bioaccumulation, 10 to 15 additional specimens are sacrificed and processed immediately to establish baseline conditions. The test and reference cages are checked on a regular schedule to determine mortalities. If bioaccumulation is being studied, several specimens are sacrificed at set time intervals over the study period. Specimens for analysis are handled and preserved as described in Subsection E3 of this appendix.

C7. Miscellaneous invertebrate Collection Techniques

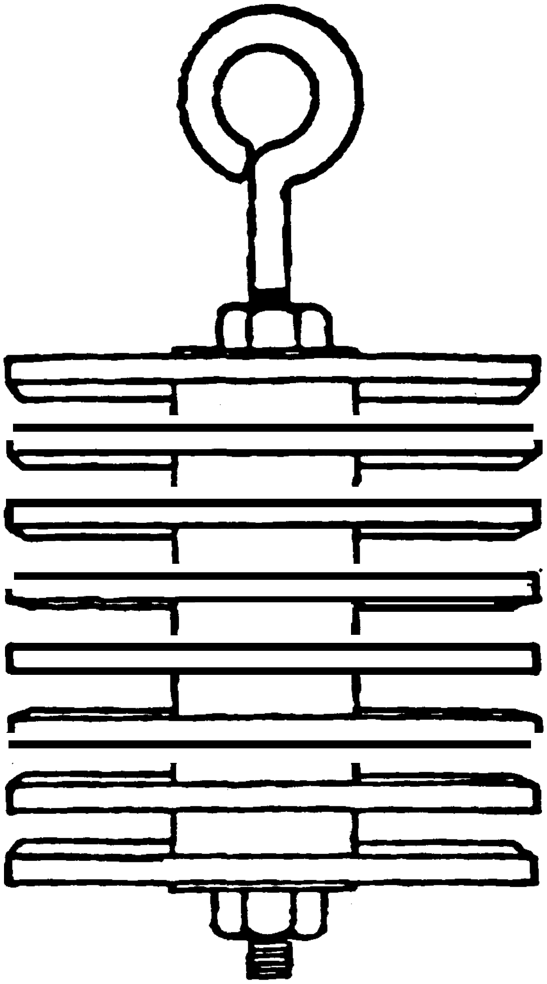
Aquatic invertebrates can be collected in a variety of other ways, depending on the species and habitats being sampled.

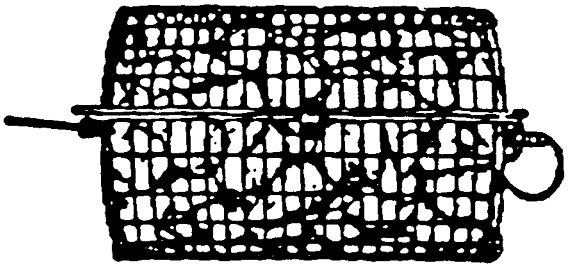
Other sampling devices that can be used include garden rakes, pocket knives, buckets, tongs, dip nets, and hands. Any of these methods would best be used for collection of organisms for tissue analysis and not for ecological surveys since they are difficult to quantify.

D. FISH FIELD COLLECTION Techniques

Collection techniques for gathering biotic information on both freshwater and marine fish species include trawling, seining, hook and line, and in situ bioassays. Electroshocking is used in freshwater systems only.

Exhibit 12A-5
SUBSTRATE SAMPLERS





D1. Trawls

The trawl method of sampling fish consists of dragging an open net through a body of water with a boat. The net is set at the appropriate operating depth to catch the species of interest. This sampling method is used In large, open-water areas of reservoirs, lakes, rivers, estuaries, and oceans. Irregular bottoms or areas with snags or large debris items are difficult to sample by trawl. Otter trawls (Exhibit 12A-6) are commonly used because they can be operated from a relativety small boat.

The otter trawl method is used to sample bottom species while midwater species are often sampled by a modified otter trawl (beam trawl) system.

Because many pollutants concentrate in sediments, bottom trawling is useful in collecting organisms that are associated with sediments. This sampling method can be used to collect specimens for tissue analysis or for ecological surveys to describe comparative populations (i.e., potentially impacted area versus reference area). However, there are limitations to using trawls to describe the entire population because some species are able to avoid being captured in the net.

Otter trawls are composed of two rectangular “otter boards” attached to the forward end of each side of the net. These boards are used to hold the mouth of the net open. The opening of the smaller trawls is about 16 to 20 feet. The length of line used to fish the trawl depends on the depth of the body of water. The preferred angle on the line is at least 5 feet of line per foot of depth. The net Is a semi-balloon modified shrimp trawl with .75-inch mesh, and it often has an additional liner of .25-inch mesh In the end of the net (cod end) to retain smaller fish. The bottom line of the net mouth Is a lead line to keep the net fishing the bottom, and the top line includes floats to keep the net open.

Small trawls can be operated by two people in a medium-sized power boat. While the trawl can be hauled in by hand, a winch is more useful, especially when the catch is expected to be large.

The length of time for fishing with the trawl depends on the expected abundance of organisms. The time usually varies from 5 to 15 minutes and begins when the net starts fishing the bottom. After the net Is hauled back on deck, specimens collected are handled as appropriate for the study program. A detailed discussion of fish handling and preservation techniques used in the field is included in Subsection D5 (Target Fish Species) of this appendix.

Other miscellaneous gear includes life jackets, wet-weather gear (even in dry weather), gloves, and containers to hold the catch into for sorting and examination. Before collecting fish with bottom trawls, some information is required to determine expected sediment contamination levels. Personal protective gear is used when necessary.

D2. Electrofishing

Electrofishing is a freshwater fish sampling method that uses a pulsating direct current (DC) electroshocker, which stuns fish when the electric current travels through water with a resistance between 300 ohms and 30,000 ohms. Alternating current (AC) or nonpulsing DC methods are available but are not as desirable because higher fish mortality occurs with AC. Pulsating DC often gives better results than nonpulsing DC (Smith-Root, n.d.).

Electrofishers can readily be used to collect specimens for tissue analysis or to obtain population estimates or other population factors for creeks or small rivers in ecological surveys. When using electrofishing in ecological studies, several factors should be considered. These include size selectivity (larger fish

Exhibit 12A-6
OTTER TRAWL

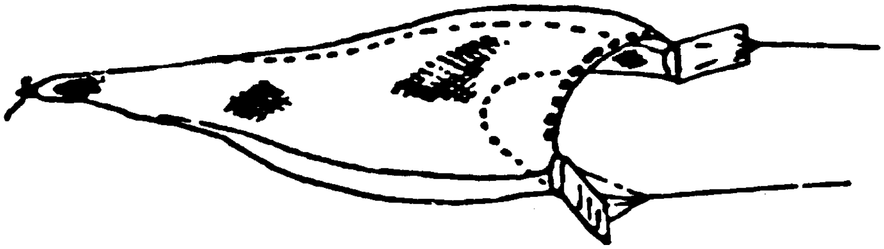
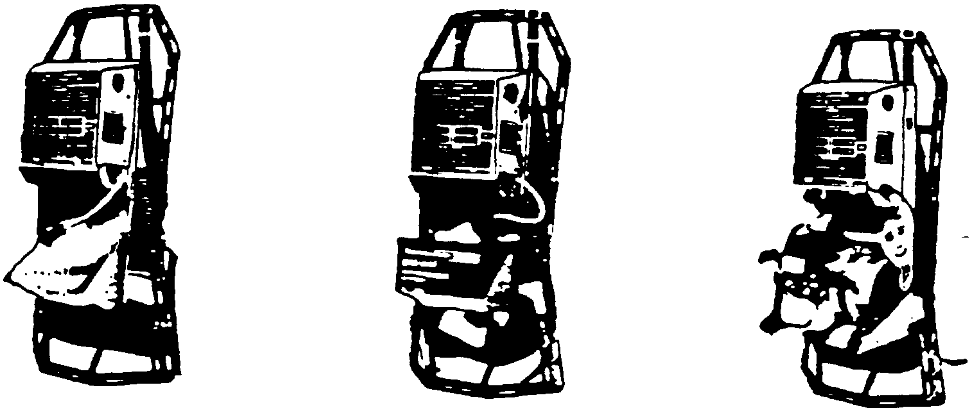
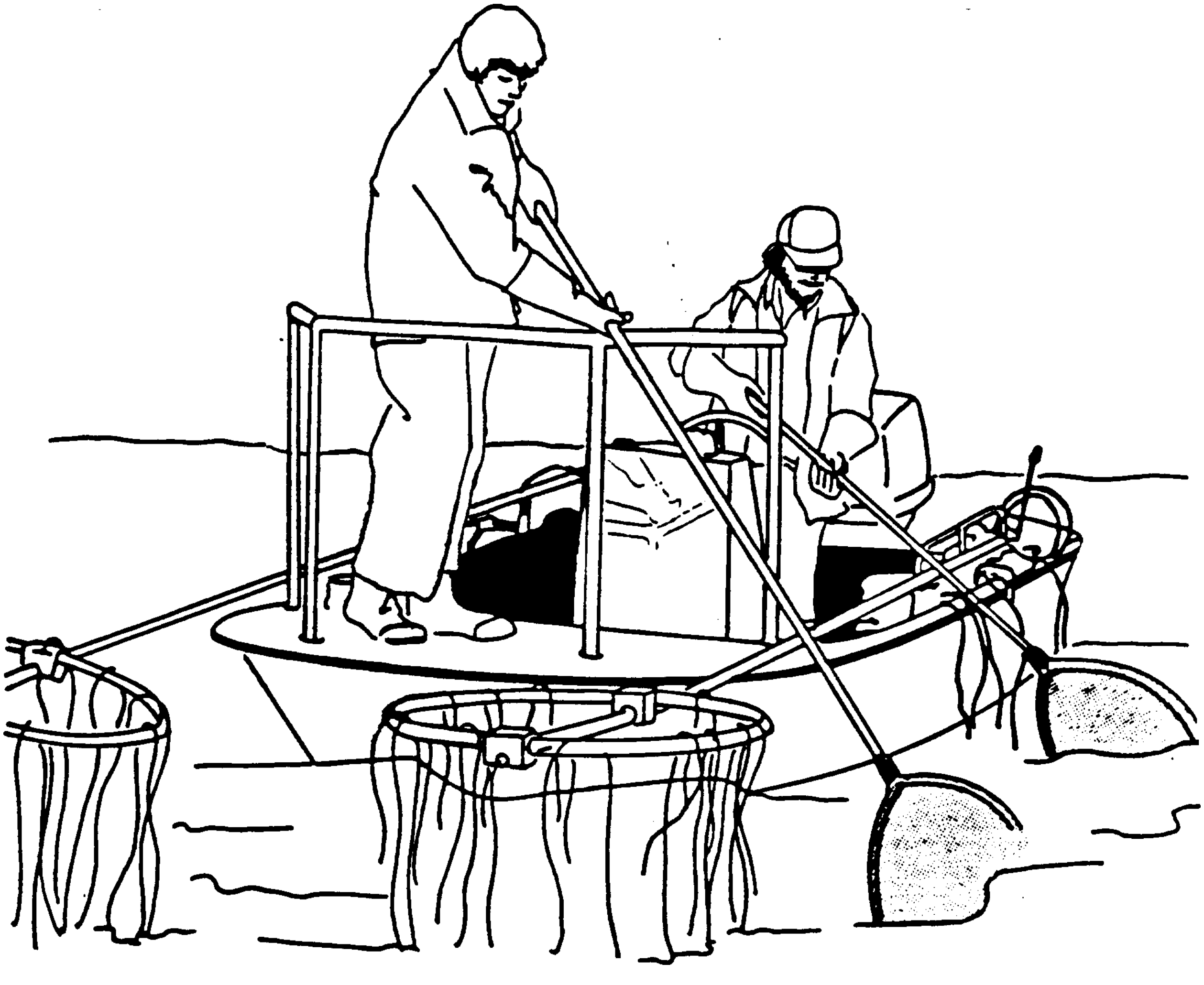


Exhibit 12A-7
BACKPACK AND BOAT ELECTROSHOCKERS





are more easily stunned than smaller fish); behavioral and habitat preference differences between species; and water conductivity, temperature, depth, and turbidity.

Electrofishing in creeks and small rivers can be done with a backpacking model pulsating DC electroshocker (top of Exhibit 12A-7). The backpacker system includes the electroshocker control unit and a 12-volt battery mounted in a specially designed backpack unit, the anode pole, and the cathode screens. The circular anode unit is mounted on a pale, which can be outfitted with a small mesh net to capture stunned fish. Other gear needed includes along-handled, fine-mesh dip net to capture fish and a bucket to hold specimens. Because electroshockers have a high-voltage output, other important equipment includes nonleaking, chest-high wading boots and nonleaking rubber electrician's gloves with long cuffs. Life jackets are also worn.

Waters that cannot be waded in can be electrofished by boat (Exhibit 12A-7). The anode is clamped rigidly ahead of the boat and extends into the water. One person guides the boat with oars or a motor while one or two operators dip stunned fish. In waters too deep to wade, larger fish are more often taken by the boat method rather than by the backpack method. The same safety equipment is used in boat *electro* shocking as for the backpack method. The boat electroshocker is equipped with a "dead man" switch that allows for a quick disconnect of the electrical impulse if a person falls in the water.

Some knowledge of expected species and their suitable habitat is helpful in electrofishing. When stunned with a DC system, a fish will often be drawn toward the anode. However, in running waters, it can be swept downstream. Polarized dark glasses can aid in finding stunned fish. Collected organisms are placed In a water-filled bucket until processing can take place. Organisms to be used for tissue analysis are processed as described in Subsection D5 (Target Fish Species) of this appendix.

D3. Seining

Seining involves the use of a long strip of netting hung between a float line and a lead-weighted line that is pulled through the water either by boat or, in shallow waters, by hand. This method is most often used in shallow sandy beach areas in either fresh or salt water. Beach seining is a simple sampling method that can collect fish samples for tissue analysis and can provide some information on species variability in ecological studies. Because certain sizes and types of fish can easily escape a beach seine, its use in ecological studies is limited.

A small beach seine consists of a nylon net equipped with cork or plastic floats on the top and a leader steel-weighted line on the bottom. The size of the net will depend on the area to be sampled, but a typical size is approximately 10 meters long and 3 meters deep. Mesh size can vary with the species of interest. Hauling lines are attached to the top and bottom lines by a short bridle. This type of small seine can be operated by two people. If the water is shallow, no boat is needed. One person anchors one side of the seine on the beach, while the other deploys the seine through the area to be fished. Both ends are then pulled on shore as quickly as possible, making sure that the bottom line remains on the bottom. Collected organisms are processed according to the study plan using techniques as described in Subsection D5 – Target Fish Species of this appendix.

D4. hook and Line

Fishing with a hook and line involves the use of a hand-held rod or trolling bailed hooks or other lures. While this method is not usually acceptable in ecological surveys, it is often the best way to obtain a few specimens for chemical analysis when other methods are not possible. Occasionally, fish freshly caught by nonstudy-team personnel are used in tissue analysis studies if enough information is known regarding the location of catch. This study can also provide information regarding human consumption of local species.

D5. In Situ Bioassay

Local fish species can be used in field boassays in the same manner as was described for macroinvertebrates in Subsection C3 of this appendix.

Target Fish Species

Before sampling fish for tissue analysis, the study team identifies possible target species based on the following:

- Geographic location
- Available habitat
- Ease of capture and identification
- Pollution tolerance
- Use as a sport fish
- Nonmigratory habits

Exhibit 12A-8 lists possible target species by geographic location. While trout are identified as one of the preferred target fish species, caution is exercised in using these fish because in many areas, especially in the east, trout are stocked on a “put and take” basis. The local agency responsible for stocking can be contacted to determine when fish were stocked in a particular area. A period of 3 months is considered to be the minimum time span for trout to acquire a reasonable concentration of ambient pollutants (Freed et al., 1980).

The season during which fish are collected for tissue analysis is also an important consideration. The spawning season should be avoided whenever possible because fish are often stressed during this time; they also have different feeding habits, fat content, and respiration rates, which can influence pollutant uptake and clearing.

Exhibit 12A-8
TARGET FISH SPECIES FOR USE IN TISSUE ANALYSIS

I. Target Species (East of Appalachian Mountains)

***Brook Trout *(Salvelinus fontinalis)*
***Small Mouth Bass (*Micropterus dolomieui)*
***Large Mouth Bass (*Micropterus salmoides*)
***Channel Catfish (*Ictalurus punctatus)*
**Brown Trout (*Salmo trutta*)
**Rainbow Trout (*Salmo gairdneri*)
**Bluegill (*Lepomis macrochirus*)
**Pumpkinseed (*Lepomis gibbosus*)
**Black Crappie (*Pomoxis nigromaculatus*)
**Striped Bass *(Morone saxatilis)*
*Carp (*Cyprinus carpio*)

II. Target Species (West of Appalachian Mountains and East of Rocky Mountains)

***Rainbow Trout (*Salmo gairdneri*)
***Brook Trout (*Salvelinus fontinalis*)
***Small Mouth Bass (*Micropterus dolomieui)*
***Large Mouth Bass (*Micropterus salmoides*)
***Channel Catfish (*Ictalurus punctatus)*
**Striped Bass (*Morone saxatilis)*
**Yellow Perch (*Perca flavescens*)
**Walleye (*Stizostedion vitreum*)
**Bluegill (*Lepomis macrochirus)*
*Brown Trout (*Salmo trutta)*
*Carp *(Cyprinus carpio)*

III. Target Species (West of and Including Rocky Mountains)

***Rainbow Trout (*Salmo gairdneri)*
***Brook Trout (*Salvenilus fontinalis)*
***Small Mouth Bass (*Micropterus dolomieui)*
***Large Mouth Bass (*Micropterus salmoides)*
***Channel Catfish (*Ictalurus punctatus)*
**Bluegill (*Lepomis macrochirus*)
**Striped Bass *(Morone saxatilis)*
*Cut-throat Trout (*Salmo clarki)*
*Brown Trout (*Salmo trutta)*
*Carp *(Cyprinus carpio)*

*** Preferred target species
** Good target species
* Acceptable target species

Source: Freed et al., 1980.

E. BIOLOGICAL FIELD SAMPLE PROCESSING AND PRESERVATION TECHNIQUES

EI. Vegetation

Samples of vegetation collected from the site and intended for classification are initially placed in a ridged collector's box. Samples should be kept moist and may be refrigerated when the collector returns to the laboratory. After identification, samples may be pressed and mounted for permanent records.

Vegetation samples collected for tissue analysis are placed in 1-gallon paper bags and labeled. information on the label Includes the date, time, weather, collector, plant type, site, identification number, and proposed analysis.

The bag is stapled or clipped shut, labeled with the identification numbers, and placed in a larger plastic bag. Several paper bags may be necessary to collect 30 grams of material; 1 gram of plant tissue can suffice for most analyses that require the same analytical processing. However, more than 30 grams should be taken if multiple testing or other special processing are required. The plastic bag is then placed in a coder with ice, ice packs, or dry ice. Care is taken to keep cooler water from contacting collected plant material. Samples remain in coders for shipment.

E2. Terrestrial Vertebrates

Once the specimens are collected, organisms to be used for tissue analysis are killed. Each animal is described by weight, measurement, sex, and other general items. All specimens are photographed. The following tissues can be removed using stainless steel scalpels: muscle and associated fatty deposits (lipids), liver, kidneys, and possibly hair and claw samples for metal analysis. Stomach or crop contents can be removed and preserved for identification. Any anomalies are noted and photographed. Sections of the anomalous tissues may be taken for analysis. Tissues are immediately wrapped in cleaned aliuminum foil (dull side in), labeled, and frozen in the field using dry ice. Hair and claw samples are placed in plastic bags and labeled. Tissue samples are kept frozen until they are delivered to the laboratory. Surgical gloves are used during the dis setting process.

E3. Aquatic Macroinvertebrates

Invertebrates collected for tissue analysis are sorted by species, counted, measured (when appropriate), and weighed to assure that each single sample consists of at least 100 grams. Crustaceans are washed using distilled water to remove particulate matter, either wrapped in cleaned aluminum foil (dull side in) or placed in Contract Laboratory Program cleaned glass vials, labeled, and frozen using dry ice. Samples are packed in ice chests and kept frozen until they are delivered to the laboratory. Bivalve mollusks are removed from their shells with a stainless steel knife for the examination of organochlorine compounds or with a plastic knife for the examination of metals. Tissues are purged using distilled water, wrapped in aluminum foil (dull side in), labeled, and frozen as described above. For organic analysis, organic-free water and blanks should be employed to document contamination control. Surgical gloves are worn while handling invertebrate samples. Glove manufacturers should be contacted to determine if gloves area source of contamination and, if so, what compounds are typical.

Exhibit 12A-9
FISH PROCESSING PROCEDURES

1. Wash fillet board and table with local water supply (river, lake, etc.). Distilled water may be used.

2.** Clean knives with acetone and wipe board and table with acetone rinse. Rinse all with local water supply or distilled water.

3. Rinse table and knives between specimens with distilled water; alternately, a previously cleaned knife (#2 above) can be used for each specimen.

4. Take scale sample just posterior of gill and place in scale envelope.

5. Take weight (kg) and length (mm), and record on data sheets.

6. Fillet according to Exhibit 12A-11.

7. Wrap fillets in aluminum foil, and secure with 2-inch masking tape.

   a. If large, individually
   b. If small, combine

8. Label package with

   a. Date and time of collection and preparation
   b. Location (river, lake, etc.)
   c. Species
   d. Sample number
   e. Project number
   f. Sampler's/preparer's name

9. Place in bag and store in ice chest with dry ice.

**Note: If volatile analyses are required, acetone use is discouraged and methanol can be used as a substitute.

Source: Michigan Department of Natural Resources.

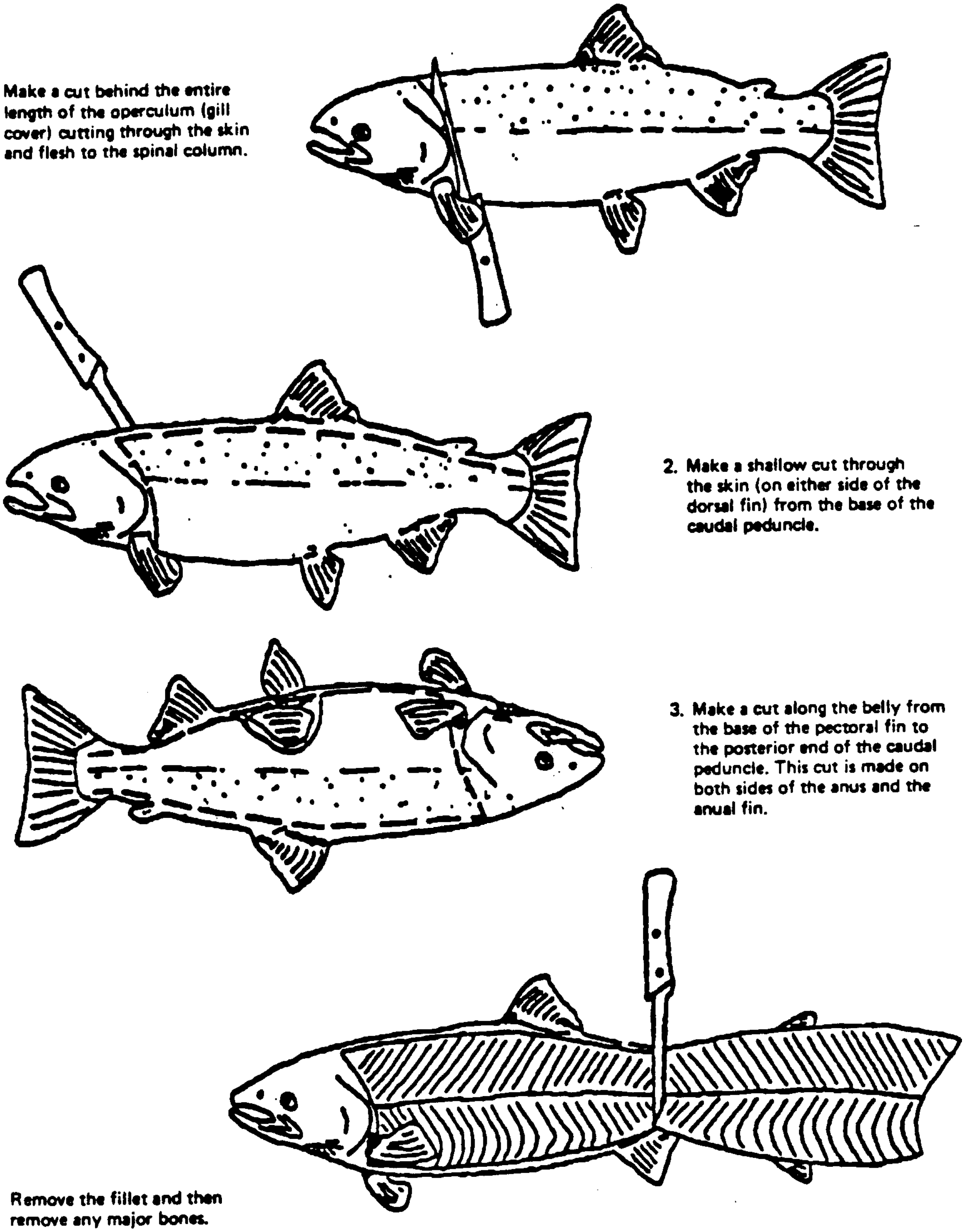
Exhibit 12A-10
FISH COLLECTION EQUIPMENT CHECKLIST

Fillet table (formica top with long legs)
Wrapping table (aluminum, folding)
Fillet knives (1 large and 1 small)
Steel
Clear plastic packaging bags
Garbage bags
Fillet boards--polycarbonate
Water bucket
Wash brush
Garbage pail--6-gallon plastic or wastebasket
Data sheets
Procedure forms--fillet technique, skin-on or skin-off
Plastic bag ties
Scissors
2-inch masking tape
Marking pens and pencil
24-inch-wide roll of heavy-duty aluminum foil
Fish-scale envelope
Tripod
Fish-spring scale
Fish-measuring board
Ice chests
Paper towels
Acetone (wash bottle)**
Dry ice

**May need to substitute methanol (see Exhibit 12-9).

Source: Michigan Department of Natural Resources.

Exhibit 12A-11
PREPARATION OF "STANDARD FILLETS"



1. Make a cut behind the entire length of the operculum (gill cover) cutting through the skin and flesh to the spinal column.

2. Make a shallow cut through the skin (on either side of the dorsal fin) from the base of the caudal peduncle.

3. Make a cut along the belly from the base of the pectoral fin to the posterior end of the caudal peduncle. This cut is made on both sides of the anus and the anual fin.

4. Remove the fillet and then remove any major bones.

Exhibit 12A-12
STANDARD EDIBLE PORTIONS OF SELECTED SPORT AND COMMERCIAL FISH

Standard Edible Portion	Common Names	Scientific Name
Skin-on Fillet	Yellow perch	*Perca flavescens*
(all below to next heading)	Walleye	*Stizostedion vitreum*
	Sauger	*Stizostedion canadense*
	Largemouth bass	*Micropterus salmoides*
	Smallmouth bass	*Micropterus dolomieui*
	Bluegill	*Lepomis macrochirus*
Skin-on	Pumpkinseed	*Lepomis gibbosus*
	Rock bass	*Ambloplites rupestris*
Fillet	White perch	*Morone americana*
	Black crappie	*Pomoxis nigromaculatus*
	White crappie	*Pomoxis annularis*
	Green sunfish	*Lepomis cyanellus*
	Longear sunfish	*Lepomis megalotis*
	Warmouth	*Lepomis gulosus*
	Sucker family	*Catostomidae*
	Lake whitefish	*Coregonus clupeaformis*
	Lake trout	*Salvelinus namaycush*
	Rainbow trout	*Salmo gairdneri*
	Brown trout	*Salmo trutta*
	Brook trout	*Salvelines fontinalis*
	Splake	*Salvelinus poticalis**
	Lake trout	*Salvelinus namaycush*
	Atlantic salmon	*Salmo salar*
	Coho salmon	*Oncorhynchus kisutch*
	Chinook salmon	*Oncorhynchus tshawytscha*
	Pink salmon	*Oncorhynchus gorbuscha*
	Black bullhead**	*Ictalurus melas*
	Brown bullhead**	*Ictalurus nebulosus*
	Yellow bullhead**	*Ictalurus natalis*
	Channel catfish	*Ictalurus punctatus*
	Muskellunge	*Esox masquinongy*
	Northern pike	*Esox lucius*
	Round whitefish	*Prosopium cylindraceum*

Exhibit 12A-12
(continued)

Standard Edible Portion	Common Names	Scientific Name
Skin-off Fillet (all below to next heading)	Lake herring (cisce)	*Coregonus artedii*
	Chubs (bloater)	*Coregonus hoyi*
	carp	*Cyprinus carpio*
	Freshwater drum	*Aplodinotus gruniens*
	Bigmouth buffalo	*Ictiobus cyprinellus*
	Burbot	*Lots Iota*
	Quillback	*Carpiodes cyprinus*
	Lake sturgeon	*Acipenser fulvescens*
Headless, gutted, whole Fish	Rainbow smelt	*Osmerus mordax*

---

* Hybrids between brook trout (S. fontinalis) and lake trout (S. namaycush) are known as splake.

**Depending on local consumptive practice, bullheads may be considered "skin-off" species since they are skinned before consumption.

Source: Modified from Michigan Department of Natural Resources.

Invertebrates collected for ecological assessment are preserved in the field with either a 4- to 7-percent formal in solution (dependent on sample use and fragile nature of animals) or with 70-percent buffered ethanol. Each sample is labeled with sampling location, depth, sample number, species (or lowest taxonomic level practicable), number of individual organisms collected, sampling method, date, project number, sampler, and team leader.

E4. Fish

Fish collected for tissue analysis are handled according to procedures outlined in the Michigan Department of Natural Resources (MDNR) Fish Processing Procedures (Exhibit 12A-9) and in the Field Collection Equipment Checklist (Exhibit 12A-10). Exhibit 12A-11 shows the procedure for preparation of MDNR's "standard fillets," and Exhibit 12A-1 2 lists the standard edible portions of selected sport and commercial fish. Any marine fish that may be associated with a hazardous waste site and is not on this list will require input from local individuals as to which tissues are consumed. Other fish tissues (i.e., liver, bone, etc.) may need to be analyzed depending on contaminants involved and where they may accumulate.

SECTION 13

SPECIALIZED SAMPLING TECHNIQUES

13.0 GENERAL

This section discusses several specialized sampling techniques that have been used by contractors on hazardous waste sites. The reader may develop other techniques for specific site needs. In those cases and in cases where the techniques listed here are modified for use on a specific site, careful documentation of the exact procedures used should be provided. This section does not discuss analytical techniques, since analytical methods would vary depending on the data quality objectives, the compounds of concern, the media, and the exact sampling technique. The Contract Laboratory Program plans to issue a "Field Methodology Catalog" In the summer of 1987 that will contain field analytical techniques suitable for analyses of the samples collected by using the techniques in this section.

13.1 WIPE SAMPLING

13.1.1 Scope and Purpose

This guideline discusses the steps required for obtaining a wipe sample. Wipe samples may be used to document the presence of carcinogenic substances or other toxic materials. In addition, wipe sampling is commonly used to ascertain that site or equipment decontamination has been acceptably effective.

13.1.2 Definitions

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. This person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

Wipe Sample

A sample used to assess surface contamination. The terms "wipe sample," "swipe sample," and "smear sample" have all been used synonymously. For purposes of this section, the sample will be termed 'Wipe sample."

13.1.3 Applicability

This guideline is applicable when a sample of the substances on a surface is needed. Surfaces may include walls, floors, ceilings, desk tops, equipment, or other large objects that are potentially contaminated.

13.1.4 Responsibilities

The SM or designee Is responsible for deciding when wipe sampling is needed.

Field personnel are responsible for performing the actual sampling, maintaining sample integrity, and preparing the proper chain-of-custody forms.

13.1.5 Records

Records of wipe sampling include completed chain-of-custody forms and appropriate entries in the field logbook. If the sample collected is to be analyzed using the National Contract Laboratory Program (CLP), then CLP forms must be completed as discussed in Section 5.

13.1.6 Procedures

Wipe sampling can be an integral part of the overall sampling program. Wipe sampling can help to provide a picture of contaminants that exist on the surface of drums, tanks, equipment, or buildings on a hazardous waste site or that exist in the homes of a populace at risk.

Wipe sampling consists of rubbing a moistened filter paper over a measured area of 100 cm^2 to 1 m^2. The paper is then sent to the laboratory for analysis. The results are related back to the known area of the sample. A proper sampling procedure is essential to ensure a representative, uncontaminated sample.

13.1.6.1 Equipment Required

The following equipment is needed for wipe sampling:

- Whatman 541 filter paper or equivalent, 15 cm ,
- Disposable, chemical-protective gloves
- Solvent to wet filter paper

13.1.6.2 Wipe Sampling Steps

The steps involved in obtaining a wipe sample are listed below

- Using a clean, impervious disposable glove, such as a surgeon's glove, remove a filter paper from the box. (Note: Although it is necessary to change the glove if it touches the surface being wiped, a new glove should be used for each sample to avoid cross contamination of samples. A new glove should always be used when collecting a new sample.)
- Moisten the filter with a collection medium selected to dissolve the contaminants of concern as specified in the sampling plan. Typically, organic-free water or the solvent used in analysis is used. The filter should be wet but not dripping.
- Thoroughly wipe approximately 1 m^2 of the area with the moistened filter. Using a 1 m^2 stencil will help in judging the size of the wipe area. If a different size area is wiped, record the change in the field logbook. if the surface is not flat, be sure to wipe any crevices or depressions.

- Without allowing the filter to contact any other surface, fold it with the exposed side in, and then fold it over to form a 90-degree angle in the center of the filter.

- Place the filter (angle first) into a clean glass jar, replace the top, seal the jar according to quality assurance requirements, and send the sample to the appropriate laboratory.

- Prepare a blank by moistening a filter with the collection medium. Place the blank in a separate jar, and submit it with the other samples.

- Document the sample collection In the field Iogbook and on appropriate forms, and ship samples per procedures listed In Section 6.

13.1.7 Region-Specific Variances

No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revision to this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

13.1.8 Information Sources

EBASCO. “Dioxin Sampling.” ***REM III Program Guidelines.*** Prepared for U.S. Environmental Protection Agency. 28 February 1986.

NUS Corporation. “Site-Specific Site Operations Plans.” REM/FIT Contract.

13.2 HUMAN HABITATION SAMPLING

13.2.1 Scope and Purpose

This subsection provides general guidance for the planning, method selection, and implementation of sampling activities used to determine the potential for human exposure to contaminants that are present in residential environment.

13.2.2 Definitions

Human Habitation Areas
Any place people may spend extended periods of time, such as their homes or offices.

13.2.3 Applicability

This subsection discusses sampling techniques that are similar in collection methodology to other types of samples, such as environmental soil and water, but are biased to emphasize potential human exposure to contaminants moving into the residential environment.

13.2.4 Responsibilities

Human habitation sampling is the most sensitive of all environmental sampling activities. This sensitivity must be addressed by community relations, health and safety, and sample collection personnel and should be their key responsibilities. Community relations personnel must coordinate with the EPA to gain site access for the samplers by care fully informing the residents of activities being performed and by answering any questions the residents might ask. This difficult task must be performed in a manner that will not overly alarm or excite people before definitive data can be collected to determine the true exposure assessment.

The health and safety (risk assessment) personnel must be responsible for informing management and community relations personnel of the potential exposure risks. Health and safety personnel will assist in sample plan preparation and will aid the community relations personnel in correctly answering questions. The risk assessment is also used in determining safety measures for samplers. Later the health and safety personnel will use the analytical data to make a final health risk assessment. Finally, the sampling personnel, aside from their normal responsibilities, must be made aware of the resident's perspective. Workers who are educated and more comfortable with hazardous environments must understand the potential health and economic impacts on the people involved and must conduct themselves in a comparable manner.

13.2.5 Records

Records generated during human habitation sampling will include telephone conversation notes, access permission slips, field notebooks, sample result databases, and quality assurance review documentation.

13.2.5.1 Telephone Conversation Notes

As part of the initial community relations and site investigative activities, the EPA will make telephone calls to public officials, property owners, and other involved persons. These telephone conversations must be documented, taking care to note any commitments that are made or activities that are discussed. The EPA should make ceils again just before sampling to reaffirm permission to sample.

13.2.5.2 Access Permission Slips

A critical record that pertains to human habitation sampling activities is the property owner's consent to enter the property. Records such as these are important in the event that any litigation activities take place. Sampling personnel must be aware, however, that consent can be withdrawn at anytime.

13.2.5.3 Field Notebooks

Specific field records should be documented in accordance with the requirements set forth in the Quality Assurance Project Plan (QAPjP). (See Section 6.)

13.2.5.4 Sample Results Databases

Human habitation sampling efforts will create sample result database records that are critical for health risk analysis and statistical evacuations.

13.2.5.5 Quality Assurance Review Documentation

To ensure the quality, consistency, and completeness of the data, reports and other records generated must be reviewed by persons other than those involved with the record generation. Records documenting this review should be kept as a check against errors.

13.2.6 Procedures

This subsection describes several types of samples pertaining to human habitation. These samples can be related to the potential for human exposure to contaminants in the residential environment. Samples taken from the air in and near the house or from the lawn, gardens, swimming pools, crops, farm animals, and other media related to human habitation are collected generally in the same manner as other environmental samples. (See Sections 7, 8, 10, 11, and 12 of this compendium.)

13.2.6.1 Vacuum Bag

if a vacuum cleaner is present in a residence being sampled, the vacuum bag can be an excellent source for a representative sample. The bag contains material from the air and home surfaces that may potentially expose humans through dermal, ingestion, and inhalation pathways. The vacuum bag should be removed from the vacuum' and the sample collected as if it were a normal soil sample. Information on the period of use of the bag should be obtained.

13.2.6.2 Air Conditioner Filter

if there is a central air conditioner or heating unit present in a residence, the filters used with the system are another source for collecting samples representative of the residential environment. Filters are removed and placed in large plastic bags for shipment to the laboratory for analysis. Information on the period of use of the filter(s) should be obtained.

13.2.6.3 Dust Sweep

Dust sweep samples are applicable to residential sampling if an area exists where sufficient volume can be found. Areas such as attics, crawl spaces, basements, and garages are possible locations. Dust sweep samples are collected by sweeping dust into a pile and then transferring the dust to the sample containers by using an appropriate tool, such as a stainless steel spoon. Alternately, an industrial vacuum cleaner with a high-efficiency filter, such as use for asbestos removal, can be used. The sample volume needed will vary depending on the types of contaminants suspected. If only low-volume areas exist, surface wipe samples may be an alternative method. Infrequently dusted furniture (tall cabinets, refrigerator tops or coils, etc.) may be a good source.

13.2.6.4 Sump or Drain Sediment

Sump or drain locations are potential sampling points for representative samples. The sediment that collects over a period of time, or backs up in the sump, is collected as a normal soil sample.

13.2.6.5 Lint Traps

The lint traps in clothes washers and dryers may contain sufficient quantities of material for a sample. It is important to recognize that such material has been subjected to heat, water, and various laundry products.

13.2.7 Region-Specific Variances

Human habitation sampling should have a site-specific sampling plan, and all regions should be informed about current innovative developments. No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

13.2.8 Information Sources

NUS Corporation. *Superfund Training Manual.*

13.3 TCDD SAMPLING

13.3.1 Scope and Purpose

This subsection provides general information on performing 2,3,7,8 tetrachlorodibenzo-p-dioxin (TCDD) analysis. The user should be aware that the procedures for use in sampling TCDD are often revised and should refer to the latest procedures. EPA Regional Sample Control Center (RSCC) should be contacted about preferred collection techniques.

13.3.2 Definitions

None.

13.3.3 Applicability

This sampling is applicable to sample collection work that deals with the collection and analysis of TCDD.

13.3.4 Responsibilities

The SM for a particular site or the designee is responsible for deciding when TCDD sampling is required.

Field personnel are responsible for performing the actual sampling, maintaining the sample integrity, and preparing the proper chain-of-custody forms.

13.3.5 Records

Records of TCDD sampling include chain-of-custody forms, TCDD sampling forms, and appropriate entries in the field logbook. Samples collected and sent to a CLP lab must be accompanied by the CLP forms discussed in Section 5.

13.3.6 Procedures

13.3.6.1 Sampling Activities

TCDD is usually sampled as a contaminant in soil or sediment. Because TCDD binds tightly to the soil, it is most often found in near-surface soils, unless the contaminated material was used as fill or consists of transported sediments. Sampling for TCDD in soils is similar to other types of soil sampling with the exception that a thorough blending of the sample is of greater importance and that the sampling equipment must be rigorously cleaned. Because the "action levels" associated with TCDD contamination are very low, the SM should consider using sampling equipment (stain less steel spoons, etc.) that has been cleaned In a laboratory using CLP procedures. The SM should dispose of the equipment after only one sample is taken. This greatly decreases the possibility of cross contamination.

13.3.6.2 Blending Procedure

Samples for TCDD must be properly blended before analysis. One technique involves using a 1-quart stainless steel blender cup. The blender cup should be no more than three-quarters full. Personnel should avoid placing stones in the blender cup. In addition, large clumps of soil should be broken up.

The sample is then returned to the blending station. The blender is placed on a sample drop sheet, and the following occurs:

- Pulse blender five times.
- Invert blender cup several times and shake.
- Repeat this procedure six times for a total of 30 pulses.
- Allow the blender to sit for 2 to 5 minutes to allow all dust to settle. The blended sample is then dispersed into a jar that has been placed in a plastic bag or "haggle" with a rubber band closure at the neck to reduce the possibility of contaminating the outside of the sample jar.

The sample is removed from the blender cup by using scoopulas, which will be disposed of when the sample jar has been filled. The baggie and rubber band are removed and put in the designated receptacle. The sample jar may be spray rinsed with 1,1,1-trichloroethane (1,1,1 -TCE) to further reduce the possibility of contamination.

The jar is rebagged in a clean baggie, tagged, and processed for shipping.

Any material remaining in the blender cup is disposed of in the waste receptacle. The blender cup is filled (one- quarter to one-half full) with soapy water, agitated (blended) for 30 seconds, and, if necessary, scrubbed with a brush. The cup is then rinsed with distilled water, alcohol, and 1,1,1 -TCE and allowed to drip dry.

13.3.6.3 Field Quality Control Requirements

The quality control requirements listed below for dioxin sampling maybe used.

- Do not composite field samples.
- Homogenize solid samples in the field using a mechanical blender or send an undisturbed sample to the laboratory for homogenization. Laboratory soil homogenization techniques are discussed in Subsection 13.6.
- Keep samples away from light.

For each batch of up to 20 samples from one site, the fallowing samples should be added for quality control purposes to the shipment

- include two performance audit samples.
- include one field blank composed of soil taken by field personnel from a clean area at the site.
- Add another field blank of soil that will be labeled on the bottle and on the packing list with "to be spiked by laboratory."
- Include one decontamination rinsate sample that was obtained from the last 1,1,1 -TCE rinse of the blender. Label the bottle and packing list with ”1,1,1 -trichloroethane decontamination rinsate.”

13.3.7 Region-Specific Variances

Sampling and blending techniques for TCDD vary from region to region. in Region ill, each sample “batch’ consists of 24 samples. The laboratory duplicates one analysis to bring the total number of results to 25. The QA samples included as part of each batch include the following:

- One field duplicate
- One field blank (actually background soil)
- One field background marked "to be spiked”
- One PE sample (selected and provided by the QA section after discussion with the SM or RPM)

if the number of samples is fewer than 19, an additional PE or duplicate may be added to the batch. Because variances become dated rapidly, the user should contact the EPA RPM for current variances and the RSCC for the latest procedures before initiating TCDD sampling. Other regional variances will be incorporated within Revision 01 of this document.

13.3.8 Information Sources

U.S. Environmental Protection Agency. “Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual.” Region IV, Environmental Services Division. 1 April 1986. (See Appendix 13-B.)

13.4 CONTAINER SAMPLING

13.4.1 Purpose and Scope

This subsection provides general Information on available references for use in planning and implementing sampling programs involving the movement and opening of closed containers of sizes varying from bottles to large tanks. Collecting samples of containerized materials can be an important part of a field investigation. The samples are analyzed to determine the presence and magnitude of the threat to the environment.

13.4.2 Definitions

Container
Any drum, bottle, can, bag, and the like, with a capacity of 120 gallons or less.

Tanks
Bulk tanks, such as railroad tank cars, and large above- and below-ground tanks with a capacity of more than 120 gallons Including tank trailers.

13.4.3 Applicability

This guideline is, applicable when a sample of the contents of a closed container is needed. In general, a container sampling program will have one of the following objectives:

- To determine the presence of hazardous materials onsite
- To characterize the range of materials onsite
- To characterize container contents for such purposes as bulking for disposal

13.4.4 Responsibilities

The SM or designee is responsible for deciding when container sampling is needed. Sampling personnel will be responsible for collecting representative samples, preserving sample integrity, and adhering to chain-of-custody procedures.

13.4.5 Records

Conditions, markings, and observations of containers found on a hazardous waste site, will. be recorded in the site logbook. Chain-of-custody forms and the appropriate CLP forms will be completed. Photographs are important.

14.4 RESPONSIBILITIES

It is the responsibility of the survey and mapping task leader to ensure that the proper techniques are followed throughout the project.

14.5 RECORDS

All field notes should be kept In bound books. Each book should have an index. Each page of field notes should be numbered and dated and should show the initials of all crew members. The person taking field notes will be identified in the log. Information on weather (wind speed / wind direction, cloud cover, etc.) and on other site conditions should also be entered in the notes. Graphite pencils or water proof ballpoint pens should be used. Erasing is not acceptable; use a single strike-through and initial it. The notekeeping format should conform to the *Handbook of Survey Notekeeping* by William Pafford. A survey work drawing with grid lines and at the scale of the topographic map should be prepared for all survey field work.

Aerial photography film annotation should include, at a minimum, the date of exposure, flight number, and exposure number. Additional Information would include radar and barometric altitude, time, latitude, longitude, heading, pitch. roll, and drift angles.

Photogrammetric mapping should be In ink on mylar or scribed; maps should be 22 inches by 34 inches or as directed by the survey and mapping task leader.

14.6 PROCEDURES

14.6.1 Surveying -General

Survey requirements may necessitate survey accuracies of the third order; however, the second order may be required on some occasions and lower accuracies on other occasions. For the majority of sites, all surveys shall be third-order plane surveys as defined in the standards and specifications in Exhibit 14-1.

Third-order plane surveys and horizontal angular measurements should be made with a 20-second or better transit. Angles should be doubled, with the mean of the doubled angle within 10 seconds of the first angle. Distance measurements should be made with a calibrated tape corrected for temperature and tension or with a calibrated electronic distance meter instrument (EDMI). When using EDMI, the manufacturer's parts per million (ppm) error continues to be applied, as well as corrections for curvature and refraction.

14.6.1.1 Third-Order Vertical Survey

Land surveys are to be completed by a surveyor who is licensed and registered in the state where the survey is conducted. When practical, vertical control will be referenced to the National Geodetic Vertical Datum (NGVD) of 1929, obtained from a permanent bench mark. If possible, level circuits should close on a bench mark whose elevation is known (other than the starting bench mark). If the circuit closes on the original bench mark, the last point in the circuit must be used as a turning point. The following criteria should be met in conducting the survey

Exhibit 14-1
STANDARDS FOR THIRD-ORDER PLANE SURVEYS

Principal Use:

Small engineering projects and small-scale topographies mapping.

Traverse	
Number of bearing courses between azimuth checks	30 to 30 [30]*
Astronomical bearings standard error of results	8".0 [6".0]*
Azimuth closure at azimuth checkpoint not to exceed (use the smaller value)	30" $\sqrt{N}$ or 8".0 per [20" $\sqrt{N}$]* station
Standard error of the mean for length measurements	1 in 30,000 [1 in 20,000]*
Position closure per loop in feet after azimuth adjustment	1:5,000 checkpoint or 3.34 $\sqrt{M}$, whichever is smaller
Leveling	
Levels of error of closure per loop in feet	0.05 $\sqrt{M}$

● Figures in brackets are commonly used in preparing specifications for bid.

N = then number of stations for carrying bearing
M = the distance in miles

- Instruments should be pegged regularly.
- Rod levels should be used.
- Foresight and backsight distances should be reasonably balanced.
- No side shot should be used as a turning point in any level loop.
- Elevation readings should be recorded to 0.01 foot and estimated to 0.005 foot using a calibrated rod.

Temporary monuments should be set and referenced for future recovery. Ail monuments should be described in the field notes and should consist of a permanent mark scribed on facilities such as sidewalks, paved roads, or curbs. Sufficient description should be provided to facilitate their recovery.

14.6.1.2 Property Surveys

All property surveys should be performed in accordance with good land surveying practices and should conform to ail pertinent federal and state laws and regulations governing land surveying in the area where the work is being accomplished. The surveyor shall be licensed and registered in the state where the survey is conducted.

Upon completion of the project, ail original field note books, computations, and pertinent reference materials should be delivered to the SM for retention in the site file. The surveyor may keep photostatic copies of the material.

All field note reductions should be checked and marked in such a way that a visual inspection of the field notes will confirm that checks have been made. All office ‘entries in field notebooks should be made in colored pencil.

The office worker who reduces or checks field notes should initial each page worked on in the color used on that page.

14.6.1.3 Traverse Computations and Adjustment

Traverses will be closed and adjusted in the following manner

- Step one– Bearing closures will be computed and adjusted ii within limits.
- Step two-Coordinate closures will be computed using adjusted bearings and unadjusted field distances.
- Step three-Coordinate positions will be adjusted if the traverse closes within the specified limits. The method of adjusting shall be determined by the surveyor.
- Step four– Final adjusted coordinates will be labeled as “adjusted coordinates.” Field coordinates should be specifically identified as such.

- Step five-The direction and length of the unadjusted error of closure, the ratio of error over traverse length, and the method of adjustment should be printed with the final adjusted coordinates.

14.6.1.4 Level Circuit Computations and Adjustments

Level circuits will be closed and adjusted in the following manner

- For a single circuit, elevations will be adjusted proportionally, provided the raw closure is within the prescribed limits for that circuit.
- In a level net where the elevation of a point is established by more than one circuit, the method of adjustment should consider the length of each circuit, the closure of each circuit, and the combined effect of ail the separate circuit closures on the total net adjustment.

14.6.1.5 Monitoring Well Surveys

Monitoring well locations are surveyed only after the installation of the tamperproof locking cap well casing cover, which is set in concrete. The horizontal plane survey accuracy is ± 1 foot (unless greater accuracy is desired) and is measured to any point on the well casing cover. The vertical plane survey must be accurate to ± 0.01 foot. Three elevations are measured, including the fallowing:

- Top of the inner well casing (on the lip)
- Top of the outer protective casing (on the lip, not the cap)
- Finished concrete pad adjacent to the outer well casing

The point at which the elevation was measured should be scribed so that water level measurements may be taken at the same location. Note: The SM should ensure that the surveying party is given the keys to the locking cap before starting the survey.

14.6.2 Aerial Photography

Aerial photography for nonphotogrammetic use can be obtained from the following agencies:

- Environmental Monitoring System Laboratory (EMSL), Las Vegas, Nevada
- Environmental Photographic Interpretation Center (EPIC), Warrenton, Virginia
- National Cartographic Information Center, Reston, Virginia
- Soil Conservation Service, U.S. Department of Agriculture; Eastern or Western Laboratory, Asheville, North Carolina, or Salt Lake City, Utah, respectively

- Forest Service, U.S. Department of Agriculture, Washington, D.C. (for the eastern United States and Alaska), or the appropriate regional forester in Forest Service Regions 1-6 (Montana, Colorado, New Mexico, Utah, San Francisco, and Portland)

State and local transportation departments, zoning commissions, and planning divisions or local universities may also have useful aerial photographs. The EPA Enviropod, which consists of two 70-mm cameras mounted in a pod that can be attached to a light plane, is available through EPA regional offices. Aerial photographs may be obtained rapidly using the Enviropod and EPA photographic laboratories for developing the film. The photographs are not suitable for photogrammetric use. Photogrammetric aerial photography is usually contracted.

14.6.2.1 Contracting Aerial Photography

The following provisions should be included in the contract

- Business Arrangements-These Include such Items as the cost of the aerial survey, posting of a performance bond, assumption of risks and damages, provision for periodic inspection of work, reflights, cancellation privileges, schedule for delivery and payments, and ownership and storage of negatives.
- Area to be Photographed –This includes location, size, and boundaries. These are ordinarily indicated on flight maps (1:24,000 scale) supplied by the purchaser.
- Type of Photographic Film and Filter-This includes such items as ASA exposure rating (ASA 100 is usually specified). The dimensional stability of the film base may also be specified.
- Negative Scale –The maximum scale deviation normally. allowed is ± 5 percent.
- The Aerial Camera-A National Bureau of Standards calibration report meeting U.S. Geological Survey standards for photogrammetric mapping is required. Other camera specifications include size of negative format, method of flattening film during exposure, type of shutter, focal length (usually 6 Inches), distortion characteristics of the lens, and resolving power.
- Position of Flight Lines – Lines are to be parallel, oriented in the correct compass direction, and within a stated distance from positions drawn on flight maps.
- Overlap-This is usually set at 55 to 65 percent (the average is 60 percent) along the line of flight and 15 to 45 percent (the average is 30 percent) between adjacent lines. At the ends of each flight line, two photo centers should fail outside the boundary of the tract.
- Print Alignment- Crab or drift is not to affect more than 10 percent of the print width for any three consecutive photographs.
- Tilt-This should not exceed 2 or 3 degrees for a single exposure, or average more than 1 degree for the entire project.
- Time of Photography-The season of the year and the time of day (or minimum sun angle) are usually Specified. The aerial photography should be conducted in the spring or fall when deciduous vegetation is bare and the ground is essentially free of snow cover. Ideal flight times are between 10:00 a.m. and 2:00 p.m. local standard time, or when the sun is at a minimum of 30 degrees above the horizon. Cloud or fog cover should not exceed 10 percent.

- Base Maps– If base maps or radial line plots are required, responsibility for ground control (field surveying) should be established.

- Film Processing – Included here are procedures for developing and drying negatives and for indexing and editing film rolls, plus a description of the type of photographic paper (weight, finish, and contrast) to be used.

- Quality of Negatives and Prints– Negatives and prints should be free from stains, scratches, and blemishes that detract from the Intended use.

- Materials to be Delivered-Two sets of contact prints and one set of index sheets are usually supplied. A copy of the original flight log may also be specified. Additional items such as enlargements, mosaics, maps, or plan -and profile sheets should be listed in detail. One set of contact prints should be delivered to the project manager within 5 days of the date of the photography, unless otherwise specified. The SM should arrange for additional sets of prints to be delivered at the same time if needed.

14.6.2.2 Photogrammetric Mapping

The scale of the mapping photography should be suitable for the preparation of a topographic map by photogrammetic methods at a scale and contour Interval requested by the project, usually a 1“ = 50’ scale and 2-foot contour intervals. Larger areas or areas with great differences In elevation may require a different scale.

Map accuracy shall meet or exceed the fallowing minimum standards

- For horizontal accuracy, 90 percent of all defined points should be within 1/40 Inch of their true position, and 100 percent of all defined points should be within 1/20 inch of their true position.

- For vertical accuracy, 90 percent of all contours shall be within one-half of a contour Interval, and 100 percent of all contours shall be within one contour interval. Ninety percent of all spot elevations should be accurate to within one-fourth of the contour interval, and all spot elevations should be within one-half of the contour Interval.

- Mapping should show all planimetric features including, but not limited to, buildings, walks, roads, fences, ditches, trees, utility pales, tanks, drums, lagoons, pits, ponds, and other such features visible on the photograph, as well as contours and spot elevations on roads, dikes, and ditch inverts. Assemblages of containers (e.g., drums, laboratory bottles) may be indicated by a symbol rather than by depicting individual containers. The height and estimated number of such containers should be depicted within the symbol.

- All horizontal and vertical control points should be shown on the final map along with a tabulation of coordinates and elevations. The description, origin, and elevations of the bench marks used for the mapping control should be shown on the map.

- The horizontal coordinate system should be referenced to a local recoverable baseline at the site. The state plane coordinate system should be used when it is readily available near the site. ‘

- Photographic control points must be kept outside the hazardous areas where possible.

- The map should show the basis of bearing, north arrow, date of photography, names of streets and highways, project number, project name, and a bar scale.

14.6.3 Remote Sensing

The standards for remote sensing imagery will be determined on a project specific and instrument-specific basis. Remote sensing data are used In environmental surveys and risk assessments. Methods include, but are not limited to, the fallowing:

- Satellite photography (LANDSAT, Skylab)
- Radar (side-looking airborne radar, plan positive indicator)
- Thermal imagery (infrared detectors, line scanning, Infrared photography)
- Multiband spectral imaery
- Low-altitude helicopter photography (stereograms)
- Continuous strip photography

The National Cartographic Information Center (NCIC) provides information about and access to cartographic data generated by federal, state, and local governmental bodes and by private sources. NCIC does not hold these data; It functions as a link between the user and the desired material. Requests for information may be submitted to the following agency

National Cartographic Information Center
U.S. Geological Survey
507 National Center
Reston, Virginia 22092

Records of aerial photographic coverage of the United States and outlying areas and of space imagery are maintained at the EROS Data Center in Sioux Falls, South Dakota. The Earth Resources Observation Systems (EROS) program gathers and uses remotely sensed data, collected by satellite and aircraft, of natural features and those made by humans on the earth's surface. Reference fries, consisting of microfilms of available data primarily from LANDSAT I and II, formerly known as Earth Resources Technology Satellilite (ERTS), maybe viewed at 20 locations across the United States. Purchases of such data may be made from the fallowing:

EROS Data Center
U.S. Geological Survey
Sioux Falls, South Dakota 57198

14.6.4 Hydrographic Surveys . .

Hydrographic surveys deal with the measurement and definition of the configuration of the bottom and adjacent land areas of oceans, lakes, rivers, harbors, and other bodies of water.

The size of the body of water willdictate the type of survey required to perform the necessary mapping. Surveys should conform to the requirements set forth in the *Hydrographic Survey Manual* by the U.S. Department of Commerce.

14.7 REGION-SPECIFIC VARIANCES

No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

14.8 INFORMATION SOURCES

American Society of Photogrammetry. *Manual of Photogrammetry.* 4th ad.

Averes, T. Eugene. *Interpretation of Aerial Photographs.* 2nd ed. Minneapolis, Minnesota: Burgens Publishing Company.

Federal Geodetic Control Committee. *Specification to Support Classification, Standards of Accuracy, and General Specifications of Geodetic Control Surveys.* July 1975. (Revised June 1980.)

Manual of Photographic Interpretation. Menasha, Wisconsin: Banta Publishing Company.

Moffitt, Francis H., and Harry Bouchard. *Surveying.* New York: Mtext Educational Publishers.

Pafford, William F. *Handbook of Survey Notekeeping.*

Umbach, Melvin J. *Hydrographic Survey Manual.* 4th ed. U.S. Department of Commerce, National Oceanographic and Atmospheric Administration.

SECTION 15

FIELD INSTRUMENTATION

15.0 INTRODUCTION

Section 15 provides basic information on operating various places of equipment that are typically used in the field. The purpose of this section is not to provide standard operating procedures or to establish performance criteria for field instruments. The purpose is to provide a narrative description of some instrument use approaches and techniques that have been tested on certain projects. In Fall 1987, the Contract Laboratory Program (CLP) will publish a "Field Screening Methods Catalog" that will contain detailed discussions of field analytical methods, including use of field instruments for analysis. The CLP catalog will provide a consolidated reference for use by EPA, contractors, state and local agencies, and potentially responsible parties (PRPs) who will be conducting field analysis. When this compendium is updated, it will reflect the information contained in the CLP catalog. The updated compendium will also contain information on any additional instruments that were found useful by contractors but were not included in the catalog. field monitoring instruments are used whenever the data quality objectives specify Level I and II analytical support as adequate.

The objective of Level i analysis is to generate data that are generally used in refining sampling plans and in estimating the extent of contamination at the site. This type of support provide real-time data for health and safety purposes. Additional data that can be obtained effectively by Level I analyses include pH, conductivity, temperature, salinity, and dissolved oxygen for water (see Sections 8 and 10), as well as some measurement of contamination using various kits (see Subsection 7.6).

Level I analyses are generally effective for total vapor readings using portable photoionization of flame ionization meters that respond to a variety of volatile inorganic and organic compounds (see Section 15).

Level I analysis provides data for onsite, real-time total vapor measurement, evaluation of existing conditions, refinement of sampling location, and health and safety evaluations. Data generated from Level 1 support are generally considered qualitative in nature, although limited quantitative data also can be generated. Data generated from this type of analysis provide the following:

- Identification of soil, water, air, and waste locations that have a high likelihood of showing contamination through subsequent analysis
- Real-time data to be used for health and safety consideration during site reconnaissance and subsequent intrusive activities
- Quantitative data if a contaminant is known and the instrument is calibrated to that substance

On the other hand, field analysis (see Section 7) involves the use of portable or transportable instruments that are based at or near a sampling site. Field analysis should not be confused with the process of obtaining total organic readings using portable meters. These instruments typically are used in obtaining data that is defined by data quantity objectives as Level 1. (See Section 7 for a discussion of DQO data levels.) The analytical techniques associated with these instruments are derived from the experiences of a number of contractors and EPA personnel.

Equipment users also should consult the applicable manufacturer's operating manuals, which will provide a more comprehensive guide to all facets of using field equipment. Several of the procedures discussed below refer to sections of the manufacturer's manual that are too voluminous to reproduce here. Finally, all equipment calibrations and readings that occur in the field must be recorded in the site-specific logbook.

Exhibit 15-1, modified from Tables 7-1 and 7-2 of "Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities," NIOSH / OSHA / USCG / EPA, October 1985, presents a summary of the characteristics of classes of instruments, specific examples of which are discussed in detail below.

15.1 PHOTOVAC 10A1O

15.1.1 Scope and Purpose

Subsection 15.1 discusses the use, calibration, and maintenance of the Photovac 10A1O.

15.1.2 Definitions

Carrier Gas
The gas used to transport a gaseous sample through the chromatographic column and onto the detector of a gas chromatography. In the Photovac, the carrier gas is ultra-pure air.

Photoionization Detector (PID)
The detector uses an ultraviolet light source to ionize individual molecules that have an ionization potential less than or equal to that rated for the ultraviolet light source. Gaseous contaminants are ionized as they emerge from the column, 'and the ions are then attracted to an oppositely charged electrode, causing a current and finally an electric signal to the strip chart recorder.

Retention Time
The total time required for a volatile chemical to traverse and emerge from chromatographic column into the detector, measured from the time of injection onto the column.

Site Manager (SM)
The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

Standard
This is a known concentration of a known chemical that is used to perform quantitative analysis. Either the chemical constituent(s) can be in a solution with distilled water so that a headspace is present, or it can be completely vaporized in the volatile organic analysis (VOA) vial. A syringe can be used to withdraw some of the headspace gas after the vial is agitated, and this gas can be injected into the column for chromatographic analysis. The retention times of the standard are then compared to the retention times of unknown peaks in a sample.

Volatile Contaminants
Chemicals that are characterized by low boiling points and high. vapor pressures.

Exhibit 15-1
FIELD INSTRUMENTS

Exhibit 15-1
FIELD INSTRUMENTS*

Instrument	Hazard Monitored	Application	Detection Method	Limitations	Ease of Operation	General Care and Maintenance	Typical Operating Times
Ultraviolet (UV) Photoionization Detector (PID) (Photovac 10A10) (HNU PI-101)	Many organic and some inorganic gases and vapors.	Detects total concentrations of many organic and some inorganic gases and vapors. Some identification of compounds is possible if more than one probe is used.	Ionizes molecules using UV radiation; produces a current that is proportional to the number of ions.	Does not detect methane. Does not detect a compound if the probe used has a lower energy level than the compound's ionization potential. Response may change when gases are mixed. Other voltage sources may interfere with measurements. Readings can only be reported relative to the calibration standard used. Response is affected by high humidity.	Effective use requires that the operator understands the operating principles and procedures, and is competent in calibrating, reading, and interpreting the instrument.	Recharge or replace battery. Regularly clean and maintain the instrument and accessories.	10 hours; 5 hours with strip chart recorder.
Flame Ionization Detector (FID) with Gas Chromatography Option (OVA 128)	Many organic gases and vapors.	In survey mode, detects the total concentrations of many organic gases and vapors. In gas chromatography (GC) mode, identifies and measures specific compounds. In survey mode, all the organic compounds are	Gases and vapors are ionized in a flame. A current is produced in proportion to the number of carbon atoms present.	Does not detect inorganic gases or some synthetics. Sensitivity depends on the compound. Should not be used at temperatures less than 40°F (4°C) Difficult to absolutely identify compounds.	Requires experience to interpret data correctly, especially in the GC mode. Specific identification requires calibration with specific analyte of interest.	Recharge or replace battery. Monitor fuel and/or combustion air supply gauges. Perform routine maintenance as described in the manual. Check for leaks.	8 hours; 3 hours with strip chart recorder.

Exhibit 15-1
(continued)

Instrument	Hazard Monitored	Application	Detection Method	Limitations	Ease of Operation	General Care and Maintenance	Typical Operating Times
		are ionized and detected at the same time. In GC mode, volatile species are separated.		High concentrations of contaminants or oxygen-deficient atmospheres require system modification. In survey mode, readings can be only reported relative to the calibration standard used.			
Combustible Gas Indicator (CGI) (MSA Explosimeter)	Combustible gases and vapors.	Measures the concentration of a combustible gas or vapor.	A filament, usually made of platinum, is heated by burning the combustible gas or vapor. The increase in heat is measured.	Accuracy depends, in on the difference between the the calibration and sampling temperatures. Sensitivity is a function of the differences in the chemical and physical properties between the calibration gas and the gas being sampled. The filament can be damaged by certain compounds such as silicones, halides, tetraethyl lead, and oxygen-enriched atmospheres. CGI does not provide a valid reading under oxygen-deficient conditions.	Effective use requires that the operator understands the operating principles and procedures.	Recharge or replace battery. Calibrate immediately before use.	Can be used for as long as the battery lasts, or for the recommended interval between calibration whichever is less.

Exhibit 15-1
(continued)

Exhibit 15-1
(continued)

Instrument	Hazard Monitored	Application	Detection Method	Limitations	Ease of Operation	General Care and Maintenance	Typical Operating Times
Oxygen Meter (MSA Oxygen Meter)	Oxygen (O_2).	Measures the percentage of O_2 in air.	Uses an electrochemical sensor to measure the partial pressure of O_2 in the air and converts that reading to O_2 concentration.	Must be calibrated before use to compensate for altitude and barometric pressure. Certain gases, especially oxidants such as ozone, can affect readings. Carbon dioxide (CO_2) poisons the detector cell.	Effective use requires that operator understands the operating principles and procedures.	Replace detector cell according to manufacturer's recommendations. Recharge or replace batteries before expiration of the specified interval. If the ambient air is more than 0.5% CO_2, replace or rejuvenate the O_2 detector cell frequently.	8 to 12 hours.
Direct-Reading Colorimetric Indicator Tube (Draeger)	Specific gases and vapors.	The compound reacts with the indicator chemical in the tube, producing a stain whose length or color change is proportional to the compound's concentration.	The measured concentration of the same compound may vary among different manufacturer's tubes. Many similar chemicals interfere. Greatest sources of error are (1) how the operator judges stain's end-point and (2) the tube's limited accuracy. Affected by high humidity.	Minimal operator training and expertise required.	Do not use a previously opened tube even if the indicator chemical is not stained. Check pump for leaks before and after use. Refrigerate before use to maintain shelf life of about 2 years. Check expiration date of tubes. Calibrate pump volume at least quarterly. Avoid rough handling that may cause channeling.		

Exhibit 15-1
(continued)

Instrument	Hazard Monitored	Application	Detection Method	Limitations	Ease of Operation	General Care and Maintenance	Typical Operating Times
Gamma Radiation Survey Instrument (Thyac III)	Gamma radiation.	Environmental radiation monitor.	Scintillation detector.	Does not measure alpha or beta radiation.	Extremely easy to operate, but requires experience to interpret data. Rugged, good in field use.	Must be calibrated annually at a specialized facility.	Can be used for as long as the battery lasts, or for the recommended interval between calibrations, whichever is less.
Portable Infrared (IR) Spectrophotometer	Many gases and vapors.	Measures concentration of many gases and vapors in air. Designed to quantify one- or two-component mixtures.	Passes different frequencies of IR through the sample. The frequencies adsorbed are specific for each compound.	In the field, must make repeated passes to achieve reliable results. Requires 115-volt AC power. Not approved for use in a potentially flammable or explosive atmosphere. Interference by water vapor and carbon dioxide. Certain vapors and high moisture may attach the instrument's optics, which must then be replaced.	Requires personnel with extensive experience in IR spectrophotometry.	As specified by manufacturer.	

*Source: Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, Tables 7-1 and 7-2, NIOSH/OSHA/USCG/EPA, October 1985.

15.1.3 Applicability

This procedure is applicable to Photovac 10A10s used for field and laboratory analysis.

15.1.4 Responsibilities

The SM Is responsible for monitoring the implementation of these procedures.

15.1.5 Records

Training records, maintenance records, and calibration records will be generated and maintained by the responsible organization. Maintenance, calibration, and results obtained in the field will be recorded in the site logbook.

15.1.6 Procedures

Before beginning the set-up and operation of 10A10, the following precautions should be carefully reviewed. Because of its special capabilities 10A10 requires special treatment.

1. NEVER remove the top panel with the Instrument connected to the MAINS (electrical supply); always disconnect the instrument first because of the danger of electric shock.

2. The 10A10 must always be connected to the carrier gas supply, and a continuous stream of carrier gas must be passed through the column. This arrangement maintains the column in peak condition and ready for use with a minimum of delay.

3. NEVER Inject liquid samples, however small, Into the 10A10. It is an all-gas system and is not designed to accept liquids, which will cause gross contamination and necessitate a thorough overhaul.

4. Read carefully the section in the manufacturer's manual on battery care. Avoid overcharging the batteries; otherwise, their life will be impaired.

5. Except when charging batteries, <u>always</u> unplug the unit from the MAINS (electrical supply) when it is not in use.

6. When transferring the unit from extremely cold environments into warm, humid conditions, be alert to the likelihood of condensation; if possible, allow some time for the instrument to warm up before using.

7. Establish that the Photovac 10A10 can detect the contaminate being tested for (see Exhibit 15-2). Two criteria can be followed:

    a. The Ionization potential of the compound must be less than 11 electron volts (eV).

b. The boiling point of the compound must allow for its elution through an ambient temperature column. Higher boiling points will not allow this to occur.

15.1.6.1 Startup Procedure

1. The preferred carrier gas Is Linde Air Ultra Zero or Its equivalent (with less than 0.1 ppm total organic contamination). Fit the supply cylinder with a highquality, two-stage gas chromatography (GC) regulator. Connect the regulator to the CARRIER IN fitting with 1/8-inch Teflon tubing and a brass, quick-disconnect fitting.

2. Set the flowrate to 10 ± 1 ml/min by adjusting the CARRIER FLOW adjustment. Make a_ note of the setting for future use. Check the flowrate by attaching a flow meter with 1 ml/min or better accuracy to the OUT gas fitting.

“ 3. Check that the electrical controls are set as fallows:

a. Move POWER SWITCH to OFF.

b. Move CHARGE SWITCH to OFF.

c. Move ATTENUATION SWITCH to 100 (least sensitive).

d. Move OFFSET dial to zero.

e. Connect than recorder to the coaxial OUTPUT connector, using the lead provided.

f. Set the chart recorder to 100 mV full scale and chart speed to 2 cm/min.

g. Plug the POWER CORD Into the panel socket and connect to the 115V 60 Hz AC supply the red AC indicator light will come on.

The instrument is now in its POWER DOWN condition and is ready for starting.

4. With the chart recorder off, switch on the POWER switch. The red source OFF indicator may light and stay on for up to 5 minutes. During this time, the lamp-start sequence is being automatically initiated. If more than 5 minutes Is required, an adjustment must be made to the screw next to the lamp (under the aluminum housing).

5. As soon as the SOURCE OFF light is extinguished, the meter will show a high reading that should fail rapidly as conditions in the photoionizing chamber stabilize. The reading should become steady after approximately 5 minutes.

6. Establish an acceptable baseline on the chart recorder.

7. The instrument is now ready for calibration and use.

8. The user may now make sample injections from 1 to 1,000 I (can be larger In certain situations, I.e., low-level air monitoring).

9. Reminder NEVER inject liquid samples into the Photovac.

Exhibit 15-2

SOME COMPOUNDS THAT CAN BE DETECTED USING THE PHOTOVAC 10S SERIES OF PORTABLE GCs

	eV
Acetaldehyde	10.21
Acetic acid	10.37
Acetone	9.69
Acetylene	11.41
Acetylene dichloride	9.80
Acetylene tetrabromide	
Acrolein	10.10
Acrylonitrile	10.91
Allene	9.83
Allyl alcohol	9.67
Allyl chloride	10.20
Aminoethand	9.87
Ammonia	10.15
Aniline	7.70
Anisole	8.22
Arsine	9.89
Benzaldehyde	9.53
Benzene	9.25
Benzenethiol	8.33
Benzyl chloride	10.16
Benzonitrile	9.71
Benzotrifluoride	9.68
Bromobenzene	8.98
1-Bromobutane	10.13
2-Bromobutane	9.98
1-Bromobutanone	9.54
1-Bromo-2-chloroethane	10.63
Bromochloromethane	10.77
Bromodichloromethane	
1-Bromo-3-chioropropane	
Bromoethane	10.28
Bromoethene	9.80
Bromoform	10.48
1-Bromo-3-hexanone	9.26
Bromoethane	10.53
Bromoethyl ethyl ether	10.08
1-Bromo-2-methylpropane	10.09
2-Bromo-2-methylpropane	9.89
1-Bromopentane	10.10
1-Bromopropane	10.18
2-Bromopropane	10.08
1-Bromopropene	9.30
2-Bromopropene	10.06
3-Bromopropene	9.70
2-Bromothiophene	8.63
O-bromotoluene	8.79
M-bromotoluene	8.81
P-bromotoluene	8.67
1,3-Butadiene	9.07

	eV
2,3-Butadiene	9.23
N-Butanal	9.83
2-Butanal	9.73
N-Butane	10.63
1-Butanethiol	9.14
2-Butanone	.9.53
Iso-butanol	10.47
Sec-butanol	10.23
Tert-butanol	10.25
2-Butanol	10.1
1-Butene	9.58
Cis-2-butene	9.13
Trans-2-butene	9.13
3-Butene nitrile	10.39
N-butyl acetate	10.01
Sec-butyl acetate	9.91
N-butyl alicohol	10.04
N-butyl amine	8.71
I-butyl amine	8.70
S-butyl amine	8.70
T-butyl amine	8.64
N-butyl benzene	8.69
I-butyl benzene	8.68
T-butyl benzene	8.68
Butyl cellosolve	8.68
N-butyl mercaptan	9.15
I-butyl ethanoate	9.95
Iso-butyl mercaptan	9.12
I-butyl methanoate	10.46
1 -Butyne	10.18
2-Butyne	9.85
N-butyraldehyde	9.86
Carbon disulfide	10.13
Carbon tetrachloride	11.28
Cellosolve acetate	
Chlorobenzene	9.07
Chlorobromomethane	
1-Chloro-2-bromoethane	10.63
1-Chlorobutane	10.67
2-Chlorobutane	10.65
1-Chlorobutanone	9.54
1-Chloro-2,3 epoxy propane	10.60
Chloroethane (ethyl chloride)	10.97
Chlorethene	10.00
2-Chloroethoxyethene	10.61
1-Chloro-2-fluorobenzene	9.16
1-Chloro-3-fluorobenzene	9.21
.1-Chloro-2-flouroethene (cis)	9.87
1-Chloro-2-fluoroethene(trans)	9.87
Chloroform	11.37

Exhibit 15-2
(continued)

	eV
O-chloroiodobenzene	8.35
1-Chloro-2-methylbenzene	8.72
1 Chloro-3-methylbenzene	8.61
1-Chloro-4-methylbenzene	8.78
Chloromethylethyl ether	10.08
Chloromethylmethyl ether	10.25
1-chloro-2-methylpropane	10.66
Chloroprene	
1-Chloropropane	10.82
2-Chloropropane	10.78
3-Chloropropene	10.04
P-chlorostyrene	
2-Chlorothiophene	8.68
O-chlorotoluene	8.83
M-chlorotoluene	8.83
P-chlorotoluene	8.70
Cumene (i-propyl benzene)	8.75
Crotonaldehyde	9.73
Cyanoethene	10.91
Cyanogen bromide	10.91
3-Cyanopropene	10.39
Cyclobutane	10.50
Cyclohexane	9.98
Cyclohexanone	9.14
Cyclohexene	8.95
Cyclo-octatetraene	7.99
Cyclopentadiene	8.55
Cyclopentane	10.52
Cyclopentanone	9.26
Cyclopentene	9.01
Cyclopropane	10.06
2-Decanone	9.40
1,3-Dibromobutane	
1,4-Dibromobutane	
Dibromochloromethane	10.59
Dibromochloropropane	
1,1-Dibromoethane	10.19
Dibromemethane	10.49
1,2-Dibromopropane	10.26
2,2-Dibromopropane	
1,2-Dichlorobenzene	9.07
1,3-Dichlorobenzene	9.12
1,4-Dichlorobenzene	8.94
1,3-Dichlorobutane	
1,4-Dichlorobutane	
1,4-Dichloro-2-butene (cis)	
2,2-Dichlorobutane	
2,3-Dichlorobutane	
3,4-Dichlorobutene (Freon 12)	

	eV
Dichlorodifluoromethane	11.75
1,1-Dichloroethane	11.06
1,2-Dichloroethane	11.04
Cis-dichloroethene	9.65
Trans-dichloroethene	-9.68
Dichloroethyl ether	
Dichloromethane	11.35
1,2-Dichloropropane	10.87
1,3-Dichloropropane	10.85
1,1-Dichloropropanone	9.71
2,3-Dichloropropene	9.82
Dicyclopentadiene	7.74
Dibutyl amine	7.69
Diethoxymethane	9.70
Diethyl amine	8.01
Diethyl ether	9.53
N-diethyl formamide	8.89
Diethyl ketone	9.32
Diethyl sulfide	8.43
1,2-Difluorobenzene	9.31
1,4-Difluorobenzene	9.15
Difluorodibromomethane	11.18
Difluoromethylbenzene	9.45
1,1-Dimethoxyethane	9.65
Dimethoxymethane	10.00
Diiodomethane	9.34
Diisobutyl ketone	9.04
Diisopropylamine	7.73
Dimethyl amine	8.24
2,3-Dimethylbutadiene	8.72
2,2-Dimethyl butane	10.08
2,2-Dimethyl butane-3-one	9.18
2,3-Dimethyl butane	10.02
2,3-Dimethyl-2-butene	8.30
3,3-Dimethyl butanone	9.17
Dimethyl disulfide	8.46
Dimethyl ether	10.00
Dimethylformamide	9.45
3,5-Dimethyl-4-heptanone	9.04
2,2-Dimethyl-3-pentanone	8.98
2,2-Dimethyl-propane	10.35
Dimethyl sulfide	8.69
Di-n-propyl disulfide	8.27
Di-n-propyl ether	9.27
Di-i-propyl ether	9.20
Di-n-propyl amine	7.84
Di-n-propyl sulfide	8.30
Epichlorohydrin	10.80
Ethane	11.65
Ethanal	10.21

Exhibit 16-2
(continued)

	eV
Ethanol	10.62
Ethanethiol (ethyl mercaptan)	9.29
Ethene (ethylene)	10.52
Ethyl acetate	10.11
Ethyl amine	8.86
Ethyl amyl ketone	9.10
Ethyl benzene	8.76
Ethyl bromide	10.29
Ethyl butyl ketone	9.02
Ethyl chloride (chloroethane)	10.98
Ethyl chloroacetate	10.20
Ethyl ethanoate	10.10
Ethyl disulfide	8.27
Ethylene chlorohydrin	10.90
Ethylene dibromide (EDB)	10.37
Ethylene glycol dinitrate	
Ethylene oxide	10.56
Ethyl formate	10.61
Ethyl iodide	9.33
Ethyl methanoate	10.61
Ethyl isothiocyanate	9.14
Ethyl methyl sulfide	8.55
Ethyl propanoate	10.00
Ethyl trichloroacetate	10.44
Ethylidene chloride	
Ethynylbenzene	8.82
Mono-fluorobenzene	9.20
Mono-fluoroethene	10.37
Mono-fluoromethanal	11.4
Fluorotribromomethane	10.67
O-fluorotoluene	8.92
M-fluorotoluene	8.92
P-fluorotoluene	8.79
Freon 11 ($CFCl_3$)	11.77
Freon 12 (CF_2Cl_2)	12.91
Freon 13 (CF_3Cl)	12.91
Freon 13 B-1^3	12.08
Freon 14 (neat)	16.25
Freon 22 ($CHClF_2$)	12.45
Freon 113 (CF_3CCl_3)	11.78
2-Furaldehyde	9.21
Furan	8.89
Furfuryl alcohol	
Furfural	9.21
Hexachloroethane	
N-hexane	10.18
N-heptane	10.07
2-Heptanone	9.33
4-Heptanone	9.12
1-Hexene	9.46

	eV
Hexanone	
Hexamethylbenzene	7,85
Hydrazine	
Hydrogen cyanide	13.91
Hydrogen selenide	9.88
Hydrogen sulfide	10.46
Hydrogen telluride	9.14
Iodine	9.28
Iodobenzene	8.73
1-Iodobutane	9.21
2-Iodobutane	9.09
Iodoethane (ethyl iodide)	9.33
Iodomethane (methyl iodide)	9.54
1-Iodo-2-methylpropane	9.18
1-Iodo-2-methylpropane	9.02
1-Iodopentane	9.19
1-Iodopropane	9.26
2-Iodopropane	9.17
O-Iodotoluene	8.62
M-iodotoluene	8.61
P-iodotoluene	8.50
Isoamyl acetate	9.90
Isoamyl alcohol	10.16
Isobutane	10.57
Isobutyl amine	8.70
Isobutyl acetate	9.97
Isobutyl alcohol	10.47
Isobutyl formate	10.46
Isobutyraldehyde	9.74
Isopentane	10.32
Isoprene	8.85
Isopropyl acetate	9.99
Isopropyl alcohol	10.16
Isopropyl amine	8.72
Isopropyl benzene	8.75
isopropyl ether	9.20
Isovaleraldehyde	9.71
Mesitylene	8.40
Mesityl oxide	9.08
Methanol	10.85
Methyl acetate	10.27
Methyl acrylate	10.72
Methyl amine	8.97
Methyl bromide	10.53
2-Methyl-1,3-butadiene	8.85
2-Methylbutanal	9.71
2-Methylbutane	10.31

Exhibit 15-2
(continued)

	eV
2-Methyl-1-butene	9.12
3-Methyl-1-butene	9.51
3-Methyl-2-butene	8.67
Methyl n-butyl ketone	9.34
Methyl butyrate	10.07
Methyl cellosolve	
Methyl chloroacetate	10.35
Methyl chloride	11.28
Methyl chloroform	11.25
Methylcyclohexane	9.85
4-Methylcyclohexene	8.91
Methylcyclopropane	9.52
Methyl dichloroacetate	10.44
Methyl ethanoate	10.27
Methyl ethyl ketone	9.53
Methyl ethyl sulfide	8.55
2-Methyl furan	8.39
Methyl iodine	9.54
Methyl isobutyl ketone	9.30
Methyl isobutyrate	9.98
1-Methyl-4-isopropylbenzene	
Methyl isopropyl ketone	9.32
Methyl methacrylate	9.74
Methyl methanoate	10.82
Methyl mercaptan	9.44
2-Methylpentane	10.12
3-Methylpentane	10.08
2-Methylpropane	10.56
2-Methylpropanal	9.74
2-Methyl-2-propanol	9.70
2-Methylpropene	9.23
Methyl n-propyl ketone	9.39
Methyl styrene	8.35
Morpholine	8.88
Naphthalene	8.10
Nitric oxide	9.25
Nitrobenzene	9.92
Nitrotoluene	9.43
N-nonane	
5-Nonanone	9.10
N-octane	
3-Octanone	9.19
4-Octanone	9.10
1-Octene	9.52

	eV
N-pentane	10.35
Pentachloroethane	11.28
1,3-Pentadiene (cis)	8.59
1,3-Pentadiene (trans)	8.56
Pentafluorobenzene	9.84
Pentamethylbenzene	-7.92
N-pentanal	9.82
2,4-Pentanedione	8.87
2-Pentanone	9.39
3-Pentanone	9.32
1-Pentene	9.50
Perchloroethylene	9.32
Perfluoro-2-butene	11.25
Perfluoro-1-heptene	10.48
N-perfluoropropyl iodide	10.36
(N-perfluoropropyl)-iodomethane	9.96
(N-perfluoropropyl)-methyl ketone	10.58
Phenol	8.69
Phenyl ether	8.09
Phenyl isocyanate	8.77
Phosphine	9.96
Pinene	8.07
Propadiene	10.19
N-propanal	9.95
Propane	11.07
1-Propanethiol	9.20
N-propanol	10.51
Propanone	9.69
Propenal (acrolein)	10.10
Propene	9.73
Prop-1-ene-2-ol	8.2
Prop-2-ene-1-ol	9.67
Propionaldehyde	9.98
N-propyl acetate	10.04
N-propyl alcohol	10.20
N-propyl amine	8.78
N-propyl benzene	8.72
Propylene	9.73
Propylene dichloride	
Propylene oxide	10.22
N-propyl ether	9.27
N-propyl formate	10.54
Propyne	10.36
Pyridine	9.32
Styrene	8.47

Exhibit 15-2
(continued)

	eV
Tetrabromoethane	
Tetrachloroethene	9.32
1,1,1,2-Tetrachloroethane	
1,1,2,2-Tetrachloroethane	
1,2,3,4-Tetrafluorobenzene	9.61
1,2,3,5-Tetrafluorobenzene	9.55
1,2,3,5-Tetrafluorobenzene	9.39
Tetrafluoroethene	10.12
Tetrahydrofuran	9.54
Tetrahydropyran	9.26
1,2,4,5-Tetramethylbenzene	8.03
2,2,4,4-Tetramethyl-3-pentanone	8.65
1,1,1,2-Tetrachloropropane	
1,2,2,3-Tetrachloropropane	
Thioethanol	9.29
Thiomethanol	9.44
Thiophene	8.86
1-Thiopropanol	9.20"
Toluene	8.82
Tribromoethene	9.27
1,1,1-Trichlorobutanone	9.54
1,1,1-Trichloroethane	11.25
1,1,2-Trichloroethane	
Trichloroethene	9.45
Trichloromethyl ethyl ether	10.08
1,1,2-Trichloropropane	
1,2,3-Trichloropropane	
Triethylamine	7,50
1,2,4-Trifluorobenzene	9.37
1,3,5-Trifluorobenzene	9.32
Trifluoroethene	10.14
1,1,1-Trifluoro-2-iodoethane	10.10
Trifluoroiodomethane	10.40
Trifluoromethylbenzene	9.68
Trifluoromethylcyclohexane	10.46
1,1,1-Trifluoropropene	10.9
Trimethyl amine	7.82
1,2,3-Trimethylbenzene	8.48
1,2,4-Trimethylbenzene	8.27
1,3,5-Trimethylbenzene	8.39
2,2,4-Trimethyl pentane	9.86
2,2,4-Trimethyl-3-pentanone	8.82
N-valeraldehyde	9.82
Vinyl acetate	9.19
Vinyl benzene (styrene)	8.47
Vinyl bromide	9.80
Vinyl chloride	10.00

	eV
4-Vinylcyclohexene	8.93
Vinyl ethanoate	9.19
Vinyl fluoride	10.37
Vinyl methyl ether	8.93
O-xylene	.8.56
M-xylene	8.56
P-xylene	8.45

Source: Photovac Technical Bulletin No. 11

* Many compounds with an ionization potential of 10.6 eV or less will also be detected by the Photovac TIP (Total Ionizables Present) Monitor.

15.1.6.2 Field Operation

1. Before any field analyses, use the following steps to determine that the instrument is operational. This should occur before the instrument is taken into the field.

2. Check that the lecture bottle carrier gas supply is adequate (charge supply is 1,800 psi and should last approximately 3 days).

3. Set the pressure regulator to zero (fully counter clockwise) and turn on the main valve of the lecture bottle.

4. Slowly turn the regulator control clockwise until air begins to escape from the quick disconnect connection. Allow the line to purge for a few seconds.

5. Plug the quick-disconnect fitting into the free CARRIER IN port. Shut off and disconnect the air supply in use (usually a laboratory supply). Adjust the lecture bottle regulator to approximately 40 pounds per square inch gauge (psig). Set the required flowrate by using a bubble tube.

6. With the instrument in the power-down mode, disconnect the AC power supply. Allow 15 minutes for the effect of the gas line switchover to subside. This lack of AC power automatically switches the instrument to battery power. The instrument is now completely self-contained and, together with a battery powered recorder, maybe taken into the field. Check the battery charge on the Photovac.

7. The instrument is now ready to be run through the startup procedures as discussed in Subsection 15.1.6.1.

8. if there are significant changes in ambient temperature (greater than 10F) when the instrument is moved from place to place, the column will require time to stabilize thermally. At higher sensitivities, a nonthermally stabilized column will manifest itself as baseline drift.

9. DO NOT conduct analyses while batteries are charging because heat generated during battery recharge will affect column retention times and may cause baseline drift.

15.1.6.3 Shutdown Procedure

1. Turn the POWER SWITCH to OFF.

2. Reduce the carrier gas flow to 2 cc/rein.

3. if the instrument is being returned from the field, be sure to store the instrument hooked up to a larger laboratory carrier-gas supply.

4. Maintain the battery as indicated in the manufacturer’s manual.

5. Unplug the unit except when charging batteries.

15.1.6.4 Maintenance and Calibration Schedule*

Function	**Frequency**
Battery charge when Instrument has been operating exclusively on WALL current with no use of battery	Every 3 months for 10 hours on LOW
• Battery charge when instrument has been operated off batteries	After each use, 1-1/2 hours of HIGH charge for every hour of use (DO NOT OVERCHARGE)
. Calibration (running standards)	With each use
• Septum change	After approximately 50 injection
• Column reconditioning	Every 3 months or after heavy use, or when installing a new column

---

* The maintenance and calibration functions must be documented

15.1.6.5 Calibration Procedure

1. Photovac Incorporated conducts an Instrument calibration and Includes the chromatogram as a component of that instrument's instruction manual. A check of the instrument's performance can be accomplished by duplicating the factory calibration check and comparing the results. Since the Photovac is not a direct read out instrument and instrument response can be checked by running standards and comparing retention times on different days, a calibration should be performed by running standards only. This should be done before, during, and after an analysis. The concentration and identity of the standards are left up to the user, but it is recommended that an aromatic (i.e., benzene) and a chlorinated hydrocarbon (i.e., trichloroethylene) be included. The calibration can be performed as follows:

- Prepare a standard for water or air analysis. Most standards run on the Photovac range from 0.5 to 1.0 ppm.
- Obtain a syringe and withdraw an aliquot of headspace gas that will result in peaks that are large enough to see and not so large that they do not fit on the chart paper. (Note: Water standards should be vigorously shaken for approximately 2 minutes before an aliquot is taken for injection.)
- Compare peaks of Identical standard injections made before, during, and after analyses.
- If peak heights of the above injections change significantly, note the sensitivity lost or gained on the chart paper and include this information on the resulting report.

15.1.6.6 Column Maintenance

1. The standard Photovac 10A10 is equipped with two columns. Column #l is a l-foot *long,* l/8-inch outside diameter (OD) Teflon tube packed with CSP-20M. Column #2 is a 4-foot long, l/8-inch ODTeflon tube packed with 5 percent SE-30 on 60-80 mesh Chromosorb G. Column

#l is suitable for running blanks and other quick scans but will not achieve significant separation. Column #2 is suitable for running field surveys and analyses requiring detailed separations.

2. New columns must be conditioned overnight with ultra-high purity helium (FR) or nitrogen at a temperature of 100°C at a maximum flowrate of 100 cc/min. Reconditioning of alder columns Is accomplished under the same conditions.

3. To gain access to the columns, use the following procedure:

a Disconnect the AC cord.

b. Disconnect the chart recorder lead.

c. Disconnect the lecture bottle carrier gas supply.

d. Remove the four Phillips screws securing the panel to the case, and remove the screw attaching the lid retainer to the lid. (Never remove the panel while the instrument is connected to the main power supply.)

e. Grasp the panel assembly by the cylinder damp. Gently lift the rear of the panel dear of the case rim, and ease the panel assembly backward from the front rim. Lift the panel assembly dear.

f. Gently unplug the circuit board from the wire harness connection. Remove the nine Phillips screws from the gold box, and lift dear the lid / circuit board subassembly. The interior of the column/ ion cell chamber is now accessible.

g. To remove the column, locate the two fittings at each end of the column (ion cell body and injection part). Using a 5/6 inch open-ended wrench, loosen these fittings. Unscrew the fitting with the finger and remove the column.

h. To replace the column, reverse the previous steps and take special care not to damage the thread on the fitting. Make the fittings finger tight and use the 5/16-inch open-ended wrench to give an additional 1/8 turn to assure that the fittings seat.

15.1.6.7 Septum Change

The 10A10 contains a Teflon-faced, silicone-rubber, 0.25-inch diameter septum. Hamilton “Micro Sep” F-138 is suitable. The septum can easily be replaced as fallows:

1. Unscrew the septum retainer.
2. Extinct the old septum with a fine pair of tweezers.
3. Insert the new septum with the Teflon facedown.
4. Carefully screw the retainer back into place firmly, but without Overtightening.

5. A 10- to 20-minute stabilization period maybe required because the carrier gas flow is temporarily interrupted when the septum is changed.

15.1.6.8 Troubleshooting

A list of common troubleshooting techniques for the Photovac 10A10 is provided in Exhibit 15-3.

15.1.7 Region-Specific Variances

No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

15.1.8 Information Sources

Horgan, L Proposed Guidelines for Photovac 10A10 for the Surveillance and Analysis Division. U.S. Environmental Protection Agency. 1983.

Photovac incorporated. *Photovac 10A1O Operating Manual.*

15.2 HNU PI-101

15.2.1 Purpose

Subsection 15.2 discusses the use, maintenance, and calibration of the HNU PI-101

15.2.2 Definitions

None.

15.2.3 Theory and Limitations

15.2.3.1 Theory

The HNU is a portable, nonspecific, vapor/ gas detector employing the principle of photoionization to detect a variety of chemical compounds, both organic and inorganic.

The HNU contains an ultraviolet (UV) light source within its sensor chamber. Ambient air is drawn into the chamber with the aid of a small fan. If the ionization potential (IP) of any molecule present in the ambient air is equal to or lower than the energy of the UV light source, ionization will take place, causing a deflection in the meter. Response time is approximately 90 percent at 3 seconds. The meter reading is expressed in parts per million (ppm). All readings must be stated as equivalent readings that depend on the calibration gas being used. For example, the standard gas used to calibrate the HNU is benzene, which allows the instrument to provide results in benzene equivalence. Exhibit 15-4, modified from the *"lnstrnction*

Exhibit 15-3

TROUBLESHOOTING PROCEDURES
FIELD EQUIPMENT PHOTOVAC 10A10

Problem	Probable Cause	Remedy
1. No chromatographic response	There is no carrier gas flow.	Check at OUT port with flow gauge.
	Batteries are flat (if on battery operation).	Plug into AC and check again.
	Electrometer is saturated.	Turn ATTENUATION to 10, set meter to O. If OFFSET reads 10 or more, the instrument is saturated. Allow to self-purge until clear.
	Syringe is plugged. ,	Try a new syringe.
	UV source is not on.	Check SOURCE ON light; if it is on, see item 9 in this exhibit.
2. Unacceptable baseline drift	Unit has been subjected to large temperature change.	Allow to stabilize.
	A very concentrated sample has recently been introduced, resulting in excessive tailing.	Allow to self-purge until clear.
Unacceptable baseline drift	Unacceptable contamination levels are in carrier gas supply.	Change carrier gas supply, and allow instrument to stabilize.
	The unit is charging, and the resulting heat is affecting the column.	Turn CHARGE switch to OFF.

Exhibit 15-3
(continued)

Problem	Probable Cause	Remedy
3. Deterioration of sensitivity	Syringe has leaky plunger.	Try a new syringe.
	Column needs conditioning.	Condition column.
	Septum is leaking.	Change septum.
	Column fittings leak.	Disassemble and check for leaks around fittings, while under pressure, with soap solution.
4. Unacceptable low frequency noise	Column needs conditioning.	Condition column.
5. Peaks elute very slowly	Carrier flowrate is too slow.	Adjust flowrate.
6. Peaks eluting too fast	Carrier flowrate is too high.	Adjust flowrate.
7. Peak has flat top	Electrometer has saturated.	Dilute sample and repeat.
8. Peak is misshapen, with considerable tailing	Flow is too slow.	Adjust flow.
Peak is misshapen, with considerable tailing	There is an improper injection technique.	Repeat.
	Compound is wrongly matched to column; perhaps too polar.	Select appropriate column,
	Peak is developing from an earlier injection (overlap of peaks),	Allow greater time between injections, or install shorter column.

Exhibit 15-3
(continued)

Problem	Probable Cause	Remedy
Source OFF light stays on after 5 min.	Batteries are low (if battery operation).	Plug in AC connector.
	Tube driver Is mismatched.	Contact Photovac for advice (416/881 -8225).
9. Electrometer does not return to zero after startup	Electrometer Is saturated.	Allow to self-purge.

If problems persist after trying all suggested remedies, contact Photovac Incorporated for advice.

Photovac inc.
Unit 2
134 Doncaster Avenue
Thornhill, Ontario, Canada L3T 1L3
41 6/881 -8225 Telex: 066-964634

Manual for Mode/ PI-101 Photoionization Analyzer" HNU Systems Inc., 1975, lists the relative sensitivities for various gases.

15.2.3.2 Limitations

1. If the IP of a chemical contaminant is greater than the UV light source, this chemical will not be recorded. Some contaminants cannot be determined by any sensor/ probes.

2. It should be noted, specifically, that the HNU will not detect methane.

3. During cold weather, condensation may form on the UV light source window, resulting in erroneous results.

4. Instrument readings can be affected by humidity and powerlines, making it difficult to interpret readings.

5. Total concentrations are relative to the calibration gas (usually benzene) used. Therefore, true contaminants and their quantities cannot be identified. Also, while the instrument scale reads O to 2,000 ppm, response is linear (to benzene) from O to about 600 ppm. Greater concentrations may be "read at a higher or lower level than the true value.

6. Wind speeds of greater than 3 miles an hour may affect fan speed and readings, depending on the position of the probe relative to wind direction.

15.2.4 Applicability

This procedure is applicable to HNU PI-101 instruments used for air monitoring.

15.2.5 Responsibilities

The SM Is responsible for monitoring the implementation of these procedures.

15.2.6 Records

Training records, maintenance records, and calibration records will be generated and maintained by the responsible organization. The maintenance, calibration, and results obtained in the field will be recorded in the site logbook.

15.2.7 Procedure

15.2.7.1 Maintenance and Calibration Responsibilities

The instrument user is responsible for properly calibrating and operating the instrument. When the instrument is scheduled for or requires maintenance, these functions should be conducted only by qualified individuals. If possible, maintenance responsibilities should be restricted to one or two individuals who will also bear responsibilities for logging the equipment in and out. Documentation of instrument user, dates of

Exhibit 15-4
RELATIVE SENSITIVITIES FOR VARIOUS GASES
(10.2 eV Lamp)

species	Photoionization Sensitivity*
P-xylene	11.4
M-xylene	11.2
Benzene	10.0 (reference standard)
Toluene	10.0
Diethyl sulfide	10.0
Diethyl amine	9.9
Styrene	9.7
Trichloroethylene	8.9
Carbon disulfide	7.1
Isobutylene	7.0
Acetone	6.3
Tetrahydrofuran	6.0
Methyl ethyl ketone	5.7
Methyl isobutyl ketone	5.7
Cyclohexanone	5.1
Naptha (86% aromatics)	5.0
Vinyl chloride	5.0
Methyl isocyanate	4.5
Iodine	4.5
Methyl mercaptan	4.3
Dimethyl sulfide	4.3
Allyl alcohol	4.2
Propylene	4.0
Mineral spirits	4.0
2,3-Dichloropropene	4.0
Cyclohexene	3.4
Crotonaldehyde	3.1
Acrolein	3.1
Pyridine	3.0
Hydrogen sulfide	2.8
Ethylene dibromide	2.7
N-octane	2.5
Acetaldehyde Oxime	2.3

Exhibit 15-4
(continued)

Species	Photoionization Sensitivity*
Hexane	2.2
Phosphine	2.0
Heptane	1,7
Allyl chloride (3-chloropropene)	1.5
Ethylene	1.0
Ethylene oxide	1.0
Acetic anhydride	1.0
Alpha pinene	.0.7
Dibromochloropropane	0.7
Epichlorohydrin	0.7
Nitric oxide	0.6
Beta pinene	0.5
Citral	0.5
Ammonia	0.3
Acetic Acid	0.1
Nitrogen dioxide	0.02
Methane	‘ 0.0
Acetylene	0.0
Ethylene	0.0

---

*Expressed in ppm (v/v).

Source: *Instruction Manual for Model PI-101 Photoionization Analyzer,* HNU Systems, Inc., 1975.

use, Instrument identification number, maintenance and calibration functions, and project identification should be maintained.

15.2.7.2 Operator Qualifications

The HNU, although a relatively simple instrument to use, can be incorrectly operated if the user is not thoroughly familiar with its operation. An appropriate training and certification procedure must be developed and incorporated into the responsible organization's training procedures. The users must complete the training and be certified for HNU operation before using the instrument in the field. Refresher courses should be obligatory every 6 months. Courses are given by the manufacturer, by commercial entitles, and by EPA at their Cincinnati, Ohio, and Edison, New Jersey, facilities.

15.2.7.3 Startup / Shutdown Procedures

Startup

1. Check the FUNCTION switch on the control panel to make sure it is in the OFF position. Attach the probe to the readout unit. Match the alignment key, and twist the connector clockwise until a distinct locking is fait.

2. Turn the FUNCTION witch to the BATTERY CHECK position. Check that the indicator reads within or beyond the green battery arc on the scale plate. if the indicator is below the green arc, or if the red LED comes on, the battery must be charged before using.

3. To zero the instrument, turn the FUNCTION switch to the STANDBY position and rotate the ZERO POTENTIOMETER until the meter reads zero. Wait 15 to 20 seconds to confirm that the zero adjustment is stable. if it is not, then readjust.

4. Check to see that the SPAN POTENTIOMHER is set at the appropriate setting for the probe being used (5.0 for 9.5 eV probe, 9.8 for 10.2 eV, and 5.0 for 11.7 ev).

5. Set the FUNCTION switch to the desired ppm range. A violet glow from the UV lamp source should be observable at the sample inlet of the probe/ sensor unit. (Do not look directly at the glow, since eye damage could result.)

6. Listen for the fan operation to verify fan function.

7. Check instrument with an organic point source, such as a "magic marker," before survey to verify instrument function.

Shutdown

1. Turn FUNCTION switch to OFF.

2. Disconnect the probe connector.

3. Place the instrument on the charger.

15.2.7.4 Maintenance and Calibration Schedule

Function	Frequency
• Perform routine calibration	Prior to each use*
• Initiate factory checkout and calibration	Yearly or when malfunctioning or after changing UV light source
• Wipe down readout unit	After each use
• Clean UV light source window	Every month or as use and site conditions dictate
• Clean the ionization chamber	Monthly
• Recharge battery	After each use

---

* During extended field use, the HNU PI-101 must be calibrated at least once every three days.

15.2.7.5 Calibration Procedure No. 1

For HNU calibration canisters without regulators:

1. Run through startup procedures as in Subsection 15.2.7.3.

2. Fill a sampling bag with HNU calibration gas of known contents.

3. Connect HNU probe to sampling bag by using flexible tubing.

4. Allow sample bag contents to be drawn into the probe, and check response in ppm.

5. Adjust the span potentiometer to produce the concentration listed on the span gas cylinder.Thfs procedure shall be followed only until the span potentiometer reaches the following limits

Probe	initial Span Pot. Setting	Maximum Acceptance Span Pot Setting
9.5 eV	5.0	1.0
10.2 eV	9.8	8.5
11.7eV	5.0	2.0

6. If these limits are exceeded, the instruments must be returned for maintenance and recalibration. This maintenance will be done only by qualified individuals.

7. Each responsible organization must develop a mechanism for the documentation of calibration results. This documentation includes the fallowing:

a. Date inspected

b. Person who calibrated the instrument

c. The instrument number (Serial number or other ID number)

d. The results of the calibration (ppm, probe eV, span potentiometer setting)

e. identification of the calibration gas (source, type, concentration)

15.2.7.6 calibration Procedure No. 2

For HNU calibration canisters equipped with a regulator

1. Run through startup procedures as described in Subsection 15.2.6.3.

2. Connect a sampling hose to the regulator outlet and the other end to the sampling probe of the HNU.

3. Crack the regulator valve.

4. Take a reading after 5 to 10 seconds.

5. Adjust span potentiometer using the steps outlined in step No. 5 of Subsection 15.2.7.5,

6. Calibration documentation should be as in step No. 7 in Subsection 15.2.7.5.

15.2.7.7 Cleaning the UV Light-Source Window

1. Turn the FUNCTION switch to the OFF position, and disconnect the sensor/ probe from the Readout / Control unit.

2. Remove the exhaust screw located near the base of the probe. Grasp the end cap in one hand and the probe shell in the other. Separate the end cap and lamp housing from the shell.

3. Loosen the screws on the top of the end cap, and separate the end cap and ion chamber from the lamp and lamp housing, taking care that the lamp does not fall out of the lamp housing.

4. Tilt the lamp housing with one hand over the opening so that the lamp slides out of the housing into your hand.

5. The lamp window may now be cleaned using lens paper with any of the following compounds:

   a. Use HNU Cleaning Compound on all lamps except the 11.7 eV.

b. Clean the 11.7 eV lamp with a freon or chlorinated organic solvent. Do not use HNU cleaner, water, or water miscible silvents (i.e., acetone and methanol).

6. Fallowing cleaning, reassemble by first sliding the lamp back into the lamp housing. Place the ion chamber on top of the housing, making sure the contacts are properly aligned.

7. Place the end cap on top of the ion chamber, and replace the two screws. Tighten the screws only enough to seal the O-ring. Do not overtighten.

8. Line up the pins on the base of the lamp housing with pins inside the probe shell, and slide the housing assembly into the shell it will fit only one way.

9. Replace the exhaust screw.

15.2.7.8 Cleaning the Ionization Chamber

1. Turn the FUNCTION switch to the OFF position, and disconnect the sensor/probe from the Readout / Control unit.

2. Remove the exhaust screws located near the base of the probes. Grasp the end cap in one hand and the probe shell in the other. Separate the end cap and lamp housing from the shell.

3. Loosen the screws on the top of the end cap, and separate the end cap and Ion chamber from the lamp and lamp housing, taking care that the lamp does not fall out of the lamp housing.

4. The ion chamber may now be cleaned according to the following sequence:

a. Clean with methanol using a Q-tip.

b. Dry gently at 50°C to 60°C for 1/2 hour.

5. Place the Ion chamber on top of the housing, making sure the contacts are properly aligned.

6. Place the end cap on top of the ion chamber and replace the two screws. Tighten the screws only enough to seal the O-ring. Do not overtighten.

7. Line up the pins on the base of the lamp housing with pins inside the probe shell, and slide the housing assembly into the shell. It will fit only one way.

15.2.7.9 Troubleshooting

The fallowing steps should be performed only by a qualified technician:

1. The meter does not respond in any switch position (including BATT CHK).

a. Meter movement is broken.

(1) Tip instrument rapidly from side to side. Meter needle should move freely and return to zero.

b. Electrical connection to meter Is broken

(1) Check all wires leading to meter.

(2) Clean the contacts of quick-disconnects.

c. Battery is completely dead.

(1) Disconnect battery.

(2) Check voltage with a volt-ohm meter.

d. Check 2 mp fuse.

e. If none of the above salves the problem, consult the factory.

2. Meter responds in BAIT CHK position, but reads zero or near zero for all others.

a. Power supply is defective.

(l) Check power supply voltages as shown in Figure 11 of the HNU *Instruction Manual.* If any voltage is out of specification, consult the factory.

b. input transistor or amplifier has failed.

(1) Rotate zero control; meter should deflect up or down as control is turned.

(2) Open probe. Both transistors should be fully seated in sockets.

c. Input signal connection is broken In probe or readout.

(1) Check input connector on printed circuit board. The Input connector should be firmly pressed down.

(2) Check components on back of printed circuit board. All connections should be solid, and no wires should touch any other object.

(3) Check all wires in readout for solid connections.

3. Instrument responds correctly In BAIT CHK and STBY but not in measuring mode.

a. Check to see that the light source Is on. Do not look directly at UV light source, since eye damage could result.

(1) Check high-voltage power supply.

(2) Open end of probe, remove lamp, and check high voltage on lamp ring.

(3) If high voltage Is present at all above points, light source has probably failed. consult the factory.

4. Instrument responds correctly In all positions, but signal is lower than expected.

a. Check span setting for correct value.

b. Clean window of light source.

c. Double check preparation of standards.

d. Check power supply 160 V output.

e. Check for proper fan operation. Check *fan* **voltage.**

f. Rotate span setting. Response should change if span potentiometer is working properly.

5. Instrument responds In all switch positions, but is noisy (erratic meter movement).

a. Open circuit in feedback circuit. Consult the factory

b. Open circuit in cable shield or probe shield. Consult the factory.

6. Instrument response is slow ard/or irreproducible.

a. Fan is operating Improperly. Check fan voltage.

b. Check calibration and operation.

7. The battery indicator is low.

a. Indicator comes on if battery charge is low.

b. Indicator also comes on if ionization voltage is too high.

15.2.8 Region-Specific Variances

No region-specific variances have been Identified; however, all future variances will be incorporated in subsequent revisions to this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

15.2.9 Information Sources

HNU Systems, Inc. *Instruction Manual for Model PI-1OI Photoionization Analyzer.* 1975.

Ecology and Environment FIT *Operation and Field Manual: HNU Systems PI-101 Photoionization Detector and Century Systems (Faxboro) Model OVA-128 Organic Vapor Analyzer. 1981.*

Personal Communication with Fran Connel HNU Systems, Inc. 4 January 1984.

CH2M HILL *Field Surveillance Equipment.* 1984.

Rabin, Linda J. "'Selective Application of Direct-Re&dlng Instruments at Hazardous Waste Sites," presented at American Industrial Hygiene Conference, Dallas, Texas. 1966.

15.3 ORGANIC VAPOR ANALYZER (OVA-128)

15.3.1 Scope and Purpose

The purpose of this subsection is to discuss the use, maintenance, and calibration of the OVA-128.

15.3.2 Definitions

None.

15.3.3 Theory and Limitations

15.3.3.1 Theory

The OVA uses the principle of hydrogen flame ionization for the detection and measurement of organic compounds. The OVA contains a diffusion flame of hydrogen and air that is free of ions and is nonconducting. When a sample of organic material is introduced into the flame, ions are formed, causing the flame to become conductive. Eventually this conductivity provides a meter reading because of a change in current.

15.3.3.2 Limitations

1. The OVA will not see any inorganic.
2. The OVA will "see" methane, which is explosive but relatively nontoxic. The user should. determine if the contaminant involved is or is not methane.
3. DOT shipping regulations are strict for the OVA when shipped containing pressurized hydrogen.
4. A relative humidity greater than 95 percent will cause inaccurate and unstable responses.

5. **A temperature less than 40°F will cause slow and poor response.**

6. **Actual contaminant concentrations are measured relative to the calibration gas used Therefore, specific contaminants and their quantities cannot easily be identified.**

7. As with the HNU Photoionizer, the OVA responds differently to different compounds. The table below is a list, provided by the manufacturer, of the relative sensitivities of the OVA to some common organic compounds. Since the instrument is factory calibrated to methane, all relative responses are given in percent, with methane at 100.

Compound	Relative Response
Methane	100
Ethane	90
Propane	64
N-butane	61
N-pentane	100
Ethylene	85
Acetylene	200
Benzene	150
Toluene	120
Acetone	100
Methyl ethyl ketone	80
Methyl isobutyl ketone	100
Methanol	15
Ethanol	25
Isoproply alcohol	65
Carbon tetrachloride	10
Chloroform	70
Trichloroethylene	72
Vinyl chloride	35

8. **When operated In the gas chromatography (GC) mode, chemical standards of known constituents and concentration must be analyzed by the GC. These standards must be run at the same operating conditions used in the sampling procedure, i.e., carrier gas flowrate, column type and temperature, and ambient conditions. The purpose of running standards is to determine retention times, concentrations (or instrument response), and optimal instrument operating conditions.**

15.3.4 Applicability

This procedure is applicable to ail OVA-128s used for field or laboratory applications.

15.3.5 Responsibilities

The SM is responsible for monitoring the implementation of these procedures.

15.3.6 Records

Training records, maintenance records, and calibration records will be generated and maintained by the responsible organization. The maintenance, calibration, and results obtained In the field will be recorded In the site logbook.

15.3.7 Procedure

15.3.7.1 Maintenance ● d Calibration Responsibilities

It is preferable to minimize the number of people responsible for maintenance and calibration of the OVA. These people should also be responsible for logging the equipment in and out. Documentation of instrument user, dates of use, instrument identification number, maintenance and calibration procedures, and project identification should be maintained.

15.3.7.2 Operator Qualifications

Although it Isa relatively simple instrument to use, the OVA can be Incorrectly operated if the user is not thoroughly familiar with its operation. An appropriate training and certification procedure must be developed and Incorporated Into the responsible organization's training procedures. The user must complete the training and be certified for OVA use before taking the instrument Into the field. Refresher courses should be obligatory every 6 months. Courses are offered by the manufacturer, various commercial entities, and by EPA at their Cincinnati, Ohio, and Edison, New Jersey, facilities.

15.3.7.3 Startup Procedures

1. Connect the probe / readout connectors to the side-pack assembly.

2. Check battery condition and hydrogen supply.

3. For measurements taken as methane equivalent, check that the GAS SELECT dial is set at 300.

4. Turn the electronics on by moving the INST switch to the ON position, and allow 5 minutes for warm-up.

5. Set CALIBRATE switch to X10: use CALIBRATE knob to set indicator at O.

6. Open the H_2 tank valve all the way and the H_2 supply valve all the way. Check that the hydrogen supply gauge reads between 8.0 and 12.0 psig.

7. Turn the PUMP switch ON, and check the flow system according to the procedures in Subsection 15.3.7.6.

8. Check that the BACKFLUSH and INJECT valves are in the UP position.

9. To light the flame, depress the igniter switch until a meter deflection is observed. The igniter switch may be depressed for up to 5 seconds. Do not depress for longer than 5 seconds, as it may burn out the igniter coil. If the instrument does not light, allow the instrument to run several minutes and repeat ignition attempt.

10. Confirm OVA operational state by using an organic source, such as a "magic marker."

11. Establish a background level in a clean area or by using the charcoal scrubber attachment to the probe (depress the sample inject valve) and by recording measurements referenced to background.

12. Set the alarm level, if desired.

15.3.7.4 Shutdown Procedure

1. Close H_2 supply valve and H_2 tank valve (do not overtighten valves).

2. Turn INST switch to OFF.

3. Wait until H_2 supply gauge indicates system is purged of H_2; then switch off pump (approximately 10 seconds).

4. Put instrument on electrical charger at completion of day's activities.

15.3.7.5 Maintenance and Calibration Schedule

Check particle filters	Weekly or as needed
Check quad rings	Monthly or as needed
Clean burner chamber	Monthly or as needed
Check secondary calibration	Prior to project startup
Check primary calibration	Monthly, or if secondary check is off by more than ± 10 percent
Check pumping system	Before project startup
Replace charcoal in scrubber attack ment	120 hours of use, or when background readings are higher with the inject valve down than with the inject valve up in a clean environment
Factory service	At least annually

Note: Instruments that are not in service for extended periods of time need not meet the above schedule. However, they must be given a complete checkout before their first use, addressing the maintenance items listed above.

Calibration Procedures

The following steps are to be used only by qualified service technicians:

Primary Calibration

1. Remove instrument components from the Instrument shell.

2. Turn on ELECTRONICS and ZERO INSTRUMENT on X10 scale. Gas select dial to 300.

3. Turn on PUMP and HYDROGEN. Ignite flame. Go to SURVEY MODE.

4. Introduce a methane standard near 100 parts per million (ppm).

5. Adjust R-32 Trimpot on circuit board to make meter read to standard.

6. Turn off hydrogen flame, and adjust meter needle to read 40 ppm (calibrate @X10) using the calibration adjust knob.

7. Switch to Xl 00 scale. The meter should indicate 0.4 on the 1-10 meter markings (0.4 x 100 = 40 ppm). If the reading is off, adjust with R33 Trimpot.

8. Return to X10 scale, and adjust meter needle to 40 ppm with calibration adjust knob, if necessary.

9. At the X10 scale, adjust meter to read 0.4 on the 1 to 10 meter markings using the calibration adjust. Switch to Xl scale. The meter should read 4 ppm. If the reading is off, adjust using the R31 Trimpot.

Secondary Calibration

1. Fill an air sampling bag with 100 ppm (certified) methane calibration gas.

2. Connect the outlet of the air-sampling bag to the air-sampling line of the OVA

3. Record the reading obtained from the meter on the calibration record.

Documentation

Each responsible organization should develop a system whereby the following calibration information is recorded:

- 1. Instrument calibrated (I.D. or serial number)
- 2. Date of calibration
- 3. Method of calibration

- 4. Results of the calibration
- 5. identification of person who calibrated the instrument
- 6. Identification of the calibration gas (source, type, concentration, lot number)

15.3.7.6 Pump System Checkout

“ The following steps are to be used only by qualified technicians:

1. With the pump on, hold unit upright and observe flow gauge.
2. See if ball level is significantly below a reading of 2; if so, flow is inadequate.
3. Check connections at the sample hose.
4. Clean or replace particle filters if flow is impaired or if it is time for scheduled service.
5. Reassemble and retest flow.
6. If flow Is still inadequate, replace pump diaphragm and valves.
7. If flow is normal, plug air intake.Pump should slow and stop.
8. If there is no noticeable change In pump, tighten fittings and retest.
9. If there is still no change, replace pump diaphragm and valves.
10. Document this function in the maintenance records.

15.3.7.7 Burner Chamber Cleaning

1. Remove plastic exhaust port cover.
2. Unscrew exhaust port.
3. Use wire brush to clean burner tip and electrode. Use wood stick to clean Teflon.
4. Brush inside of exhaust port.
5. Blow out chamber with a gentle airflow.
6. Reassemble and test unit.
7. Document this function in the maintenance records.

15.3.7.8 Quad Ring Service

1. Remove OVA instruments from protective shell.
2. Remove clip ring from bottom of valve.
3. Unscrew nut from top of valve.
4. Gently pull valve shaft upward and free of housing.
5. Observe rings for signs of damage; replace as necessary.
6. Lightly grease rings with silicone grease.
7. Reassemble valve; do not pinch rings during shaft insertion.
8. Document this function in the maintenance records.

15.3.7.9 Troubleshooting

Indication	Possible Causes
• High background reading (More than 10 ppm)	Contaminated hydrogen Contaminated sample line
• Continual flameout	Hydrogen leak Dirty burner chamber Dirty air filter
• Low airflow	Dirty air filter Pump malfunction Line obstruction
• flame will not light	Low battery Igniter broken Hydrogen leak Dirty burner chamber Air flow restricted
. No power to pump	Low battery Short circuit
. Hydrogen leak (Instrument not in use)	Leak in regulator Leak in valves

15.3.7.10 Hydrogen Recharging

1. High-grade hydrogen (99.999 percent) is required. Maximum pressure the instrument can handle is 2,300 psig.

2. Connect the fill hose to the REFILL FITTING on the side pack assembly with the FILL/BLEED valve in the OFF position.

3. Open H_2 SUPPLY BOTTLE valve.

4. Place FILL/BLEED valve on fill hose in BLEED position momentarily to purge any air out of the system.

5. Open the instrument TANK valve.

6. Open REFILL valve on instrument.

7. Place FILL/BLEED valve In FILL position until the instrument pressure gauge equalizes with the Hz SUPPLY BOTTLE pressure gauge.

8. Shut REFILL valve, FILL/BLEED valve, and H_2 SUPPLY BOTTLE valve, in quick succession.

9. Turn FILL/BLEED valve to BLEED until hose pressure equalizes to atmospheric pressure.

10. Turn FILL/BLEED valve to FILL position; then turn the valve to the BLEED position; then turn to OFF.

11. Close TANK on instrument.

12. Disconnect the FILL HOSE, and replace protective nut on the REFILL FITTING.

15.3.7.11 Particle Filter Servicing

Filters have been placed at two points in the air sampling line of the OVA to keep particulate from entering the instrument. The first fitter Is located in the probe assembly, and the second filter (primary filter) is located on the side pack assembly. Cleaning procedures areas follows:

1. Detach the probe assembly from the readout assembly.

2. Disassemble the probe (unscrew the components).

3. Clean the particle filter located within the probe by blowing air through the filter.

4. Reassemble the probe.

5. Gain access to the primary filter, located behind the sample inlet connector on the side pack assembly, by removing the sample inlet connector with a thin-walled, 7/16-inch socket wrench. Remove the filter, and clean as above.

6. Reassemble the sample inlet fitting and filter to the side pack assembly.

7, Check sample flowrate.

15.3.7.12 Region-Specific Variances

No region-specific variances have been identified; however, all future variances will be Incorporated in subsequent revisions to this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

15.3.7.13 information Sources

The following references were used In generating this subsection of the compendium:

Region II FIT. *Proposed Guidelines for the Organic Vapor Analyzer.* 1964.

Ecology and Environment. *FIT Operation and Field Manual: HNU Systems PI-101 Photoionization Detector and Century Systems (Faxboro) Model OVA-128 Organic Vapor Analyzer. 1981.*

Century Systems (Foxboro). Service Procedures: *Organic Vapor Analyzer;* 128GC.

CH2M HILL. *Field Surveillance Equipment.* 1984

15.4 EXPLOSIMETER

15.4.1 Scope and Purpose

This subsection provides general guidance for the understanding, use, and application of an explosimeter. The methodologies refer to explosimeters manufactured by Mine Safety Appliances Company.

15.4.2 Definitions

Explosimeter
An Instrument used to test an atmosphere for concentration of combustible gases and vapors.

Lower Explosive Limit (LEL)
The lowest concentration of a gas or vapor in air, by volume, that will explode or bum when there is an ignition source present.

Upper Explosive Limit (UEL)
The maximum concentration of a gas or vapor in air, by volume, that will explode or bum when there is an ignition source present.

15.4.3 Applicability

Explosimeters have been used during installation of monitoring wells and in and around landfills where methane gas is of primary concern. Once a monitoring well is installed, methane gas can accumulate inside the well casing and can create a potentially explosive environment.

Explosimeters have also proved useful during the excavation of buried drums and tanks. In what can sometimes seem like an Innocuous situation because of the adequate ventilation around the trench, heavier-than-air vapors can collect at the bottom of the trench to produce an explosive environment. Additionally, the explosimeter has provided service when Investigative work has discovered abandoned warehouses and storage sheds containing drums of volatile substances. The explosimeter is typically used when entering any confined space or for Initial entry on hazardous waste sites.

15.4.4 Responsibilities

Before the Instrument Is taken into the field, It should be inspected and calibrated to ensure that it is operating property. If possible, maintenance and calibration should be restricted to one or two qualified individuals.

15.4.5 Records

Logbooks should contain records of the instrument checkout and calibration procedures. Although a relatively simple instrument to use, the explosimeter can be incorrectly operated If the user Is not thoroughly familiar with Its operation. An appropriate training and certification procedure must be developed and incorporated. The users must complete the training and be certified for operation before using the explosimeter in the field. Refresher courses should be obligatory every 6 months. Courses are offered by the manufacturer, various commercial entities, and by EPA at their Cincinnati, Ohio, and Edison, New Jersey, facilities.

15.4.6 Procedures

15.4.6.1 Theory

Atypical explosimeter draws a sample of the atmosphere over a heated catalytic filament that forms a balanced electrical circuit. Combustibles that are present in the atmosphere are burned on the filament, which raises its resistance in proportion to the concentration of the combustibles In the atmosphere. The resulting imbalance of the circuit causes a deflection of the meter needle on the instrument.

15.4.6.2 Operation

The instrument must be calibrated before each field use. Calibration is performed by using a known concentration of a combustible gas that can be obtained from Mine Safety Appliances Company. Once the calibration gas Is Introduced to the instrument, adjustments can be made on an internal span control inside the explosimeter. If the explosimeter cannot be adjusted to read the standard, then the detector filament must be replaced.

To establish a zero background reading, the explosimeter should be prepared for operation in an area known to be free of combustible gases and vapors. A flush of fresh air should be passed through the instrument to zero the meter needle. The sampling line should then be placed at the point where the sample is to be collected, and the highest reading on the meter should be recorded. The graduations on the scale of the meter are in percentages of the lower explosive limit. A defection of the meter needle between zero and 100 percent shows how closely the atmosphere being tested approaches the minimum concentration required for an explosion. When the needle deflects to the extreme right side of the meter during a test, the person performing the test can reasonably assume that the atmosphere being tested is explosive. If the needle deflects to the extreme right side and then quickly returns to a position within the scale or below zero, this movement indicates that the atmosphere tested has exceeded the concentration of the UEL This means that an overabundance of the gas or vapor has displaced or consumed the "normal" air (oxygen levels of about 21 percent), creating an environment that will not explode but could explode if the oxygen levels return to normal; therefore, It is Important to continue monitoring. The user should always have the instrument on until the field team has left the atmosphere being tested and a final flush of fresh air has passed through the explosimeter to be sure that the atmosphere has been thoroughly analyzed.

15.4.6.3 Limitations and Warnings Associated with and MSA Explosimeter

As with all instruments, the user should appreciate the limits of the explosimeter's capabilities and should be sure to operate the Instrument within those limits. The following represents several important limitations:

1. The instrument Is not designed to work In an oxygen-enriched environment (oxygen above 25 percent), nor will it function properly In an oxygen-deficient atmosphere (below 19.5 percent). Therefore, it must be used in conjunction with an atmospheric oxygen indicator.

2. The Instrument will not indicate the presence of explosive or combustible mists or sprays, such as lubrication oil, or explosive dusts, such as grain or coal dusts.

3. Care should be taken when sampling over liquids so the liquid Is not drawn into the instrument.

4. The following substances may poison the detection flament: leaded gasoline, silanes, silicones, silicates, or any silicon-containing compound.

5. The relative humidity must be In the range of 10 to 90 percent.

6. The Instrument has a tolerance of 40 percent. For example, a reading of 20 percent LEL could be as high as 28 percent or as low as 12 percent.

7. The instrument must not be switched on or off unless the user is in a known combustible-free atmosphere.

8. The explosive limits for many gases and vapors are far above the threshold limit values (TLVs) for those substances.

9. Fuming acids, such as sulfuric acid and nitric acid, will also poison the detection filament.

10. The instrument Is typically calibrated with methane gas. Many other materials are explosive at concentrations below that of methane. Care must be used in a test atmosphere that may contain these types of materials. The readings obtained by the instrument are not specific. The readings indicate only that the atmosphere being measured is some percentage of the LEL of the calibration atmosphere. Therefore, the National Institute for Occupational

Safety and Health criteria shown below must be used in interpreting the readings when using the instrument In an atmosphere of unknown contaminants.

15.4.6.4 NIOSH Criteria

NIOSH guidelines on the use of the explosimeter areas follows:

1. Ten percent LEL – Limit activities in area to those that do not generate sparks; wear non-sparking gear use spark-proof equipment.

2. Twenty percent LEL – Limit all activities in area.

15.4.7 Region-Specific Variances

No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

15.4.8 Information Sources

Mine Safety Appliances Company. "instruction Manual, Model 260, Combustible Gas and Oxygen Alarm." Pittsburgh, Pennsylvania.

U.S. Environmental Protection Agency. *Standard Operating Guides.* December 1984.

NIOSH / 0SHA / USCG I EPA. *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities* October 1985.

15.5 OXYGEN INDICATOR

15.5.1 Scope and Purpose

This subsection provides general guidance for the understanding, use, and application of an oxygen indicator. The methodologies that are described refer to oxygen Indicators manufactured by Mine Safety Appliances Company.

15.5.2 Definitions

Oxygen Indicator
An instrument that provides a means to measure atmospheric oxygen concentrations. The volume percent for atmospheric oxygen is 20.95 percent.

Partial Pressure
The pressure that each gas exerts in a gas mixture (i.e., oxygen is 159 mmHg at sea level). Partial pressure is also temperature dependent.

15.5.3 Applicability

Wherever contaminants have been detected, a certain percentage of the atmosphere has been displaced, subsequently lowering the partial pressure of oxygen. In respiration, it is not the percentage of oxygen in the air, but rather its partial pressure that is important in sustaining life.

Oxygen-deficient atmospheres at hazardous waste sites often include confined spaces, such as abandoned warehouses where solvent drums are typically stored. Oxygen-deficient atmospheres could possibly be created during drum excavation in test pits where heavier-than-air vapors accumulate at the bottom of the test pit.

15.5.4 Responsibilities

Before taking the oxygen indicator into the field, the user should inspect and calibrate it to ensure its proper operation. If possible, maintenance and calibration should be restricted to one or two qualified individuals.

15.5.5 Records

Logbooks should record the oxygen indicator's checkout and calibration procedures. Although it is a relatively simple instrument to use, the oxygen indicator can be incorrectly operated if the user is not thoroughly familiar with its operation. An appropriate training and certification procedure must be developed and incorporated. The users must complete the training and be certified for operation before using the instrument in the field. Refresher courses should be obligatory every 6 months. Courses are offered by the manufacturer, by various commercial entities; and 'by E-PA at their Cincinnati, Ohio, and Edison, New Jersey, facilities.

15.5.6 Procedures

15.5.6.1 Theory

The MSA Oxygen indicator tests the partial pressure of oxygen in the atmosphere. The actual sensing device consists of an oxygen-specific permeable membrane that allows oxygen to pass into the sensor until the partial pressures equalize on both sides of the membrane. inside the sensor is an electrolyte solution that surrounds two electrodes. An oxidation-reduction reaction occurs in which the amount of current generated is directly proportional to the oxygen concentration. The change in current is detected by the meter circuit, and the needle is calibrated to indicate oxygen concentration in percentage, which is read out directly. The sensor is temperature compensated from 32°F to 104°F. The indicator response time Is increased in temperatures beyond the compensated range, partially below 32°F.

The instrument must be calibrated before using it in the field. Calibration is performed by adjusting a calibration screw when the probe is exposed to fresh air. Readings should be checked every hour in sampling areas where the temperature is not constant to attain the greatest accuracy possible.

15.5.6.2 Limitations and Warnings Associated with an MSA Oxygen Indicator

As with all instruments, the user should appreciate the limits of the oxygen indicator's capabilities and should be sure to operate it within those limits. The following represents several of the important limitations:

1. Condensation of moisture on the sensor face will cause low oxygen readings. To avoid this problem, allow the sensor to reach ambient temperature before taking readings.

2. Strong oxidants such as fluorine, chlorine, and ozone will lead to erroneously high oxygen readings when these oxidants are present in concentrations exceeding 5,000 ppm or 0.5 percent.

3. Concentrations of $C0_2$ greater than 1 percent will reduce sensor life.

4. Changes in barometric pressure because of altitude will also affect the meter reading. The instrument is calibrated for 20.8 percent oxygen at sea level (one atmosphere).

5. Relative humidity operating range is 10 to 90 percent

6. The sensor must not be touched by hands or other objects; the membrane is easily damaged.

7. Fuming acids, such as sulfuric acid or nitric acid, will poison the probe.

8. Once exposed to air, the oxygen sensor has a shelf life of approximately 1 year.

15.5.6.3 Recommended Action Levels

If the oxygen level is less than 19.5 percent, the inspection should be continued only with a self-contained breathing apparatus (SCBA) or a similar unit; the oxygen-deficient area should be identified.

If the oxygen level is more than 19.5 percent, the inspection can continue without breathing apparatus. If the cartridge will provide adequate sorbent efficiency, a cartridge respirator is acceptable. Also, the contaminant must have good warning properties, and must not react with the sorbent material in the cartridge.

If the oxygen level exceeds 25 percent, the area should be vacated, since an oxygen-rich atmosphere exists and an explosion or fire is possible.

15.5.6.4 NIOSH Criteria

Oxygen levels lower than 19.5 percent require the use of supplied-air respirators.

15.5.7 Region-Specific Variances

No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

15.5.8 Information Sources

Mine Safety Appliances Company. *"Instruction Manual* Model 260, *Combustible Gas and Oxygen Alum."* Pittsburgh, Pennsylvania.

U.S. Environmental Protection Agency. *Standard Operating Guides.* December 1984.

NIOSH / OSHA / USCG / EPA. *Occupational Safety and Health Guidance Manual for Hazardous Wrote Site Activities.* October 1985.

15.6 COMBINED COMBUSTIBLE GAS (EXPLOSIMETER) AND OXYGEN ALARM

15.6.1 Scope and Purpose

This subsection provides general guidance for the understanding, use, and application of a combined combustible gas and oxygen alarm. The methodologies refer to combined combustible gas and oxygen alarm instruments manufactured by Mine Safety Appliances Company.

15.6.2 Definitions

Explosimeter
An instrument used to test an atmosphere for concentration of combustible gases and vapors.

Lower Explosive Limit (LEL)
The minimum concentration of a gas or vapor in air by volume that will explode or burn when there is an Ignition source.

Upper Explosive Limit (UEL)
The maximum concentration of a gas or vapor in air by volume that will explode or burn when there is an ignition source.

Oxygen Indicator
An instrument that provides a means to measure atmospheric oxygen concentrations. The volume percent for atmosphere oxygen Is 20.95 percent. -

Partial Pressure
The pressure that each gas exerts in a gas mixture (Le., oxygen Is 159 mmHg at sea level). Partial pressure is also temperature dependent.

15.6.3 Applicability

The combined combustible gas and oxygen alarm can be extremely useful, since both the combustible gas and oxygen alarm are incorporated into one unit. For example, when combustible vapors are present in sufficient concentrations to displace a certain percentage of the atmosphere, this condition should be reflected as a low reading on the oxygen indicator and an elevated reading on the explosimeter. In turn, the oxygen Indicator also establishes the limits of oxygen concentration (19.5 percent to 25 percent) in which the explosimeter can function properly.

This instrument has been useful during installation of monitoring wells in and around landfills where methane gas is of concern. Confined spaces at hazardous waste sites, such as abandoned warehouses and storage sheds containing drums of volatile substances, pits, trenches, or sewers are prime examples of where the instrument has provided service.

15.6.4 Responsibilities

Before the instrument is taken into the field, it should be inspected and calibrated to ensure that it is operating properly. If possible, maintenance and calibration should be restricted to one or two qualified indiduals.

15.6.5 Records

Logbooks should record the instrument checkout and calibration procedures. Although a relatively simple instrument to use, the oxygen alarm can be incorrectly operated if the user is not thoroughly familiar with its operation. An appropriate training and certification procedure must be developed and incorporated. The users must complete the training and be certified for operation before using the instrument in the field. Courses are offered by the manufacturer, various commercial entities, and by EPA at their Cincinnati, Ohio, and Edison, New Jersey, facilities.

15.6.6 Procedures

The procedures for the confined explosimeter and oxygen indicators are the same as for the separate instruments. The reader should refer to Subsections 15.4 and 1.5.5.

15.6.7 Region-Specific Variances

No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

15.6.8 Information Sources

Mine Safety Appliances Company. "Instruction Manual, Model 260, Combustible Gas and Oxygen Alarm." Pittsburgh, Pennsylvania.

U.S. Environmental Protection Agency. *Standard Operating Guides.* December 1984.

NIOSH / OSHA / USCG / EPA. *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities.* October 1985.

15.7 VAPOR DETECTION TUBES - DRAEGER GAS DETECTOR MODEL 21/31

15.7.1 Scope and Purpose

This procedure discusses the use of Draeger tubes to determine the concentrations of specific gaseous pollutants in the field.

15.7.2 Definitions

None.

15.7.3 Theory and Limitations

15.7.3.1 Theory

A known volume of air is drawn through a reagent by using the pump and tube. The length of the color change observed in the tube translates to a ppm value.

15.7.3.2 Limitations

1. Cross sensitivity is typical.

2. Readings are not specific; there is a large degree of error (35% at 1/2 the permissible exposure limit (PEL) to 25% at 1 to 5 times the PEL).

3. A slow response time is typical.

4. Shelf life can be maintained for 2 years by refrigerating tubes.

5. Operator error in “reading” the jagged edge where the contaminant meets the indicator chemical (end point) is a major source of inaccuracy.

15.7.4 Applicability

The colorimetric tube and pump measure the concentrations of specific Inorganic and organic vapors and of gases that cause a discoloration which is proportional to the amount of material present. The detector tubes are specific for individual compounds, or groups of compounds, and require specific sampling techniques. This information is supplied with the tubes; it details the required sample volume, the proper tube preparation and insertion into the pump, and the applicability and limitations of the individual tube. Since several hundred different tubes are available, the user must consult the specific instructions for each tube.

15.7.5 Responsibilities

The SM is responsible for determining when the use of the Draeger tube is appropriate and for monitoring that the tube is properly setup for field sampling.

Personnel must be trained in the use of the detector tubes. Refresher courses should be obligatory every 6 months. Courses are offered by the manufacturer, various commercial entities, and by EPA at their Cincinnati, Ohio, and Edison, New Jersey, facilities.

15.7.6 Records

The comments dealing with the Draeger tube sampling episode should be detailed in the field logbook.

15.7.7 Procedures

15.7.7.1 Operation

A pump check should be performed each operational day. To complete this check, place an unbroken tube into the suction inlet of the pump and completely depress the bellows. The belows should not completely extend (taut chain) in fewer than 30 minutes.

15.7.7.2 Field Use

- Break off both tips of the Draeger tube(s) in the break-off eyelet located on the front pump plate.
- Tightly insert the tube into the pump head with the arrow pointing toward the pump head. If multiple tubes are used (e.g., vinyl chloride), join the tubes with the rubber tube provided, then insert the tube into the pump head.
- Fully compress the bellows and allow the bellows to re-extend until the chain is taut. Repeat as often as specified in the tube operating instructions.
- Evaluate the tube according to instructions.

15.7.7.3 In-House Handling Procedures (Check In)

- Each unit on return from the field should be subjected to the following tests with results being entered in the logbook.
- The unit will be visually examined for surface dirt, deformities, cracks, and cuts.
- The pump integrity will be checked in the following manner:

  Block the inlet with an unopened tube.
  Fully compress; then release the pump bellows. If the bellows do not completely fill (limit chain slack) in 30 minutes, the unit is operating properly. If the unit does not pass the leak test, proceed as follows:

– Remove the pump plate.
– Unscrew the valve with the special wrench.
– Clean the valve in water and dry.
- Replace the disc if it is sticky, brittle, hard, or cracked.
– Reassemble and retest.

15.7.8 Region-Specific Variances

No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

15.7.9 Information Sources

Manual of Calibration Maintenance, Service and Operation of NUS H&S Equipment and Monitoring Instruments. November 1984.

U.S. Environmental Protection Agency. Characterization *of Hazardous Waste Sites, Volume II, Available Sampling Methods.* EPA 600/X-83-018. March 1983.

15.8 FIELD EQUIPMENT- RADIATION MONITORS

15.8.1 Scope and Purpose

This subsection provides guidance in the use and implementation rationale in determining possible exposure(s) to ionizing radiation by radiation monitors. Radiation or radioactivity is the property of the nucleus of an atom to spontaneously emit energy in the form of high-energy electromagnetic waves or particles. Types of radiation that are of concern are alpha particles, beta particles, and gamma and X-radiation.

Stable atoms of an element are composed of a dense nucleus containing an equal number of protons and neutrons. Surrounding the nuleus are clouds or orbits of electrons. The number of electrons in the atom of an element equals the number of protons. The number of neutrons in the atom can vary and, if it does, the atom is known as an isotope. Most isotopes are synthetic although some, such as Cs123 and U238, occur naturally in nature. in addition, most isotopes are radioactive; they are unstable and tend to transform into an atom of a different element called a “daughter’ by releasing a particle (either alpha or beta particles) or by emission of gamma and X-rays. The type of energy released and the rate of this release (decay rate or half life) is particular to each isotope. if desired, the isotope can be identified by determining the type of energy released and by measuring the decay rate.

Radiation, unlike other chemical and physical exposures, has no real-time warning properties that are detectable by the human sensories. However, reliable radiation detectors are available.

All radiation detectors other than passive dosimeters (radiation badges) operate on the same principle; radiation causes ionization in the detection media. The ions produced are counted electronically, and a relationship is established between the number of ionizing events and the quantity of radiation present. Types of radiation detectors include the following:

- Ionization detection tubes are used primarily in high-range instruments, predominantly for detection of gamma and X-radiation.

- Proportional detection tubes inherently do not detect beta or gamma radiation; they are used primarily for detection of alpha radiation.

- Geiger-Mueller detection tubes are very sensitive to gamma and beta radiation.

- Scintillation detection media are crystal media that interact with radiation; they are highly sensitive to alpha and gamma radiation.

15.8.2 Definitions

Radiation Alert- Mini

Portable unit that detects ionizing radiation and that indicates, by using three-level scales, the actual radiation onsite with sound and light warnings and a level indicator.

ROENTGEN

The amount of gamma or X-radiation that will produce one electrostatic unit of charge in 1 cubic centimeter of dry air.

Radiation Absorbed Dose (RAD)

The quantity of radiation required for 100 ergs of energy to be absorbed by 1 gram of body tissue.

Radiation Dose Equivalent in Humans (REM)

A measure of the dose received in terms of its estimated biological effect(s) on humans.

Thermoluminescent Dosimeter (TID) Badge

A clip-on badge containing a substrate impregnated with either lithium or calcium fluoride. These materials are phosphors that store energy when exposed to ionizing radiation. When the phosphor is heated to several hundred degrees centigrade, energy is released in the form of visible light that is measured with a photometer, providing an exposure reading.

15.8.3 Applicability

For the purpose of field work and site investigations, field teams should use several types of exposure monitors during field activities. It is conceivable that during different activities (recon versus sampling), disturbing different areas of a site may expose previously undetected radiation sources.

The cross conversion of ROENTGEN, REM, and RAD depends on a “quality factor" that is specific to each radioisotope and on the energy level of the radiation. With various forms of radiation, each has a “quality factor" that is based on its estimated biological effect on humans. It, therefore, stands to reason that each radioisotope has its own respective “quality factor.”

Survey-type radiation detectors are normally calibrated against a cesium-137 gamma source. In essence, the detector is not calibrated for other isotopes. it does, however, serve as a good reference and reliative indicator for other radioisotopes. The results of survey-type radiation detectors are usually displayed by a counter or audio response, along with a readout of milliroentgen per hour (mR/hr).

15.8.4 Responsibilities

The SM should see that field personnel are equipped with TLD badges and a Radiation Alert-Mini (or similar unit) during any aspect of field work. Health and safety personnel are responsible for addressing these safety subjects in the safety plan and for seeing that TLD badges are issued and collected quarterly.

15.8.5 Records

15.8.5.1 Thermoluminescent Dosimeter (TLD) Badge

The responsible health and safety manager or designee will maintain records of TLD Issuance and results, as well as badges that are lost or exposed through nonfield (airport or dentist) activity.

15.8.5.2 Other Radiation Monitors

Health and safety personnel or their designees maintain records relative to the following:

1. Periodic calibration (according to factory specifications).

2. Major repairs (in which case the unit is to be labeled “Out of Service”).

3. Usage in the field.

4. Site safety personnel will keep records of any above background readings and action taken (to be noted on the site safety fallow-up report or by emergency phone call) to be submitted to the responsible health and safety manager.

15.8.6 Procedures

15.8.6.1 Radiation Alert- Mini

An example of a survey-type radiation detector is the Radiation Alert-Mini, manufactured by Solar Electronics, which uses a miniature geiger detector tube with a thin mica end window called the alpha window. This arrangement makes the Radiation Alert-Mini sensitive to all forms of radiation. The detector indicates all incoming radiation with an audio response and counter. The level of radiation is measured in milliroentgens per hour (mR/hr). At lower elevations natural background radiation can produce 10 to 20 counts per minute. The detector has three ranges (X1, Xl O, and Xl 00) with two alarm lights that indicate counts of 10 and 30 percent for each range, e.g., .1 mR/hr and .3 mR/hr for the Xl range, and 1 mR/hr and 3 mR/hr for the X10 range, and so on. Checkout procedures areas follows:

1. Check to see the unit is “field-ready.”

2. Check battery by switching to ON position. (Note: Field teams should bring extra batteries, especially for lengthy projects.)

3. Switch unit to AUDIO. A periodic beep and flash will indicate the unit is working, especially because of background radiation. (.01-.02 mR/hr) (Note: 10 to 20 CPM on unit.)

4. Set the scale on the unit so it falls within precautionary guidelines as follows:

If less than 2 mR/hr, continue investigation with caution.
If greater than 2 mR/hr, stop work and evacuate site.

(Note: Exact readings cannot be determined with most alert-minis. If readings above background are determined with the alert-mini, a radiation survey meter or equivalent must be used to determine exact readings before continuing operations.)

5. Note any areas that display above-background readings. If any site evacuation is needed, contact the responsible health and safety manager upon reaching an offsite "safe zone."

6. Limitations and precautions:

- When testing for alpha radiation, be sure to position the alpha window about 1.4 inch from the material under test. Alpha particles will not penetrate more than about 1 inch of air and can be shielded by thin paper or similar material.
- Avoid exposing the Radiation Alert-Mini directly to liquids and corrosive gases; also avoid extreme temperatures and direct sunlight.
- Avoid contamination by not touching the surface of material being tested.
- Calibration must be checked and performed by the factory. Annual calibration is recommended, although Its operation should be checked periodically with a low-emission source such as mantals used in gas lanterns.

15.8.6.2 Thermoluminescent Dosimeter (TLD) Badge

(Note: The TLD badge measures total quarterly cumulative. dosage to the body. ***It is by no*** *means to be used as a substitute for Radiation Alert-Mini or Thyac Ill, which measures actual site radiation.*

Radiation badges are commonly based on film dosimetry or chemical dosimetry. It is important to understand the usefulness and limitation of passive radiation dosimeters.

The conditions under which one must work are generally complex ill defined, and irregular. Perhaps the most practical method, although less accurate than real-time monitors, is to monitor radiation exposure by using dosimeters. The dosimeter, or radiation badge, usually provides enough information that the absorbed dose can be inferred from the data, The dosimeter serves as a reliable assessment of radiation exposure on a time-weighed average and activity basis. Dosimetry is a convenient method of monitoring exposure for a whole crew of individuals where other methods would otherwise be impractical, if not impossible.

Upon receipt of TLD badges for each quarter, the responsible health and safety personnel implement the following procedures:

1. Distribute TLD badges to personnel subject to potential radiation exposure during field and laboratory activities.

2. Personnel who are issued a TLD badge wear the badge on their front pockets while onsite or performing laboratory work.

3. Field team members required to go through airport baggage checks (an route to or from the site) MUST WEAR THE BADGE. (Badges packed in luggage may become exposed if passed through X-ray machines.) Do not wear badges during visits to the dentist.

4. At the end of each quarter, health and safety personnel collect the badges and return them (including the control badge) to the manufacturer (or the designated company representative) and issue new badges for the coming quarter.

5. Imitations and precautions

- Dosimetry is a measure of after-the-fact exposures.
- Badges that are not worn by workers provide little information; compliance must be monitored.
- Badges that are exposed to direct sunlight for extended periods produce false readings.
- Badges that are exposed to ionizing radiation when not in use, as in the case of security checks at airports and in the presence of color TV and microwave ovens, will produce false positive readings.

15.8.6.3 Model 490 Victoreen Thyac Ill Survey Meter

The Model 490 is a pulse-count ratemeter and power supply. With the pancake detector probe, it acts as a survey meter for alpha-beta-gamma radiation. Its range of operation is 0-80,000 cpm or 0-20 mR/hr approximate radiation intensity with appropriate detector.

Use and Operation

The instrument should be used only by persons who have been trained in the proper interpretation of its readings and in the appropriate safety procedures to be fallowed in the presence of radiation. Training courses are mandatory for all field personnel, and refresher courses should be obligatory every 6 months. Faliure to follow instructions may result in inaccurate readings and/or user hazard. Indicated battery and operational (check source) tests must be performed before each use to ensure that the instrument is functioning properly. Failure to conduct periodic performance tests in accordance with ANSI N323-1978, paragraphs 4.6 and 5.4, and failure to keep records thereof in accordance with paragraph 4.5 of the same standard could result in erroneous readings of potential danger. Do not connect or disconnect any detector while the instrument is on. Waft 2 minutes after the instrument is turned off before connecting or disconnecting any detector. Failure of transistors will occur if these instructions are not fallowed.

The Thyac Ill is designed for 100 hours of continuous use on two “D cell batteries and longer with intermittent use. Trained personnel are required to interpret its readings. The user must be sure to read the instruction manual before using. The instrument is in a weatherproof case, which contains the two operating controls (the function switch, and the response switch) on top.

A low-intensity beta check source is provided on the case. Temperature limits are -30” to + 50°C (limits for batteries may be different). The check source maybe used with a headset or an audio speaker; it may be put in a plastic bag, when appropriate, to prevent contamination.

Maintenance

Do not store the instrument with the batteries inside. Replace the batteries as indicated during the battery check performed before each use. Recalibrate the instrument periodically according to manufacturer's specifications.

15.8.6.4 Eberline Model E-120 Radiation Monitor

The Model E-120 is a gamma response radiation monitor that has dual scales (O-5 mR/hr and 0-6 CPM). This unit has three range multipliers (xO.1, x 1.0, and x 1O.O) and has adjustable response times. The general operating procedures are as follows:

Field Operation

- Switch to the battery check position to indicate the battery condition.
- Check the instrument's operation by placing a check source in a repeatable position adjacent to the detector. Move the selector switch to a range that will give an upscale reading greater than 10 percent of scale. Adjust the response control to minimize the erratic meter movements.
- Log the instrument's response value on the green tag.

In-House Handling Procedures (Check In)

- When each instrument returns from the field or at alternate 6-month maximum storage intervals,
  - Clean and visually examine the instrument for defects
  - Check its battery status
  - Validate its response to an operation check source
  - Enter the above data and any green tag data into the appropriate logbook
- At least once per year, ship each instrument to the manufacturer for recalibration.

15.8.7 Region-Specific Variances

No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. Information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practicesand requirements.

15.8.8 information Sources

Sax, N. I.. *Dangerous Properties of Industrial Material.* 6th ad. New York: Van Nostrand Reinhold Co. 1984

CH2M HILL. *Field Surveillance Equipment.* 1984.

15.9 PERSONAL SAMPLING PUMPS

15.9.1 Scope and Purpose

This subsection provides general guidance regarding the plans for, method of selection, and use of personal sampling pumps for field investigations of hazardous waste sites.

15.9.2 Definition

Personal Sample

An air sample that Is collected by a device worn on the worker; the device measures actual exposure during the work routine.

15.9.3 Applicability

This subsection discusses the use of sampling pumps for personal monitoring purposes. These guidelines are based on the objective of determining the potential exposure to a worker of air contaminants. Subsection 11.6 contains information on area sampling of ambient air.

15.9.4 Responsibilities

Field personnel must be adequately trained in the operation of personal sampling pumps. Refresher courses should be obligatory every 6 months. Courses are offered by the manufacturer, various commercial entities, and by EPA at their Cincinnati, Ohio, and Edison, New Jersey, facilities.

15.9.5 Records

Training records, maintenance records, and calibration records must be generated and maintained by the responsible organization. Specific records of field use should be noted infield notebooks as suggested in Sections 6 and 17.

15.9.6 Procedures

15.9.6.1 Preliminary Considerations

The planning, selection, and implementation of any monitoring program using personal sampling pumps require clearly defined objectives. The fallowing considerations must be examined to define what the user wants to measure:

- Worker exposure versus ambient air
- Long-term (8 hours) versus acute (momentary releases) exposure

- Vapors versus particulate

The sampling pump that is selected must also be lightweight, portable, and not affected by motion or position.

15.9.6.2 Description and Application

Personal sampling pumps come in various models. Several models offered by MSA Include the Monitaire Samplers; Models S and TD; Model C-21O Portable Pump; and the Fixt-Flo Pump, Model 1. All these models consist of a compact pump that may be clipped to the worker's belt or carried in a shift pocket so that continuous air sampling can be made. A sampling head containing the sorbent tube, filter, or other collection medium is dipped to the lapel of the worker as dose to the breathing zone as possible.

The contaminant(s) of Interest will determine the type of collection medium used with the pump. Organic and inorganic vapors, as well as particulate in the breathing zone of the worker, may be measured.

MSA Calorimetric Detector Tubes are available for measuring toxic concentrations of ammonia, carbon dioxide, carbon monoxide, chlorine, hydrogen chloride, hydrogen cyanide, hydrogen sulfide, mercury vapor, nitrogen dioxide, ozone, sulfur dioxide.

Charcoal sampling tubes are also available to provide efficient collection of organic and mercury vapors for subsequent analysis using laboratory instrumentation.

The organic vapor tube will collect compounds such as benzene, carbon tetrachloride, chloroform, dioxane, ethylene dichloride, trichloroethylene, and xylene. The mercury vapor sampling tube collects both elemental and chemically bound mercury vapors, plus particulates containing mercury.

All the above-mentioned MSA sampling pumps are rechargeable battery-operated diaphragm pumps. Flowrates maybe adjusted on all models.

As general guidance, the following procedures should be followed when using personal sampling pumps:

1. Fully charge the pump.
2. Calibrate the pump.
3. Make sure assembly does not leak by assembling the unit, covering the inlet to the sampling device, and drawing a vacuum on the assembly.
4. If no leaks occur, the sampler is ready for use.

Manufacturer's instructions should be followed for more complete guidance on using a specific model.

Certain information should be recorded in a field notebook when a personal sampling pump is used. This may include, but not be limited to the fallowing:

- Date
- Name

- Site
- Pump number
- Type of sample
- Time sampler started
- Time sampler turned off
- Flowrate
- Weather conditions

15.9.7 Region-Specific Variances

No region-specific variances have been identified; however, all future variances will be incorporated in subsequent revisions to this compendium. information on variances may become dated rapidly. Thus, users should contact the regional EPA RPM for full details on current regional practices and requirements.

15.9.8 Information Sources

MSA *Safiety Equipment Catalog. 600* Penn Center Boulevard, Pittsburgh, Pennsylvania 15235.

Cralley and Cralley. *Patty's Industrial Hygiene and Toxicology, Volume III. 1979.*

U.S. Steel Corporation. Environmental Health Services. *Environmental Health Monitoring Manual.* 1973.

15.10 OTHER MONITORING DEVICES

15.10.1 Electrochemical Gas Detector

There are many manufacturers of gas detector monitors that use electrochemical cells for detection of toxic inorganic gases. Many of these detectors are mixed oxide semiconductors (MOS) of a proprietary design, although many are of a galvanic ceil type, as previously described for the MSA oxygen indicator, but specific to the analyt gas.

Typically, one manufacturer may provide a monitor with one or more replaceable ceils. in certain instances, MOS cells for different gases can be interchanged in the same monitor. Electrochemical gas detectors are quite compact, are battery operated, have lower explosive detection (LED) readouts, and have audio alarms for present concentrations.

The Monitor Compur 4100 is an example of the MOS-based electrochemical gas detection system. The monitor offers MOS ceils for hydrogen sulfide (H_2S), hydrogen cyanide (HCN), nitrogen dioxide ($N0_2$), and phosgene ($COCl_2$).

The monitor system is designed in particular to monitor and alert the user when threshold limit values (TLV) are exceeded as follows:

H_2S – 10 ppm
HCN - 10 ppm
$N0_2$ – 5 ppm
$COCl_2$. – 0.1 ppm

Of greatest consequence many times to site investigations are phosgene and hydrogen cyanide. Electrochemical gas detection such as the monitox system offers a real-time measure of phosgene and hydrogen cyanide. Neither of these chemicals has warning properties (i.e., odor, taste) at TLV levels.

15.10.1.1 Limitations and Precaution

- Cross sensitivity to other gases can trigger false alarms.
- Chemical filter (activated charcoal) for the $C0Cl_2$ cell needs to change frequently if monitoring is in the presence of H_2S, HCl, and CL_2.
- High concentration of analyt gas, typically 100 times the TLV, can irreparably change the sensor Cell.
- Sensor cells must be protected from excessive moisture and dust-laden air.
- Service life of sensor ceils is typically 6 months during normal use.

15.10.2 Passive Dosimeters

The use of passive dosimeters or gas badges is a recent development in sampling. No energy or action is required to take the sample. Currently badges are available to sample from 15 minutes to 8 hours. These badges can be used for sampling organic vapors, formaldehyde, mercury vapor, ammonia, sulphur dioxide, and nitrogen dioxide.

Moat passive dosimeters work on the principle of diffusion. Gases and vapors enter the monitor by diffusion and are absorbed by a sorbent medium in the interior of the badge. The amount of gas or vapor adsorbed is determined by exposure time and concentration present in the monitored environment. A measured volume of an eluent is added to the monitor to desorb and disolve the contaminants. An aliquot of the eluent solution is then analyzed by analytical procedure specific to the contaminant. The weight of the contaminant is used in conjunction with the diffusion constant, as determined by the badge manufacturer, to calculate the time-weighted average worker exposure.

15.10.3 Miniram Monitor

The MINIRAM (Miniature Real-Time Aerosol Monitor) is a compact, personal size, airborne particulate monitor whose operating principle is based on the detection of scattered (nephelometric principle) electromagnetic radiation in the near infrared. The radiation scattered by airborne particles passing freely through the open sensing chamber of the monitor is sensed by a photovoltaic detector. An optical interference filter screens out light whose wavelength differs from the narrow-band pulsed source. Aerosol concentration is displayed as milligrams per cubic meter every 10 seconds. The readings are stored and integrated to provide time-weighted averages.

Calibration of the monitor Is performed by the factory against a filter gravimetric reference. The MINI-RAM has application to measuring all forms of aerosols: dusts, fumes, smokes, fogs, etc. The MINI RAM is unique in that it provides real-time semi-quantitative measurements of aerosol concentrations, unlike filtration-gravimetric methods, which require both time and laboratory facilities to complete.

The MINI RAM has particular application in monitoring ambient air for toxic aerosols or toxic elements associated or transported by aerosols.

SECTION 16

DATA REDUCTION, VALIDATION, REPORTING, REVIEW, AND USE

16.0 GENERAL

This section discusses the data validation procedures that are specific to the Contract Laboratory Program (CLP). A more detailed discussion is available in the *User's Guide to the CLP.* The section also describes data validation procedures that the Site Manager uses in evacuating any laboratory data.

16.1 NATIONAL CONTRACT LABORATORY PROGRAM - LABORATORY DATA

16.1.1 Scope and Purpose

This subsection summarizes the validation procedures used to review laboratory analyses conducted for the Contract Laboratory Program (CLP). The CLP offers routine analytical services (RAS) that deliver analyses of the Target Compound List (TCL) organic compounds, Target Analyte List (TAL) inorganic parameters, and dioxin (2,3,7,8-TCDD). Special analytical services (SAS) also are available through the CLP. These include customized or specialized analyses, quick turnaround analyses, verification analyses, analyses requiring lower detection limits than RAS methods provide, identification and quantification of nonpriority pollutant and non-TCL or non-TAL constituents, general waste characterizations, and analysis of nonstandard matrices. The validation process compares a body of data against a set of performance criteria to determine consistency and applicability to specific purposes.

16.1.2 Definitions and Abbreviations

Contract Laboratory Program (CLP)
The reader should see the *User's Guide to the CLP.*

Target Analyte List (TAL) Inorganic
23 metals and cyanide (See Section 7 of this compendium for a listing or consult the *User's Guide to the CLP.)*

Target Compound List (TCL) Organics
127 organic compounds are included on the TCL (35 volatiles, 65 semivolatiles, and 27 pesticides or PCBs) (See above.)

Routine Analytical Services (RAS)
(See the *User's Guide to the CLP.)*

Sample Management Office (SMO)
(See the *User's Guide to the CLP.)*

Site Manager (SM)
The individual responsible for the successful completion of a work assignment within budget and schedule. This person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1, 1).

Special Analytical Services (SAS)

Special Analytical Services (SAS)
(See the User's *Guide to the CLP.*)

16.1.3 Applicability

The procedures in this section apply to analyses conducted by laboratories in EPA's Contract Laboratory Program.

16.1.4 Responsibilities

Scheduling of analyses is the responsibility of the EPA Regional Sample Control Centers (RSCC). Contract laboratories analyze samples from Superfund sites under the CLP and send the reports to the Environmental Services Division (ESD). Assessment of the laboratory data package is authorized by the RSCC, which approves release of the information to the SM. Before release for use, all CLP data are reviewed and approved by the ESD of the specific EPA regional office or by its contractors to assess the applicability of each data package to its intended use. Data validators will assess the laboratory product as specified in the referenced protocols and region-specific protocols, and the validators will then make a recommendation to the ESD's regional office. ESD provides technical oversight and assistance and makes the final decision on qualifications of the laboratory data. No data are considered usable without notifying the ESD of the validation.

16.1.5 Records

The CLP RAS protocols for analyzing TCL organics, TAL inorganic, and dioxin in Superfund samples specify the report format. Examples of laboratory report forms and validation procedures for TCL organics, TAL inorganic, and dioxin are given in Appendix B, "RAS Deliverables and Data Reporting Forms," of the *User's Guide to the CLP. Several* other lengthy examples are available to the SM, such as EPA's analytical statements of work (see information sources). Laboratory report forms for SAS analyses are specified in the user-provided analytical protocol and associated quality contol (QC) procedures for each SAS request.

16.1.6 Procedures

Detailed procedures for CLP data reduction, validation, and reporting are found in the *User's Guide to the CLP.* Specific procedures for CLP validation of data are found in the standardized organic, inorganic, and dioxin CLP analytical methods; each CLP user is provided with a sample data package that contains documentation of a series of QC operations that permit an experienced chemist to determine the quality and applicability of the data. Each EPA region and CLP laboratory has established additional QC and data validation procedures.

16.2 DATA VALIDATION

16.2.1 Scope and Purpose

This section discusses both sources of data errors and approaches to reduce these errors.

16.2.2 Definitions

The reader should see Subsection 6.1.2.

16.2.3 Applicability

The procedures discussed below can be used by the SM on any project, since measurements made have inherent limitations that include the equipment and procedure Used, the skill of the person Performing the analysis, and the conditions under which it is performed. Environmental measurements are often trace analyses made at extremely low concentrations. These measurements are subject to chemical and physical interferences, instrument limitations, and uncertainties that affect the accuracy of the determination. It is essential, therefore, to minimize these factors so that the measurements accurately reflect the character of the sample collected. A systematic process to consider when measuring environmental contaminants is recommended by the American Chemical Society in “Guidelines for Data Acquistion and Data Quality Evaluation in Environmental Chemistry.” This process considers the planning, measurement, calibration standardization, quality assurance, statistical procedures, and documentation needed for high-quality analytical chemical data.

16.2.4 Responsibilities

Site Managers are ultimately responsible for obtaining valid, usable data. They are assisted by project personnel, corporate quality assurance / quality control (QA/QC) personnel, and the analyzing laboratories.

16.2.5 Records

Data validation records are included as part of the QA/QC package.

16.2.6 PROCEDURES

16.2.6.1 Exploratory (Qualitative) Investigations

Generally, analytical measurements are considered to follow a continuum of analyte concentration as shown in Exhibit 16-1. At some finite concentration, the analyte is detected at an instrument response level greater than the instrument background noise level or field blank value. Qualitative measurements depend on both the analytical method used and the concentration of the analyte in the sample.

16.2.6.2 Quantitative (Remedial, Enforcement Site Dynamics) Investigations, Reduction, and Validation

As shown in Exhibit 16-1, the numerical significance of the apparent analyte concentration increases as the analyte signal Increases above the LOD. The limit of quantitation (LOD) Is determined by the expression

$$S_t - S_b \geq K_q^s$$

where:

K_q = quantitation factor, which is usually equal to 10

$$LOQ = S_q$$

Sample analyte concentrations in the range of 3 to 10s are highly variable and are more consistent at values greater than 10s. Every analytical system contains sources of inaccuracy and imprecision that are demonstrated in the variability of replicate analyses. These inaccuracies include both systematic and random errors. Random errors are the result of (a) inherent limitations of the equipment, (b) limitations of observations, and (c) lack of care in making measurements. Random errors can be above or below the sample mean. Replicate analyses are recommended to minimize the effect of possible errors. Examples of random errors include weighing uncertainties, aliquot variabilities, sample heterogeneity, and instrument noise.

Systematic errors are consistent and bias the measurement in one direction (unless two or more systematic errors are present that affect the data in differing directions). Examples of such errors include instrument calibration error, uncompensated instrument drift, or operational errors.

These errors combine to produce measurement variability that is reflected by the indicators of measurement quality, precision, and accuracy.

- Precision is the degree of agreement among Individual measurements made under prescribed conditions using a single test procedure.
- Accuracy is the difference between an average value and the true value, when the latter is known or assumed.

Precise measurements reflect the proper use of good laboratory practices, proven methodology, and low noise instrumentation. Accuracy is confirmed by using standard reference materials and participating in interlaboratory comparison activities. Prepared standards and performance samples are available from the U.S. National Bureau of Standards, U.S. Environmental Protection Agency, U.S. Food and Drug Administration, U.S. Department of Agriculture, and various commercial sources.

16.2.6.3 Data Review and Use

The SM will perform the following for data review:

- Review data summaries and reports for transcriptional and typographical errors.
- Review and determine if sampling protocols were appropriate.
- Review and compare the data against the field and trip blanks to detect contamination from sampling (see Subsection 16.2.3).
- Review and compare field sampling replicates.
- Review laboratory QC including laboratory blanks, spike recovery, method standards, and duplicates. Are the data usable from a QC perspective?

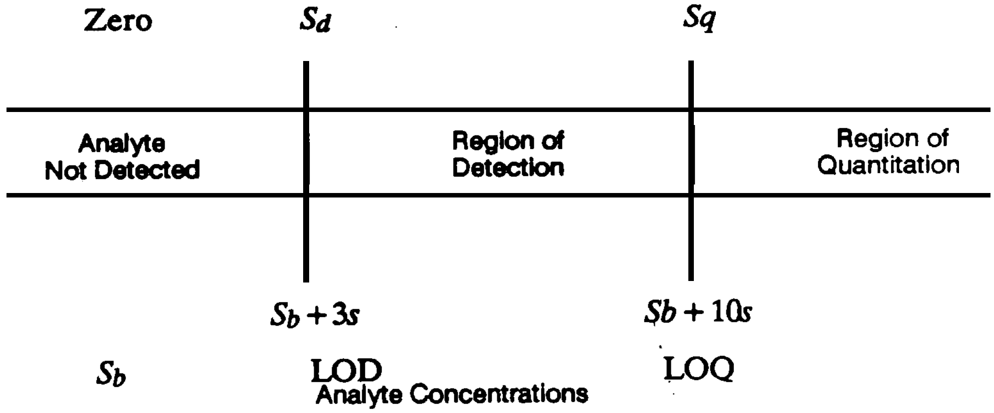
Exhibit 16-1
CONTINUUM OF ANALYTE CONCENTRATION

$$S_t - S_b \geq K_d^s$$

where:

S_t = gross signal
S_t = blank signal
K_d = response factor
s = standard deviation of measurement

This expression defines the limit of detection (LOD) where K_d is generally accepted as a value of 3



---

(1) *Anal. Chem.*, 1980, 52, 2242.

Exhibit 16-2
THE CONTENT OF VARIOUS ELEMENTS IN SOILS

Element	Common Range for Soils (ppm)	Selected Average for Soils (ppm)
Silver	0.01-5	0.05
Aluminum	10,000-300,000	71,000
Arsenic	1-50	5
Boron	2-100	10
Barium	100-3,000	430
Beryllium	0.1-40	6
Bromine	1-10	5
Carbon		20,000
Calcium	7,000-500,000	13,700
Cadmium	0.01-0.70	0.06
Chlorine	20-900	100
Cobalt	1-40	8
Chromium	1-1,000	100
Cesium	0.3-25	6
Copper	2-100	30
Fluorine	10-4,000	200
Iron	7,000-550,000	38,000
Gallium	5-70	14
Germanium	1-50	1
Mercury	0.01-0.3	0.03
Iodine	0.1-40	5
Potassium	400-30,000	8,300
Lanthanum	1-5,000	30
Lithium	5-200	20
Magnesium	600-6,000	5,000
Manganese	20-3,000	600
Molybdenum	0.2-5	2
Nitrogen	200-4,000	1,400
Sodium	750-7,500	6,300
Nickel	5-500	40
Oxygen		490,000
Potassium	200-5,000	600
Lead	2-200	10
Rubidium	50-500	10
Sulfur	30-10,000	700
Scandium	5-50	7
Selenium	0.1-2	0.3
Silicon	230,000-350,000	320,000
Tin	2-200	10
Strontium	50-1,000	200

Exhibit 16-2
(continued)

Element	Common Range for Soils (ppm)	Selected Average for Soils (ppm)
Titanium	1,000-10,000	4,000
Vanadium	20-500	100
Yttrium	25-250	50
Zinc	10-300	50
Zirconium	60-2,000	300

Source: W. Lindsay. Chemical Equilibrium in Soils.
New York: John Wiley and Sons. 1979.

- Delete unusable data and attach appropriate qualifiers to usable data. Explain limitations of qualified data.
- Review and summarize detection limits for nondetectable results.
- Review detection limits for positive but nonquantifiable data. Are appropriate qualifiers assigned?
- Review sampling design for dealing with media variability.

Background concentrations are important in the identification of site specific contamination. For each medium or operable unit, the reader should consider the following:

- Are site-specific background samples available?
- Are the data of sufficient quality to estimate site-specific background concentrations?
- If background data are lacking, can local, regional, or national averages be found and used?

It is important to understand the "background" levels of chemicals in environmental media (air, surface water, groundwater, and soil) so that remedial actions may distinguish between the elimination of ail risks and the reduction of risks to levels normally associated with the area.

"Background" is defined as the "normal ambient environmental concentration of a chemical." Background includes "natural" background and the contribution from anthropogenic (human-made) sources other than the site. "Natural" background is the range of concentrations of chemicals (primarily inorganic) naturally occurring in the environmental media. These concentrations may vary from aquifer to aquifer, depth to depth within one creek, and soil type to soil type. Anthropogenic sources include auto exhaust emissions, industrial discharges, and highway runoff.

Site-specific background samples should be taken for each environmental medium. These samples should be representative of the media on the site and should be taken at a location that is not influenced by the site. It is especially important in urban areas to take samples that can differentiate between site sources and other urban sources. When selecting the location and number of background samples, consider the variability of the medium, the number required for statistical validity, and the size of the area being defined. A minimum of three background samples should be taken in each identifiably different medium (i.e., shallow aquifer versus deep aquifer). Background values can be presented as a range, a mean, or a median; when appropriate, the confidence intervals around the mean. The appropriate measure depends on the ultimate use of the information.

if site-specific background values are not available, the reader should consult the following categories of information sources as a means of approximating background. The sources are presented in order of preference as follows:

1. Other local values, including those from other background samples taken at nearby Superfund sites; local surveys by the soil conservation service, U.S. Geological Survey (USGS); local universities; or other area-specific data sources, such as doctoral theses
2. Regional ranges and averages from USGS or other sources
3. Natural concentration ranges and averages in soil (see Exhibit 16-2)

Professional judgment will have to be exercised in selecting background values and in deciding which samples reflect site sources and which samples are consistent with background.

Once the range of background has been established, evaluation of remedial alternatives and estimation of risk can proceed.

16.3 REGIONAL VARIATIONS OF DATA VALIDATION

Each EPA region has developed variations of the CLP validation protocols for organics, inorganic, and dioxins: Because information on variances can become dated rapidly, the user should contact the EPA RPM or the RSCC that is within the ESD to obtain specific information on exceptions to these protocols. Future changes in variances will be incorporated In Revision 01 of this compendium.

16.4 INFORMATION SOURCES

U.S. Environmental Protection Agency. ***Laboratory Data Validation, Functional Guidelines for Evaluating Organics Analyses.*** Technical Directive Document No. HQ-841 0-01. Hazardous Site Control Division. May 1985.

U.S. Environmental Protection Agency. ***Statement of Work Dioxin Analysis, Soil/Sediment and Water Matrices, Multi-Concentrations, Selected Ion Monitoring (SIM) GC/MS Analysis.*** IFB WA ***86-K356.*** Sample Management Office. September 1986.

U.S. Environmental Protection Agency. ***Statement of Work, Organics Analysis, Multi-Media Multi-Concentration.*** IFB WA-87JO01, JO02, JO03. Sample Management Office. October 1966.

U.S. Environmental Protection Agency. ***Statement of Work, Inorganics Analysis, Multi-Media Multi-Concentration.*** IFB WA-85J839. Sample Management Office. July 1985. (Note: Inorganic statement of work will be updated with a new IFB to be issued in the summer of 1987.)

U.S. Environmental Protection Agency. ***User's Guide*** to ***the Contract Laboratory Program. Office*** of Emergency and Remedial Response. December **1986.**

SECTION 17

DOCUMENT CONTROL

17.1 SCOPE AND PURPOSE

This section describes procedures for the identification and control of documents that may affect the product quality for project activities. The procedures established should ensure that documents are reviewed for adequacy, completeness, and correctness and for release by authorized personnel. Changes to documents should be reviewed and approved by the authorized personnel that perform the original review and approval process or by their designees. Provisions should include identification and distribution of controlled documents; identification of personnel, position, or organizations responsible for preparing, reviewing, approving and issuing documents; and establishment of a document filing, numbering, and inventory system.

17.2 DEFINITIONS

Accountable Documents

Those documents where there is reasonable belief that they will be used as evidence during litigation. In addition to controlled documents, these documents include logbooks, field data records, sample tags / labels, chain-of-custody records, bench cards, photographs, and correspondences that contain project data of evidentiary nature.

Controlled Documents

Those documents that describe activities affecting quality which will be used for evidentiary purposes during litigation. These documents are released by authorized personnel and distributed for use by the individuals performing the activities.

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor's employee (see Subsection 1.1).

17.3 APPLICABILITY

This procedure is an applicable method to appropriately maintain the controlled and accountable evidential documents.

17.4 RESPONSIBILITIES

The originating organization will be responsible for identifying and maintaining the controlled documents in accordance with this or other quality-assurance-approved procedures.

17.5 RECORDS

Records provide the direct evidence and support for the necessary technical interpretations, judgments, and discussions concerning project activities. These records, particularly those that are anticipated to be used as evidentiary data, must directly support current or ongoing technical studies and activities and must provide the historical evidence needed for later reviews and analyses. The control of records is essential in providing evidence of technical adequacy and quality for all project activities. Records that furnish documentary evidence related to quality assurance activities will be specified, prepared and maintained. Other records to be generated during the project are specified in the work plan or task outline. Records must be legible, identifiable, and retrievable and will be protected against damage, deterioration, or loss. Requirements and responsibilities for record preparation, transmittal, distribution, retention, maintenance and disposition must be in accordance with quality-assurance-approved instructions such as those identified in this procedure.

17.6 PROCEDURES

17.6.1 Project Files

Project files are established upon Issuance of Technical Directive Documents (TDDs), Work Assignments (WAs), or award of a contract. Each project file should be identified according to site name and TDD / WA / contract number or by other appropriate means that have been documented and approved by the Site Manager (SM) or higher authority.

The SM is responsible for assuring the collection, assembly, and inventory of ail documents related to the project. The SM will designate a document custodian who will be responsible for record maintenance.

The document custodian is responsible for itemizing and, If the project size warrants, giving to the accumulated documents a unique sequential docket number. Each docket number should be logged in on a file inventory form (Exhibit 17-l). Documents should be placed Into segregated file folders according to the controlled document project Individuals who remove documents from the project file should sign out the document, give the date documents were removed, and enter the date that the documents were returned to the project file.

Access to project flies must be controlled to restrict nonproject personnel from having free and open access. An authorized access list should be placed on the central filing room door or outside each individual filing cabinet and should name the personnel who have unrestricted access to the flies. Personnel not identified on the authorized access label must obtain project file access from the document custodian or designee.

The document custodian or designee must assure that the central fifing room and individual filing cabinets are locked at the end of each day.

17.6.2 Document identification and Numbering

Every controlled document should have a unique identifier (number).

Each work plan should be identified as to project and task number (TDD/WA number), revision level number, and report status (draft /final).

Procedures and instructions must be identified and referenced as to their origination or preparer, the approving organization or personnel, the effective date, and the revision level.

Exhibit 17-1

FILE INVENTORY

Site Name ____________________

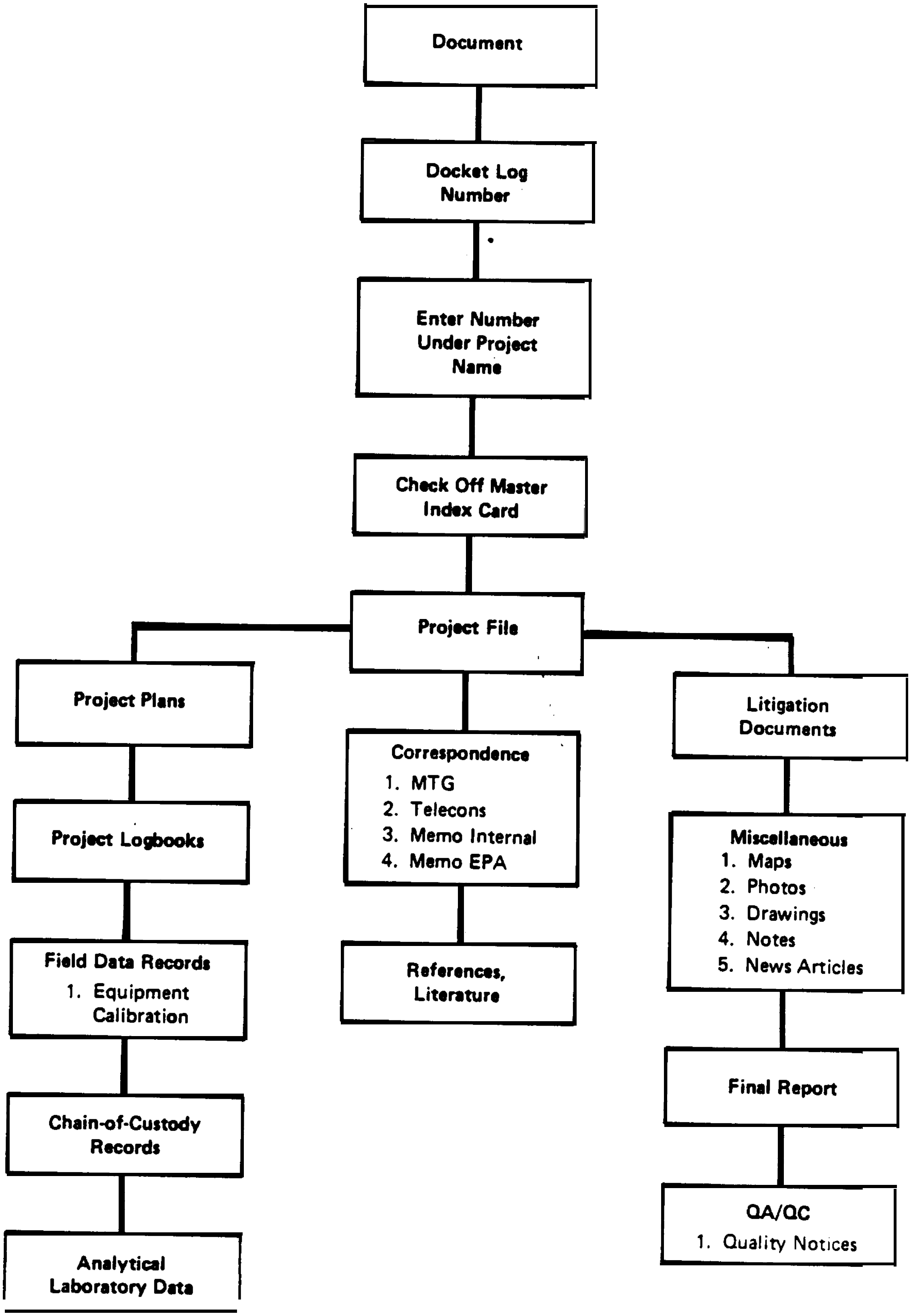
JOB No. ____________________

TDD NO. ____________________

D ____________________

Docket Number	Date of Entry	Title of Document

Exhibit 17-2
CONTROLLED DOCUMENT PROJECT FILES PROCEDURES



Each procurement document should have a sequential purchase order number or subcontract number assigned to it.

Accountable documents used by employees must be uniquely identified by serialized number or by other appropriate means. Each accountable document must be listed in a project's document inventory at the completion of each task or assignment.

Black waterproof ink must be used to record all data on or in serialized accountable documents.

Documents related to field activities, such as sample tags/ labels, chain-of-custody forms, and logbooks, will be numbered serially and their distribution will be controlled. This control is usually through the EPA office issuing the documents. The reader should refer to Section 4 of this compendium. “

17.6.3 Document Distribution

Controlled documents, such as *manuals,* procedures, instructions, and guidelines that are required for use in performing project work, should be distributed on the basis of a written, approved distribution list using a formal transmittal form, suchas shown in Exhibit 17-3, with a return receipt required.

17.6.3.1 Document Distribution to Third Parties.

All project documents generated by the Superfund contractors are the property of EPA. The distribution of such documents to stateagencies, potential responsible parties, lawyers, other regulatory agencies, or branches within the EPA must be in accordance with recommended regional EPA practices. Requests for document distribution should be in the form of a TDD, WA, or memorandum from EPA.

Distribution of internal project documents, including but not limited to photographs, logbooks, work plans, operating guidelines, sampling procedures, documentation protocols, and health and safety procedures, should be inventoried onto a chain-of-custody form by recording the transfer of the requested documents. A document transmittal form should also accompany the requested information and must record the receipt of said information as specified by the EPA. The originating request to transmit the information must come from the EPA. Otherwise, all requests from outsiders must be referred to the EPA.

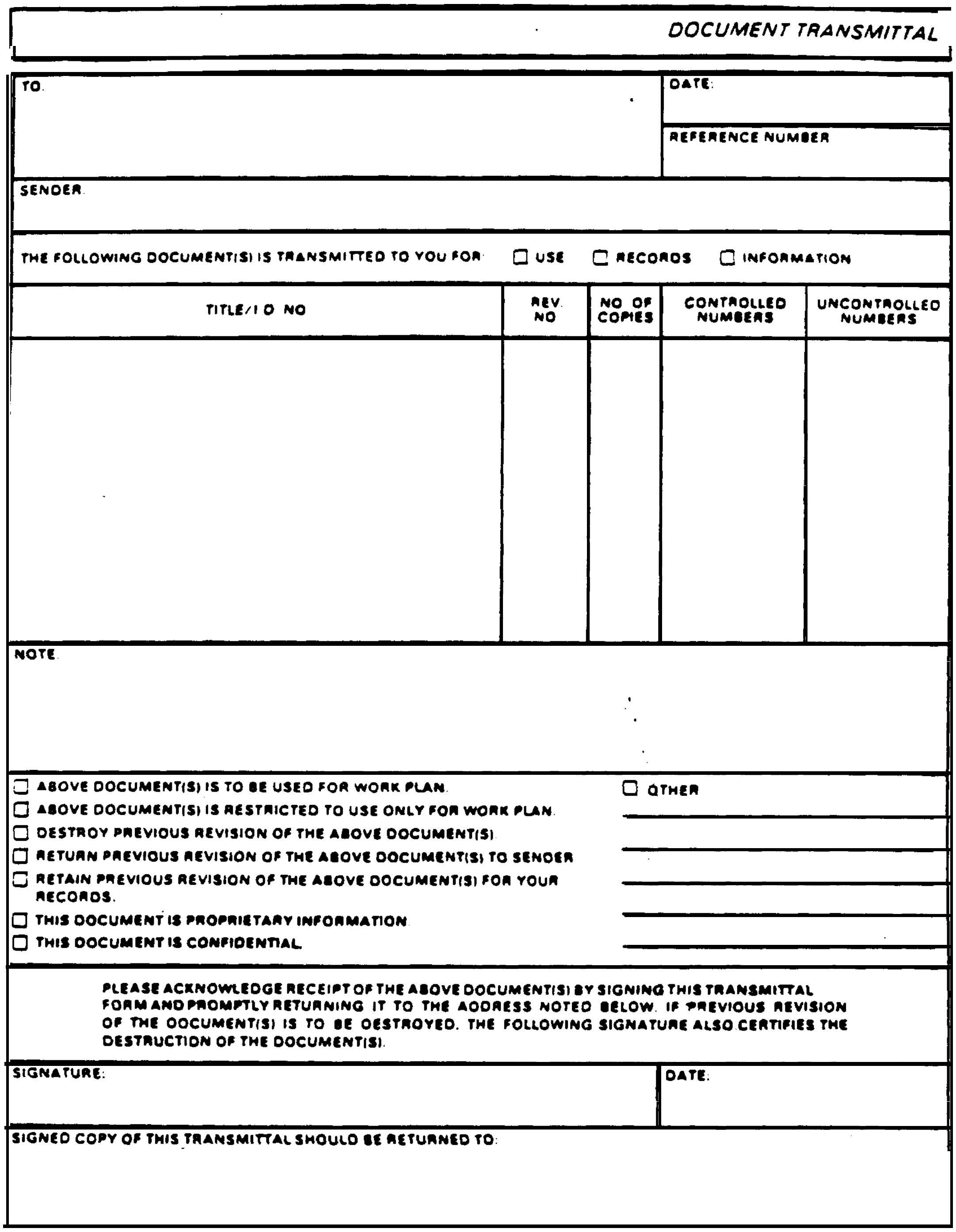
The return receipt must be documented on the controlled document transmittal log.

17.6.4 Revisions to Documentation

Major revisions to documents are subject to the same level of review and approval as the original document. Distribution of revised documents should include all holders of the original document.

Minor changes to documents, such as inconsequential editorial corrections, do not require that the revised documents receive the same review and approval as the original documents; however, they must be reviewed and approved at the highest level previously involved in review.

Exhibit 17-3
FORMAL TRANSMITTAL FORM



DOCUMENT TRANSMITTAL

TO:	DATE:
	REFERENCE NUMBER
SENDER:	

THE FOLLOWING DOCUMENT(S) IS TRANSMITTED TO YOU FOR: ☐ USE ☐ RECORDS ☐ INFORMATION

TITLE/I.D. NO	REV. NO	NO. OF COPIES	CONTROLLED NUMBERS	UNCONTROLLED NUMBERS

NOTE:

☐ ABOVE DOCUMENT(S) IS TO BE USED FOR WORK PLAN.
☐ ABOVE DOCUMENT(S) IS RESTRICTED TO USE ONLY FOR WORK PLAN.
☐ DESTROY PREVIOUS REVISION OF THE ABOVE DOCUMENT(S).
☐ RETURN PREVIOUS REVISION OF THE ABOVE DOCUMENT(S) TO SENDER.
☐ RETAIN PREVIOUS REVISION OF THE ABOVE DOCUMENT(S) FOR YOUR RECORDS.
☐ THIS DOCUMENT IS PROPRIETARY INFORMATION.
☐ THIS DOCUMENT IS CONFIDENTIAL.
☐ OTHER

PLEASE ACKNOWLEDGE RECEIPT OF THE ABOVE DOCUMENT(S) BY SIGNING THIS TRANSMITTAL FORM AND PROMPTLY RETURNING IT TO THE ADDRESS NOTED BELOW. IF PREVIOUS REVISION OF THE DOCUMENT(S) IS TO BE DESTROYED, THE FOLLOWING SIGNATURE ALSO CERTIFIES THE DESTRUCTION OF THE DOCUMENT(S).

SIGNATURE:	DATE:

SIGNED COPY OF THIS TRANSMITTAL SHOULD BE RETURNED TO:

17.6.5 Project Logbooks

Site Managers who are responsible for conducting field investigations must be issued serialized logbooks. The SM is responsible for recording all pertinent project information including, but not limited to, field work documentation; field instrumentation readings; calculations; calibration records; work plan distributions; photograph references; sample tag/label numbers; meeting information; and important times and dates of telecons, correspondences, or deliverables.

Onsite measurements and field operations are recorded in the logbooks with pertinent information necessary to explain and reconstruct sampling operations. Entries made in the log book must be dated and signed by the individual who made the entry unless entry is by the individual to whom the logbook was originally assigned. The SM or designee must sign the logbook at the close of each day; the SM may wish to review and initial each page daily.

Project logbooks are the property of the regional office and are to be turned over to the project file when a project assignment has been concluded.

As an alternative to recording detailed sampling information or instrument calibration in logbooks, separate sampling record forms may be used. However, general site information must be recorded in the logbook, and the use of such forms should be referenced in the logbook. The reader should refer also to Section 4 of this compendium.

17.6.6 Computer Codes and Documentation

Computer codes used for analysis, modeling, or design applications should be baselined, controlled, and documented. Documentation stored by computer system (e.g., chain-of-custody records and analysis reports) must be adequately safeguarded.

17.6.6.1 Documentation, Verification and Retention of Software Programs

One person must be designated as responsible for ensuring that all computer programs, whether developed internally or acquired from an outside source, are documented in sufficient detail so that each can be understood and verified by an independent reviewer. The program documentation should contain the following:

- Program Identification: Give the program name, descriptive title, and information necessary to uniquely define the current version.
- Description of Problem or Function: Define the problem to be solved or function to be performed by the program.
- Method of Solution: Summarize mathematical techniques, procedures, and numerical algorithms employed for solution.
- Related Material: List any auxiliary programs or external data files required for implementation of this program.
- Restrictions: Discuss limitations imposed by the mathematical model or computer facilities.
- Computer(s): Identify the computer(s) on which the program has been successfully executed.

- Programming languages: Indicate the languages used and approximate function of each.
- Operating Systems: Identify the software system and versions used.
- Machine Requirements: List the computer hardware required for Implementation of the program.
- Authors: Give the names and addresses of the author(s) and the Individuals currently responsible for the program.
- References: List directly related publications and other reference materials.
- User's Manual: Describe all input required for the program including input format. Include all information required for a successful computer run (e.g., special input techniques, handling of consecutive cases, default values of input parameters). Provide sample problems with control cards and physical interpretations of input and output.
- Source: List the source program as compiled or assembled.

17.6.6.2 Verification

Verification is the process of ensuring that the program performs correctly and is required for all computer programs used for quality affecting work. The extent and degree of verification will depend on the end use of the results of the analysis for which the program is employed. The extent of verification should be documented on a formal record, such as shown in Exhibit 17-4, and retained.

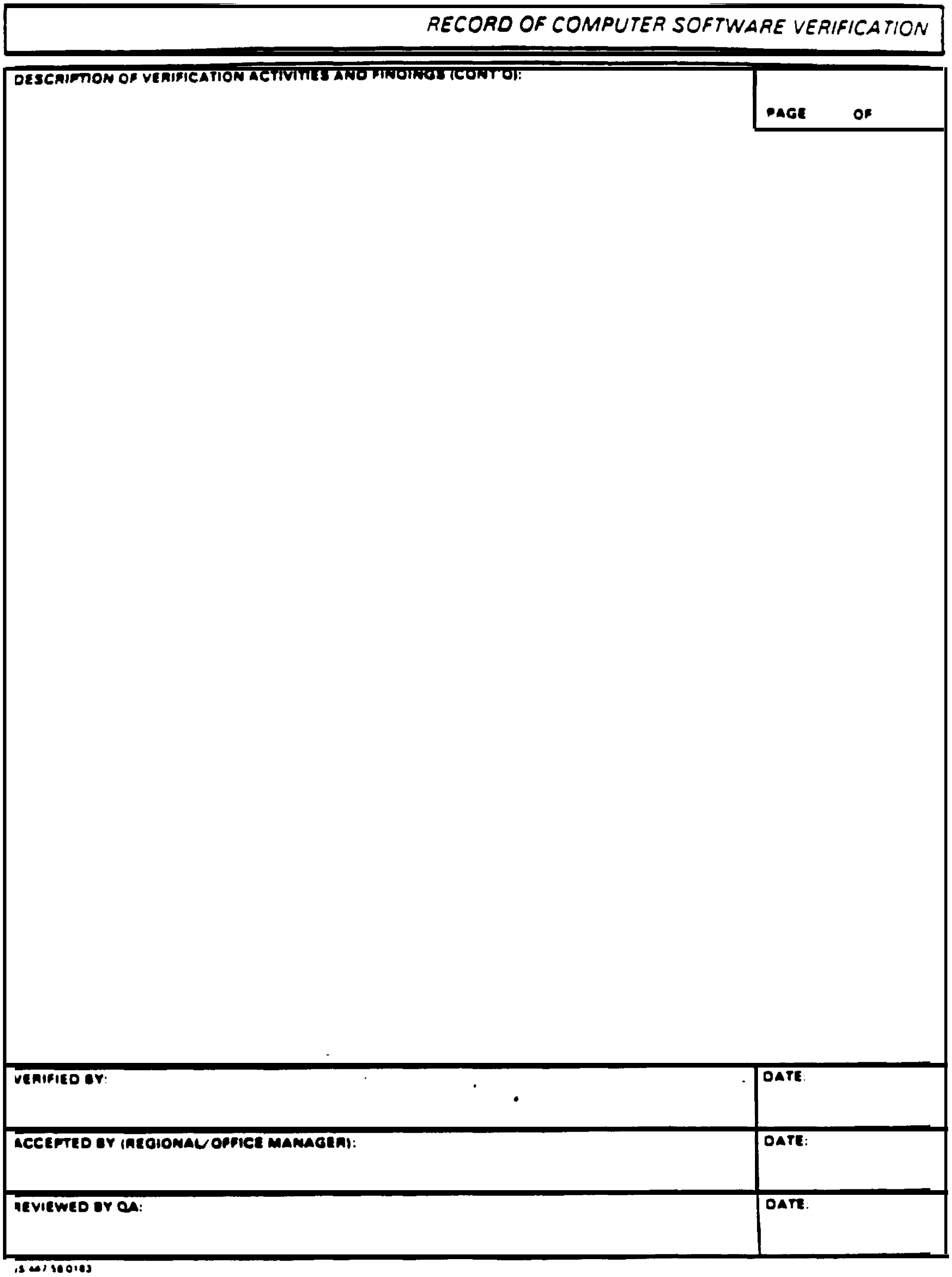
For programs that are widely used and accepted, verification maybe limited to running originator-supplied sample problems. For other programs, verification should be accomplished by checking the mathematical modeling, numerical analysis, and computer program logic, and then by doing either of the following:

- Demonstrate that the computer program solutions to a series of test problems are in substantial agreement with those obtained by a similar, independently written program in the public domain. The program from the public domain should be a generally recognized program with sufficient history to justify its applicability and validity without further demonstration.
- Demonstrate that the program's solutions to a series of test problems are in substantial agreement with those obtained by hand calculations or from accepted experimental or analytical results published in the technical literature.

The test problems chosen for program verification should be demonstrated to be representative of the range of applicability of the problems to be analyzed by the program.

The program verification should be fully documented including methods used, details of independent calculations (manual or computer), results, and conclusions. This document must be attached to the record of computer software verification.

Exhibit 17-4
RECORD OF COMPUTER SOFTWARE VERIFICATION



RECORD OF COMPUTER SOFTWARE VERIFICATION

DESCRIPTION OF VERIFICATION ACTIVITIES AND FINDINGS (CONT'D):

PAGE OF

VERIFIED BY:

DATE:

ACCEPTED BY (REGIONAL/OFFICE MANAGER):

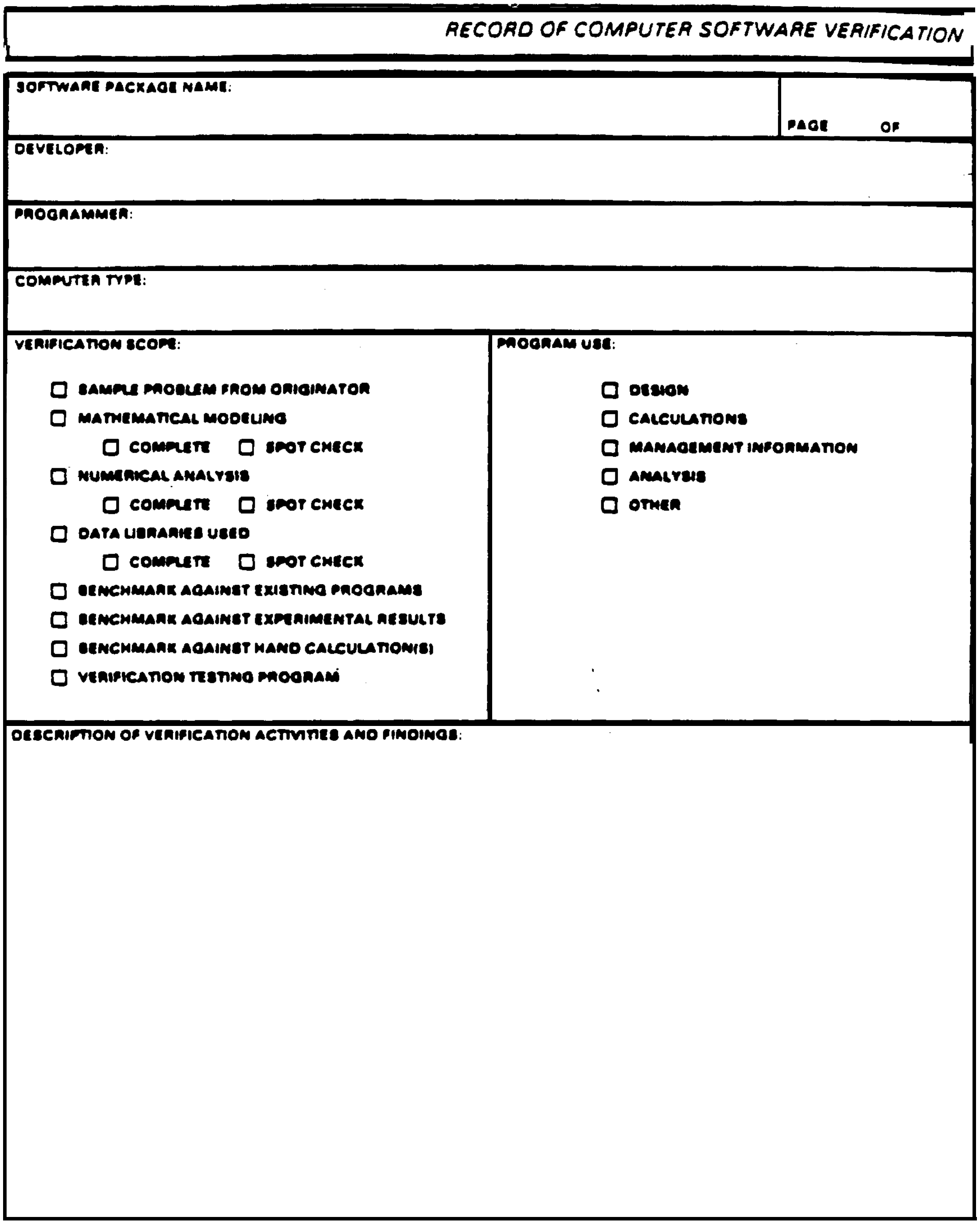
DATE:

REVIEWED BY QA:

DATE:

IS 447 5 80183

Exhibit 17-4
(continued)



RECORD OF COMPUTER SOFTWARE VERIFICATION

SOFTWARE PACKAGE NAME:

PAGE OF

DEVELOPER:

PROGRAMMER:

COMPUTER TYPE:

VERIFICATION SCOPE:

- ☐ SAMPLE PROBLEM FROM ORIGINATOR
- ☐ MATHEMATICAL MODELING
  - ☐ COMPLETE ☐ SPOT CHECK
- ☐ NUMERICAL ANALYSIS
  - ☐ COMPLETE ☐ SPOT CHECK
- ☐ DATA LIBRARIES USED
  - ☐ COMPLETE ☐ SPOT CHECK
- ☐ BENCHMARK AGAINST EXISTING PROGRAMS
- ☐ BENCHMARK AGAINST EXPERIMENTAL RESULTS
- ☐ BENCHMARK AGAINST HAND CALCULATION(S)
- ☐ VERIFICATION TESTING PROGRAM

PROGRAM USE:

- ☐ DESIGN
- ☐ CALCULATIONS
- ☐ MANAGEMENT INFORMATION
- ☐ ANALYSIS
- ☐ OTHER

DESCRIPTION OF VERIFICATION ACTIVITIES AND FINDINGS:

17.6.6.3 Retention

The documentation generated for a software program should be labeled with sufficient information to uniquely identify the version of the program to which it is applicable and should be retained in the files of the project in accordance with the applicable sections of the document control procedure described herein. A master copy of the production program disk must be maintained. No changes to this disk will be made without the proper authorization. Such authorization may be granted only after the modifications have complied with the provisions of the document control procedure.

17.6.7 Corrections to Documentation

As previously noted, the documentation in logbooks, sample tags/ labels, custody records, and other data sheets must be filled out with black ink. None of the accountable serialized documents listed are to be destroyed or thrown away, even if they are illegible or if they contain inaccuracies that require they be replaced. The person will simply void the document, note such void in the appropriate sign-out log, and maintain voided documents in a file.

If an error is made with an entry into the project logbook, a chain-of custody form, or sample tag/ label, the individual in error will draw a single line through the error and initial the error along with the appropriate date of change. The site sampler is responsible for completing necessary reports that detail sampling errors or omissions. This procedure also applies to words or figures inserted or added to a previously recorded statement.

if a sample tag/ label is lost in shipment, if a tag/ label was never prepared for a sample(s), or if a properly tagged/ labeled sample was not transferred with a formal chain-of-custody record, a written statement is prepared by the Site Manager detailing how the sample was collected. The statement should include all pertinent information, such as field logbook entries, regarding the sample and whether the sample was in the sample collector's physical possession or in a locked compartment until hand-transferred to the laboratory. Copies of the statement are distributed to the project files.

17.6.8 Confidential Information

Potentially responsible party site owners or their representatives may disclose information during investigative activities with a request for confidentiality, thus making such documents exempt for public access under the Freedom of information Act, 5 U.S.C. 9552. Only information that is specifically exempt from disclosure by other pollution control laws, (i.e., trade secret information, information compiled as investigatory records for enforcement purposes, classified information related to national security, internal rules and practices, inter-agency and intra-agency memorandums, or letters, medical records and personal fries, reports and data prepared in the regulation of financial institutions, and geological and geophysical data for oil and gas well owners and operators) must be handled as confidential in accordance with EPA's requests.

A separate, locked file must be maintained for the segregation and storage of all confidential and trade-secret information. Upon receipt, this information is directed to and recorded in a confidential inventory by the responsible individual. The information is then made available to authorized personnel, but only after it has been logged out. The information must be returned to the locked file at the concision of each working day. Confidential information may not be reproduced except upon approval by, and under the supervision of, the responsible manager. Reproduction of confidential information should be kept to an absolute minimum.

17.6.9 Disposition of Project Documents

Upon termination of the project the contents of the file are processed for storage as quality assurance records.

The cognizant project manager and document custodian are responsible for disposition of all project quality assurance records as prescribed in the work plan for that project and in the applicable procedures.

The quality assurance records retained must be dispositioned as required by the EPA. Current procedures are that all Superfund contractors' files are microfiche for transmittal to the National Archives,

17.7 REGION-SPECIFIC VARIANCES

These procedures are applicable to activities carried out in all 10 EPA regions; however, slight variations in the application of these procedures may occur. EPA Region V has indicated the following variations. Regarding Section 17,6.1, Project Files, Region V does not use the authorized-access listing approach to limit access to files, All Region V personnel have access to fries unless the files are identified as confidential. Also, Region V does not use separate file folders to segregate information. Pertaining to Section 17.6.2, Document Identification and Numbering, Region V handles field activity documents, such as sample tags and traffic reports, through a system that is independent from office file document control systems.

For Section 17.6.6, sample identification Documents, all unused fried sampling documents in Region V are kept by the person to whom they were assigned and maintained for future use. This information should be recorded In the sampling logbook.

Exhibit 17-1, File inventory, Is the same as Region V's Document Control Log Sheet. Because variances can become dated rapidly, the user should contact the EPA RPM for current information, All further regional variations will be Incorporated in Revision 01 of this compendium.

17.8 INFORMATION SOURCES

Environmental Law institute. Duties to Report or *Disclose Information on the Environmental Aspects of Business Activities.* September 1964; revised September 1985.

National Enforcement investigations Center. *Enforcement Considerations for Evaluations of Uncontrolled Hazardous Waste Disposal Sites by Contractors.* Denver, Colorado. April 1960.

Toledo Edison Company. *Quality Assurance Program Specifications for Operations Phase Suppliers/ Contractors.* Davis-Besse Nuclear Power Station. (No date of publication.)

U.S. Department of Energy. *QualityAssumnce Handbook for Geologic Investigations.* National Waste Terminal Storage Program. October 1962.

U.S. Environmental Protection Agency. *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. Office of* Monitoring Systems and Quality Assurance, Office of Research and Development. Washington, D.C. *29* December 1960.

SECTION 18

CORRECTIVE ACTION

18.1 SCOPE AND PURPOSE

The corrective action program covers the analysis of the cause(s) of any negative audit findings and the corrective actions required. This program includes the investigation of the causes of significant or repetitious unsatisfactory conditions relating to the quality of the materials, components, or services, or the failure to implementor adhere to required quality assurance practices.

This procedure establishes the methods for implementing and documenting corrective actions.

18.2 DEFINITIONS

Corrective Actions

Those actions taken in response to nonconformance reports, audit findings, *or* surveillance or monitoring findings. Audit reports require some stated specific action; other reports may often be implemented as wail.

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within a budget and schedule. The person is also referred to as Site Project Manager or the Project Manager, and is typically a contractor's employee (see Subsection 1.1).

18.3 APPLICABILITY

The corrective action procedure is applicable to those activities that affect quality control carried out at hazardous waste site investigations and that require corrective actions.

18.4 RESPONSIBILITIES

The quality assurance representative is responsible for reviewing audit reports and nonconformance reports to determine the significant or repetitious conditions adverse to quality, or the failure to implement or adhere to required quality assurance practices.

When such problems are identified, the responsible manager or the designee must investigate the causes of the problems and is responsible for defining and implementing the necessary actions to correct the problems. The responsible manager must identify the person or persons responsible for initiating the actions for remedying any immediate effects of the problems.

18.5 RECORDS

Documentation that supports major corrective actions should be maintained in the project fries and in the quality assurance files using the techniques discussed in Section 17, Document Control, of this compendium.

18.6 PROCEDURES

18.6.1 Limits for Data Acceptability

The quality of data generated by sampling, monitoring, or analyzing, is defined in terms of the following:

Accuracy The degree of agreement of a measurement (or an average of measurements of the same thing), X, with an accepted reference or true value, *T,* usually expressed as the difference between the two values, $X-T$, or the differences as a percentage of the reference or true value, 100 (X-~/~, and sometimes expressed as a ratio, X/T. Accuracy is a measure of the bias inherent in the system.

Precision: A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is best expressed in terms of the standard deviation. Various measures of precision exist depending on the prescribed similar conditions.

Completeness: A measure of the amount of the valid data obtained from a measurement system, compared with the amount that was expected to be obtained under correct normal conditions, and that was needed to be obtained in meeting the project data quality objectives.

Representativeness The degree to which data accurately and precisely represent a characteristic of population, the parameter variations at a sampling point, a process condition, or an environmental condition. it also includes how well the sampling point represents the actual parameter variations that are under study.

Comparability The confidence with which one data set can be compared with another; a qualitative characteristic that must be assured in terms of sampling, analysis, reporting, etc.

The exact values of these quality characteristics will vary depending on the analytical processes and procedures involved. The processes and procedures used throughout the project are based on established techniques and methods. In many cases, existing EPA standard operating procedures will be used. Where these are not available or suitable, nationally recognized procedures, such as those established by the American Society for Testing and Materials (ASTM) will be employed.

individual work plans will detail the recommended field activity and analytical methodology to establish that these variables are adequate to support future decisions.

18.6.2 Control of Data Acceptability

Measures must be established and documented so that conditions adverse to quality, such as deficiencies, deviations, nonconformances, defective material services and/or equipment, can be promptly identified and corrected.

The identification of conditions adverse to quality, the cause of the condition, and the corrective action taken, must be documented and reported to appropriate levels of management.

The area of concern must be audited in a timely manner to establish that the corrective action has. been accomplished.

18.6.3 Reviews

The results of audits must, within 30 days of receipt, be reviewed by the quality assurance representative to determine the need for corrective action beyond the corrective action in the audit report. If this audit review reveals that major or long-term corrective actions are needed, the responsible managers will obtain from their staffs a commitment to define and implement the necessary actions to correct the cause(s) of the problem, as well as to remedy any immediate effects of the problem. In addition, several time critical field events are short-term activities that must recieve immediate corrective-action attention. In other words, the deficiency must be effectively remediated well before completion of the event to ensure data acceptability.

18.6.4 Nonconformance

If a deficiency that affects the quality, validity, or both, of a work product is discovered after final quality verification, the project work and verification process should be reviewed for adequacy. Modifications to project work will be initiated if necessary.

18.6.5 Corrective Action Approval

Proposed major corrective actions shall be approved by the responsible manager. The quality assurance representative must be consulted and must concur with proposed major corrective actions.

18.6.6 Corrective Action Review

The quality assurance representative must review the', results of major corrective actions after implementation to determine the effectiveness of the actions and report the results of this review to the program manager.

18.6.7 Corrective Actions for Data Acceptability

Corrective action procedures for data acceptability have been determined by EPA accepted practices and methods. Section 16, Data Reduction, Validation, and Reporting, of this compendium also contains information on corrective action procedures.

18.7 REGION-SPECIFIC VARIANCES

All region-specific variations to this section will be incorporated in Revision 01 of this document, because no variations were identified during the draft review. Users information on variations.

18.8 INFORMATION SOURCES

National Enforcement Investigations Center. *Enforcement Considerations for Evaluations of Uncontrolled Hazardous Waste Disposal Sites by Contractors.* Denver, Colorado. April 1980.

Toledo Edison Company. *Quality Assurance Program Specifications for Operations Phase Suppliers/Contractors.* Davis-Besse Nuclear Power Station. (No date of publication.)

U.S. Department of Energy. *Quality Assurance Handbook for Geologic Investigations.* National Waste Terminal Storage Program. October 1982.

U.S. Environmental Protection Agency. *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans.* Office of Monitoring Systems and Quality Assurance, Office of Research and Development. Washington, D.C.

SECTION 19

QUALITY ASSURANCE AUDIT PROCEDURES

19.1 SCOPE AND PURPOSE

Each project plan must describe the internal and external performance and systems audits that will be required to monitor the capability and performance of the total measurement system(s).

Section 19 describes the activities usually accomplished In the performance of audits. The preaudit meeting, audit performance, evaluation of audit findings, postaudit meeting and audit reporting are addressed.

19.2 DEFINITIONS

Audit (Office, Field, Laboratory)

A documented activity performed in accordance with written procedures or check lists to verify, by examination and evaluation of objective evidence, that applicable elements of the quality assurance program have been developed, documented and effectively implemented in accordance with specific requirements.

Auditor

A staff member who can perform audit activities under the directions of a lead auditor. Persons classified as auditors shall not serve as audit team leaders nor perform audits independently.

External Audit

An external audit is performed by an auditor(s) not employed by the company or organization being audited. External audits are performed to verify that a subordinate participant in a project is exercising effective controls over its responsibilities for the implementation of the overall quality assurance program.

Internl Audit

An internal audit is performed by an auditor(s) employed by the company or agency to which the audit activity belongs. Internal audits are performed to verify that the developments or organizations within the company are conforming with the quality assurance program.

Lead Auditor (Audit Team Leader)

A staff member who, by virtue of education, training and experience, can organize and direct audits, can report audit findings, and can evaluate corrective actions.

Performance Audits

Performance audits are normally conducted after the data production systems are operational and are generating data. Such audits independently collect measurement data by using performance evaluation samples to determine the accuracy of the total measurement system or portions thereof.

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and is typically a contractor’s employee (see Subsection 1.1).

Systems Audits

Systems audits are regularly performed and encompass all aspects of the program. For purposes of this procedure, systems audits will consist of evaluations of all components of the applicable measurement systems to determine their proper selection and use. The total data production process, which includes onsite reviews of both field and laboratory systems and facilities for sampling, calibration, and measurement protocols, is normally covered by systems audits.

Technical Expert

A staff member who is knowledgeable in the technical ‘discipline being audited but is not qualified as an auditor.

19.3 APPLICABILITY

The audit procedure is applicable to the quality assurance audits conducted on projects dealing with Superfund hazardous waste site investigations.

19.4 RESPONSIBILITIES

The quality assurance representative is responsible for preparing and maintaining a schedule of audits as described in this procedure.

Qualifications and certification of the audit personnel should be reviewed and documented by the quality assurance representative.

The audit team leader is responsible for preparing an audit. These responsibilities include the selection of an audit team, preparation of an audit plan and audit checklist, special training and orientation of the audit team, and notification of the organization being audited.

The audit team leader and, where applicable, the other members of the audit team are also responsible for complying with the instructions identified in this procedure for conducting audits.

Audit follow-ups should be conducted by the audit team leader to verify that corrective action on audit findings is adequate and complete.

Documented findings Identified during audits are to be completed on the quality notice form (Exhibit 19-1). The quality notice form should be completed In accordance with the procedures outlined in Exhibit 19-2 (instructions) and is the responsibility of the audit team members.

19.5 RECORDS

The following records are generated in support and completion of the quality assurance audits for Superfund projects:

- Audit schedules and revisions thereto
- Audit qualification records
- Certification records (current and historical)

- Audit checklists and audit guides
- Audit plan
- Audit reports
- Written response to audit reports
- Response evaluations
- Records of audit closure

19.6 PROCEDURES

The following procedure describes the methods used in establishing and conducting an audit. Office, field, and laboratory audits may may in context but follow the generic guidelines of this procedure.

19.6.1 Audit Schedules

An audit schedule should be established for each year of the project. The schedule will include both internal and external audits, providing external audits are required.

The schedule is reviewed periodically and revised as necessary to reflect current scheduling ‘of activities that affect quality and to provide adequate coverage of the implementation of the quality assurance program.

The frequency of audits is based on the level of participation of the audited organization in activities that affect quality.

The published schedule contains the following information:

- Name and project organization (or subcontractor or consultant) to be audited
- Subject of the audit
- Scheduled date of the audit
- Audit team leader

Audits are scheduled so that the quality assurance programs covering the activities are effective during all phases of the program.

The audit schedule is distributed to all appropriate management personnel of the offices being audited. Audit schedules prepared by the quality assurance representative for specific office activities (e.g., field audits, laboratory audits, and/or office audits) are distributed to the cognizant manager.

Quality assurance personnel may conduct unscheduled audits when one or more of the following conditions exist:

- When it is necessary to determine the capability of a supplier's quality assurance program prior to award of a subcontract
- When, after the award of a contract, sufficient the has elapsed for implementation of the quality assurance program, and when it Is necessary to determine that the organization is performing in accordance with the program
- When significant changes are made to activities affecting quality, such as reorganization or major revision of quality assurance manuals, procedures, or other controlling documents
- When It is suspected that the quality of the services provided Is in Jeopardy because of non conformance with the quality assurance program
- When a systematic, Independent assessment of the program's effectiveness Is considered necessary
- When it is necessary to verify that required corrective actions have been implemented

19.6.2 Qualification and Certification of Quality Assurance Personnel

19.6.2.1 Auditor Qualification

Three categories of personnel perform audit auditor, lead auditor and technical expert. The qualifications for these three categories areas fallows

Auditor To be classified as an auditor, an individual must, as a minimum, be given specific training in the content and objectives of the quality assurance program and In 'audit procedures and be evaluated on knowledge of these documents.

Lead Auditor To be classified as lead auditor, the individual must meet the requirements for auditors. In addition, the individual should have served as a team member In the conduct of at least two audits led by a lead auditor.

Technical Expert: The technical experts are not required to be qualified as auditors. They are selected on the basis of technical expertise in the area being audited and are part of an audit team led by an auditor. They are given speific training in the preparation and use of checklists and in the conduct of an audit.

19.6.2.2 certification

The quality assurance representative documents the basis for auditor certification and provides written certification. The program office manager certifies the quality assurance representative. The certification must state the clasificatioon of the individual and the expiration date of the certification.

19.6.3 Preparation for Audits

19.6.3.1 Audit Team Selection

The audit team leader for internal audits is selected by the quality assurance representative. Audit team members are also selected by the quality assurance representative.

Individuals are selected for quality assurance audit team assignments on the basis of experience or training commensurate with the complexity or special nature of the activities to be audited. Any special abilities, specialized technical training, previous experience, personal characteristics, education, or physical capability that is applicable to the-assignment are to be considered during selection.

19.6.3.2 Written Audit Plan

The audit team leader is responsible for the preparation of a written audit plan, when specifically requested by the quality assurance representative.

The audit plan Includes the fallowing Information:

- Audit number
- Audited organization
- Subject of the audit
- Scope of the audit
- Projects or activities to be audited
- Names of the audit team members
- Schedule
- Applicable documents

19.6.3.3 Audit Checklists

The audit team leader is responsible for directing the preparation of audit checklists or an audit guide.

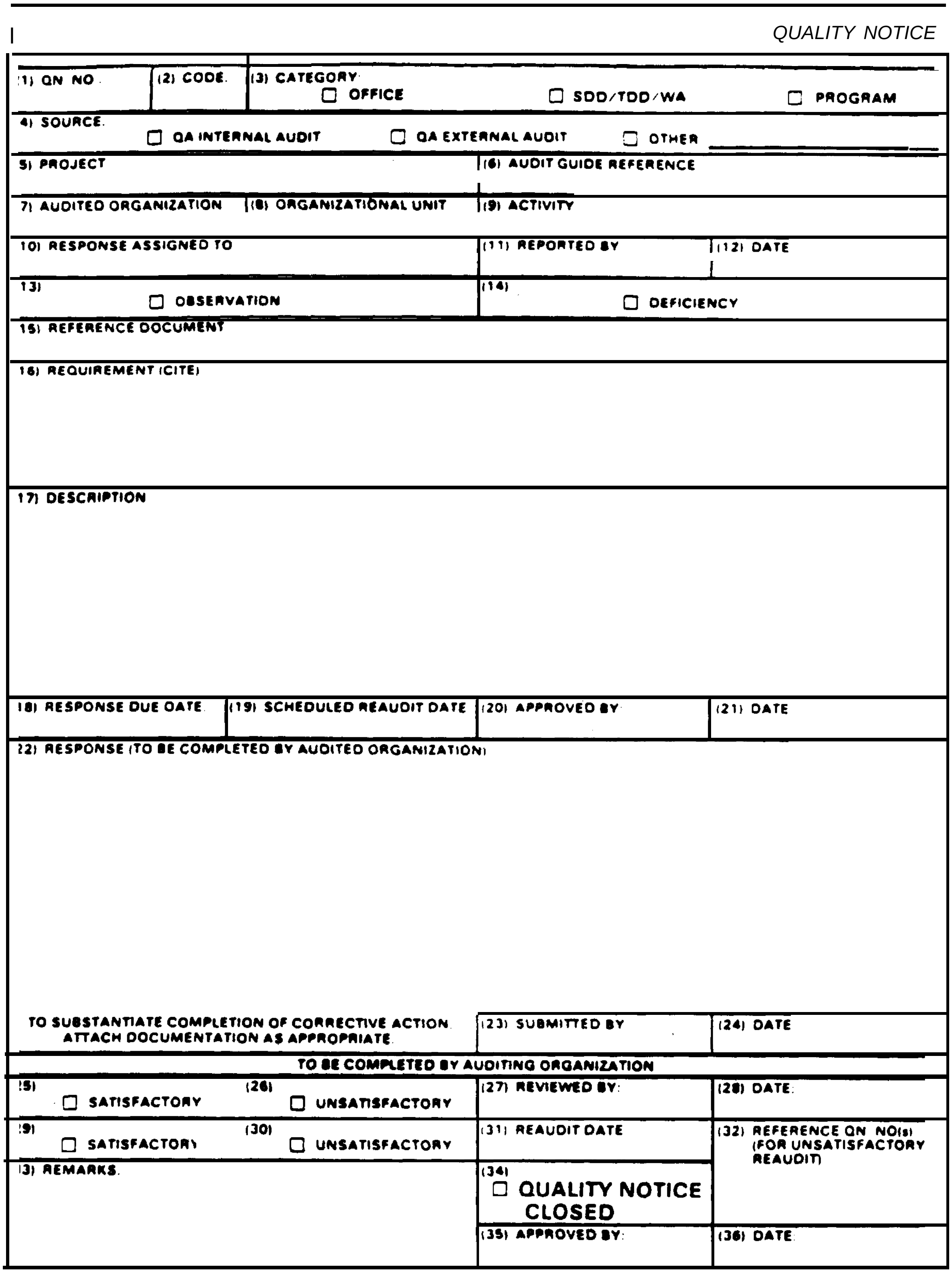
The fallowing guidelines are used in preparing checklists:

initial Baseline Audits: Checklists are based on quality assurance program documents (e.g., quality assurance manuals, plans, procedures, applicable standards).

Follow-up Audits: Checklists are based on a review and evaluation of findings from previous audits, responses to these findings, and available objective evidence of implementation of corrective action.

Periodic Audits: Checklists emphasize areas considered critical to the program at the time of the audit or found weak but not reported as a finding during a previous audit.

Exhibit 19-1
QUALITY NOTICES



QUALITY NOTICE

(1) QN NO.	(2) CODE.	(3) CATEGORY: ☐ OFFICE ☐ SDD/TDD/WA ☐ PROGRAM	
(4) SOURCE: ☐ QA INTERNAL AUDIT ☐ QA EXTERNAL AUDIT ☐ OTHER ______			
(5) PROJECT		(6) AUDIT GUIDE REFERENCE	
(7) AUDITED ORGANIZATION	(8) ORGANIZATIONAL UNIT	(9) ACTIVITY	
(10) RESPONSE ASSIGNED TO		(11) REPORTED BY	(12) DATE
(13) ☐ OBSERVATION		(14) ☐ DEFICIENCY	
(15) REFERENCE DOCUMENT			
(16) REQUIREMENT (CITE)			
(17) DESCRIPTION			
(18) RESPONSE DUE DATE	(19) SCHEDULED REAUDIT DATE	(20) APPROVED BY	(21) DATE
(22) RESPONSE (TO BE COMPLETED BY AUDITED ORGANIZATION)			
TO SUBSTANTIATE COMPLETION OF CORRECTIVE ACTION ATTACH DOCUMENTATION AS APPROPRIATE.		(23) SUBMITTED BY	(24) DATE
TO BE COMPLETED BY AUDITING ORGANIZATION			
(25) ☐ SATISFACTORY	(26) ☐ UNSATISFACTORY	(27) REVIEWED BY:	(28) DATE:
(29) ☐ SATISFACTORY	(30) ☐ UNSATISFACTORY	(31) REAUDIT DATE	(32) REFERENCE QN NO(s) (FOR UNSATISFACTORY REAUDIT)
(33) REMARKS.		(34) ☐ QUALITY NOTICE CLOSED	
		(35) APPROVED BY:	(36) DATE:

Exhibit 19-2
QUALITY NOTICE INSTRUCTIONS

The Quality Notice Form shall be used by persons performing Quality Assurance (QA) Audit or Surveillance of activities affecting the timely and *effective* formulation or implementation of a defined QA program. This form is applicable to all types of goods and services (hardware and software) provided in accordance with requirements of a QA Program. This *form may be used by project management* representatives for monitoring decisions, actions or events associated with QA programs pertinent to work performed under their jurisdiction.

The Quality Notice Form shall be used by personnel identified above to describe the condition when:

A. Specified quality for a product, process or system has been violated; i.e., a quality DEFICIENCY *(audit finding) is to be documented by* the observer and appropriate corrective action is to be committed for scheduled accomplishment by the audited/monitored organization, or

B. The capability of the audited/monitored organization to demonstrate with meaningful level of confidence, continued achievement of appropriate quality appears to be *in jeopardy; i.e.,* an OBSERVATION is to be documented by the observer and is to be acted upon by the audited/monitored organization in accordance with agreement(s) established by the observer with the audited/monitored organization.

(1) Enter identifier for each Quality Notice (QN) issued. Unless prescribed otherwise, the observer shall establish identification appropriate to his needs, e.g., 01, 02.

(2) Leave blank (this space may be used for subsequent codification and quality trend analyses).

(3) *Mark the box(es) which best describes the category of the reported observation or deficiency.*

(4) *Mark the box which describes the source of the cited* observation or deficiency (see Note 1 below).

(5) Enter *identification (e.g., name* or number) of project under which activity was performed.

(6) Enter identification *of guide used* to isolate and identify the observation or deficiency: e.g., audit checklist, detailed scope *of work, memorandum,* action item report, tickler file, etc.

(7) Enter name and location of organization subjected to audit/ *surveillance/monitoring* action.

(8) Enter name of department or section where the noted observation *or deficiency occurred.*

Identify the specific task, action or work assignment undergoing audit/*surveillance/monitoring when* the observation or deficiency was isolated and identified, e.g., performing magnetic *particle* inspection of containment vessel welds (hardware), reducing strip chart data for wind speed and wind direction (software).

(10) Enter the name of the audited/monitored organization representative responsible for providing observation or deficiency responses.

(11) Enter the observer's name.

(12) Record the date on which the observation or deficiency was *documented.*

(13) Mark this box when quality is in jeopardy as described above in Instruction B *(see Note 2 below).*

Mark this box when quality is violated as described above in Instruction A *(see Note 2 below).*

A. When item (13) is marked, enter the name and identification of *applicable document(s) containing* the specific quality requirements that should be implemented to prevent or to mitigate the conditions adverse to quality.

B. When item (14) is marked, enter the name and identification *of document(s) containing* the specific quality requirements violated.

A. When item (13) has been marked, enter (excerpt if available) specific quality requirements that should be implemented to prevent or to mitigate the conditions adverse to quality.

B. When item (14) is marked, enter excerpt from specific quality requirement violated.

Record in terse concise language a description of the observation or deficiency.

(18) Record the due date of the response from the audited/ monitored organization.

(19) Record the next scheduled date for audit/surveillance/ monitoring action to assess observation or deficiency corrective progress. When the exact date *of the assessment can not be* determined, enter "TBD" (to be determined). Enter N/A (not applicable) when assessment will not be made.

(20) Enter name of person authorized to approve the QN. Unless *prescribed otherwise,* this will be the audit team leader or the observer (see item 11).

(21) *Record date QN was approved for transmittal* to the audited/ monitored organization.

Record in detail the total response. *To be satisfactory* it must:

A. Dispose of any affected product, results, or paperwork.

B. Correct the situation that caused the QN to be issued.

C. Provide a mechanism to prevent recurrence.

D. Identify who shall do the above and,

E. When it shall be accomplished.

(23) Enter name of person in the audited/monitored organization who has submitted the response.

(24) Record the date that the response was submitted.

(25)(26) Mark the box that describes the response.

(27) Enter the name of the person who reviewed the response.

(28) Record the date the response was reviewed.

(29)(30) When an on-site assessment of the observation or deficiency is made, mark the box that describes the interim action by the audited/monitored organization. Enter N/A when an on-site assessment will not be made.

(31) Record the date the on-site assessment was made. No assessment, mark the block N/A.

(32) Record all QN numbers documenting assessment of the original observation or deficiency. No assessment, mark the block N/A.

(33) Enter comments pertinent to NUS evaluation of corrective action or conditions for closing the QN, otherwise enter N/A.

(34) When conditions are appropriate, mark the box to close the QN.

(35) Enter the name of the person who approved closing the QN.

(36) Record the date the QN was closed.

Note 1: QN's initiated by other than QA personnel are to be immediately sent to QA for action.

Note 2: Items (13) and (14) are mutually exclusive; i.e., the observer must choose and mark only *one of these two boxes.*

19.6.3.4 Audit Team Orientation

The team leader prepares the team prior to initiation of the audit and assigns specific areas for each member to audit In accordance with checklists the team has prepared. Pertinent policies, procedures, standards, instructions, manuals plans, codes, regulatory requirements, prior audit reports, and responses should be made available to the team for information and review. Also, each auditor is provided with copies of the audit plan, procedures, and checklists necessary to ensure an orderly audit. The team leader established that the auditors understand the internal and external organization and contractual interfaces and responsibilities of the organization to be audited.

19.6.4 Conduct of Audits

19.6.4.1 Audit Meeting

Upon arrival at the audit site, the audit teem leader conducts a meeting with the audit team members and cognizant management of the organization to be audited.

The following are purposes of the preeudit meeting:

- Introduce auditors
- Meet counterparts
- Confirm the scope of the audit
- Present the audit plan
- Discuss the audit sequence
- Establish channels of communication
- Schedule a postaudit meeting

19.6.4.2 Audit Performance

The audit team leader prepares audit checklists or audit guides. The depth and scope of the audit are determined and incorporated into the checklists or guides. The audit team leader establishes the ground rules for the audit and assigns to the various team members the specific areas each is to cover in the audit.

The audit checklists and guides are used to guide the audit and to provide adequate depth, scope, and continuity. However, the audit is not restricted to the checklists when evidence raises questions not specifically addressed in the checklists. The audit activity Includes the review of objective evidence to verify adequate implementation of the quality assurance program.

Audit team members record each finding (observation or deficiency) on a formal record such as a quality notice form (Exhibit 19-1). This form is prepared in accordance with the information contained in this section. When a finding is identified, sufficient investigations should be conducted to determine the basic cause of the finding.

The quality notice form is used to document the findings of internal audit activities and the resolution of the findings. Findings can be categorized as follows:

- Category A (Deficiency): Recognition of a specific requirement (e.g., program, procedure, process) that has been violated.
- Category B (Observation): Recognition of an activity or action that might be improved but is not in violation of a specific requirement. Left alone, the activity or action may develop into a deficiency (Category A).

The processing of the quality notice form is outlined in Subsection 19.6.5, Audit Follow-Up.

“ Deficiencies are written only when there is a clear violation of a specific quality assurance requirement.

Any identified findings that require immediate corrective action are reported immediately to the management of the audited organization and recorded on a quality notice form. For internal audits, the quality assurance representative is notified immediately.

19.6.4.3 Evaluation of Audit Findings

Members of the audit team draft their own findings on quality notice forms. These drafts are reviewed by the audit team leader. Findings are stated in clear, concise statements of facts that identify the problem.

19.6.4.4 Postaudit Meeting

At the conclusion of the audit, a postaudit meeting is conducted. The meeting is chaired by the audit team leader. Those in attendance should include members of the audited organization who can verify the validity of the findings and members of management who can correct the problems identified by the audit.

The objectives of the postaudit meeting are to:

- Discuss the audit findings
- Determine and resolve any errors or misunderstandings regarding the findings
- Achieve agreement of the validity of the findings and on those findings that constitute noncompliance.
- Recommend improvements or corrective actions to the audited organization
- Establish a tentative plan and schedule for the development and implementation of the corrective actions
- Schedule a fallow-up audit, if appropriate

19.6.4.5 Audit Reporting

The audit team leader is responsible for preparation of the audit report, which provides the following:

- Description of the audit scope
- Identification of the audit team
- Identification of persons contacted
- A summary of the audit findings
- Any agreements and/or recommendations for correcting deficiencies or for improving the quality assurance program, as appropriate

The report or transmittal letter must require response by the audited organization. The distribution of audit reports for internal audits includes the cognizant project managers, the quality assurance representative, and the management of the audited organization. The report is usually issued within 30 days after the audit is completed.

19.6.4.6 Audit Response

The manager of the audited organization is requested to respond to the audit report within 30 days of receipt. The response relates the corrective action taken or outlines the plan and schedule for corrective action. In the case of longterm corrective action, periodic progress reports are submitted by the manager of the audited organization to the lead auditor, the quality assurance representative and the appropriate manager.

19.6.5 Audit Follw-Up

19.6.5.1 Audit Response

The program office manager takes, in a timely manner, those actions necessary to correct the deficiencies identified during the audit.

19.6.5.2 Audit Follow-up

The audit team leader follows up all open findings in audit reports, receives audit report responses, and evaluates the responses to determine that the corrective action for each finding has been adequately completed or scheduled.

The audit team leader may accomplish follow-up as required through written communication, reaudit, or other appropriate means.

The audit team leader informs the audited organization in writing of any unsatisfactory response, indicates why the response is considered unsatisfactory, and specifies a reply due date. The quality assurance representative is informed of unsatisfactory responses by copy of the written notification.

19.6.5.3 Audit Finding Closure

Each audit finding is considered open until a satisfactory written reply (e.g., report follow-up response) has been received from the audited organization documenting that corrective action has been completed.

Only the audit team leader or, in the case of unavailability, the designee can close an audit finding. This individual indicates the closure by signing and dating the quality notice form.

All closed quality notice forms are retained as quality assurance records.

19.7 REGION-SPECIFIC VARIANCES

This procedure is applicable to all contractor, regional EPA, and state personnel who conduct hazardous waste investigations. Slight variations in the application of the project file numbers, control methods of accountable documents, or use of a transmittal letter rather than a document transmittal form may occur. However, these variations can occur only after a suitable alternative method for these control mechanisms has been reviewed, approved, and documented by the responsible RPM. The user should contact the EPA RPM for up-to-date information on variances. Future variances will be included in Revision 01 of this compendium,

19.8 INFORMATION SOURCES

National Enforcement Investigations Center. *Enforcement Considerations for Evaluations of Uncontrolled Hazardous Waste Disposal Sites by Contractors.* Denver, Colorado. April 1980.

Toledo Edison Company. *Quality Assurance Program Specifications for Operations Phase Suppliers/Contractors.* Davis-Besse Nuclear Power Station. (No date of publication.)

U.S. Department of Energy. *Quality Assurance Handbook for Geologic Investigations.* National Waste Terminal Storage Program. October 1982.

U.S. Environmental Protection Agency. *Interim Guidelines and Specifications for Preparing Qualify Assurance Project Plans.* office of Monitoring Systems and Quality Assurance, Office of Research and Development. Washington, D.C. 29 December 1980.

SECTION 20

QUALITY ASSURANCE REPORTING

20.1 SCOPE AND PURPOSE

On a periodic basis, usually monthly, quality assurance (QA) reports should be issued to the appropriate Project Manager and, as appropriate, to the responsible higher management. These reports summarize the quality assurance and quality control status of the project and any conditions adverse to quality. The QA reports address the assessment of measurement data accuracy, precision and completeness, results of any performance audits, results of system audits, any repotted nonconformances, and any significant quality assurance problems, together with recommended solutions, and any new quality assurance and quality control processes as dictated by the client.

20.2 DEFINITIONS

Report

A document that gives information for record purposes.

Site Manager (SM)

The individual responsible for the successful completion of a work assignment within budget and schedule. The person is also referred to as the Site Project Manager or the Project Manager and Is typically a contractor's employee (sea Subsection 1.1).

20.3 APPLICABILITY

This reporting procedure Is applicable to the QA tasks associated with Superfund remedial response activities.

20.4 RESPONSIBILITIES

The QA representative is responsible for providing to management the periodic reports on performance of measurement systems and data quality for the respective projects.

20.5 RECORDS

The records to be generated in compliance with this procedure are the monthly QA reports.

20.6 PROCEDURES

The following subsection describes the parameters used in assessing the quality assurance and quality control (QA/QC) status of project activities and the means of reporting such assessments.

20.6.1 Assessment of Measurement Data Accuracy

The routine procedures used for assessing the precision, accuracy, and completeness of measurement and monitoring data should be evaluated and reviewed for compliance with" nationally recognized practices and with regionally approved and documented procedures. This review should include, but not be limited to, assessment of the completeness of work plans and their reference documentation of field data collection and analytical guidelines, calibration and standardization procedures, measurement and monitoring equipment maintenance and repair records, and personnel qualification records, as well as assessment of documentation provided by field and laboratory logbooks and data sheets. Such assess ments, favorable or unfavorable, should be identified in the QA report.

20.6.2 Assessment of Performance and Systems Audits

Quality assurance performance and system audits are routinely conducted, in accordance with Section 19, Quality Assurance Audit Procedures, to determine the effectiveness of the quality assurance program and implementation. A summary of findings or observations resulting from the audits is assessed and reported to the responsible manager. The summary includes a brief description of the organization or section(s) being audited, responsible personnel, dates of audit activities, and particular type of audit (internal or external), as well as, a concise description of particular activity findings and recommended actions to be taken to clear up such findings.

20.6.3 Nonconformances

The QA representative reports any nonconformances that may have occurred during the course of project activities. Nonconformances may occur as a result of an identified or suspected deficiency in an approved document (e.g., technical report, analysis, calculations, or computer program) or an activity that is not conducted in accordance with the established plans or procedures. The reported nonconformances are also accompanied by a brief description of the activity or activities to be performed to clear up the nonconformances.

20.6.4 Assessment of Quality Assurance Problems and Solutions

A section of the QA report is devoted to identifying any problems, solutions, or accomplishments of the overall quality assurance program. This section analyzes the general QA/QC status of the program and identifies any satisfactory or unsatisfactory trends in the implementation of the program.

Any problems in the program or problems in the implementation of the program must be detailed clearly and documented along with the appropriate and complete actions needed to solve the problem.

Any new QA program development or any unusual QA project activities should also be documented in this section.

20.7 REGION-SPECIFIC VARIANCES

EPA Region VI requires the submittal of a final QA report for each project. The final report must be complete enough to evaluate the objectives for data quality, the audits, the laboratory data, and so on. It should include method validation and sampling designs. The user should contact the EPA RPM for up-to-date information on variances. Future regional variations will be Identified and incorporated In Revision 01 of this compendium.

20.8 INFORMATION SOURCES

National Enforcement investigations Center. *Enforcement Considerations for Evaluations of Uncontrolled Hazardous Waste Disposal Sites by Contractors.* **Denver, Colorado. April 1980.**

Toledo Edison Company. *Quality Assurance Program Specifications for Ope-"ens Phase Suppliers/Contractors.* **Davis-Besse Nuclear Power Station. (No date of publication.)**

U.S. Department of Energy. Quality Assurance *Handbook for Geologic Investigations.* **National' Waste Terminal Storage Program. October 1982.**

U.S. Environmental Protection Agency. *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans.* **Office of Monitoring Systems and Quality Assurance, Office of Research and Development. Washington, D.C. 29 December 1980.**

☆U.S. GOVERNMENT PRINTING OFFICE: 1988-548-158/67077

CATEGORY 3: FIELD MEASUREMENTS

Section 3.2

Standard Operating Procedure for Calibration and Field Measurement Procedure for the YSI Model 6-Series Sondes and Data Logger

STANDARD OPERATING PROCEDURE FOR CALIBRATION AND FIELD MEASUREMENT PROCEDURES FOR THE YSI MODEL 6-SERIES SONDES AND DATA LOGGER (INCLUDING: TEMPERATURE, pH, SPECIFIC CONDUCTANCE, TURBIDITY, DISSOLVED OXYGEN, CHLOROPHYLL , RHODAMINE WT, ORP, AND BARAMETRIC PRESSURE).

The Office of Environmental Measurement and Evaluation
Ecosystem Assessment – Ecology Monitoring Team
EPA New England - Region 1
11 Technology Dr
North Chelmsford, MA 01863

The controlled version of this document is the electronic version viewed on-line only. If this is a printed copy of the document, it is an uncontrolled version and may or may not be the version currently in use.

This document contains direction developed solely to provide internal guidance to U.S. Environmental Protection Agency (EPA) personnel. EPA retains the discretion to adopt approaches that differ from these procedures on a case by case basis. The procedures set forth do not create any rights, substantive or procedural, enforceable at law by a party to litigation with EPA or the United States.

Revised by: Tim Bridges, Benjamin Brill and Tom Faber

Originally prepared by: Tom Faber 6/20/05
(Tom Faber) Date

Reviewed by: David J. McDonald 6/21/05
(Dave McDonald, Team Leader) Date

Approved by: Kat Kipp 6/21/05
(Katrina Kipp, Manager) Date

Revision Page

Date	**Rev#**	**Summary of Changes**	**Sections**
4/23/02	0	Initial Approval	
5/31/02	1	Changed DO requirement to < 1.0mg/l	5.5.1.8
7/18/02	2	Added Oxygen Solubility Table - Billie Gould	11.0 (added)
1/9/03	3	Conductivity from .15% to 15% (WP problem - thanks C. Porfert)	Table 7.2
7/9/03	4	Added values to Oxygen Solubility Table and Sonde Calibration Form - Kosuke Kawai Changed zero DO criterion from 1.0 mg/l to 0.5mg/l – TF	11.0 5.5.1.8
7/25/03	5	Updated App. B, and parameter updates - TF	App. B, 5.5.1.7, 5.3.1
8/5/04	6	Updated calibration information & cal. form - TF	App. B, 5.0
6/07/05	**7**	General update and added parameters – BB, TB, TF	all

Table of Contents

Tables:

1.0 Scope and Application

The purpose of this standard operating procedure (SOP) is provide a framework for calibrating sondes used to measure water quality parameters for ground water and surface water. Water quality parameters include temperature, pH, dissolved oxygen, conductivity/specific conductance, turbidity, and chlorophyll, oxidation/reduction potential and rhodamine.

This SOP is written specifically for the YSI model 6-Series Sondes (which include the 600R, 600XL, 600XLM, 6820, 6920 and 6600 models), the YSI 650 MDS (Multi parameter Display System) display/logger, and YSI EcoWatch software. The general calibration processes discussed herein are applicable to other manufactures sondes and displays/loggers. Consult the manufacture's instruction manuals for specific procedures.

2.0 Summary of Methods

This document describes a process for calibrating and performing water quality field measurements using YSI 6-Series Sondes.

3.0 Health and Safety Warnings

3.1 All proper personal protection clothing and equipment is to be worn.

3.2 The standard solutions for calibrating conductivity contain Iodine and Potassium Chloride. When using the standards, avoid inhalation, skin contact, eye contact or ingestion. If skin contact occurs remove contaminated clothing immediately. Wash the affected areas thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, consult the Material Data Safety Sheets (MSDS) for prompt action, and in all cases seek medical attention immediately.

3.3 The standard solutions for calibrating turbidity contain Styrene divinylbenzene copolymer spheres. While the material is not volatile and has no known physical effects on skin, eyes, or on ingestion, general health and safety precautions should be adopted to minimize unnecessary contact. If skin contact occurs remove contaminated clothing immediately. Wash the affected areas thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, consult the MSDS for prompt action, and in all cases seek medical attention immediately

3.4 The standard solutions for calibrating pH contain deionized water, potassium acid phthalate, inert dye, potassium phosphate, sodium phosphate, potassium chloride, and preservatives (no mercury or formaldehyde). Avoid inhalation, skin contact, eye contact or ingestion. If skin contact occurs remove contaminated clothing immediately. Wash the affected areas thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, consult the MSDS for prompt action, and in all cases seek medical attention immediately.

3.5 The Zero DO solution contains sodium sulfite and in some cases a trace amount of cobalt chloride.

This solution should be handled with care; the cobalt chloride is a suspected carcinogen. If skin contact occurs remove contaminated clothing immediately. Wash the affected areas thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, consult the MSDS for prompt action, and in all cases seek medical attention immediately.

3.6 Rhodamine WT dye should be handled with care. The active indgredient in this dye is trimettlic acid. Very little is known about its long term effects on humans so it should be handled with care. If contact occurs, wash the affected areas thoroughly with large amounts of water. If inhalation, eye contact or ingestion occurs, consult the MSDS for prompt action, and in all cases seek medical attention immediately.

3.7 The Zobell solution used for calibrating ORP contains potassium chloride, potassium ferrocyanide (trihydrate), and Potassium ferricyande. If contact occurs, wash the affected areas thoroughly with large amounts of water. Cyanides in general are often considered toxic to humans. For more info, see the MSDS.

3.8 Follow the most updated Boat Safety SOP when conducting sampling from a boat.

4.0 Equipment and Supplies

4.1 NIST traceable thermometer (only needed once per year)
4.2 pH Standards of 4, 7, and 10
4.3 Conductivity standards (concentration dependent upon expected field conditions)
4.4 Turbiditiy standards (concentration dependent upon expected field conditions)
4.5 Deionized and tap water
4.6 Calibration cups
4.7 YSI Sonde with attached pH/ORP, Conductivity, Dissolved Oxygen, Turbidity, Chlorophyll, and Rhodamine probes
4.8 YSI 650 MDS Multiparameter Display System (display logger)
4.9 Sonde communications cable
4.10 Notebook
4.11 Pen
4.12 Disposable gloves, goggles and safety glasses
4.13 Zobell Solution
4.14 Rhodamine WT dye
4.15 (Access to) Princo Mercury Barometer
4.16 N.I.S.T. traceable thermometer
4.17 Batteries

5.0 Calibration

Check the display/logger to determine the battery level in the display/logger to see if recharging or new batteries are necessary. Prior to calibration, all instrument probes on the sonde must be cleaned according to the manufacture's instructions. Failure to perform this step can lead to erratic measurements. The probes must also be cleaned by rinsing with deionized water before and after immersing the probe in a calibration solution. For each of the calibration solutions provide just enough volume so that the probe and the temperature sensor are sufficiently covered. When done with the calibration solutions do not return it to the original bottle, save solution in separate container or dispose of it properly. When using the Sonde for long-term deployment and using the "Autosleep RS232, and Autosleep SDI12" functions, the instrument must be calibrated in these modes. For manual measurements this function should be turned off (see section 5.5.1.3) prior to calibration.

5.1 Temperature

For instrument probes that rely on the temperature sensor (pH, dissolved oxygen/specific conductance, and oxidation-reduction potential), the sonde temperature sensor needs to be checked for accuracy against a thermometer that is traceable to the National Institute of Standards and Technology (NIST). This accuracy check should be performed at least once a year, and the date and results of the check kept on file. Below is the verification procedure.

5.1.1 Once a year, the accuracy of the instrument must be verified by checking the endpoints of the desired temperature range. For example, if the desired temperature range is 0°C to 40.0°C, the instrument must be with in the +/-0.15°C of both end points.

5.1.2 Place a thermometer that is traceable to the NIST into the water and wait for both temperature readings to stabilize.

5.1.3 Compare the two measurements. The instrument's temperature sensor must agree with the reference thermometer within the accuracy of the sensor (+/- 0.15°C). If the measurements do not agree, the instrument may not be working correctly and the manufacturer should be contacted.

5.2 pH

The pH of a sample is determined electrometrically using a glass electrode. Choose the appropriate standards that will bracket the expected values at the sampling locations. For this procedure three standards will be used (pH 4, pH7, & pH10). If the probe is slow to response refer to the section 6.0 Troubleshooting.

5.2.1 Rinse probe with deionized water and shake off excess water. Allow the buffered samples to equilibrate to the ambient temperature.

5.2.2 Place the probes (at least pH and temperature probes) on the sonde into the pH 7 buffer.

5.2.3 On the display/logger use the up/down arrow keys to highlight the "Calibrate" option and press the enter key.

5.2.4 Highlight the “pH” option and press enter.

5.2.5 Highlight the “3-point” option and press enter.

5.2.6 Input the value of the buffer, which is 7.00 and press enter.

5.2.7 Wait for the value of pH to stabilize and then press enter. Wait for “Calibrated” message. If an “Out of Range” message appears, do not accept, check the probe and refer to operator’s manual or section 6.0 Troubleshooting.

5.2.8 Place the pH probe into a pH 4.00 buffer.

5.2.9 Press enter key to continue calibration

5.2.10 When prompted, enter the pH of the second buffer, “4.00”. Wait for “Calibrated” message, and press any key to continue.

5.2.11 Rinse probe with deionized water and shake off excess water

5.2.12 Place the pH probe into a pH 10.00 buffer.

5.2.13 Press enter key to continue calibration

5.2.14 When prompted, enter the pH of the third buffer, “10.00”. Wait for “Calibrated” message, and press any key to continue.

5.2.15 Rinse probe with deionized water and shake off excess water.

5.2.16 Exit the calibration menu and go to the “Sonde Run” mode. Insert probe into pH 7 buffer and make sure it is reading correctly (± 0.05). If buffer reading is not correct, repeat the calibration procedure.

5.3 Specific Conductance

Conductivity is used to measure the ability of an aqueous solution to carry and electrical current. Specific conductance is the conductivity value corrected at 25°C.

5.3.1 Place the cleaned probes into the specific conductivity standard solution, making sure that the specific conductivity probe is **fully submerged.** For studies where conductivity is a critical parameter (non-critical parameters will be identified in the QAPP), the accuracy of the instrument must be verified by checking the endpoints of the desired conductivity range to insure linearity. Calibrate with one of the standards (the high standard) and check the instrument with a low standard. At the end of the monitoring period check the instruments with both standards. If you are using a small amount of calibration solution or standards that are easily contaminated first rinse the probe(s) with the conductivity standard. Where conductivity is a non-critical measurement you can check and calibrate the instrument with one calibration solution.

5.3.2 Return to the display/logger main menu and select "Calibrate" and press enter.

5.3.3 Select "Conductivity" and press enter.

5.3.4 Select "SpCond" and press enter.

5.3.5 Enter the standard concentration in mS/cm and press enter. The standard concentration should be just above the highest concentrations you expect to measure.

5.3.6 After the specific conductivity reading has stabilized press enter to calibrate. Wait for the "calibrated" message to appear. If the Sonde should report "Out of Range" do not override the error message, instead recheck the standard and go to the section 6.0 Troubleshooting for more help.

5.3.7 Exit the calibration menu and go to the "Sonde Run" mode and record the concentration (make sure it is reading with in 5% of standard value).

5.3.8 To check the calibration with a second standard (low), rinse probe with deionized water and insert probe in second standard and make sure it is reading with in 10%. A second standard is used to check the calibration at the low range and to bracket the expected concentrations. This must be performed when conductivity is a critical measurement.

5.4 Turbidity

The turbidity method is based upon a comparison of intensity of light scattered by a sample under defined conditions with the intensity of light scattered by a standard reference solutions. Critical to the instrument's operation is that the lens covering the detection unit is kept clean both during calibration and field use. The turbidity probes used on the YSI 6-Series sondes include an automated optics wiper. This wiper can be activated using the display/logger. The calibration and post calibration check should be performed in the laboratory before and after sampling

The following procedure is specified for the YSI 6136 Probe. (Note there is a different procedure for the older YSI 6026 Probe). With the use of the 6136 probe you **must** use the extended probe guard and the black bottom calibration cup. Use only YSI (or a certified equivalent) calibration standard, for more information refer to the owners manual.

5.4.1 Check to make sure the turbidity probe and wiper are clean and free from any material.

5.4.2 Activate the wiper to make sure it is wiping and parking correctly.

5.4.3 Allow the standard samples to equilibrate to the ambient temperature.

5.4.4 Clean all of the probes on the sonde with deionized water. Shake off excess water.

5.4.5 Place the sonde in the black bottom calibration cup containing the 0.0 NTU standard (which can be deionized water).

5.4.6 Using a stand to hold the sonde separate the calibration cup from the bottom of the Sonde by a distance equal to the width of 3 fingers (two inches). (The distance from the threads on the sonde to the bottom of the calibration cup should be equal to the length of the extended probe guard.)

5.4.7 From the "Calibrate" Menu, on the display/logger, select the "Turbidity" option and press enter.

5.4.8 Select the "2-point" option and press enter.

5.4.9 Enter "0.0" as the first calibration standard and press enter.

5.4.10 Select the "clean optics" option to activate the automated wipers. Once the cleaning process is completed, wait for the turbidity measurement to equilibrate, and then press the enter key.

5.4.11 Place the probe in the second standard (10 NTU or 11.3 NTU is the common standard solution). This second standard should be slightly above the highest concentration that is expected to be measured in the field. It is not necessary to clean the probe before placing into the second standard. Shake off excess DI water.

5.4.12 Press enter to continue calibration.

5.4.13 Enter the concentration of the second calibration standard (10 NTU or 11.3 NTU is the common solution of use) and press enter.

5.4.14 Again, select the "clean optics" option to activate the automated wipers. Once the cleaning process is completed, wait for the turbidity measurement to equilibrate, and then press the enter key.

5.4.15 Exit the "calibration" mode and enter the "Sonde Run" mode. Make sure it is reading with in +/- 10 % of the original concentration. If the buffer reading is not correct, repeat the calibration procedure.

5.5 Dissolved Oxygen

Dissolved oxygen (DO) content in water is measured using a membrane electrode. The DO probe's membrane and electrolyte solution should be inspected for any damage or air bubbles prior to calibration. If air bubbles or damage are present, replace the membrane according to manufacturer suggestions. (After changing the membrane, for accurate measurements, you must wait 6 - 12 hours before use to allow the membrane to equilibrate) YSI 6-Series DO probe must be calibrated using the calibration cup provided with the sonde or by wrapping the sonde probe guard with a wet towel.

The DO is calibrated in the field prior to taking measurements and the final post calibration (verification) check should also be performed in the field before the instrument is turn off and after all measurements are taken.

When calibrating DO and not using the auto sleep function the instrument must be turned on (warmed up) for 15 minutes prior to calibration. When calibrating the DO for unattended sampling and using the auto sleep function, the instrument should not be warmed up before calibrating (it should be calibrated when the instrument is cool, since it is cool when the instrument is taking readings).

Calibration of the DO probe requires inputting the current barometric pressure. The YSI 650 display/logger has a barometer within the unit and automatically provides this during the calibration procedure. Other display/loggers may not supply the barometric pressure, in this case you will need a separate barometer.

Two calibration procedures are listed below for dissolved oxygen, one for sampling applications and one for long-term monitoring applications.

5.5.1 Calibration Procedure for Discrete Sampling (non deployment) Applications

The dissolved oxygen probe is calibrated each day prior to use. An initial inspection and calibration should be performed the day before to assure the membrane is in good shape the instrument is working properly. Follow the procedure below to calibrate.

5.5.1.1 Clean all of the probes on the sonde with tap (or clean ambient water) water. Shake off excess water.

5.5.1.2 Place approximately 1/8 inch of water in the bottom of the calibration cup. Place the probe end of the sonde into the cup. Engage only 1 or 2 threads of the calibration cup to insure the DO probe is vented to the atmosphere. [An equivalent alternative method is to wrap the probe guard (which is attached to the sonde) with a wet towel and place the sonde in a 5 gallon bucket with 1 inch of water in it.] Make sure that the DO and temperature probes are NOT immersed in water and that the Sonde cup is not in direct sunlight. Wait approximately 10 minutes for the air in the calibration cup to become water saturated and for the temperature to equilibrate.

5.5.1.3 For manual sampling applications the dissolved oxygen probe is continuously pulsing, therefore the "Autosleep RS232" function should be deactivated. (The "Autosleep SDI12" does not effect the manual sampling and can remain on.) From the "Main" menu on the display/logger, select the "System Setup" option and press enter. Then select the "Advanced" option and press enter. Select the "Autosleep RS232" option and press enter to obtain the "off" setting. Then press the "ESC" button until returning to the main menu.

5.5.1.4 From the calibration menu select the "Dissolved Oxy" option, then the DO% option (Note: For the YSI 6-Series Sondes, calibration of dissolved oxygen by the DO% procedure also results in the calibration of the DO mg/l mode and vice versa.)

5.5.1.5 Enter the current barometric pressure in mm of Hg. The correct pressure will automatically apear, double check this value with the reading provided in the lower right hand corner of the display.

5.5.1.6 Press enter and then wait for the DO% reading to equilibrate. Press enter to accept the calibration. Press enter again to return to the calibration menu.

5.5.1.7 Immediately enter the "Sonde Run" mode and record the temperature, dissolved oxygen in mg/l and %, and the barometric pressure used for calibrating. The DO should be with in ± 0.2 of saturation value. If not, go to section 5.5.1.4 to recalibrate.

5.5.1.8 For critical DO (non-critical parameters will be identified in the QAPP) applications verify the probe with a zero DO solution.

1) Place the probe in a zero DO solution.
2) Verify the probe reads < 0.5mg/l (or to the range specified in QAPP)
3) Rinse probe and store the probe in tap water.

5.5.1.9 Fill the calibration cup half way with tap water and screw on to the sonde. The sonde is now ready for use.

5.5.2 Calibration Procedure for Continuous Monitoring (deployment) Applications

When the instrument will be used for long term monitoring applications, the "Autosleep RS232, and Autosleep SDI12" function must be activated before calibration. After making sure this function is on, follow steps 5.5.1.1-5.5.1.9 (skip 5.5.1.3 and turn the instrument on after 5.5.1.2) in

"Calibration Procedure for Sampling Applications". If the instrument has been in the run mode, switch to a different mode or turn off the instrument and allow the instrument to cool for 10 minutes before calibrating the DO.

5.6 Chlorophyll

Note: This procedure is under development and is draft.

Chlorophyll is found in nature in various forms bound within biological matter. It is a key component in the photosynthesis process and is measured because of its correlation with the suspended phytoplankton in the water, which provides an assessment of the overall quality of the water. The classical method of determining chlorophyll in the environment is a labor-intensive and time-consuming process that needs to be completed in the laboratory. The probe utilizes a property of chlorophyll that it fluoresces, meaning it emits a higher wave length (lower energy) light when irradiated with light of a particular wavelength. This method is not intended to replace the far more accurate method of calculating chlorophyll in the laboratory, but provide an estimate of chlorophyll concentrations in an efficient manner.

The most accurate estimates require having standards of with known amounts of phytoplankton, determined in the laboratory, but this method of calibration will determine relative fluorescence which will later be paired with a few grab samples to provide an estimate of the concentrations of chlorophyll with the minimal lab work.

This calibration method requires corresponding grab samples to be analysed by the laboratory to provide meaningful chlorophyll a values. It is a two point calibration to determine the relative fluorescence of the sample and to see if there is any drift in the fluorescence value throughout the sampling process. The first standard is deionized water and the second standard can be an Acridine Orange, Rhodemine B or Rhodemine WT dye. This methodology will used Rhodamine WT. See page 5-23 in YSI operation manual for preparation of standard and approximate chlorophyll values.

5.6.1 Check to make sure the chlorophyll probe and wiper are clean and free from any material.

5.6.2 Activate the wiper to make sure it is wiping and parking correctly.

5.6.3 Allow the standard samples to equilibrate to the ambient temperature.

5.6.4 Clean all of the probes on the sonde with deionized water. Shake off excess water.

5.6.5 Place the sonde in the calibration cup containing the deionized water.

5.6.6 From the "calibrate" Menu, on the display/logger, select the "chlorophyll" option and press enter.

5.6.7 Select the "2-point" option and press enter.

5.6.8 Enter "0.0" as the first calibration standard and press enter.

5.6.9 Select the "clean optics" option to activate the automated wipers. Once the cleaning process is completed, wait for the chlorophyll measurement to equilibrate, and then press the enter key.

5.6.10 Place the probe in 0.5mg/l Rhodemine WT dye standard (see page 5-23 of the operation manual for the correct value to enter). It is not necessary to clean the probe before placing into the second standard. Shake off excess DI water.

5.6.11 Press enter to continue calibration.

5.6.12 Select the "clean optics" option to activate the automated wipers. Once the cleaning process is completed, wait for the chlorophyll measurement to equilibrate, and then press the enter key.

5.6.13 Exit the "Calibration" mode and enter the "Sonde Run" mode make sure it is reading with in +/- 20 % of the second concentration. If the standard reading is not correct, repeat the calibration procedure.

5.7 Rhodamine WT (dye tracking)

Rhodamine WT is a fluorescent dye traditionally used to track water flow. It has a similar property to chlorophyll, in that it fluoresces; it emits a lower energy, higher wavelength light when it is irradiated by a particular wavelength of light. The probe emits light at a particular wavelength that can determine the concentration of the Rhodamine in the water by collecting the lower energy light beams that are reemitted.

This method of calibration will utilize deionized water and up to two additional standards. The standards used should bracket the expected concentration range. The probe has the ability to determine concentration up to 200 ppb. It is important that the standard and sensor are in thermal equilibrium for calibration.

5.7.1 Check to make sure the Rhodamine WT probe and wiper are clean and free from any material.

5.7.2 Activate the wiper to make sure it is wiping and parking correctly.

5.7.3 Allow the standard samples to equilibrate to the ambient temperature.

5.7.4 Clean all of the probes on the sonde with deionized water. Shake off excess water.

5.7.5 Place the sonde in the calibration cup containing the deionized water.

5.7.7 From the "Calibrate" Menu, on the display/logger, select the "Rhodamine WT" option and press enter.

5.7.8 Select the "2-point" or "3-point" option and press enter.

5.7.9 Enter "0.0" as the first calibration standard and press enter.

5.7.10 Place the probe in DI water and select the "clean optics" option to activate the automated wipers. Once the cleaning process is completed, wait for the rhodamine measurement to equilibrate, and then press the enter key.

5.7.11 Shake off excess DI water and place the probe in the second standard.

5.7.12 Press enter to continue calibration.

5.7.13 Enter the concentration of the second calibration standard and after Rhodamine concentration has equilibrated press enter.

5.7.14 Again, select the "clean optics" option to activate the automated wipers. Once the cleaning process is completed, wait for the Rhodamine measurement to equilibrate, and then press the enter key.

5.7.15 Wash the probe in DI water and shake off excess water before placing probe in third standard (if necessary) and press Enter.

5.7.16 Enter the concentration of the third standard. After Rhodamine has equilibrated, press enter.

5.7.15 Exit the "calibration" mode and enter the "Sonde Run" mode. Make sure it is reading with in +/- 5 % or 1 ug/l (which ever is greater) of the second concentration. If the reading is not correct, repeat the calibration procedure.

5.8 Oxidation Reduction Potential (ORP)

ORP is measuring the difference in potential between two electrodes, one a chemically inert electrode and the other a reference electrode. This measurement is made by a combination pH/ORP probe. Though ORP varies greatly with temperature, there is no temperature based correction program installed in the sonde or data logger. For the Zobell solution that will be used for this method of calibration, consult the chart on page 5-3 of the YSI operation manual. Temperature also must by taken into account when reporting ORP.

5.8.1 Allow the Zobell solution to equilibrate to the ambient temperature.

5.8.2 Clean all of the probes on the sonde with deionized water. Shake off excess water.

5.8.3 Place the probes (at least pH/ORP and temperature probes) in the Zobell solution.

5.8.4 Wait for temperature to stabilize. On the display/logger use the up/down arrow keys to highlight the "Calibrate" option and press the enter key.

5.8.5 Look up the millivolt (mv) value at this temperature from the millivolt versus temperature correction table found in the YSI manual or with the standard. Enter the temperature-corrected ORP value into the instrument.

5.8.6 Enter the sonde run menu. The value should be unchanged. If not, refer to operator's manual or section 6.0 Troubleshooting.

5.9 Barometric Pressure

Barometric Pressure is measured by the 650 MDS data logger and used for depth and dissolved oxygen calculations. It needs to be standardized to a NIST traceable barometer at least once a year. The procedure involves using the mercury barometer located in room 172.

5.9.1 Determine the uncorrected height of the column of mercury in mmHg by twisting the cistern adjusting screw to place triangular pin to barely touch the surface of mercury in the cistern reservoir.

5.9.2 The height of mmHg must be adjusted for temperature based on the thermal expansion of mercury. Using the thermometer hanging from the front of the barometer, the temperature of the mercury can be determined and then translated in the thermal expansion in mmHg using the chart in room 172.

5.9.3 The value in mmHg must further be adjusted to compensate for latitude. OEME is located at 42.6 degrees North. For this latitude: at a temperature corrected 700 mmHg, the latitude adjustment would subtract .23 mmHg, while at a temperature corrected 800 mmHg, the latitude adjustment would subtract .26 mmHg. For temperature corrected values in between those two points, interpolate linearly for an approximate value.

5.9.4 Once the temperature-and-altitude-corrected value has been determined, the 650 MDS should be powered on. In the main menu, select system set up and press enter.

5.9.5 Using the down arrow, scroll down to calibrate barometer. Press enter.

5.9.6 Record the Baro offset value.

5.9.7 While the mmHg value is still highlighted, press enter. Key in the local barometric pressure. Press enter. Record the new Baro offset. The barometric pressure calibration is complete.

6.0 Troubleshooting

6.1 Occasionally problems are encountered during a calibration and the instrument must be uncalibrated to return the instrument to factory settings. Uncalibration can be performed following these steps.

6.1.1 Access the desired parameter to uncalibrate in the calibrate menu.

6.1.2 When prompted to input a number for a standard, hold the enter key down and press the "esc" key. Highlight the "yes" key and press enter.

(Please note: This procedure is the equivalent of entering the command "uncal" from the YSI 610 logger at the numeric calibration prompt.)

6.2 pH

6.2.1 Refer to the Sonde Performance Worksheet

6.2.1 If a probe is slow to respond, recondition the probe according to the "Sonde Care and Maintenace Section" of the users manual.

6.2.2 To check the condition of the probe record the millivolts for each buffer. The millivolt output is the unprocessed pH output, the acceptable tolerance for each buffer is shown below:

Buffer 4 = +180 +/- 50 mv
Buffer 7 = 0 +/- 50 mv
Buffer 10 = -180 +/- 50 mv

When the probe is new, the ideal number are close to 0 and 180, then as the probe begins to age, the numbers will move and shift to the higher side of the tolerance.

6.2.3 After recording the pH millivolts for the calibration points determine the slope of the sensor. This is the difference between the two calibration points. For example, if we recorded a + 5 mv for buffer 7 and a -175 for buffer 10 the slope would be 180. The acceptable range for the slope is 165 to 180. Once the slope drops below 165, the sensor should be replaced

6.3 Conductivity

6.3.1 Refer to the Sonde Performance Worksheet

6.3.2 When the calibration has been accepted, check the conductivity cell constant which can be found in the sonde's "Advanced Menu" under "Cal Constants". The acceptance range is 4.55 to 5.45. Numbers outside this range usually indicated a problem in the calibration process or a contaminated standard was used.

6.4 Turbidity

6.4.1 To confirm that the turbidity probe wiper is functioning properly follow the procedure below

6.4.2 The output of the probe should increase when you place your fingers in front of the optics. If this doesn't happen replace the probe or check with the manufacture

6.4.2 The wiper should be parked at approximately 180 degrees opposite of the optics. The wiper should reverse directions during the wipe cycle. If the wiper does not park correctly on reverse direction then make sure that the bottom edges of the wiper are clean and free of mud, sediment, or other fouling, replace the wiper if needed. If this doesn't not help replace the probe or contact the manufacturer.

6.5 Dissolved Oxygen

6.5.1 Refer to the Sonde Performance Worksheet

6.5.2 Go to the Sondes "Report" menu and enable the "DO Charge". Now go to the "Run" menu and start the sonde in the "Sonde Run" mode. Record the DO Charge after about 5 minutes. The number should be between 25 and 75. If this is not true contact the manufacturer or replace the probe.

6.5.3 When the calibration is complete go to the sonde's "Advanced Menu" and to the "Cal Constants" and record the "DO Gain". The gain should be between 0.7 and 1.4. If this is not true contact the manufacturer or replace the probe.

6.6 Chlorophyll, Rhodamine WT, ORP

For these parameters, see Principles of Operation located in the operation manual.

6.7 For additional troubleshooting refer to the operations manual or call YSI technical support at 1-800-897-4151 and ask for technical support.

7.0 Measurements

Sondes can be used for either discrete sample measurements or be deployed for a period of time to record measurements. Each of these types of measurements requires different configurations of the sonde memory and display logger. Each procedure for configuration and operation of the sondes is discussed below. The procedures described below involving using the sonde memory to log data. Display/loggers can be used to store data, however this requires the display/logger to remain with the sonde during monitoring.

7.1 Discrete sample measurements

7.1.1 From the main menu select the "Sonde Run" option and press enter.

7.1.2 Place the Sonde into the water to be analysed, and watch the variations in the desired parameters.

7.1.3 After a few minutes or when the variations are less than:

0.1°C temperature
0.02su pH
0.02mg/l D.O.
5 uS/cm conductivity
0.5 NTU Turbidity

Log the measurements in the project's log book.

7.1.4 If the measurement is to be logged in the sonde memory, the select the "Log one sample" option from the Sonde Menu, and press enter.

7.1.5 If a series of measurements from one site is to be logged in the sonde memory, select the "Start Logging" option from the Sonde Menu and press enter. After a pre-determined amount of time select the "Stop Logging" option to stop logging measurements.

7.2 Deploying Sonde for Unattended Logging

When calibrating the DO for unattended sampling and using the auto sleep functions the instrument should **not** be warmed up before calibrating (it should be calibrated when the instrument is cool, since it is cool when the instrument is taking readings). If the instrument has been in use, turn the instrument off and allow the instrument to cool for 10 minutes before calibrating the DO.

While similar to discrete sampling in operation of the sonde, unattended logging requires setting up the memory of the sonde to record data.

7.2.1 Be sure the data logger is not powering the sonde and there are batteries in good condition in the sonde. As you precede the battery life in days will be displayed.

7.2.2 From the Sonde menu select the "Run/Unattended sample" option and press enter.

7.2.3 Follow the prompts on the screen to prepare the sonde for unattended sampling including:
- sample interval time
- logging start date
- logging start time
- logging duration (days)
- file name to store data (no more than 8 characters)
- Site name (associated with file name but not critical)
- battery life (check to make sure it will cover length of time sampling)
- memory space
- View parameters to log

7.2.4 Once these items have been reviewed and are correct, toggle down to "Start Logging" and hit enter, it should then display "stop logging".

7.2.5 The sonde will now begin logging parameters at the next sample interval. If not already attached, place the probe protector on the sonde. Turn the display/logger off and disconnect the communications cable sonde. Place the communications port plug on the sonde. Place the sonde in the desired sample location and securely anchor sonde using the bail provided on top of the sonde.

7.2.6 The sonde is now in place and will continue to record until reaching the specified end time of logging.

8.0 Post Sampling Verification and Data Evaluation

During use of the sondes in the field, the instrument probes experience "drift" and may operate outside of their excepted range. To determine the amount of drift the probes must be checked against their calibration standards.

8.1 Dissolved Oxygen post sampling verification

The dissolved oxygen should be checked in the field at approximately every 5 stations or every couple of hours and after the last sampling point. It should be checked before the instrument is powered off.

8.1.1 Clean all of the probes on the sonde with tap (or clean ambient water) water. Shake off excess water.

8.1.2 Place approximately 1/8 inch of water in the bottom of the calibration cup. Place the probe end of the sonde into the cup. Engage only 1 or 2 threads of the calibration cup to insure the DO probe is vented to the atmosphere. [An equivalent alternative method is to wrap the probe guard (which is attached to the sonde) with a wet towel and place the sonde in a 5 gallon bucket with 1 inch of water in it.] Make sure that the DO and temperature probes are NOT immersed in water and that the Sonde cup is not in direct sunlight. Wait approximately 10 minutes for the air in the calibration cup to become water saturated and for the temperature to equilibrate.

8.1.3 Record the temperature, dissolved oxygen in mg/l and %, and the barometric pressure. The dissolve oxygen value should be within ±0.5 mg/l or of the saturation value (which is based on barometric pressure and temperature and can be found in Table 11). If the data does not meet this requirement it should not be reported or reported as estimated data in the final report.

8.1.4 For critical (non-critical parameters will be identified in the QAPP) DO applications verify the probe with a zero DO solution. This can be performed in the laboratory after sampling

1) Place the probe in a zero DO solution.
2) Verify the probe reads < 0.5mg/l (or to the range specified in QAPP)
3) Rinse probe and store the probe in tap water.

8.2 pH, conductivity, turbidity post sampling verification

8.2.1 Allow the standards equilibrate to the ambient temperature.

8.2.2 Clean all of the probes on the sonde with deionized water. Shake off excess water.

8.2.3 Place sonde instrument probes in reference standard solution of the particular parameter (eg. pH, specific conductivity, etc.).

8.2.4 From display/logger main menu, select the "run" option and press enter. Allow measurements to equilibrate, then write down result of measurement in log book.

8.2.5 Before and after placing the probes in the standard clean all of the probes on the sonde with deionized water and shake off excess water. Repeat for each reference standard solution.

8.2.6 These results should be compared with the below quality control goals. Data not meeting these criteria should be deleted or reported as estimated.

Table 8.1: Quality Control Goals for Sondes

PARAMETER	Post Calibration check accuracy goals
pH	±0.3 with pH 7 buffer and other bracketing buffer (pH4 or pH10)
Conductivity	± 10% of standard or 20 uS/cm (which ever is greater)
Dissolved Oxygen	± 0.5 mg/l of sat. value
Turbidity	± 20% or +/-2 NTU (which ever is greater) For zero +/-1 NTU
ORP	± 10 mV
Rhodamine WT	± 10% or 1 ug/l (which ever is greater)

8.3 Adjacent Measurement Check (for deployed sondes)

8.3.1 When sondes are deployed adjacent measurement checks shall be performed with a second instrument. The number of adjacent measurement check will depend on the quality of the monitored water and the project objectives. At a minimum these shall be performed during sonde retrieval. Adjacent measurements shall be measured at the depth of the sonde and at the surface. (Surface reading are taken to assess stratification that may exist).

8.3.2. At the same depth, the difference between the adjacent measurement and the recorded values by the sonde should not be less than the below quality control goals. Data not meeting this criterion should be deleted or reported as estimated.

Table 8.2: Quality Control Goals between the Adjacent Measurements and Deployed Sonde

PARAMETER	Adjacent Measurements accuracy goals
Temperature	0.5 °C
pH	0.5
Conductivity	15%
Dissolved Oxygen	+/-0.7 mg/l
Turbidity	30% or 3 NTU (which ever is greater)
Rhodamine WT	20% or 5 ug/l (which ever is greater)

9.0 Data Management and Records Management

All results of calibration must be documented and kept in a project's log book. At a minimum the following should be kept as part of the documentation: the instrument's manufacture model number, instrument identification number, standards used to calibrate the instruments, calibration date, the instrument readings, and the analyst.

10.0 References

United States Geological Survey, National Field Manual for the Collection of Water-Quality Data Techniques of Water-Resources Investigations, Book 9. Last update 1998.
http://water.usgs.gov/owq/FieldManual/index.html

Wagner J.W., and others, 2000, Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting U.S. Geological Survey Water-Resources Investigation Report 00-4252

YSI, 2001, 650 MDS Operations Manual

YSI, 2001 YSI Environmental Monitoring Systems Operations Manual (6-Series)

YSI, 1997, WQMONITOR For Environmental Monitoring Systems

YSI technical notes:
http://www.ysi.com/extranet/EPGKL.nsf/SearchDocs/1F24980CDDEE02AC85256CEF00763EC1!OpenDocument

11.0 Appendix A: Oxygen Solubility in Water

Table 11.1: Oxygen Solubility in Water (oxygen values are in mg/L)
(from Ch. 6 of the USGS, National Field Manual for the Collection of Water-Quality Data.)

Temp.	Pressure (mmHg)																		
(°C)	**795.0**	**790.0**	**785.0**	**780.0**	**775.0**	**770.0**	**765.0**	**760.0**	**755.0**	**750.0**	**745.0**	**740.0**	**735.0**	**730.0**	**725.0**	**720.0**	**715.0**	**710.0**	**705.0**
0.0	15.3	15.2	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5
0.5	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3
1.0	14.8	14.7	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.2
1.5	14.6	14.5	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.2	13.1	13.0
2	14.4	14.3	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8
2.5	14.2	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6
3.0	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.5
3.5	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.6	12.5	12.4	12.3
4.0	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.6	12.5	12.4	12.3	12.2	12.1
4.5	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.1	12.0
5.0	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.8
5.5	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.8	11.7	11.7
6.0	13.0	12.9	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.3	12.2	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5
6.5	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.3	12.2	12.1	12.0	11.9	11.9	11.8	11.7	11.6	11.5	11.5	11.4
7.0	12.7	12.6	12.5	12.4	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2
7.5	12.5	12.4	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.3	11.2	11.1
8.0	12.4	12.3	12.2	12.1	12.1	12.0	11.9	11.8	11.7	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	11.0
8.5	12.2	12.1	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8
9.0	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.5	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.8	10.8	10.7
9.5	11.9	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.6
10.0	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4
10.5	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.8	10.7	10.6	10.5	10.5	10.4	10.3
11.0	11.5	11.4	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.3	10.2
11.5	11.4	11.3	11.2	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1
12.0	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.0	10.0
12.5	11.1	11.1	11.0	10.9	10.8	10.8	10.7	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.9
13.0	11.0	10.9	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.7
13.5	10.9	10.8	10.7	10.7	10.6	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.6
14.0	10.8	10.7	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5
14.5	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4
15.0	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3
15.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2
16.0	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.1
16.5	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.0
17.0	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9
17.5	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8
18.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7
18.5	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.7
19.0	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6
19.5	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5
20.0	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4
20.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3
21.0	9.3	9.2	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.2
21.5	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.1

Table 11.1: Oxygen Solubility in Water (oxygen values are in mg/L) -continued

Temp.	Pressure (mmHg)																		
	795	**790**	**785**	**780**	**775**	**770**	**765**	**760**	**755**	**750.0**	**745**	**740**	**735**	**730**	**725**	**720**	**715**	**710**	**705**
22	9.1	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.1
22.5	9.0	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0
23.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9
23.5	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8
24.0	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8
24.5	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7
25.0	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6
25.5	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6
26.0	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5
26.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4
27.0	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.3
27.5	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.3
28.0	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2
28.5	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
29.5	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0
30	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0
30.5	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7	7	6.9
31	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1	7	7	6.9	6.9	6.8
31.5	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7	7	6.9	6.9	6.8	6.8
32	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7	7	6.9	6.9	6.8	6.8	6.7
32.5	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7	7	6.9	6.9	6.8	6.8	6.7	6.7
33	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7	7	6.9	6.9	6.8	6.8	6.7	6.7	6.6
33.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7	7	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6
34	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.5
34.5	7.3	7.3	7.2	7.2	7.1	7.1	7	7	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5
35	7.3	7.2	7.2	7.1	7.1	7	7	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4

Appendix B: Performance check Work sheet

Date of Calibration: ______________ Performed by: ____________________ Sonde ID: ____________

DO membrane changed? Y N

Note: Should wait 6 to 8 hours before final DO calibration, run sensor for 15 minutes in Discrete Run to accelerate burn-in. Note: Change wiper if probe will not park correctly.

Turbidity wiper changed? Y N

Wiper parks 180° from optics? Y N

Record battery voltage: __________

Record the following diagnostic numbers <u>after</u> calibration.

Conductivity cell constant	___________	*Range 5.0 ± .45*
pH MV Buffer 4	___________	*Range +180 ± 50 MV*
pH MV Buffer 7	___________	*Range 0 MV ± 50 MV*
pH MV Buffer 10	___________	*Range -180 ± 50 MV*

<u>Note</u>:
Span between pH 4 to 7 and 7 to 10, MV numbers should be **165 to 180 MV**

DO charge	___________	*Range 50 ± 25*
DO gain	___________	*Range -0.7 – +1.5*

Record Calibration Values

	Actual	Sonde after cal
Temperature	____________	____________
Conductivity	____________	____________
pH 4	____________	____________
pH 7	____________	____________
pH 10	____________	____________
Turbidity(0)	____________	____________
Turbidity(10)	____________	____________
DO	____________	____________

Turbidity Standards used in the calibration _________ Manufacturer and PN____________________

DISSOLVED OXYGEN SENSOR OUTPUT TEST (after DO calibration probe in saturated air)

The following tests will confirm the proper operation of your DO sensor. The DO charge and gain must meet spec before proceeding.

650 Datalogger	**PC w/ Ecowatch**
Turn off 650	Stop discrete and unattended sampling
wait 60 seconds	Confirm that auto-sleep RS-232 is enabled (found in Advanced Menu under Setup)
Power up 650	Wait 60 seconds
go to the Run mode	Start discrete sampling at 4 seconds
watch the DO % output	Watch the DO % output, it must display a positive number and decrease with each 4 second sample, eventually stabilizing to the calibration value in approximately 40 to 60 seconds
	Note: it must display a positive number and decrease with each 4 second sample, eventually stabilizing to the calibration value in approximately 60 to 120 seconds

Note: You can disregard the first two samples, they can be affected by the electronics warm-up.

The **ACCEPT/REJECT** criteria is as follows:

The DO output in % must start at a positive number and decrease during the warm up.
Example: 117, 117, 114, 113, 110, 107, 104, 102, 101, 100, 100.
Should the output display a negative number or start at a low number and climb up to the cal point, the probe is rejected and <u>must not be deployed</u>.

<u>Notes:</u>

______ **ACCEPT** _______ **REJECT**

Downloaded file name and location: ______________________________

Rev 1.0 5/16/05 TB

Appendix C: Sonde Calibration & Verification Form (Rev. 7; 6/07/05)

Survey Name ____________________
YSI 650 # ______________________

Initial Calibration

Date ___________ Time ___________ Performed by ____________________

	DO					pH				SpCond			Turbidity		
Model/ Instrument#	Temp (C)	B.P. (mmHg)	Sat.Value (mg/L)	Sat.Value (%)	Zero DO (mg/L)	pH 7	pH 4	pH 10	Check w/pH 7	_____	_____	Check w/____	0 (NTU)	_____ (NTU)	Check w/ _____
Accept.Criteria			+/- 0.2		(<0.5)	✓	✓	✓	+/- 0.05	✓	✓	+/-5%	✓	✓	+/-10%

Post Verification

Date ___________ Time ___________ Performed by ____________________

	DO						pH				SpCond.			Turbidity		
Model/ Instrument #	Temp (C)	B.P. (mmHg)	Sat. Value Table (mg/L)	DO (mg/L)	ZeroDO (mg/L)	**Met Criteria**	pH 7	pH 4	pH 10	**Met Criteria**	_____	_____	**Met Criteria**	0 (NTU)	_____ (NTU)	**Met Criteria**
Accept.Criteria				+/-0.5	<0.5	Yes or no	+/-0.3	+/-0.3	+/-0.3	Yes or no	+/-10% or 20uS/cm	+/-10% or 20uS/cm	Yes or no	+/-1	+/-20% or +/-2	Yes or no

Note: A DO calibration check should be performed before, during and after the survey.

CATEGORY 3: FIELD MEASUREMENTS

Section 3.3

Water Level Measurement

WATER LEVEL MEASUREMENT

SOP#: 2043
DATE: 10/03/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to set guidelines for the determination of the depth to water and floating chemical product (i.e., gasoline, kerosene) in an open borehole, cased borehole, monitoring well or piezometer.

Generally, water level measurements taken in boreholes, piezometers, or monitoring wells are used to construct water table or potentiometric surface maps and to determine flow direction as well as many other aquifer characteristics. Therefore, all water level measurements at a given site should be collected within a 24-hour period with a great deal of accuracy. Certain situations may necessitate that all water level measurements be taken within a shorter time interval. These situations may include:

1. The magnitude of the observed changes between wells appears too large.
2. Atmospheric pressure changes.
3. Aquifers which are tidally influenced.
4. Aquifers affected by river stage, impoundments, and/or unlined ditches.
5. Aquifers stressed by intermittent pumping of production wells.
6. Aquifers being actively recharged due to precipitation event.
7. Occurrence of pumping.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure or other procedure limitations. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0 METHOD SUMMARY

A survey mark should be placed on the casing for use as a reference point for measurement. Generally, the reference point is made at the top of casing or "stickup," but often the lip of the riser pipe is not flat. Another measuring reference should be located on the grout apron. The measuring point should be documented in the site logbook and on the groundwater level data form (Appendix A). Every attempt should be made to notify future field personnel of such reference point in order to ensure comparable data and measurements.

Prior to measurement, water levels in piezometers and monitoring wells should be allowed to stabilize for a minimum of 24 hours after well construction and development. In low yield situations, recovery may take longer. All measurements should be made to an accuracy of 0.01 feet.

In general, working with decontaminated equipment, proceed from least to most contaminated wells. Where many wells are to be sampled (i.e., greater than ten), measurements may be taken in a systematic manner to insure efficiency and accuracy. Open the well and monitor headspace with the appropriate monitoring instrument to determine the presence of volatile organic compounds. Lower water level measurement device into well until water surface or bottom of casing at least twice is encountered.

Measure distance from water surface to reference point on well casing at least twice and record in site logbook and/or groundwater level data form. Remove all downhole equipment, decontaminate as necessary, and replace casing cap. Note that if floating hydrocarbon product is present, a special dual liquid water level indicator is required.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING AND STORAGE

This section is not applicable to this standard operating procedure (SOP).

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

1. The chalk used on steel tape may contaminate the well.

2. Cascading water may obscure the water mark or cause it to be inaccurate.

3. Many types of electric sounders use metal indicators at five-foot intervals around a conducting wire. These intervals should be checked with a surveyor's tape (preferably with units divided in hundredths of a foot) to insure accuracy.

4. If there is oil present on the water, it can insulate the contacts of the probe on an electric sounder or give false readings due to thickness of the oil. It is recommended to determine the thickness and density of the oil layer in order to determine the correct water level. A special liquid water level indicator is required.

5. Turbulence in the well and/or cascading water can make water level determination difficult with either an electric sounder or steel tape.

6. An airline measures drawdown during pumping. It is only accurate to 0.5 foot unless it is calibrated for various drawdowns.

5.0 EQUIPMENT/APPARATUS

There are a number of devices which can be used to measure water levels. The device must be capable of attaining an accuracy of 0.01 feet, and calibrated on a regular basis.

Field equipment includes:

C Air monitoring equipment

- Well depth measurement device
- Electronic water level indicator
- Metal tape measure
- Airline
- Chalk
- Ruler
- Logbook
- Paper towels
- Groundwater water level data forms
- pH meter (optional)
- Specific conductivity meter (optional)
- Thermometer (optional)

6.0 REAGENTS

No chemical reagents are used in this procedure; however, decontamination solutions may be necessary. If decontamination of equipment is required, refer to the SOP for Sampling Equipment Decontamination, and the site specific work plan.

7.0 PROCEDURES

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or pre-clean equipment, and ensure that it is in working order.
4. Prepare scheduling and coordinate with staff, clients, and regulatory agency, if appropriate.
5. Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.
6. Identify and mark all sampling locations.

7.2 Procedures

Procedures for determining water levels are as follows:

1. Make sure water level measuring equipment is in good operating condition.
2. If possible and when applicable, start at those wells that are least contaminated and proceed to those wells that are most contaminated.
3. Clean all equipment entering well by the following decontamination procedure:
    - Triple rinse equipment with deionized water.
    - Wash equipment with an Alconox solution which is followed by a deionized water rinse.
    - Rinse with an approved solvent (e.g., methanol, isopropyl alcohol, acetone) as per the work plan, if organic contamination is suspected.
    - Place equipment on clean surface such as a teflon or polyethylene sheet.
4. Remove locking well cap, note well ID, time of day, elevation (top of casing) and date in site logbook or an appropriate groundwater level data form.
5. Remove well casing cap.
6. If required by site-specific condition, monitor headspace of well with a photoionization detector (PID) or flame ionization detector (FID) to determine presence of volatile organic compounds, and record in site logbook.
7. Lower electric water level measuring device or equivalent (i.e., permanently installed transducers or airline) into the well until water surface is encountered.
8. Measure the distance from the water surface to the reference measuring point on the well casing or protective barrier post and record in the site logbook. In addition, note that the water level measurement was from the top of the steel casing, the top of the PVC riser pipe, the ground surface, or some other position on the well head.
9. The groundwater level data forms (Form 1, Appendix A) should be completed as

follows:

- Site Name: Site name
- Logger Name: Person taking field notes.
- Date: Date when the water levels are being measured.
- Location: Monitor well number and physical location.
- Time: Time (military time) at which the water level measurement was recorded.
- Depth to Water: Water level measurement in feet, tenths, or hundredths of feet, depending on the equipment used. Two measurements are required to insure accuracy.
- Comments: Any information the field personnel feels to be applicable may be included here.
- Measuring Point: Marked measuring point on PVC riser pipe, protective steel casing or concrete pad surrounding well casing from which all water level measurements for individual wells should be measured. This provides consistency in future water level measurements.

10. Measure total depth of well (at least twice to confirm measurement) and record in site logbook or on groundwater level data form.

11. Remove all downhole equipment, replace well casing cap and locking steel caps.

12. Rinse all downhole equipment and store for transport to next well. Decontaminate all equipment as outlined in Step 3 above.

13. Note any physical changes, such as erosion or cracks in protective concrete pad or variation in total depth of well, in field logbook and on groundwater level data form.

8.0 CALCULATIONS

To determine groundwater elevation above mean sea level, use the following equation:

$$E_W = E - D$$

where:

E_W = Elevation of water above mean sea level (ft) or local datum

E = Elevation above sea level or local datum at point of measurement (ft)

D = Depth to water (ft)

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

The following general quality assurance procedures apply:

1. All data must be documented on standard chain of custody forms, field data sheets, groundwater level data forms, or within personal/site logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation, and they must be documented.

3. Each well should be tested at least twice in order to compare results.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA, or corporate health and safety practices.

12.0 REFERENCES

U.S. Environmental Protection Agency, 1986. RCRA Groundwater Monitoring Technical Enforcement Guidance Document, pp. 207.

U.S. Environmental Protection Agency, 1987, A Compendium of Superfund Field Operations Methods. EPA/540/p-87/001 Office of Emergency and Remedial Response Washington, D.C. 20460.

APPENDIX A

Groundwater Level Data Form

FORM 1. Groundwater Level Data Form

PAGE __ OF __

SITE NAME:________________________________

LOGGER NAME: ______________________ ___

LOG DATE: ________________________________ ___

W.A #: ________________________________

Well I.D.	TIME	Well Elevation (T.O.C.)	Depth to Bottom of Well (ft)	Depth to Water (ft)	COMMENTS (pH, temperature, specific conductance)

MEASUREMENT REFERENCE POINT FROM __ TOP OF GROUND OR __ TOP OF CASING

Weather Conditions:

Other significant observations:

CATEGORY 3: FIELD MEASUREMENTS

Section 3.4

General Field Sampling Guidelines

GENERAL FIELD SAMPLING GUIDELINES

SOP#: 2001
DATE: 08/11/94
REV. #: 0.0

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to provide general field sampling guidelines that will assist REAC personnel in choosing sampling strategies, location, and frequency for proper assessment of site characteristics. This SOP is applicable to all field activities that involve sampling.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0 METHOD SUMMARY

Sampling is the selection of a representative portion of a larger population, universe, or body. Through examination of a sample, the characteristics of the larger body from which the sample was drawn can be inferred. In this manner, sampling can be a valuable tool for determining the presence, type, and extent of contamination by hazardous substances in the environment.

The primary objective of all sampling activities is to characterize a hazardous waste site accurately so that its impact on human health and the environment can be properly evaluated. It is only through sampling and analysis that site hazards can be measured and the job of cleanup and restoration can be accomplished effectively with minimal risk. The sampling itself must be conducted so that every sample collected retains its original physical form and chemical composition. In this way, sample integrity is insured, quality assurance standards are maintained, and the sample can accurately represent the larger body of material under investigation.

The extent to which valid inferences can be drawn from a sample depends on the degree to which the sampling effort conforms to the project's objectives. For example, as few as one sample may produce adequate, technically valid data to address the project's objectives. Meeting the project's objectives requires thorough planning of sampling activities, and implementation of the most appropriate sampling and analytical procedures. These issues will be discussed in this procedure.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

The amount of sample to be collected, and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest. Sample preservation, containers, handling, and storage for air and waste samples are discussed in the specific SOPs for air and waste sampling techniques.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

The nature of the object or materials being sampled may be a potential problem to the sampler. If a material is homogeneous, it will generally have a uniform composition throughout. In this case, any sample increment can be considered representative of the material. On the other hand, heterogeneous samples present problems to the sampler because of changes in the material over distance, both laterally and vertically.

Samples of hazardous materials may pose a safety threat to both field and laboratory personnel. Proper health and safety precautions should be implemented when handling this type of sample.

Environmental conditions, weather conditions, or non-target chemicals may cause problems and/or interferences when performing sampling activities or when sampling for a specific parameter. Refer to the specific SOPs for sampling techniques.

5.0 EQUIPMENT/APPARATUS

The equipment/apparatus required to collect samples must be determined on a site specific basis. Due to the wide variety of sampling equipment available, refer to the specific SOPs for sampling techniques which include lists of the equipment/apparatus required for sampling.

6.0 REAGENTS

Reagents may be utilized for preservation of samples and for decontamination of sampling equipment. The preservatives required are specified by the analysis to be performed. Decontamination solutions are specified in ERT SOP #2006, Sampling Equipment Decontamination.

7.0 PROCEDURE

7.1 Types of Samples

In relation to the media to be sampled, two basic types of samples can be considered: the environmental sample and the hazardous sample.

Environmental samples are those collected from streams, ponds, lakes, wells, and are off-site samples that are not expected to be contaminated with hazardous materials. They usually do not require the special handling procedures typically used for concentrated wastes. However, in certain instances, environmental samples can contain elevated concentrations of pollutants and in such cases would have to be handled as hazardous samples.

Hazardous or concentrated samples are those collected from drums, tanks, lagoons, pits, waste piles, fresh spills, or areas previously identified as contaminated, and require special handling procedures because of their potential toxicity or hazard. These samples can be further subdivided based on their degree of hazard; however, care should be taken when handling and shipping any wastes believed to be concentrated regardless of the degree.

The importance of making the distinction between environmental and hazardous samples is two-fold:

(1) Personnel safety requirements: Any sample thought to contain enough hazardous materials to pose a safety threat should be designated as hazardous and handled in a manner which ensures the safety of both field and laboratory personnel.

(2) Transportation requirements: Hazardous samples must be packaged, labeled, and shipped according to the International Air Transport Association (IATA) Dangerous Goods Regulations or Department of Transportation (DOT) regulations and U.S. EPA guidelines.

7.2 Sample Collection Techniques

In general, two basic types of sample collection techniques are recognized, both of which can be used for either environmental or hazardous samples.

Grab Samples

A grab sample is defined as a discrete aliquot representative of a specific location at a given point in time. The sample is collected all at once at one particular point in the sample medium. The representativeness of such samples is defined by the nature of the materials being sampled. In general, as sources vary over time and distance, the representativeness of grab samples will decrease.

Composite Samples

Composites are nondiscrete samples composed of more than one specific aliquot collected at various sampling locations and/or different points in time. Analysis of this type of sample produces an average value and can in certain instances be used as an alternative to analyzing a number of individual grab samples and calculating an average value. It should be noted, however, that compositing can mask problems by diluting isolated concentrations of some hazardous compounds below detection limits.

Compositing is often used for environmental samples and may be used for hazardous samples under certain conditions. For example, compositing of hazardous waste is often performed after compatibility tests have been completed to determine an average value over a number of different locations (group of drums). This procedure generates data that can be useful by providing an average concentration within a number of units, can serve to keep analytical costs down, and can provide information useful to transporters and waste disposal operations.

For sampling situations involving hazardous wastes, grab sampling techniques are generally preferred because grab sampling minimizes the amount of time sampling personnel must be in contact with the wastes, reduces risks associated with compositing unknowns, and eliminates chemical changes that might occur due to compositing.

7.3 Types of Sampling Strategies

The number of samples that should be collected and analyzed depends on the objective of the investigation. There are three basic sampling strategies: random, systematic, and judgmental sampling.

Random sampling involves collection of samples in a nonsystematic fashion from the entire site or a specific portion of a site. Systematic sampling involves collection of samples based on a grid or a pattern which has been previously established. When judgmental sampling is performed, samples are collected only from the portion(s) of the site most likely to be contaminated. Often, a combination of these strategies is the best approach depending on the type of the suspected/known contamination, the uniformity and size of the site, the level/type of information desired, etc.

7.4 QA Work Plans (QAWP)

A QAWP is required when it becomes evident that a field investigation is necessary. It should be initiated in conjunction with, or immediately following, notification of the field investigation. This plan should be clear and concise and should detail the following basic components, with regard to sampling activities:

- Objective and purpose of the investigation.
- Basis upon which data will be evaluated.
- Information known about the site including location, type and size of the facility, and length of operations/abandonment.
- Type and volume of contaminated material, contaminants of concern (including concentration), and basis of the information/data.
- Technical approach including media/matrix to be sampled, sampling equipment to be used, sample equipment decontamination (if necessary), sampling design and rationale, and SOPs or description of the procedure to be implemented.
- Project management and reporting, schedule, project organization and responsibilities, manpower and cost projections, and required deliverables.
- QA objectives and protocols including tables summarizing field sampling and QA/QC analysis and objectives.

Note that this list of QAWP components is not all-inclusive and that additional elements may be added or altered depending on the specific requirements of the field investigation. It should also be recognized that although a detailed QAWP is quite important, it may be impractical in some instances. Emergency responses and accidental spills are prime examples of such instances where time might prohibit the development of site-specific QAWPs prior to field activities. In such cases, investigators would have to rely on general guidelines and personal judgment, and the sampling or response plans might simply be a strategy based on preliminary information and finalized on site. In any event, a plan of action should be developed, no matter how concise or informal, to aid investigators in maintaining a logical and consistent order to the implementation of their task.

7.5 Legal Implications

The data derived from sampling activities are often introduced as critical evidence during litigation of a hazardous waste site cleanup. Legal issues in which sampling data are important may include cleanup cost recovery, identification of pollution sources and responsible parties, and technical validation of remedial design methodologies. Because of the potential for involvement in legal actions, strict adherence to technical and administrative SOPs is essential during both the development and implementation of sampling activities.

Technically valid sampling begins with thorough planning and continues through the sample collection and analytical procedures. Administrative requirements involve thorough, accurate documentation of all sampling activities. Documentation requirements include maintenance of a chain of custody, as well as accurate records of field activities and analytical instructions. Failure to observe these procedures fully and consistently may result in data that are questionable, invalid and non-defensible in court, and the consequent loss of enforcement proceedings.

8.0 CALCULATIONS

Refer to the specific SOPs for any calculations which are associated with sampling techniques.

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

Refer to the specific SOPs for the type and frequency of QA/QC samples to be analyzed, the acceptance criteria for the QA/QC samples, and any other QA/QC activities which are associated with sampling techniques.

10.0 DATA VALIDATION

Refer to the specific SOPs for data validation activities that are associated with sampling techniques.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety procedures.

Appendix B-2
Sample Collection Parameters for Volatile, Semivolatile, and Pesticide/PCB Analysis

Analysis	Matrix	Containers	Volume/ Mass	Special Notes	Preservative	Holding Time[5]
Volatiles	Water	At least two 40 mL glass containers with Teflon-lined septa and open top screw-caps.	Fill to capacity		Preserve to a pH of 2 and cool to 4°C immediately after collection.	14 days
	Soil	At least two 120-mL wide mouth glass containers or closed end tubes. Medium level samples may also be collected in pre-weighed vials containing 10 ml of methanol. See Special Notes.	Fill to capacity	Headspace should be avoided. Medium level samples: The sample vial, with 10 ml of methanol and all labeling, is weighed to the nearest 0.1 g prior to the addition of the sample. Approximately 5 g of sample is added to the vial. The sample vial with sample is weighed to the nearest 0.1 g. The initial weight, final weight, and sample weight will be recorded and provided to the laboratory.	Cool all samples to 4°C immediately after collection. Methanol for medium level soil samples. See Special Notes.	14 days
	Low Level Soils by Modified SW-846 Method 5035	Two EnCore^{TM}, or equivalent, sample containers with approximately 5 g of sample **OR** Two Pre-prepared, tared, closed-system purge-and-trap vials with sodium bisulfate and approximately 5 g of sample. **AND** One tared glass vial with 10 mL of methanol and approximately 5 g of sample and one 60 mL glass vial with sample. **OR** Two 60 mL wide mouth glass vials with sample.	5 g 5 g 5 g Fill to capacity		Cool all samples to 4°C immediately after collection. Sodium Bisulfate for low-level soils in pre-prepared, pre-weighed vials.	48 hours for Encore samples. 14 days for methanol preserved samples.

---

[5] This holding time is calculated from the time of sample collection. It is recommended that samples be shipped to the lab the same day that they are collected, or as soon as possible thereafter.

Analysis	Matrix	Containers	Volume/ Mass	Special Notes	Preservative	Holding Time[1]
Semi-Volatiles	Water	At least two 1 L or 1quart amber glass container, fitted with screw-caps lined with Teflon.	Fill to capacity	If amber containers are not available, the samples should be protected from light.	Cool all samples to 4°C immediately after collection.	7 days
	Soil	Use one 8 oz wide-mouth glass jar or two 4 oz wide-mouth glass jars.	Fill to capacity		Cool all samples to 4°C immediately after collection.	14 days
Pesticides/ Aroclors	Water	At least two 1 L or 1 quart amber glass container, fitted with screw-caps lined with Teflon.	Fill to capacity	If amber containers are not available, the samples should be protected from the light.	Cool all samples to 4°C immediately after collection.	7 days
	Soil	Use one 8 oz wide-mouth glass jar or two 4 oz wide-mouth glass jars.	Fill to capacity		Cool all samples to 4°C immediately after collection.	14 days

CATEGORY 3: FIELD MEASUREMENTS

Section 3.5

Pressure Transducer Maintenance and Download

DOCUMENT TYPE: Standard Operating Procedure

TITLE: Pressure Transducer Maintenance and Download

INSTRUMENTATION: In-Situ Mini-Troll Pressure Transducer

PREPARED BY: Alison Millar-Camp, Environmental Scientist

REVISED BY:

REVIEWED BY: Jan Kilduff, Ph.D., Quality Assurance Officer

APPROVED BY: Marshall K. Cheung, Ph.D., Laboratory Director

Table of Contents

Document No.:	***SP 011***
***Copy provided to*:**	**Jan Kilduff, Ph.D.**
***Title*:**	Laboratory Director
	29 Palms Laboratory
	47-250 Dillon Road
	Coachella, CA 92236
***Copy provided by*:**	**Alison Millar-Camp**
***Title*:**	Environmental Scientist
Date:	August 3, 2004

1. Scope and Application

1.1. This standard operating procedure describes the process that will govern the collection of data from the three installed In-situ Mini-troll Pressure transducers before any groundwater sampling event, or sooner between events

1.2. Information gathered will contribute to the overall understanding of the aquifer system and support groundwater monitoring project design with historical water level data.

2. Summary of Method

2.1. Measure and record water level with Water Level meter according to SP006
2.2. Connect Communication cable to Laptop and Transducer cable
2.3. Open In-situ software
2.4. Connect software to probe.
2.5. Extract data
2.6. Stop recording
2.7. Delete old data
2.8. Set up new datalogging session
2.9. Start manual recording
2.10. Close software
2.11. Disconnect communtication cable
2.12. Transfer/Convert data from .BIN file to Excel file
2.13. Make a CD of files for archival storage in GIS Office
2.14. Graph data to visually represent water levels

3. Comments

3.1. This procedure can be done before or after purging the well, or anytime between sampling events.

3.2. Not all Teflon cables attached to the Transducer are secured well, so while working with or around cable, hold one hand securely on it.

4. Apparatus

4.1. Laptop computer with a serial port and Win-Situ software installed
4.2. Geotech Tuff Tape Water Level Measuring Device (depth sounder)
4.3. Communication cable
4.4. Sampling Logbook to record level from Depth sounder and location of downloaded data
4.5.

5. Reagents

5.1. Distilled Water to Rinse Probe

6. Procedure

6.1. Measure water level with depth sounder according to SP006.
6.2. Turn computer on
6.3. Plug male serial end of Communication cable to laptop.
6.4. Unscrew cap from top of Teflon cable in Well casing
6.5. Screw top of Teflon cable to proper end of the communication cable

6.6. Open In-situ software on laptop (not data manager)
6.7. On left side of screen in the Table of Contents (TOC), click on *Com-1 9600*
  6.7.1. If not showing, then in larger screen select the find button
6.8. On TOC screen, click on *11745: minitroll Pro* to show Parameters
6.9. Double-click on *Test MW#*
  6.9.1. This will open Test MW# Window
6.10. Click "*Extract*" button in new window on Right side of screen.
6.11. While downloading the data or blocks, battery life of transducer
6.12. After data has been downloaded, a new window opens "Extract Data-Launch Data Manager" which shows where the data is being stored with the pathway shown.
6.13. Click *View* to look at the file and check the logging dates.
6.14. Write down where data is stored
6.15. Close window
6.16. Click *Stop* test
6.17. *Delete* test
6.18. Then create a new test by clicking "*Add*" to open Test Wizard
6.19. Name new test by Well name, ie MW3
6.20. Confirm that both Temperature and Depth have been selected.
6.21. Click *Next*
6.22. Make sure *Linear* is selected
6.23. Click Next
6.24. Change **Seconds** to equal 0
6.25. Change **Minutes** to equal 20
6.26. Should now read Day=0, Hour=0, **Min=20**, **Sec=0**, Tenths=0
6.27. Click *Next*
6.28. Select *Manual Start*
6.29. Click *Finish*
  6.29.1. Wizard will close
6.30. **Start** recording
6.31. Start window will open, Press *OK*
6.32. In Test window box, 'Stopped on' line will say "Running"
  6.32.1. Do Not Stop or Extract until next time you download data. It is recording
6.33. *Close* window
6.34. Close program
6.35. Remove cable from Teflon Transducer cable and laptop.
6.36.
6.37. This sensitivity adjustment causes the sounder to be activated only by contact with the water column instead of by condensation within the well casing above the water column.
6.38. Without moving the tape, turn the sensitivity dial clockwise to exactly the position where the light and buzzer activate.

6.39. Take measurement off tape at top of well casing in feet.
6.40. Determine height of well casing above ground in feet with tape measure.
6.41. Calculate depth to water (static water level) using the following equation:
  6.41.1. Depth (ft)= Measurement off tape (ft) – casing above ground (ft)

6.42. Record static water level in Groundwater Monitoring Logbook #13A, following the Field Record Template for Groundwater Sampling.
6.43. Remove tape from well and rinse with distilled water.
6.44. Dry tape completely and store with the sounder turned off.

7. Maintenance

7.1. The tape on the Tuff Tape depth sounder can be cleaned Liquinox if necessary.
7.2. The sounder itself and reel can be cleaned with a water-dampened cloth if necessary.
7.3. The probe at the end of the tape can be cleaned with Liquinox and a soft brush to remove silt or mud if necessary.
7.4. If the depth sounder will be stored for more than 6 months between uses, the 9-volt battery should be removed.

8. Bibliography

8.1. Fisher WLT Water-Level Indicator Operating Manual. Fisher Research Laboratory, 200 W. Willmott Road, Los Banos, CA 93635.
8.2. Geotech Tuff Tape Water Level Measuring Device Instruction Manual (11/00).

CATEGORY 3: FIELD MEASUREMENTS

Section 3.6

Standard Operating Procedure pH, EPA 150.1 – HACH

DOCUMENT TYPE: Standard Operating Procedure

TITLE: pH, EPA 150.1

INSTRUMENTATION: HACH EC10 pH Meter

PREPARED BY: Marshall K. Cheung, Ph.D., Laboratory Director ___________________

REVISED BY: Marshall K. Cheung, Ph.D., Laboratory Director ___________________

REVIEWED BY: Anne Cheung, Laboratory Manager ___________________

APPROVED BY: Marshall K. Cheung, Ph.D., Laboratory Director ___________________

Table of Contents

Document No.:	***PP 0001 – 015***
***Copy provided to*:**	**Marshall K. Cheung, Ph.D.**
***Title*:**	Laboratory Director
	29 Palms Laboratory
	47-250 Dillon Road
	Coachella, CA 92236
***Copy provided by*:**	Marshall K. Cheung, Ph.D.
***Title*:**	Laboratory Director
Date:	July 28, 2004

1. Scope and Application

1.1. This method is applicable to the analysis of drinking, surface and saline waters, domestic and industrial wastes and acid rain (atmospheric deposition).
1.2. It is applicable to field as well as laboratory analysis.

2. Summary of Method

2.1. Instrument setup procedure is followed.
2.2. The meter is calibrated using certified standards.
2.3. The calibration is verified with an independent certified standard (initial calibration verification).
2.4. The pH of a sample is determined electrometrically using a combination electrode.
2.5. Continuing calibration verification is carried out using the independent certified standard.

3. Sample Handling and Preservation

3.1. Samples should be analyzed as soon as possible preferably in the field at the time of sampling.
3.2. The sample containers should be filled completely and kept sealed prior to analysis because high-purity waters and waters not at equilibrium with the atmosphere are subject to changes when exposed to the atmosphere.
3.3. Stable pH, conductivity and temperature conditions must be demonstrated prior to groundwater sample collection (see SOP #SP002- Groundwater Sampling).

4. Interferences

4.1. The glass electrode, in general, is not subject to solution interferences from color, turbidity, colloidal matter, oxidants, reductants or high salinity.
4.2. Coatings of oily material or particulate matter can impair electrode response. Gentle wiping or detergent washing, followed by distilled water rinsing can usually remove these coatings. An additional treatment with hydrochloric acid (1 + 9) may be necessary to remove remaining film.
4.3. Variation in temperature causes pH values to differ. This interference can be controlled with instruments having temperature compensation or by calibrating the electrode-instrument system at the temperature of the samples.
4.4. If compensation or calibration at the same temperature is not possible, it should be noted by reporting both the pH and the temperature at the time of analysis.

5. Apparatus

5.1. *HACH* EC10 Portable pH/mV/Temperature Meter - Model 50050
5.2. *HACH* One Combination pH Electrode - Model 48600-22
5.3. Magnetic stirrer and Teflon-coated stirring bar (for lab analysis)

6. Reagents/Supplies

6.1. VWR pH 7.00 Buffer Solution Yellow (Cat. No. 34170-130)
6.2. VWR pH 7.00 Buffer Solution Yellow (Cat. No. 34170-130)-different lot
6.3. VWR pH 4.00 Buffer Solution Red (Cat. No. 34170-127)
6.4. VWR pH 10.00 Buffer Solution Blue (Cat. No. 34170-133)
6.5. Ricca Deionized Water (Cat. No. 9150-5)
6.6. Kimberly-Clark Kimwipes EX-L (Cat. No. 34120)

7. Procedure

7.1. *Instrument Setup* (Refer to *HACH* EC10 Manual)

7.1.1. Power-up and Self-Diagnostics Checkout
  7.1.1.1. Disconnect the electrode and temperature probe from the meter.
  7.1.1.2. Attach BNC shorting cap to the BNC connection on the meter.
  7.1.1.3. Press the **I/O** key to turn the instrument on.
  7.1.1.4. Install new 9V battery when low battery indicator appears on the display.
  7.1.1.5. Press **I/O** key to turn the meter off.
  7.1.1.6. Press and hold the **YES** key while pressing the **I/O** key.
    7.1.1.6.1. The instrument automatically performs electronic and hardware diagnostic tests, and a system countdown will display 1-8.
    7.1.1.6.2. The meter will stop on test 7.
  7.1.1.7. When “0” is displayed, press each key (including the **I/O** key) within 10 seconds to complete this test.
    7.1.1.7.1. The numeric digits will change.
    7.1.1.7.2. If all keys are not pressed within 10 seconds, or if a key is not responding properly, *E-7* will appear.
    7.1.1.7.3. If problems are found during self-test, the meter will display the error code until **YES** is pressed.
    7.1.1.7.4. If there is an error, begin Power-up and Self-Diagnostics Checkout again (7.1.1).
    7.1.1.7.5. Refer to Table 2 *Error Codes* on page 19 of the instrument manual.
  7.1.1.8. After the keypad test (7), the meter will display test 8 and then the meter will turn off.
  7.1.1.9. Make sure that the BNC shorting cap is securely attached to the BNC connection of the meter and then press the **I/O** key. The meter will be in the MEASURE mode as indicated on the display.
  7.1.1.10. Press the **MODE** key until the pH mode indicator is displayed.
  7.1.1.11. Press the **CAL** key.
  7.1.1.12. When the display flashes 7.00, press the **YES** key.
  7.1.1.13. Press the **MODE** key. The current slope (SLP) will be displayed.
  7.1.1.14. Press the **YES** key.
  7.1.1.15. The meter advances to MEASURE and reads a steady 7.00.
  7.1.1.16. Turn meter off.
  7.1.1.17. Remove the BNC shorting cap from the input connector.
7.1.2. Install the HACH One combination pH electrode.
  7.1.2.1. Attach the BNC connector of the electrode to the BNC connection of the pH meter.
  7.1.2.2. Attach the ATC/DIN Connector of the electrode to the ATC/DIN connection of the pH Meter.
7.1.3. Thoroughly rinse electrode with deionized water.
7.1.4. Blot with Kimwipe.
7.1.5. Instrument is ready for calibration.

7.2.Instrument Calibration

7.2.1. Allow standard pH buffer solutions to equilibrate to room temperature (20-30^{o} C).
7.2.2. Turn the pH meter on.
7.2.3. Using the MODE key, set the meter to “pH” mode.
7.2.4. Depress the dispenser button on the electrode until a “click” is heard, then release.
7.2.4.1.Repeat until electrolyte gel emerges from the reference outlet (See Model 48600 HACH One Combination pH Electrode Instruction Manual).
7.2.4.1.1. If no gel emerges, the hole may need to be unplugged with a needle.
7.2.4.1.2. If this does not help, the gel unit may need to be replaced if low.
7.2.4.2. Rinse the electrode with deionized water and blot dry with Kimwipe.
7.2.5. Place the pH electrode into 7.00 buffer solution (Yellow).
7.2.5.1. Make sure that the electrode tip is at least 1 inch below the surface of the solution.
7.2.5.1.1. If access to magnetic stirrer is available, place clean magnetic stir rod into buffer solution.
7.2.5.1.2. Wait for reading to stabilize while stirring on magnetic stirrer.
7.2.5.1.3. If not magnetic stirrer is used, gently agitate probe in buffer manually.
7.2.6. Press the **CAL** key.
7.2.7. **P1** will be displayed under pH reading.
7.2.8. Wait until “ready” is displayed and then press the **YES** key.
7.2.9. Remove electrode, rinse with deionized water and blot dry with Kimwipe.
7.2.10. Click electrolyte pump button two (2) times.
7.2.11. Place electrode into either 4.00 or 10.00 buffer solution depending on the expected pH range of the sample to be measured.
7.2.11.1. If expected pH range of the sample is greater than 7.00, use the 10.00 buffer (Blue).
7.2.11.2. If the expected pH range of the sample is less than 7.00, use the 4.00 buffer (Red).
7.2.12. Make sure that the electrode tip is at least 1” below the surface of the solution.
7.2.12.1. If access to magnetic stirrer is available, place clean magnetic stir rod into buffer solution.
7.2.12.2. Wait for reading to stabilize while stirring on magnetic stirrer.
7.2.12.3. If no magnetic stirrer is used, gently agitate probe in buffer manually.
7.2.13. Wait until “ready” is displayed and then press the **YES** key.
7.2.14. Slope is displayed. Record slope in HACH ph Meter Log, Logbook #30 A.
7.2.15. Remove electrode, rinse with deionized water and blot dry with Kimwipe.
7.2.16. Click electrolyte pump button two (2) times.
7.2.17. Take pH of a second standard pH 7.0 buffer as a calibration check (*initial calibration verification-ICV*).
7.2.17.1. If pH is within 0.05 pH units of the expected value (acceptable *precision*), calibration is verified. Proceed to 7.2.6.6.
7.2.17.2. If pH is outside this range, reread pH of calibration check standard.
7.2.17.3. If pH is within range, proceed to 7.2.6.6.
7.2.17.4. If pH is still outside range, reread fresh buffer standard.
7.2.17.5. If pH is outside range, recalibrate (7.2).

7.2.18. Retake pH of calibration standards and record reading for each in HACH pH Meter Log, Logbook #30 A.

7.2.19. Dispense gel electrolyte if the reading becomes unstable, erratic, or if stabilization takes too long (greater than two minutes).

7.3. Take sample measurements.

7.3.1. For laboratory analyses, allow samples and buffer solutions to come to room temperature (20 – 30°C).

7.3.2. Thoroughly rinse pH electrode with deionized water and blot dry with Kimwipe.

7.3.3. Insert rinsed and dried electrode into the sample.

7.3.4. Record the pH value and the temperature of samples in appropriate bound logbook (Surface Water Monitoring Log, Logbook #21 A, or Groundwater Monitoring Log, Logbook #13 A).

7.3.5. Analyze a calibration check standard (*continuing calibration verification- CCV*) with every ten samples to re-check the validity of the calibration curve.

7.3.5.1. If the CCV is within 0.05 of the expected value, continue with sample analysis.

7.3.5.2. If the CCV differs by more than 0.05, follow the steps below.

7.3.5.2.1. If the CCV does not come within 0.05 of the expected value, then the calibration check standard should first be reread.

7.3.5.2.2. If the repeat analysis result still differs by greater than 0.05, a fresh calibration check standard should be read.

7.3.5.2.3. If this calibration check standard does not meet the criteria, a new calibration must be performed and all samples analyzed since the last valid calibration must be rerun.

8. Calculation

8.1. The pH meter reads directly in pH units. Report pH to the nearest 0.01 unit and the temperature to the nearest 0.1°C.

9. Bibliography

9.1. HACH EC10 Portable pH/mV/Temperature Meter Model 50050 Manual.

9.2. Model 48600 HACH One Combination pH Electrode Instruction Manual.

9.3. EPA Method 150.1.

9.4. Standard Methods for the Examination of Water and Wastewater, 20th Edition, Method No. 4500-H+, p 4-87, (1998).

CATEGORY 3: FIELD MEASUREMENTS

Section 3.7

Standard Operating Procedure Conductivity, EPA 120.1 – HACH

DOCUMENT TYPE: Standard Operating Procedure

DOCUMENT CLASS: Physical Property Procedure

TITLE: Conductivity, EPA 120.1

INSTRUMENTATON: HACH CO150 Conductivity Meter

PREPARED BY: Marshall K. Cheung, Ph.D., Laboratory Director ___________________

REVISED BY: Marshall K. Cheung, Ph.D., Laboratory Director ___________________

REVIEWED BY: Anne Cheung, Laboratory Manager ___________________

APPROVED BY: Marshall K. Cheung, Ph.D., Laboratory Director ___________________

Table of Contents

Document No.:	***PP 002 - 014***
***Copy provided to*:**	**Marshall K. Cheung**
***Title*:**	Laboratory Director
	29 Palms Laboratory
	47-250 Dillon Road
	Coachella, CA 92236
***Copy provided by*:**	**Jan Kilduff**
***Title*:**	Quality Assurance Officer
Date:	July 28, 2004

1. Scope and Application

1.1. This method is applicable to the analysis of drinking, surface and saline waters, domestic and industrial wastes and acid rain (atmospheric deposition).

2. Summary of Method

2.1. The specific conductance of a sample is measured by use of a self-contained conductivity meter, Wheatstone bridge-type, or equivalent.

2.2. Samples are preferably analyzed at 25^{o}C. If not, corrections for temperature are made and result reported at 25^{o}C.

3. Comments

3.1. Instrument must be standardized with certified calibration solutions before use daily.

3.2. Conductivity cell must be kept clean.

3.3. Temperature variations and corrections represent the largest source of potential error.

3.4. Results are reported as specific conductance, µS/cm at 25^{o}C.

4. Sample Handling and Preservation

4.1. Analyses can be performed either in the field or laboratory.

4.2. If analysis is not completed within 24 hours of sample collection, sample should be filtered through a 0.45µm filter and stored at 4^{o}C. Filter and apparatus must be washed with reagent water and pre-rinsed with sample before use.

5. Apparatus

5.1. *HACH* CO150 Conductivity Meter

5.2. *HACH* Model 50161 Conductivity Probe

6. Reagents/Supplies

6.1. Calibration Standards

   6.1.1. VWR traceable ONE-SHOT conductivity calibration standard – 100 µmhos/cm with certificate of analysis (Cat. No. 23226-651)

   6.1.2. VWR traceable ONE-SHOT conductivity calibration standard – 1000 µmhos/cm with certificate of analysis (Cat. No. 23226-652)

   6.1.3. VWR traceable ONE-SHOT conductivity calibration standard – 10,000 µmhos/cm with certificate of analysis (Cat. No. 23226-653)

6.2. Continuous Calibration Check Standard (CCV)

   6.2.1. VWR traceable ONE-SHOT conductivity calibration standard (second bottle different from Calibration Standard 6.1.2) – 1000 µmhos/cm with certificate of analysis (Cat. No. 23226-652)

6.3. Ricca Deionized Water (Cat. No. 9150-5)

6.4. Kimberly-Clark Kimwipes EX-L (Cat. No. 34120)

7. Procedure

7.1. *Instrument Setup* (Refer to the *HACH* CO150 Manual)

7.1.1. Power-up and Self-Diagnostics Checkout

7.1.1.1. Disconnect the conductivity probe from the meter.

7.1.1.2. Press **I/O** key to turn the meter on.

7.1.1.3. Install 9V battery when low battery indicator appears on the display.

7.1.1.4. Press **I/O** key to turn the meter off.

7.1.1.5. Press and hold the **YES** key while pressing the **I/O** key.

7.1.1.6. The instrument automatically performs electronic and hardware diagnostic tests, and a system countdown will display 1-8.

7.1.1.6.1. If *E-3* appears in the display, check to make sure the conductivity probe is not attached.

7.1.1.7. The meter will stop on test 7.

7.1.1.7.1. When “0” is displayed, press each key (including the **I/O** key within 10 seconds to complete this test.

7.1.1.7.2. The numeric digits will change.

7.1.1.7.3. If all keys are not pressed within 10 seconds, or if a key is not responding properly, *E-7* will appear.

7.1.1.7.4. If problems are found during self-test, the meter will display the error code until YES is pressed.

7.1.1.7.5. Refer to Table 10 *Error Codes* on page 31 of the instrument manual.

7.1.1.7.6. If there is an error, begin Power-up and Self-Diagnostics Checkout (7.1.1) again.

7.1.1.8. After the keypad test (7), the meter will display test 8 and then the meter will turn off.

7.1.2. Instrument Setup

7.1.2.1. Press the **I/O** key.

7.1.2.2. Press the **SETUP** key to enter the setup menu.

7.1.2.3. Turn automatic temperature compensation (S-1) to “ON” using an **ARROW** key and then press the **YES** key.

7.1.2.4. Set the reference temperature (S-2) to 25^{o}C using an **ARROW** key and then press the **YES** key.

7.1.2.5. Set the temperature compensation (S-3) to 25^{o}C using an **ARROW** key and then press the **YES** key.

7.1.2.6. Turn automatic Auto Shutoff (S-4) to “ON” using an **ARROW** key and then press the **YES** key.

7.1.2.7. Return to measure mode by pressing **MODE** key.

7.1.3. Install conductivity probe.

7.1.4. Thoroughly rinse conductivity probe with deionized water and blot with Kimwipe.

7.1.5. Instrument is ready for calibration.

7.2. Instrument Calibration

7.2.1. Allow the 100, 1000 and 10,000 µS/cm standard solutions to come to room temperature (20 – 30^{o}C).

7.2.2. Using the **MODE** key set the meter to “Cond” mode.

7.2.3. Place the conductivity probe into the 1000 µS/cm standard solution.

- 7.2.3.1. Immerse the tip to or beyond the vent holes.
- 7.2.3.2. Agitate the probe vertically to make sure air bubbles are not entrapped.

7.2.4. If the reading differs from the certified value listed on the bottle by more than 10%, a calibration is necessary.

7.2.5. To calibrate, an adjustment value must be entered.

7.2.6. To approximate an adjustment value, subtract 40 μS from displayed value if standard temperature is below 25 °C and add 40 μS to displayed value if standard temperature is above 25 °C.

7.2.7. Press **CAL** key three (3) times to enter screen for entering adjustment value (display should read 1999).

7.2.8. Use **ARROW** keys to change digits followed by the **YES** key to enter.

7.2.9. After the last digit is entered, the meter will automatically begin calibration and display the adjusted value of the calibration standard solution at the reference temperature.

7.2.10. Continue increasing or decreasing adjustment value until displayed value is within 10% of certified value.

7.2.11. Record the temperature and the calibrated result.

7.2.12. Record the values for 100 and 10,000 μS/cm standards.

7.2.13. Prepare calibration curve (See ***8. Calibration Curve***).

7.2.14. Measure conductance of a 1000 μS/cm standard (different from standard used to calibrate) as a calibration verification standard *(initial calibration verification -ICV*) to verify validity of curve.

- 7.2.14.1. If the conductivity of the ICV is within 10% of the expected value based on the calibration curve, the calibration is verified. Continue with sample measurement (7.3).
- 7.2.14.2. If the conductivity of the ICV differs by more than 10% from the expected value, see corrective action in 8.7.

7.3. Take sample measurements.

7.3.1. Allow samples to come to room temperature (20 – 30°C).

7.3.2. Thoroughly rinse conductivity probe with deionized water and dry with Kimwipe.

7.3.3. Insert rinsed and dried probe into sample.

7.3.4. Record the conductivity value and the temperature of samples.

7.3.5. Analyze the 1000 μS/cm calibration verification standard (*continuing calibration verification – CCV*) with every ten samples to re-check the validity of the calibration curve.

- 7.3.5.1. If the CCV is within 10% of the expected value, continue with sample analysis.
- 7.3.5.2. If the CCV differs by more than 10%, see corrective action in 8.7.

8. Calibration Curve

8.1. Obtain a standard curve by plotting the three calibration standard values that were run by the above procedure against expected conductivity in μS/cm.

8.2. Perform regression analysis of calibration data to evaluate correlation.

8.3. Plot best-fit line.

8.4. For the curve to be valid, the correlation of points with the residual line must meet following criteria:

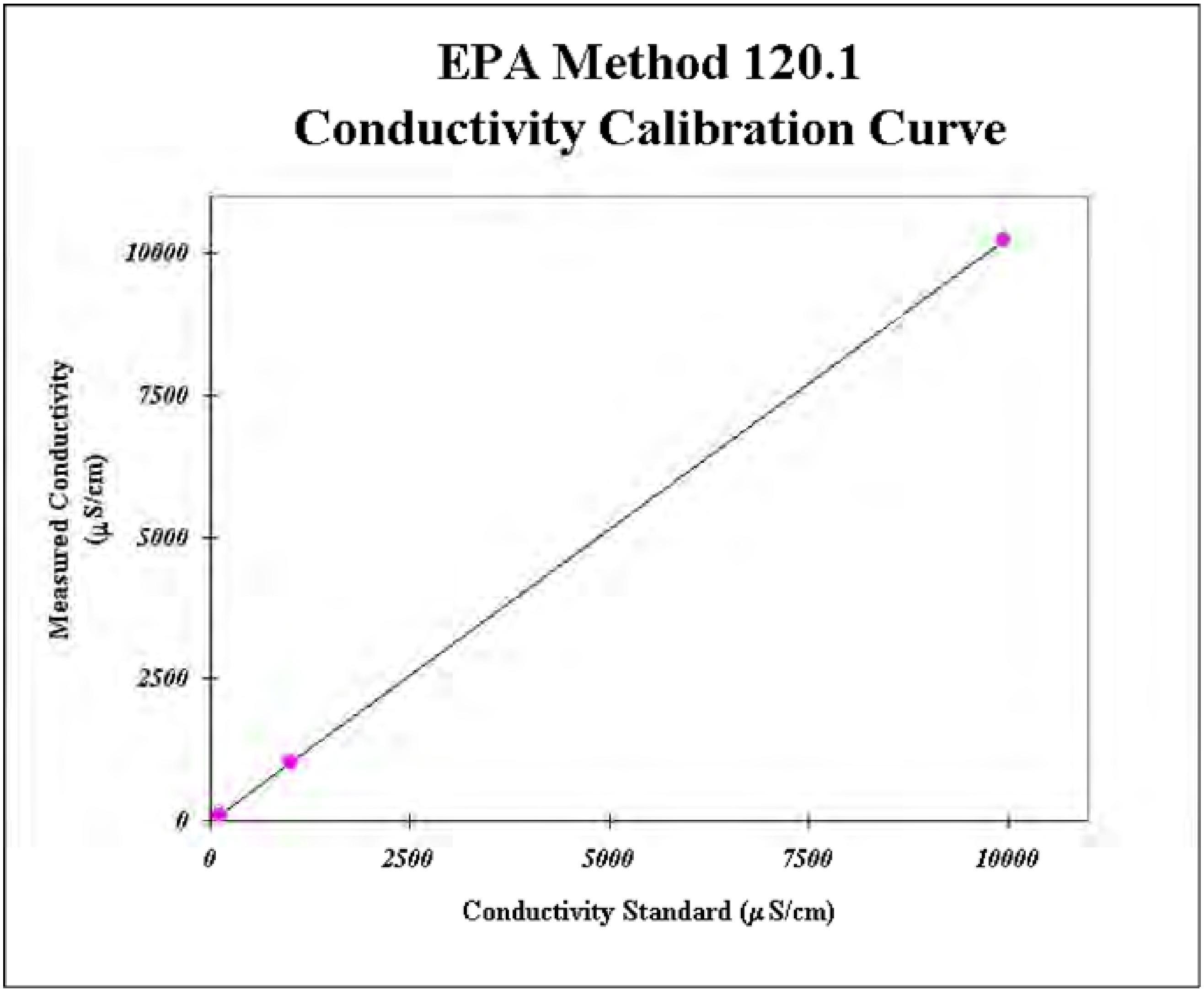
- 8.4.1. Relative percent standard deviation of the response factor (RF) must be less than 15%.
- 8.4.2. R^2 must be greater than or equal to 99%.

        - 8.4.3. If the relative percent standard deviation of the RF is greater than 15% or the R^2 value is less than 0.99, then the calibration standards must be reanalyzed to achieve an acceptable curve.
- 8.5. Prior to sample analysis, calibration verification (*initial calibration verification –ICV*) is performed (7.2.14).
- 8.6. During sample analysis, calibration verification (*continuing calibration verification-CCV*) is done at a frequency of 10% (7.3.6).
- 8.7. The order of corrective action for Calibration Verification Standard problems are:
    - 8.7.1. If the Calibration Verification Standard (ICV or CCV) does not come within 10% of the expected value, then the standard should first be rerun.
    - 8.7.2. If the repeat analysis result still differs by greater than 10%, a fresh standard should be prepared and analyzed.
    - 8.7.3. If the fresh standard does not meet the criteria, a new calibration must be performed.

9. Bibliography

9.1. *HACH* CO150 Conductivity Meter Manual
9.2. EPA Method 120.1
9.3. Standard Methods for the Examination of Water and Wastewater, *20th Edition*, Method No. 2510, p 2-44 to 2-47, (1998).

10. Calibration Curve



Conductivity Standard (*μS/cm)*	**Measured Conductivity (*μS/cm)***		**Check Standard**	***Date:***9/8/00
109	105			***Std. Dev.*** =0.040
998	1032		1009	***Relative % Std. Dev.*** =3.92
9959	10241			
				R^2 =1.000
				m =1.028
				y-intercept =0.000

CATEGORY 3: FIELD MEASUREMENTS

Section 3.8

Standard Operating Procedure Dissolved Oxygen, EPA Method 360.1 – VWR Scientific

DOCUMENT NO.: PP006

DOCUMENT TYPE: Standard Operating Procedure

DOCUMENT CLASS: Physical Property Procedure

TITLE: Dissolved Oxygen, EPA Method 360.1

ANALYTE: CAS # O Oxygen 7782-44-7

STORET No. : 00299

INSTRUMENTATION: VWR Scientific Dissolved Oxygen Meter
Model 4000

PREPARED BY: Marshall K. Cheung, Ph.D., Laboratory Director ___________________

REVISED BY: Marshall K. Cheung, Ph.D., Laboratory Director ___________________

REVIEWED BY: Anne Cheung, Laboratory Manager ___________________

APPROVED BY: Marshall K. Cheung, Ph.D., Laboratory Director ___________________

Table of Contents

Document No.:	***PP 0006 – 1.0 - 006***
Copy provided to:	29 Palms Band of Mission Indians
Title:	Tribal Council
Address:	46-200 Harrison Place Coachella, CA 92236
Copy provided by:	**Jan Kilduff, Ph.D.**
Title:	Laboratory QA Officer
Date:	August 4, 2004

1. Scope and Application

1.1 The membrane probe method for dissolved oxygen is recommended for those samples containing materials which interfere with the modified Winkler, iodometric procedure (*EPA Method 360.2*) such as sulfite, thiosulfate, polythionate, mercaptans, free chlorine or hypochlorite, organic substances readily hydrolyzed in alkaline solutions, free iodine, intense color or turbidity and biological flocs.

1.2 Membrane electrodes provide an excellent method for DO analysis in polluted waters, highly colored waters, and strong waste effluents.

- ***1.2.1.*** They are recommended for use especially under conditions that are unfavorable for use of the iodometric method, or when that test and its modifications are subject to serious errors caused by interferences.
- ***1.2.2.*** The membrane probe method is recommended as a substitute for the modified Winkler procedure in monitoring of streams, lakes, outfalls, etc., where it is desired to obtain a continuous record of the dissolved oxygen content of the water under observation.

1.3 The membrane probe method may be used as a substitute for the modified Winkler procedure in BOD determinations.

2. Summary of Method

2.1 The instrumental probe for determination of dissolved oxygen in water is dependent upon electrochemical reactions.

2.2 Oxygen-sensitive membrane electrodes of the polarographic or galvanic type are composed of two solid metal electrodes in contact with supporting electrolyte separated from the test solution by a selective membrane.

2.3 Under steady-state conditions, the current or potential can be correlated with DO concentrations.

- ***2.3.1.*** The "diffusion current" is linearly proportional to the concentration of molecular oxygen.
- ***2.3.2.*** The current can be converted easily to concentration units (e.g., rnilligrams per liter) by a number of calibration procedures.

2.4 Interfacial dynamics at the probe-sample interface are a factor in probe response and a significant degree of interfacial turbulence is necessary. For precision performance, turbulence should be constant.

3. Sample Handling and Preservation

3.1 Because membrane electrodes offer the advantage of analysis *in situ* they eliminate errors caused by sample handling and storage.

3.2 If sampling is required, collect the sample in a 300 mL BOD incubation bottle.

- ***3.2.1*** Special precautions are required to avoid entertainment or solution of atmospheric oxygen or loss of dissolved oxygen.
- ***3.2.2*** Where surface water samples are collected from shallow depths (less than 5 feet), use of an APHA-type sampler is recommended.
- ***3.2.3*** Use of a Kemmerer type sampler is recommended for surface water samples collected from depths of greater than 5 feet.
  - ***3.2.3.1*** When a Kemmerer sampler is used, the BOD sample bottle should be filled to overflowing (overflow for approximately 10 seconds).

3.2.3.2 Outlet tube of Kemmerer should be inserted to bottom of BOD bottle.

3.2.3.3 Care must be taken to prevent turbulence and the formation of bubbles when filling bottle.

3.3 At time of sampling, the sample temperature should be recorded as precisely as required.

3.4 Do not delay the determination of dissolved oxygen in the samples.

4. Interferences

4.1 Dissolved organic materials are not known to interfere in the output from dissolved oxygen probes.

4.2 Dissolved inorganic salts are a factor in the performance of dissolved oxygen probe.

4.2.1 Probes with membranes respond to partial pressure of oxygen, which in turn is a function of dissolved inorganic salts.

4.2.2 Conversion factors for seawater and brackish waters may be calculated from dissolved oxygen saturation versus salinity data (Table I).

4.2.3 Conversion factors for specific inorganic salts may be developed experimentally.

4.2.4 Broad variations in the kinds and concentrations of salts in samples can make the use of a membrane probe difficult.

4.3 Reactive compounds can interfere with the output or the performance of dissolved oxygen probes.

4.4 Reactive gases, which pass through the membrane probes, may interfere.

4.4.1 For example, chlorine will depolarize the cathode and cause a high probe-output. Long-term exposures to chlorine will coat the anode with the chloride of the anode metal and eventually desensitize the probe.

4.4.2 Alkaline samples in which free chlorine does not exist will not interfere.

4.4.3 Hydrogen sulfide will interfere with membrane probes if the applied potential is greater than the half-wave potential of the sulfide ion.

4.4.3.1 If the applied potential is less than the half-wave potential, an interfering reaction will not occur, but coating of the anode with the sulfide of the anode metal can take place.

4.4.3.2 Prolonged use of membrane electrodes in waters containing gases such as hydrogen sulfide (H_2S) tends to lower cell sensitivity.

4.4.3.3 Eliminate this interference by frequently changing and calibrating the membrane electrode.

4.5 Dissolved oxygen probes are temperature sensitive, and the DO meter provides temperature compensation.

4.6 Plastic films used with membrane electrode systems are permeable to a variety of gases besides oxygen, although none is depolarized easily at the indicator electrode.

5. Apparatus

5.1 VWR Scientific Dissolve Oxygen Meter, Model No. 4000

5.2 Sample bottles-300 mL ±3 mL capacity BOD incubation bottles with tapered ground glass pointed stoppers and flared mouths.

6. Reagent

- ***6.1*** Reagent Water
- ***6.2*** Compressed Air
- ***6.3*** Sodium Sulfite, Na_2SO_3

7. Instrument Check Out Procedure

- ***7.1*** It is recommended that this procedure be performed when the meter is received and any time operation problems arise.
- ***7.2*** This procedure verifies the proper operation of the VWR Model 4000 Dissolved Oxygen Meter.
- ***7.3*** Attach the dissolved oxygen electrode to the DIN connector on top of the meter.
- ***7.4*** Press **POWER** key to turn meter on. If battery indicator remains on, replace battery or use line adapter.
- ***7.5*** Press the **POWER** key to turn meter off.
- ***7.6*** Press and hold the **YES** key while pressing the **POWER** key. The instrument automatically performs electronic and hardware diagnostic tests.
- ***7.7*** After code 7, a "0" will appear on the display. Press each key once in any order (the numeric digits will change). Note: All keys must he pressed within 10 seconds to complete test 7.
- ***7.8*** After the keypad test, the meter will display Test 8 and then the meter will turn off.
- ***7.9*** If any problems are found during self-test, the meter will display the operator assistance code until acknowledged (with the **YES** key).

8. Instrument Setup Mode Functions

- ***8.1*** SALINITY TOGGLE (1-1)
  - ***8.1.1*** The SALINITY TOGGLE function is used to activate and deactivate the salinity correction feature.
  - ***8.1.2*** If this function is enabled, the meter will proceed to the SALINITY FACTOR function (**7.2**).
  - ***8.1.3*** If this function is disabled, the meter will proceed to the BAROMETRIC PRESSURE function (**7.3**).
- ***8.2*** SALINITY FACTOR (1-2)
  - ***8.2.1*** The SALINITY FACTOR function is used to set the salinity correction factor.
  - ***8.2.2*** The SALINITY FACTOR range is 0 to 40 ppt (parts per thousands).
  - ***8.2.3*** The default value is 0 ppt.
  - ***8.2.4*** Use the SCROLL key to set the salinity correction factor accordingly (answer YES to accept a new value).
- ***8.3*** BAROMETRIC PRESSURE (1-3)
  - ***8.3.1*** The BAROMETRIC PRESSURE function is used to set the atmospheric pressure correction factor (in the units mm Hg).
  - ***8.3.2*** The BAROMETRIC PRESSURE range is 540-850 mmHg. The default value is 760.
  - ***8.3.3*** Use the SCROLL key to set the current barometric pressure which can be obtained locally, press YES key to accept value.

8.4 AUTOCALIEBRATION TOGGLE (2 - 2)

- ***8.4.1*** The AUTOCALIBRATION TOGGLE function is used to activate and deactivate the autocalibration feature.
- ***8.4.2*** If this function is enabled, the meter will perform calibrations without the need for editing; upon reaching "ready", the meter automatically sets the standard value to 101.7%.
- ***8.4.3*** This feature is used only for calibrations performed using- water saturated air as the calibration standard (i.e. the Calibration sleeve or B.O.D. bottle with a small amount of distilled or deionized water and tightly closed around electrode).
- ***8.4.4*** If this function is disabled, the meter will require editing of the value corresponding to the calibration standard (in this case, air-saturated water).

8.5 ELECTRODE "ZEROING" (2 - 3)

- ***8.5.1*** The ELECTRODE ZERO function is used to perform a zeroing of the electrode.
- ***8.5.2*** If the electrode has been polarized such that it is in a steady state, it may be zeroed.
  - ***8.5.2.1*** Place the electrode into an oxygen scavenging solution (such as 20% sodium sulfite) (see Sec. ***8.1***) for at least five minutes and then perform a zeroing.
  - ***8.5.2.2*** When the ELECTRODE ZERO function is entered, “0” is displayed and is flashing.
  - ***8.5.2.3*** To activate the zeroing of the electrode, press the SCROLL key.
  - ***8.5.2.4*** After pressing SCROLL key, "l” will be displayed.
  - ***8.5.2.5*** The meter will take measurements and perform stability checking.
    - ***8.5.2.5.1*** When the input has stabilized, the "ready" annunciator will light and the main readout will display "000.0" for approximately 5 seconds. .
    - ***8.5.2.5.2*** NOTE: Zeroing of the electrode is not necessary unless measuring 3 mg/L or less.

8.6 PRINT MODES (3 - 1)

- ***8.6.1*** This function determines when the printer will be sent data.
- ***8.6.2*** When the code for the PRINT MODES is displayed, the current setting (1 or 2) will flash in the rightmost position of the main readout.
  - ***8.6.2.1*** If “1" (Manual PRINT) is displayed, no automatic output to the printer will occur. Press the PRINT key at any time while in the measure mode to initiate a printout.
  - ***8.6.2.2*** If “2” (Print on ready) is displayed, the meter will print when the "ready" display is flashing.

8.7 To exit out of the SETUP mode, simply press the "mode" key to access either Concentration (ppm or mg/L) or % Saturation (% SAT) measure mode.

9. Calibration

9.1 The following calibration procedure should be performed at the beginning of each day for maximum performance.

9.2 Prior to operation, connect electrode to the meter and power up. Allow the electrode to polarize before attempting a calibration of the electrode.

9.2.1 Dissolved oxygen electrodes are continuously polarized when they are connected to the instrument.

9.2.2 Polarization when the electrode is new or has been unplugged for more than an hour will take 20-30 minutes.

9.2.3 Interrupted connections of less than one hour will take between 20-25 minutes to repolarize.

9.3 Calibration Procedure

9.3.1 Enable the SALILNITY TOGGLE (***7.1***) function on the DO meter.

9.3.2 Determine specific conductance of the sample to be measured according to SOP #PP005.

9.3.3 Set the SALILNITY FACTOR (***7.2***) using the Table I.

9.3.4 Determine the elevation of the sampling site using GPS SOP #SP003.

9.3.5 Set the BAROMETRIC PRESSURE function (***7.3***) according to the elevation using Table II.

9.3.6 Set the AUTOCALIBRATION TOGGLE function to ON (***7.4***).

9.3.7 "Zeroing" the Electrode

9.3.7.1 Add 20 g anhydrous sodium sulfite, Na_2SO_3 to 100 mL reagent water.

9.3.7.2 Connect the electrode to the meter and turn the power on.

9.3.7.3 Place the electrode in the sodium sulfite solution (***8.3.1***).

9.3.7.4 Swirl a few times and proceed to the SETUP mode of the meter (Sec. ***7.5***).

9.3.8 Calibration Procedure

9.3.8.1 Prepare a calibration standard by bubbling compressed air into 50 mL reagent water for 5 minutes.

9.3.8.2 Position the tip of the electrode one inch above the surface of the water.

9.3.8.3 Press CAL key.

9.3.8.3.1. Display will show four dashes (- - - -) indicating the unit is in the CALIBRATIOM mode.

9.3.8.3.2. In addition, "SP" indicating slope is displayed in the lower display field.

9.3.8.4 When the electrode is calibrated, the READY light will come on and the calibration slope is displayed.

9.3.8.5 Press **YES** key to accept calibration.

9.3.8.6 Press **MODE** key to select mg/L (ppm).

9.3.8.7 Place electrode in the calibration standard, and when "READY' light is displayed, record calibration value.

9.3.8.8 Rinse the electrode thoroughly and blot dry. Additional measurements can now be made.

10. Procedure

10.1 Take care in changing membrane to avoid contamination of sensing element and also trapping of minute air bubbles under the membrane, which can lead to lowered response and high residual current.

10.2 Record the temperature and the specific conductivity of the sample solution.

10.3 Correct for salinity by converting specific conductivity to salinity using Table I and entering the salinity value into the SALINITY FACTOR function.

10.4 For different elevations, refer to Table II to set the BAROMETRIC PRESSURE function (***7.3***).
10.5 Perform calibration of the DO meter.
10.6 Insert probe into the sample and provide sufficient sample flow across membrane surface to overcome erratic response by gently stirring the solution with the probe.
10.7 Meter will display DO reading in mg/L and temperature simultaneously.
10.8 When finished, store electrode in "calibration sleeve" or B.O.D. bottle with reagent water covering the bottom of the bottle and press **POWER** key to turn unit off.
10.9 Using proper measurement technique, an accuracy of ±0.1 mg DO/1L and a precision of ±0.05 mg DO/ L can be obtained.

11. Bibliography

11.1 Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 450, Method 422F (1975).
11.2 EPA Method 360.1
11.3 Operator's manual for VWR Dissolved Oxygen Meter, Model 4000.

Table I

Salinity/Conductivity Table

Estimate the salinity correction factor by using the following table:

(to the nearest whole number, input value into meter)

(20°C) in mS/cm	Salinity in ppt	(20°C) in mS/cm	Salinity in ppt	(20°C) in mS/cm	Salinity in ppt
5	**3.0**	23	**15.5**	42	**30.2**
6	**3.6**	24	**16.2**	44	**31.8**
7	**4.3**	25	**17.0**	46	**33.5**
8	**4.9**	26	**17.8**	48	**35.1**
9	**5.6**	27	**18.5**	50	**36.7**
10	**6.3**	28	**19.3**	52	**38.4**
11	**6.9**	29	**20.0**	54	**40.1**
12	**7.6**	30	**20.8**	56	**41.8**
13	**8.3**	31	**21.6**		
14	**9.0**	32	**22.3**		
15	**9.7**	33	**23.1**		
16	**10.4**	34	**23.9**		
17	**11.2**	35	**24.7**		
18	**11.9**	36	**25.5**		
19	**12.6**	37	**26.2**		
20	**13.3**	38	**27.0**		
21	**14.1**	39	**27.8**		
22	**14.8**	40	**28.6**		

Table II

Elevation barometric pressure table

This table is used to determine the barometric pressure at certain elevations. The correspondence is based on the assumption that at sea level the barometric pressure is 760. After determining the barometric pressure from the table or a local weather service, in put this reading into the instrument (see calibration instructions for VWR Model 4000).

Elevation in feet	**Barometric pressure in mm**
0	760
500	746
1000	733
1500	720
2000	708
2500	695
3000	683
3500	671
4000	659
4500	647
5000	635
5500	624
6000	613
6500	601
7000	590
7500	579
8000	568
8500	559
9000	548
9500	538
10000	527
10500	517
11000	506

CATEGORY 3: FIELD MEASUREMENTS

Section 3.9

Standard Operating Procedure Portable Turbidimeter

29 Palms Laboratory
47-250 Dillon Road
Coachella, Ca 92236
Phone: 760-398-6767
Fax: 760-398-0046

Title: **Portable Turbidimeter**
Number: **PP0010**
Release Date: **April 16, 2003**
Revision Date: **April 16, 2003**
Version: **1.0**

DOCUMENT TYPE: Standard Operating Procedure

DOCUMENT CLASS: Physical Property Procedure

TITLE: Portable Turbidimeter, Model 2100
US EPA, Method 180.1

PREPARED BY: Alison Millar, Environmental Technician II ____________________

REVISED BY: Alison Millar, Environmental Technician II ____________________

REVIEWED BY: Stephanie Hull, Environmental Scientist II ____________________

APPROVED BY: Marshall K. Cheung, Ph.D., Laboratory Director ____________________

Table of Contents

Document No.:	***PP0010-005***
Copy provided to:	**Marshall K. Cheung**
Title:	Laboratory Director 29 Palms Laboratory 47-250 Dillon Road Coachella, CA 92236
Copy provided by:	**Alison Millar**
Title:	Environmental Technician II
Date:	July 28, 2004

1. Scope and Application

1.1. This method is applicable to the analysis of drinking, surface and saline waters in the range of 0 to 1000 nephelometric turbidity units (NTU).
1.2. More turbid samples should be diluted prior to analysis.

2. Summary of Method

2.1. The method is based upon a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions.
2.2. The higher the intensity of scattered light, the higher the turbidity.
2.3. StablCal standard suspensions are used to create a calibration curve.
2.4. Samples are transferred to sample cells that are carefully wiped free of dust and moisture.
2.5. Cuvettes are inserted into the chamber with a consistent orientation.
2.6. Turbidity units are recorded according to results. (See Results, p.5)

3. Comments

3.1. NTU's are considered comparable to the previously reported Formazin Turbidity Units (FTU) and Jackson Turbidity Units (JTU).
3.2. Dark glass sample cell should be handled by the securely fastened lid.
3.3. Store StablCal standards at room temperature, preferably in drawer labeled Turbidity in 29 Palms Laboratory.
3.4. Keep lit closed when not in use.
3.5. Make sure that there are no air bubbles in sample cell before placing into Turbidimeter.
3.6. Wipe sample cell well with Kimwipe to remove any fingerprints, and apply a drop of silicone oil to exterior of cell to mask any minor imperfections in the surface.
3.7. A Formazin calibration should done once every 3 months

4. Sample Handling and Preservation

4.1. Preservation of the sample is not practical; analysis should begin as soon as possible.
4.2. Refrigeration or icing to 4^{o}C, to minimize microbiological decomposition of solids is recommended.

5. Interferences

5.1. Coarse floating debris that settles out rapidly will give unstable low readings.
5.2. Presence of color in sample water due to dissolved substances that absorb light will cause turbidities to be low.
5.3. Air bubbles will cause higher turbidity readings.

6. Apparatus

6.1. Portable Turbidimeter, Model 2100P
6.2. Silicone Oil
6.3. Oiling cloth
6.4. Quick reference card
6.5. Four AA batteries

7. Reagents

7.1. Reagent Water (NanoPure)
7.2. StablCal Turbidity Standards: ≤0.1-NTU, 20-NTU, 100-NTU, 800-NTU

8. Procedure

8.1. Turn instrument on
8.2. Calibrate the meter.
8.2.1. Insert the “0.1” turbidity sample cell calibration standard into the cell compartment by aligning the orientation mark on the cell with the mark on the front of the cell compartment.
8.2.2. Close shield.
8.2.3. Press CAL and the CAL and S 0 icons will be displayed with the “0” will be flashing.
8.2.4. Press READ on keypad.
8.2.4.1. The instrument will count from 60 to 0, read the blank and use it to calculate a correction factor for the next standard measurement. The display will automatically increment to the next standard.
8.2.5. Remove sample cell.
8.2.6. The display will show S 1 with the “1” flashing and the 20 NTU value.
8.2.7. Insert the “20” cell into the well compartment and close cover.
8.2.8. Press READ.
8.2.8.1. The instrument will count from 60 to 0, read the blank and use it to calculate a correction factor for the next standard measurement. The display will automatically increment to the next standard.
8.2.8.2. If the value is incorrect, edit the value by pressing the → key to scroll to the correct number.
8.2.8.3. Repeat sample reading with new 20 NTU standard.
8.2.9. Remove sample cell.
8.2.9.1. The display will show the S 2 with the “2” flashing.
8.2.10. Insert “100” NTU standard sample into the well compartment.
8.2.11. Press READ.
8.2.11.1. The instrument will count from 60 to 0, read the blank and use it to calculate a correction factor for the next standard measurement. The display will automatically increment to the next standard.
8.2.11.2. If the value is incorrect, edit the value by pressing the → key to scroll to the correct number.
8.2.12. Remove calibration sample cell.
8.2.12.1. The display will show the S 3 with the “3” flashing and 800 NTU for the next sample.
8.2.13. Place 800 NTU calibration sample cell into well compartment.
8.2.14. Press READ.
8.2.14.1. The instrument will count from 60 to 0.
8.2.14.2. The display will then increment back to SO.
8.2.15. Remove calibration sample cell.
8.2.16. Press CAL to accept the calibration.

8.3. Preform Calibration Curve
8.3.1. Place a known standard in cell compartment

8.3.2. Press READ
8.3.3. Record Value
8.3.4. Place different known standard into cell well.
8.3.5. Press READ
8.3.6. Record Value
8.3.7. Repeat 8.3.1 three more times for a total of five recorded values.
8.3.7.1. Proceed to section 9.0 for calculations

8.4. Take sample readings.
8.4.1. Fill sample cell to white horizontal line with sample.
8.4.2. Wipe sample cell well with Kimwipe and lightly oil with silicone and wipe off.
8.4.3. Insert sample cell with vertical line forward.
8.4.4. Close lid.
8.4.5. Press READ
8.4.6. Record value of sample in NTU's.

9. Calculation

9.1. Using Excel graph the difference between the expected NTU value and the recorded actual value to find the slope. (See section 12.0 for Calibration Curve)

9.2. If created diluted sample.
9.2.1. Multiply sample readings by appropriate dilution to obtain final reading.
9.2.2. Sample calculation: If sample is diluted in half (1:1), the turbidity result would be the value displayed multiplied by two.
9.2.2.1.Diluted sample turbidity reading: 5.4.
9.2.2.2.Turbidity (NTU)= 5.4 x 2 = 10.8 NTU
9.2.2.3.Reported as 11 NTU (See Results p.5)

10. Results

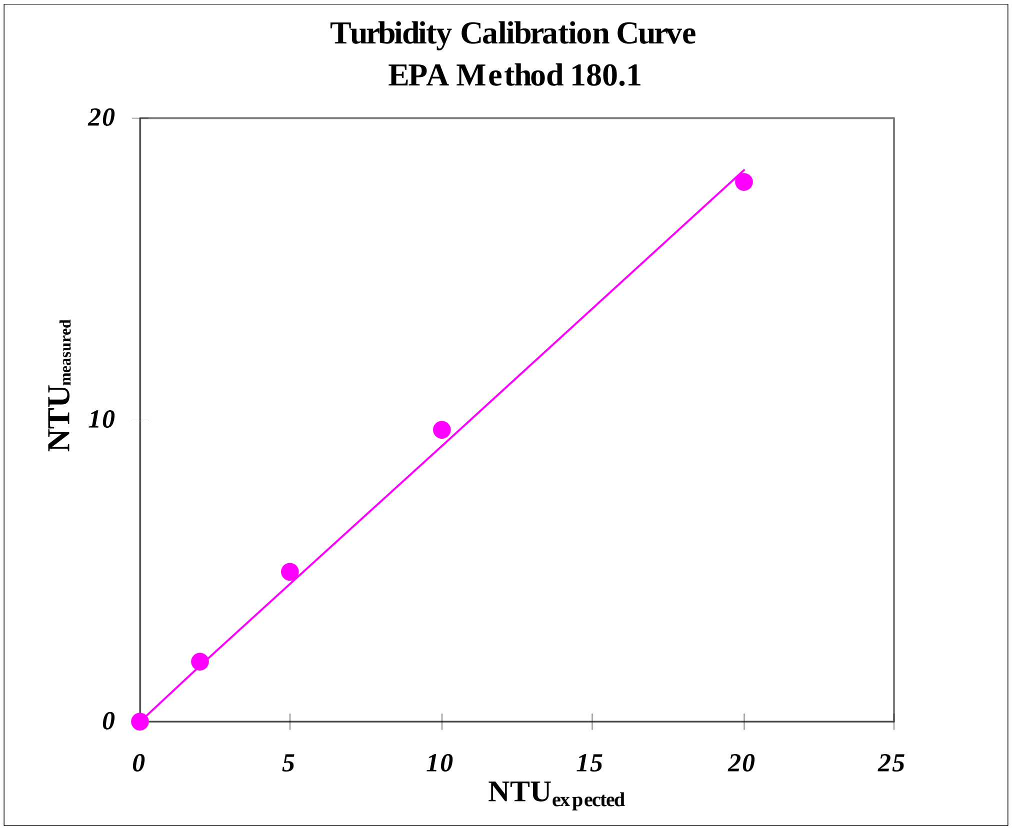
10.1. Report results as follows:

NTU	Record to nearest:
0.0-1.0	0.05
1-10	0.1
10-40	1
40-100	5
100-400	10
400-1000	50

11. Bibliography

11.1. Hach Company Manual for Portable Turbidimeter, Model 2100P (Cat. No. 46500-88)
11.2. EPA Method 180.1
11.3. Hach Quick Reference Card for Portable Turbidimeter.

12. Calibration Curve



Turbidity Expected (NTU)	Measured Turbidity (NTU)	RF	
0.00	0.00	-	Average RF =0.964 Std. Dev. =0.0492 Relative % Std. Dev. =5.10 R^2 =0.997 m =0.913 y-intercept =0.00
2.00	2.00	1.000	
5.00	4.97	0.994	
10.00	9.68	0.968	
20.00	17.86	0.893	

CATEGORY 4: GROUNDWATER SAMPLING AND PURGING

Section 4.1

Superfund Program Representative Sampling Guidance Volume 5: Water and Sediment Part 2 – Ground Water

OSWER Directive 9360.4-16
EPA xxx/x-xx/xxx
PBxx-xxxxxx
December 1995

SUPERFUND PROGRAM

REPRESENTATIVE SAMPLING GUIDANCE

VOLUME 5: WATER AND SEDIMENT

PART II -- Ground Water

Interim Final

Environmental Response Team

Office of Emergency and Remedial Response
Office of Solid Waste and Emergency Response

U.S. Environmental Protection Agency
Washington, DC 20460

Notice

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication.

The policies and procedures established in this document are intended solely for the guidance of government personnel for use in the Superfund Program. They are not intended, and cannot be relied upon, to create any rights, substantive or procedural, enforceable by any party in litigation with the United States. The Agency reserves the right to act at variance with these policies and procedures and to change them at any time without public notice.

For more information on Ground-Water Sampling procedures, refer to the U.S. EPA *Compendium of ERT Ground-Water Sampling Procedures*, OSWER Directive 9360.4-06. Topics covered in this compendium include: sampling equipment decontamination; ground-water monitoring well installation, development, and sampling; soil gas sampling; water level measurement; controlled pump testing; slug testing.

Please note that the procedures in this document should be used only by individuals properly trained and certified under a 40-hour hazardous waste site training course that meets the requirements set forth in 29 CFR 1910.120(e)(3). This document should not be used to replace or supersede any information obtained in a 40-hour hazardous waste site training course.

Questions, comments, and recommendations are welcomed regarding the *Superfund Program Representative Sampling Guidance, Volume 5 -- Water and Sediment, Part II -- Ground Water*. Send remarks to:

Mr. William A. Coakley
Chairman, Representative Sampling Committee
U.S. EPA - ERT
Raritan Depot - Building 18, MS-101
2890 Woodbridge Avenue
Edison, NJ 08837-3679

Disclaimer

This document has been reviewed under U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

The following trade names are mentioned in this document:

Teflon® is a registered trademark of E.I. DuPont de Nemours and Company of Wilmington, Delaware

Geoprobe® is a registered trademark of Geoprobe, Inc. of Salina, Kansas

Gilian® is a registered trademark of Gilian Instrument Corporation of Wayne, New Jersey

Contents

List of Figures

List of Tables

1.0 INTRODUCTION

1.1 OBJECTIVE AND SCOPE

This is Part II of the fifth volume in a series of guidance documents that assist Superfund Program Site Managers, On-Scene Coordinators (OSCs), Remedial Project Managers (RPMs), and other field staff in obtaining representative samples at Superfund sites. The objective of representative sampling is to ensure that a sample or a group of samples accurately characterizes site conditions.

Most hazardous waste site investigations utilize some form of a ground-water sampling or monitoring program to fully characterize the nature and extent of contamination. Because site conditions may differ, experienced hydrogeologists and geochemists should be consulted to establish the most suitable types of sampling and monitoring for each site.

The purpose of this document is to address representative ground-water sampling. Ground-water modeling and monitoring well installation are briefly introduced but are not addressed in detail in this document. References on these topics are provided in Section 1.6

The representative ground-water sampling principles discussed in this document are applicable throughout the Superfund Program. The following chapters will help field personnel to assess available information, select an appropriate sampling approach and design, select and utilize field analytical/geophysical screening methods and sampling equipment, incorporate suitable types and numbers of quality assurance/quality control (QA/QC) samples, and interpret and present the site analytical data.

As the Superfund Program has developed, the emphasis of the response action has expanded beyond addressing emergency response and short-term cleanups. Each planned response action must consider a variety of sampling objectives, including identifying threat, delineating sources of contamination, and confirming the achievement of clean-up standards. Because many important and potentially costly decisions are based on the sampling data, Site Managers and other field personnel must characterize site conditions accurately. To that end, this document emphasizes the use of cost-effective field analytical and geophysical screening techniques to characterize the site and aid in the selection of sampling locations.

1.2 UNIQUE CHARACTERISTICS OF GROUND WATER

The following are media-specific variables of ground water that should be considered when performing representative ground-water sampling:

- Homogeneity - Ground water, as a medium, is usually homogeneous, especially when compared to other media such as soil, air, or waste.
- Seasonal and Localized Variation in Flow - Seasonal and localized variations in ground-water flow should be considered when developing a ground-water assessment program. Seasonal variations are generally controlled by weather. Surface streams gain or lose water to the subsurface when flood or drought conditions are present. Localized variations in flow are caused by nearby, outside influences, as when a production well creates a cone of depression in the water table.
- Inaccessibility for Investigation - Ground water is often inaccessible to standard grab sampling techniques. Because ground water is subsurface, wells must often be drilled and completed for sampling if no existing wells are available. Sampling ground water is generally more complicated, labor-intensive, time-consuming, and expensive than sampling other media.
- Natural Background Composition - Knowledge of the natural background composition is necessary in order to determine the effects of a site on the ground water. Background or control monitoring wells are necessary to determine ambient composition.
- Water Treatment - Ground-water samples are often extracted from existing residential or commercial wells that have been treated with softeners or have been filtered or altered in other ways. Sampling (times, parameters, methods, preservatives, etc.) may have to be altered in order to compensate for or avoid treatment variables.
- Reproducibility of Sampling Results - Ground water is a flowing water body below the earth's surface. Physical and chemical characteristics may vary over time and space because of the

factors listed above (e.g., seasonal variation). Contaminants tend to flow through ground water in a plume or plug of varying concentration; contamination sources may discharge in pulses or as a continuous flow; and contaminants may react with ground water to chemically transform over time. Because of this flowing nature, contaminant or natural constituent concentrations can vary. This variation could affect duplicating sample results over an extended time period. Contaminants will most often continue to be detected in ground water, but sample concentration ranges may be altered, either by an increase or a decrease, or contaminant by-products may be detected.

1.3 REPRESENTATIVE SAMPLING

Representative ground-water sampling ensures that a sample or group of samples accurately reflects the concentration of the contaminant(s) of concern at a given time and location. Analytical results from representative samples reflect the variation in pollutant presence and concentration throughout a site.

In addition to the variables introduced due to the characteristics of the sample media (as discussed in Section 1.2), this document concentrates on those that are introduced in the field. These latter variables relate to site-specific conditions, the sampling design approach, and the techniques for collection and preparation of samples. The following variables affect the representativeness of samples and subsequent measurements:

- Media variability - The physical and chemical characteristics of ground water.

- Contaminant concentration variability - Variations in the contaminant concentrations throughout the site and/or variables affecting the release of site contaminants into ground water on or away from the site.

- Collection and preparation variability - Deviations in analytical results attributable to bias introduced during sample collection, preparation, and transportation (for analysis).

- Analytical variability - Deviations in analytical results attributable to the manner in which the sample was stored, prepared, and analyzed by the on-site or off-site laboratory. Although analytical variability cannot be corrected through representative sampling, it can lead to the false conclusion that error is due to sample collection and handling procedures.

1.4 REPRESENTATIVE SAMPLING OBJECTIVES

Representative sampling objectives for ground water include the following:

- Identify the presence of contamination, including source, composition, and characteristics. Determine if it is hazardous.

- Establish the existence of an imminent or substantial threat to public health or welfare or to the environment.

- Establish the existence of potential threat requiring long-term actions.

- Develop containment and control strategies.

- Evaluate treatment options.

Note: Clean-up goals are generally established for ground water and are not considered a sampling objective.

1.4.1 Identify Contamination and Determine Hazard

One of the first objectives during a response action at a site is to determine the presence, identity, and potential threat of any hazardous materials. Field screening techniques can be used for rapid detection of contaminants. Upon confirming the presence of hazardous materials, sample and/or continue screening to identify their compositions and determine their concentrations.

1.4.2 Establish Imminent or Substantial Threat

Establishing threat to the public or environment is a primary objective during any response action. The data obtained from characterizing the contaminants will help the Site Manager to determine whether an imminent or substantial threat exists and whether a response action is necessary. The type and degree of threat determines the rate at which a response action is taken.

1.4.3 Determine Long-Term Threat

Site conditions may support a long-term threat that is not imminent or substantial. Characterization of the contaminants can assist the Site Manager to determine the need for long-term remediation and response. Samples should be collected in a manner that enables their use for evaluating the site under the Hazard Ranking System.

1.4.4 Develop Containment and Control Strategies

Once the chemical constituents and threat have been determined, many strategies for ground-water containment and control are available. Analytical data indicating the presence of chemical hazards are not in themselves sufficient to select a containment or control strategy. Site reconnaissance and historical site research provide information on site conditions and the physical state of the contaminant sources; containment and control strategies are largely determined by this information. For example, trenching and pump and treat systems can prevent spread of contamination in an aquifer.

1.4.5 Evaluate Treatment Options

The contaminants should be identified, quantified, and compared to action levels (e.g., maximum contaminant levels (MCLs) for drinking water). Where regulatory action levels do not exist, site-specific clean-up levels are determined by the Region (often in consultation with the Agency for Toxic Substances and Disease Registry (ATSDR)) or by State identification of Applicable or Relevant and Appropriate Requirements (ARARs). If action levels are exceeded, a series of chemical and physical tests may be required to evaluate possible treatment options.

1.5 CONCEPTUAL SITE MODEL

A conceptual site model is a useful tool for selecting sampling locations. It helps ensure that sources, migration pathways, and receptors throughout the site have been considered before sampling locations are chosen. The conceptual model assists the Site Manager in evaluating the interaction of different site features. Risk assessors use conceptual models to help plan for risk assessment activities. Frequently, a conceptual model is created as a site map (see Figure 1) or it may be developed as a flow diagram which describes potential migration of contaminants to site receptors (See Appendix A).

A conceptual site model follows contaminants from their sources, through migration pathways (e.g., air, ground water), and eventually to the assessment endpoints. Consider the following when creating a conceptual site model:

- The state(s) of each contaminant and its potential mobility
- Site topographic features
- Meteorological conditions (e.g., wind direction/speed, average precipitation, temperature, humidity)
- Human/wildlife activities on or near the site

The conceptual site model in Figure 1 is an example created for this document. The model assists in identifying the following site characteristics:

> *Potential Sources*: Site (waste pile, lagoon); drum dump; agricultural activities.
>
> *Potential Migration Pathway (Ground Water)*: Leachate from the waste pile, lagoon, drum dump, or agricultural activities.
>
> *Potential Migration Routes*: Ingestion or direct contact with water from the aquifer (e.g., ingestion of drinking water, direct contact when showering).
>
> *Potential Receptors of Concern*:
>
> > Human Population (Residents/Workers): Ingestion or direct contact with contaminated water from the aquifer.

Preliminary site information may provide the identification of the contaminant(s) of concern and the level(s) of the contamination. Develop a sampling plan based upon the receptors of concern and the suspected sources and pathways. The model may assist in the selection of on-site and off-site sampling locations.

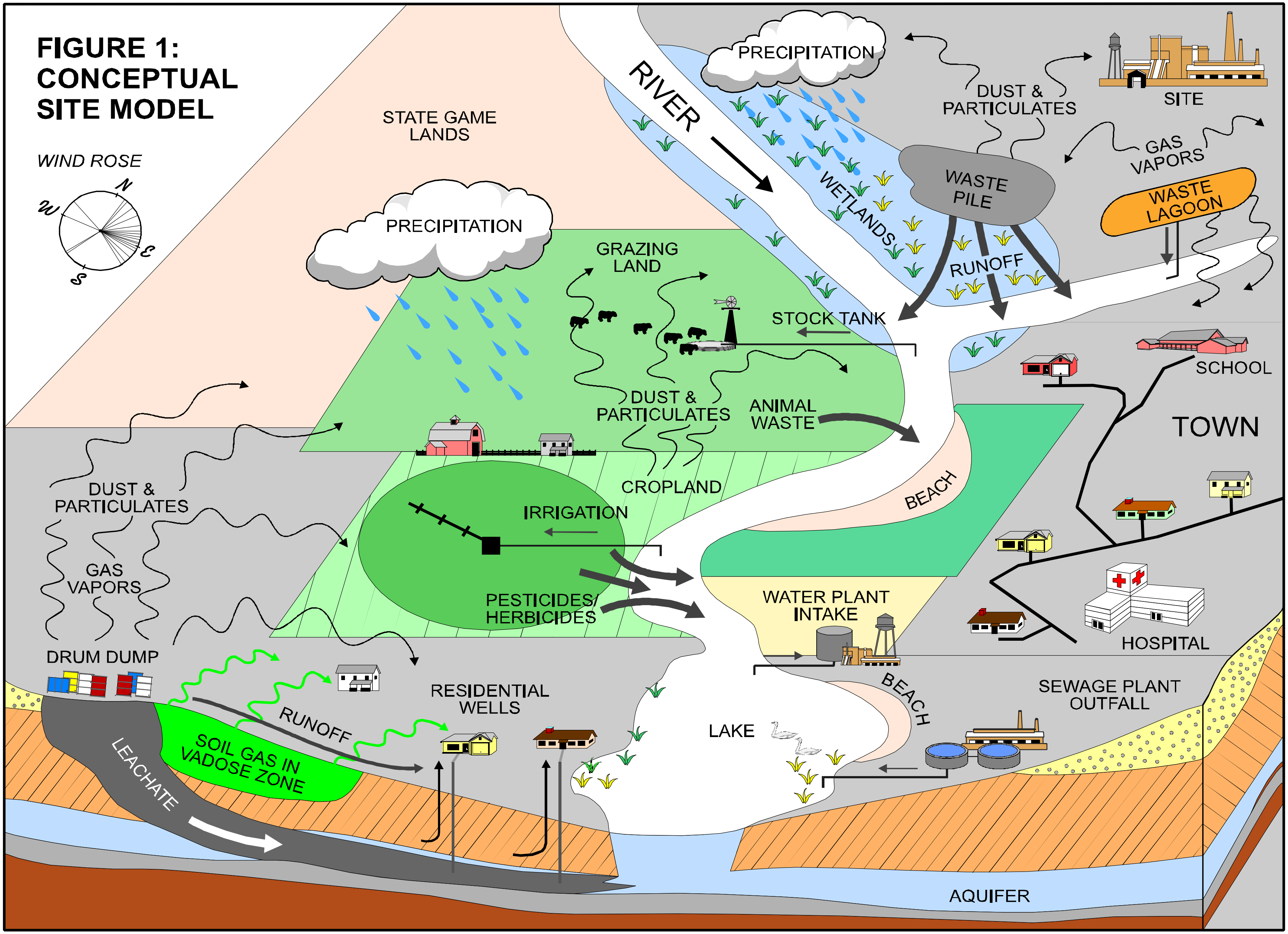


FIGURE 1: CONCEPTUAL SITE MODEL

1.6 OVERVIEW OF GROUND-WATER MONITORING WELL INSTALLATION AND GROUND-WATER MODELING

Ground-water monitoring well installation and ground-water modeling are complex issues which fall outside the scope of this document. Many standard operating procedures (SOPs) covering ground-water monitoring well installation techniques have been published. Monitoring well installation and ground-water modeling are briefly introduced here with several specific items for consideration. Refer to existing SOPs and other reference documents for more in-depth study.

1.6.1 Ground-Water Monitoring Well Installation

For most Superfund response actions where ground-water sampling is performed, existing ground-water production wells (commercial or residential) are used, if available, to obtain samples. Chemical data obtained from this type of well depict the general quality of water that is being delivered to the user community. Ground water is usually a composite of multiple aquifer strata which may mask the presence of narrow or small contaminant plumes from a single stratum. For this reason, production wells are not suitable for detailed source, case-preparation, or research types of monitoring. Such detailed monitoring efforts require wells designed to determine the geologic and hydrologic quality at specific locations and depths. The following items must be considered for ground-water sampling from monitoring wells:

- Drilling method
- Monitoring well components
- Monitoring well location
- Well diameter
- Well depth
- Well screen location

Refer to the U.S. EPA *A Compendium of Superfund Field Operations Methods*, OSWER Directive 9355.0-14; *Compendium of ERT Ground-water Sampling Procedures*, OSWER Directive 9360.4-06; *RCRA Ground-Water Monitoring Technical Enforcement Guidance Document*, OSWER Directive 9950.1; and *RCRA Ground-Water Monitoring: Draft Technical Guidance*, EPA/530-R-93-001, for specific details on monitoring well installation. The latter two documents should be referenced for information on locating, installing, and developing monitoring wells.

Locating Monitoring Wells

Often, one well is sited near the center of the contaminant plume just downgradient from the contamination source. Another well is installed downgradient of the contaminant source, outside the limits of the plume. For background data, one well may be placed outside of the contaminant plume, upgradient of the contaminant source. Additional wells may be installed to track the amount of contaminant dispersion taking place.

Determining the depth to sample is critical for successful ground-water monitoring. Sampling depth depends on the contaminant density, the aquifer characteristics, and the slope of the water table or potentiometric surface. The number of wells necessary to monitor ground water varies depending on many factors. For example, if an impoundment contamination source is higher than the surrounding landscape, leachate may flow locally in all four downgradient directions. In this case, at least four wells are needed to monitor plume movement, plus a background well may be desired in an unaffected area. In addition, some wells may be installed at more than one depth in a contaminant plume to verify vertical flow or spread of contamination at different depths.

See Driscoll, 1986, pp. 715-16 for more information on locating monitoring wells.

Well Casing and Well Screen

Select a well casing material based on water quality, well depth, cost, borehole diameter, drilling procedure, and Federal, state, and local regulations. Types of casing materials include: steel, polyvinyl chloride (PVC), fiberglass, and Teflon®. Common well casing diameters range from 2 inches to 12 inches or greater, and depend on well type, well size, well depth, and subsurface geology. Often a series of progressively smaller-diameter well casings are used from the ground surface to the well depth.

A well screen is a filtering device which permits water to enter the well from the saturated aquifer while preventing sediment from entering the well. A well screen has slots or perforations and attaches to the well casing. It can be constructed of metal, plastic, or other material. Important criteria for selecting a well screen include: a large percentage of open area, nonclogging slots, resistance to corrosion, and a sufficient column and collapse strength.

See Driscoll, 1986, pp. 413-431, and Fetter, 1993, pp. 339-344 for more information regarding well casing. See Driscoll, 1986, pp. 395-405, and Fetter, 1993, pp. 345-346 for more information regarding well screens. See U.S. EPA, November 1992, pp. 6-16 - 6-38 for advantages and disadvantages of selecting well casing and screen materials.

1.6.2 Ground-Water Modeling

Ground-water models, like conceptual site models, can be useful when selecting sampling approaches, objectives, and locations. Ground-water models developed for Superfund sites attempt to provide an estimation of how the actual ground-water system functions.

There are many types of ground-water models available (e.g., physical, analog, mathematical). The International Ground-Water Modeling Center (IGWMC) has developed a ground-water model definition which emphasizes the importance of describing a ground-water system mathematically. The IGWMC defines a ground-water model as "a non-unique, simplified, mathematical description of an existing ground-water system, coded in a programming language, together with a quantification of the ground-water system the code simulates in the form of boundary conditions, system parameters, and system stresses."

A ground-water model may be useful throughout site investigation activities because it can be adjusted as conditions in the actual ground-water system become better defined. The data which are generated by the model can be used to refine sampling approaches and locations as necessary. Typically, a ground-water modeling report will include data (results), along with a discussion of activities such as model calibration and conceptual model development. A suggested format for a ground-water modeling report can be found in U.S. EPA *Ground-Water Issue: Fundamentals of Ground-Water Modeling* (EPA/540/S-92/005).

1.7 EXAMPLE SITE

An example site, presented at the end of each chapter, illustrates the development of a representative ground-water sampling plan that meets Superfund Program objectives for early actions or emergency responses.

2.0 GROUND-WATER SAMPLING DESIGN

2.1 INTRODUCTION

The purpose of ground-water sampling is to provide technical information relative to the nature and condition of subsurface water resources at a specific time and place. Designs to monitor the status of ground water range from the studies of naturally occurring geochemical constituents to the detection or assessment of contamination within a ground-water system.

Ground-water sampling objectives include identifying threats, delineating sources and extent of contamination, determining treatment and disposal options, and confirming the attainment of targeted clean-up levels. Representative sampling designs are developed to most accurately characterize the hydrogeologic system and its interaction with the environment. Sampling protocols must integrate detailed sampling methodology, techniques and practices to ensure valid assessment. Sampling methodology and practice may be the most common source of assessment error. Consequently, sampling methodology and practice collectively demand careful preparation, execution, and evaluation to accurately characterize the hydrogeologic system or its subsystems. (For additional information see: U.S. EPA *Ground Water, Volume II: Methodology,* EPA/625/6-90/016b; and Palmer, Christopher M., *Principles of Contaminant Hydrogeology*.)

There are many methods and types of equipment useful for site characterization and sample collection. Selection of these factors is a critical component of a site-specific sampling design.

A properly developed ground-water sampling design defines the sampling purpose, protects site worker health and safety, effectively utilizes resources, and minimizes errors. The sampling design will vary according to the characteristics of the site. When developing a sampling design, consider:

- Prior actions at the site (e.g., sampling events, compliance inspections)
- Regional ground-water properties and characteristics
- Potential on-site waste sources (e.g., impoundments, waste piles, drums)
- Topographic, geologic, hydrologic, and meteorologic conditions of the site
- Flora, fauna, and human populations in the area

2.1.1 Pre-Sampling Plan Investigation

The pre-sampling plan investigation provides the planner with information critical to the development of a sound ground-water sampling design. Integration of all pertinent facts regarding the site history, the population(s) affected, and concentrations of substances on a site must be reviewed. After all of the pertinent information has been processed and incorporated into a thorough site pre-evaluation, the sampling plan can be developed. Considerations for sampling plan modification should be reviewed as necessary in light of the complex nature of ground-water resource dynamics.

Site History

Review of the site's history helps assess the natural and man-made impacts on a site. Geographic, geologic, tax, and fire insurance maps can indicate the status of the site. These maps can usually be found at local and collegiate libraries or municipal and county tax offices. Aerial photographs are helpful in reviewing operational use of the site. Archival aerial photographs may show changes in operation and site condition over time. This information can be correlated with information from potentially responsible parties.

Hydrogeologic information is critical to developing a sampling plan. A ground-water system is site specific, depending upon local geology, land and subsurface use, precipitation and water use, proximity to water bodies, and hydrogeologic parameters affecting contaminant transport. Hydrologic and hydrogeologic information can be found in libraries or requested from the U.S. Geological Survey (USGS), Water Resources Division, or state geological agencies and their water branches. Inspection histories can be used to determine prior health status of the site in view of possible trends. Local, state, and federal agencies dealing with health or environmental inspection can provide such historical information about a site.

Affected Populations

Human population statistics for the selected area can establish the number of people threatened by the contaminant exposure. Include populations affected by projected migration of contaminants within the ground-water system. Knowing the interaction of the contaminant within a ground-water system and the potential regional populations exposed to the contaminant will focus the sampling plan to the source and possible pathways of the contaminant. Wildlife populations in the area must be studied as well. Wildlife in ponds, lakes, streams, rivers, and bays is often affected by contaminants transported by ground water discharging into surface water. Information regarding regional wildlife populations and susceptibility to hazardous substances can be obtained from federal and state wildlife and conservation agencies.

Detection Levels versus Maximum Contaminant Levels

Sampling plan development must also address the concentration level of the contaminant within the ground-water system in relation to the maximum contaminant levels (MCLs) allowed within a public water system. Refer to the Federal Register for the levels requiring enforceable action. Knowledge of the chemical contaminant interaction within the ground-water system can add insight into the fate of the contaminant (soluble or insoluble in water; less or more dense than water; the nature of reactivity with sediment or geology of the subsurface). Correlate the concentration level versus the location of these concentrations. A sequence of order can then be applied to the locations. Ideally, a pattern may develop that can be related to the ground-water system and its dynamics. In the case of a single location, investigate potential sources in the surrounding area either by working backwards from an identified contaminant spot to a potential source, or from a potential source to an identified contaminant spot. Also consider source-to-current-location pathways and projected pathways when developing a sampling plan.

2.1.2 Types of Information Provided by Ground-Water Sampling Assessment

There are several types of information that a ground-water sampling assessment provides. These include but are not limited to: measure of ground-water quality, contaminant concentrations compared to action levels, selection of the appropriate response action, and determination of ground-water flow and contaminant plume movement.

Measure of Ground-Water Quality

Ground-water sampling assessments provide information concerning measure of ground-water quality of a site or region. Water quality is classified according to many categories and its intended use. Drinking water is especially subject to guidelines. A sampling assessment of ground water can determine whether the quality of the water has been maintained, upgraded, or allowed to degrade. The natural and artificially induced characteristics of ground water from a specific site or region can be established by ground-water sampling assessments -- specifically, the chemical, biological, and physical characteristics of the ground water.

Contaminant Concentrations Compared to Action Levels

Ground-water sampling assessments provide a single contamination level for a particular sampling location, or a set of contamination levels for several sampling locations within a site. Comparison to action levels in ARARs determines the basis for further action. Thus, sampling can evaluate potential hazards and represent a condition of ground-water character requiring enforceable action procedures.

Selection of Appropriate Response Action

The level of contaminant concentration as determined through sampling assessments is a critical factor in selecting a site response action. Depending upon the degree or level of contaminant concentration, contaminant frequency, or number of locations established as contaminated, and the site's potential threat to human health or the environment, a rapid or extensive clean-up program can be formulated, as well as temporary or short-term responses (e.g., provision of bottled water).

A sampling assessment may not always indicate contamination of the site. Careful examination of sampling protocol must consider the range of explanations. A miscalculation of suspected source sites; gross procedure error in sampling, laboratory analysis, or documentation; or error at many other points in sampling protocol could be the source of assessment error. These errors are addressed more extensively in Chapter 5.

If quality assurance/quality control (QA/QC) procedures have been followed for ground-water sampling assessment, then it is possible that sources of contamination may originate from above ground systems (e.g., lead entering tap water in the proximity of the facility). In any case, a sampling assessment at the least can characterize the natural ground-water conditions, which can be used as a control or comparison.

Determination of Ground- Water Flow and Contaminant Plume Movement

Knowing the direction of ground-water flow is important when evaluating a contaminated aquifer. When contamination enters the ground at a higher head (gradient) than exists at nearby shallow wells, these wells may become contaminated. Ground water flows from higher head to lower head. The direction of water movement may be determined using water-elevation data from a minimum of three wells. See Driscoll, 1986, pp. 79-85 and Freeze and Cherry, 1979, pp. 168-236 for more information regarding ground-water flow.

Ground-water tracers, such as dye or salt may be used to track ground-water flow velocities and contaminant plume movement. A tracer is placed in one well and the time of its arrival in a second well downgradient from the first well is noted. The dilution of the tracer detected in the second well can indicate the contaminant dilution rate and help determine the contaminant source concentration as well as the width, depth, and spreading velocity of the plume. Tracers also may be used to help determine aquifer porosity, hydraulic conductivity, and dispersivity.
The tracer selected must be detectable in extremely low concentrations and must not react chemically or physically with the ground-water or aquifer composition. See Driscoll, 1986, pp. 84-85 for more information regarding ground-water tracers.

2.1.3 Site Reconnaissance

A site reconnaissance can be conducted at an earlier date or immediately prior to sampling activities. It allows field personnel to assess actual, current site conditions, evaluate areas of potential contamination, evaluate potential hazards associated with sampling, and finalize a sampling plan. Site reconnaissance activities for a ground-water assessment include: observing and photographing the site; noting site access and potential evacuation routes; noting potential safety hazards; inventorying and recording label information from drums, tanks, or other containers; mapping process and waste disposal areas such as landfills, impoundments, and effluent pipes; mapping potential contaminant migration routes such as drainage, streams, and irrigation ditches; noting the condition of animals and/or vegetation; noting topographic and/or structural features; noting and mapping existing ground-water monitoring or other types of wells for potential sampling; and siting potential locations for new monitoring wells if necessary. Field personnel should use appropriate personal protective equipment when engaged in any on-site activities. Consider the following site-specific factors while performing a site reconnaissance:

- Sampling Objectives - Sampling is conducted typically to comply with regulations for the detection or assessment of suspected contamination within the subsurface. The information gathered aids in the identification of known and unknown substances present within the site and the level and extent of contamination of the environment. The information is used to document the condition of the ground-water system as an initial assessment, a record of development, or as evidence of remediation efficiency and compliance.

- Sample Collection and Toxicity - The samples collected are intended to document the absence or measure the presence of contaminants. The measure of acute or chronic toxicity is evaluated by assessing the site's extent of contamination, the time period in relation to the extent, and health hazards associated with the contaminant exposure time frame.

- Statistical Concerns - A site visit will familiarize the sampling planner with the environment to be sampled. Conspicuous indicators of potential contamination sources or contamination effects may suggest use of a judgmental or bias sampling design. A geostatistical sampling method can be cost-effective and time-efficient when compared to strictly random or random-stratified procedures. When using less random methods, the choice of sampling locations should be documented and justified. Employ random sampling in addition to bias sampling and include background or control samples for a thorough representation of the ground-water character. (See Section 2.3 for a discussion of sampling approaches.) (For additional information see Keith, Lawrence H., *Principles of Environmental Sampling*.)

- Timing of the Response - Consider seasonal variation when evaluating a site. Predictions of bad weather can influence technique and design. The urgency of the action weighed against seasonal constraints may dictate the options available within the targeted budget.

- Site-Specific Factors Affecting Ground-Water Flow Many factors of a site control the path or direction of ground-water flow. A combination of geologic survey information with the site reconnaissance can better familiarize the planner with the dynamics of the hydrogeologic system. The local geology of a site can determine the direction and rate of ground-water movement by means of its orientation and composition (e.g., horizontal, tilted or vertical structures, and confining clay versus unconfining sand and gravel). The degree of development of a site and its local topography can affect the ground-water flow (e.g., parking lot runoff disproportionally delivers water quantities to the subsurface and greater slopes afford less infiltration of water to the subsurface). The extent and type of vegetation can affect the amount of rainfall that actually recharges an aquifer system. Dense vegetation and high evapo-transpiration from vegetation allows very little water to descend to the subsurface. Seasonal variations can cause reversal of ground-water flow direction. This is usually associated with water bodies such as streams, rivers, ponds, and lakes. Water may flow to or from streams depending upon its surface elevation in relation to adjacent water table surfaces. During flood conditions, water usually flows from rivers toward the surrounding subsurface. During drought, water moves toward the lower level of the stream surface from higher ground-water surfaces. (Consult U.S. EPA *Handbook, Ground Water*, EPA/625/6-87/016, Chapter 4: Basic Hydrogeology.)

- Analytical Parameters - The site reconnaissance can help develop the list of analytical parameters. For example, a reconnaissance may indicate the presence of battery casings. Lead would then be a substance of concern. The site may contain constraints that may or may not allow a variety of tests to be performed. The cost-effectiveness of testing within the site's constraints can lead to limited options available to properly analyze the ground-water system. Testing methods may vary within one site (e.g., monitoring well sampling, hydroprobe extraction, etc.) in order to evaluate multiple criteria vital to the site assessment.

- Degradation (or Transformation) Products - Sites may contain degradation (or transformation) products, or by-products, of the contaminant that are detectable and potentially as hazardous as the contaminant itself. Sampling for the product can lead to clues of the source substance location and its reactive status within the subsurface.

- Sampling Order - The sampling plan should address a specific order of sampling locations (and depths at a single location) to be developed. In order to use equipment efficiently, the plan should attempt to sample from "clean" to "dirty" locations, reducing the potential for contaminants to affect relatively less contaminated locations. Typically, the background or "clean" location of a site is hydrologically upgradient from the suspected contaminant "hot spot." Depending upon the nature of the contaminant (e.g., a "sinker" or "floater"), the sampling at different depths within a column of water in a monitoring well should also follow a sequence.

2.2 PARAMETERS OF CONCERN, DATA QUALITY OBJECTIVES, AND QUALITY ASSURANCE MEASURES

2.2.1 Parameters of Concern

Drinking water populations, contaminants, and migration pathways are additional parameters that should be considered when developing a sampling plan. Often, ground-water contamination goes undetected because it is not directly visible. Drinking water odor or taste complaints by residents close to the site are usually the initial indication of ground-water contamination and potential health hazards. The sampling data should accurately delineate the extent of ground-water contamination, determine the impact on drinking water populations, and indicate potential migration pathways to such populations. It is important to design the sampling plan to determine where contaminants are most highly concentrated, and to locate areas of decreasing detectable concentrations and those not yet contaminated.

2.2.2 Data Quality Objectives

Data quality objectives (DQOs) state the level of uncertainty that is acceptable for data collection activities and define the certainty of the data necessary to make decisions. The overall goal of DQOs for a representative ground-water sampling plan are to acquire thorough and accurate information about subsurface water conditions at a site. DQOs are unique and site specific and should address the contaminant's interaction with the immediate site environment. When establishing DQOs for a particular project, consider:

- Decision(s) to be made or question(s) to be answered
- Why analytical data are needed and how the results will be used
- Time and resource constraints on data collection
- Descriptions of the analytical data to be collected
- Applicable model or data interpretation method used to arrive at a conclusion
- Detection limits for analytes of concern
- Sampling and analytical error

2.2.3 Quality Assurance Measures

To ensure that analytical samples are representative of site conditions, quality assurance measures must be associated with each sampling and analysis event. The sampling plan must specify QA measures, which include, but are not limited to, sample collection, laboratory SOPs, sample container preparation, equipment decontamination, field blanks, replicate samples, performance evaluation samples, sample preservation and handling, and chain-of-custody requirements. Quality assurance components are defined as follows:

- Precision - Measurement of variability in the data collection process

- Accuracy (bias) - Measurement of bias in the analytical process; the term "bias" throughout this document refers to (QA/QC) accuracy measurement

- Completeness - Percentage of sampling measurements which are judged to be valid

- Representativeness - Degree to which sample data accurately and precisely represent the characteristics and concentrations of the source/site contaminants

- Comparability - Evaluation of the similarity of conditions (e.g., sample depth, sample homogeneity) under which separate sets of data are produced

Refer to Chapter 5, Quality Assurance/Quality Control (QA/QC), for more detailed ground-water QA/QC information.

2.3 REPRESENTATIVE GROUND-WATER SAMPLING APPROACHES AND SAMPLE TYPES

Judgmental sampling is the primary representative sampling approach used for ground water. Other representative sampling approaches for ground water such as random, systematic grid, and systematic random sampling are described below. For information on the other types of sampling approaches, refer to U.S. EPA, *Superfund Program Representative Sampling Guidance*, Volume 1 -- *Soil*, OSWER Directive 9360.4-10.

2.3.1 Judgmental Sampling

Judgmental sampling is the biased selection of sampling locations at a site, based on historical information, visual inspection, sampling objectives, and professional judgment. A judgmental approach is best used when knowledge of the suspected contaminant(s) or its origins is available. Judgmental sampling includes no randomization in the sampling strategy, precluding statistical interpretation of the sampling results. Criteria for selecting sampling locations are dependent on the particular site and level of contamination expected.

Once a contaminant has been detected in the ground water, the source and extent must be identified. To do this, an understanding of the contaminant characteristics and the local geologic and hydrogeologic conditions is needed. Characteristics of the contaminant and any daughter (degradation) products must be known in order to understand how the material may be transported (both vertically and laterally) from the contamination source. Knowledge of the local hydrogeology is needed in order to identify areas or zones that would facilitate contaminant migration, such as water bodies and gravelly or sandy soils. The permeability of the underlying rock type should be analyzed, as well as its depth, which will help to narrow the potential sampling area. For example, if the underlying bedrock strikes northeast to southwest, then sampling of an aquifer should also be in this direction, unless cross-contamination between aquifers has already been identified.

When appropriate (based on sampling objectives, availability, sampling parameters, and budget), sample available local residential or commercial wells following a relatively systematic pattern based on the geology of the area. In the example given in the paragraph above, wells would be sampled along a line northeast to southwest. If the number of wells available is not sufficient to adequately identify the extent of contamination, then additional monitoring wells could be installed.

During a ground-water assessment, the selection of locations for monitoring well installation is done with a judgmental approach. This is generally because monitoring wells are complex, expensive, and time-consuming to install. In order to best determine the nature of a suspected contaminant plume, monitoring wells need to be placed in areas most likely to intercept the plume. Using a random, systematic grid or a systematic random approach would likely result in too many wells that miss the contaminant plume. Even placement of background or control monitoring wells favors a judgmental approach. Locations are selected based on the site reconnaissance and the planner's knowledge of the suspected contaminants, site geology, and hydrology.

2.3.2 Random, Systematic Grid, and Systematic Random Sampling

Random, systematic grid, and systematic random sampling are generally not used for ground-water sampling because sampling points are pre-determined from either existing wells or monitoring wells which are placed by judgment. However, these approaches may be useful for soil gas testing to assist in the siting of new monitoring wells. They can also be useful for conducting Geoprobe® sampling, if necessary. For additional information on these sampling approaches, refer to U.S. EPA, *Superfund Program Representative Sampling Guidance*, Volume 1 -- *Soil*, OSWER Directive 9360.4-10.

2.3.3 Grab versus Composite Sample Types

Grab samples are essentially the only type of samples collected for ground water. Unlike surface water, ground water is not composited. Each ground-water sample is representative of a discrete location and horizon in the subsurface.

2.4 SAMPLING PLAN

To develop a successful and practical representative ground-water sampling plan, the following site-specific information is required:

- Site Location - The location of the site will often influence the size of the sampling area and whether sampling should be conducted on or off site or a combination of both.

- Local Geology and Hydrology - Local geology and hydrology can determine whether off-site sampling is necessary and defines ground-water sampling boundaries and locations. For example, if an aquifer is very deep or there is a confining layer between the ground surface and the aquifer, then sampling within a small area may be all that is necessary in order to determine the extent of contamination within that aquifer.

- Topography - Topography will control the direction of surface runoff and may give clues to subsurface conditions. For example, wells in valleys may not be of the same aquifer as wells on a hill.

- Analytical Parameters - If contaminants are initially unknown, then a broad spectrum of analytical parameters is usually collected. As more information about the site becomes available (through screening or laboratory analysis), the number of parameters can be streamlined or altered in order to more effectively characterize the site. If the contaminant is known, then concentrate on sampling for it and its degradation products.

- Sampling Budget - Budget constraints inevitably affect operations. A combination of screening and analytical techniques minimizes expenses while still providing an acceptable level of quality for the sampling data.

- Physiochemical Nature of Suspected Contamination When designing the sampling plan, take into account the physical and chemical nature of the suspected contaminants, then design the sampling plan to facilitate efficient detection of the contaminants through sampling methodology, equipment, and analyses. For example, the water density or solubility of a contaminant may provide an indication of the contaminant's physical location within the water column.

  Water has a specific gravity of one. Some chemical compounds, such as many complex petrochemicals, have a specific gravity of greater than one, and are therefore more dense than water. These substances tend to sink and include chlorinated solvents, wood preservatives, other coal tar wastes, and pesticides. These compounds are referred to as *dense nonaqueous phase liquids* (DNAPLs), or "sinkers". On the other hand, a specific gravity of less than one will allow a contaminant to float on or near the water table, and includes many fuel oil products and byproducts (e.g., gasoline, benzene, toluene, ethyl benzene, xylene (BTEX), and other straight chain hydrocarbons). These compounds are referred to as *light nonaqueous phase liquids* (LNAPLs), or "floaters". Nonaqueous phase liquids (NAPLs) tend to exist as separate layers in the water column. A substance with a specific gravity value near to or equal to one will generally dissolve in the water column (e.g., acetone, phenols, and creosote). Because of the potential stratification in the water column due to NAPL substances, sampling location with respect to the suspected contaminant location within the well should always be considered.

LNAPLs commonly occupy the capillary fringe zone above the water table. In a confined aquifer, these compounds are found along the upper surface of the permeable unit and also within the overlying confining layer.

DNAPLs cause additional representative sampling concerns. These compounds move downward under the influence of gravity until reaching a less permeable formation where they may either accumulate, move downslope along the bedrock, or penetrate fractures. Special precautions should be taken during drilling at sites suspected of DNAPL contamination; ensure that the drilling does not induce the spread of free-phase DNAPL contaminants. Monitoring well installation should be suspended when a DNAPL or low permeability lithogic unit is encountered. Fine-grained aquitards (e.g., silt or clay) should be assumed to permit downward DNAPL migration. For guidance on sites with potential DNAPL contamination, see U.S. EPA *Estimating the Potential for Occurrence of DNAPL at Superfund Sites*, OSWER Directive 9355.4-07.

Additional elements which should be addressed in a representative ground-water sampling plan include:

- Sample Number - The number of samples collected depends on the number of sample locations. Normally one sample is taken at each location, except for QA/QC requirements (e.g., replicates, and matrix spike/matrix spike duplicates). If there are multiple, discreet aquifers at the site, then samples of each may be necessary. Splitting samples also requires an increase in the number of samples.

- Sample Volume - The sample volume is dependent on the analytical parameters. It is also dependent on whether the contaminant is known or unknown. A greater volume is generally needed when the contaminant is unknown because a larger suite of parameters is usually selected.

- Sample Location - Sample location is generally dictated by the availability of existing monitoring, residential, or commercial wells. New monitoring wells are located by judgmental methods.

- Sample Depth - Sampling depth is typically the bottom or screened zone of a well. However, there may be times when certain stratigraphic horizons within the water column may need to be discreetly sampled (e.g., capturing "floaters" or "sinkers"). (Procedures for addressing stratified samples are discussed in Section 4.4.)

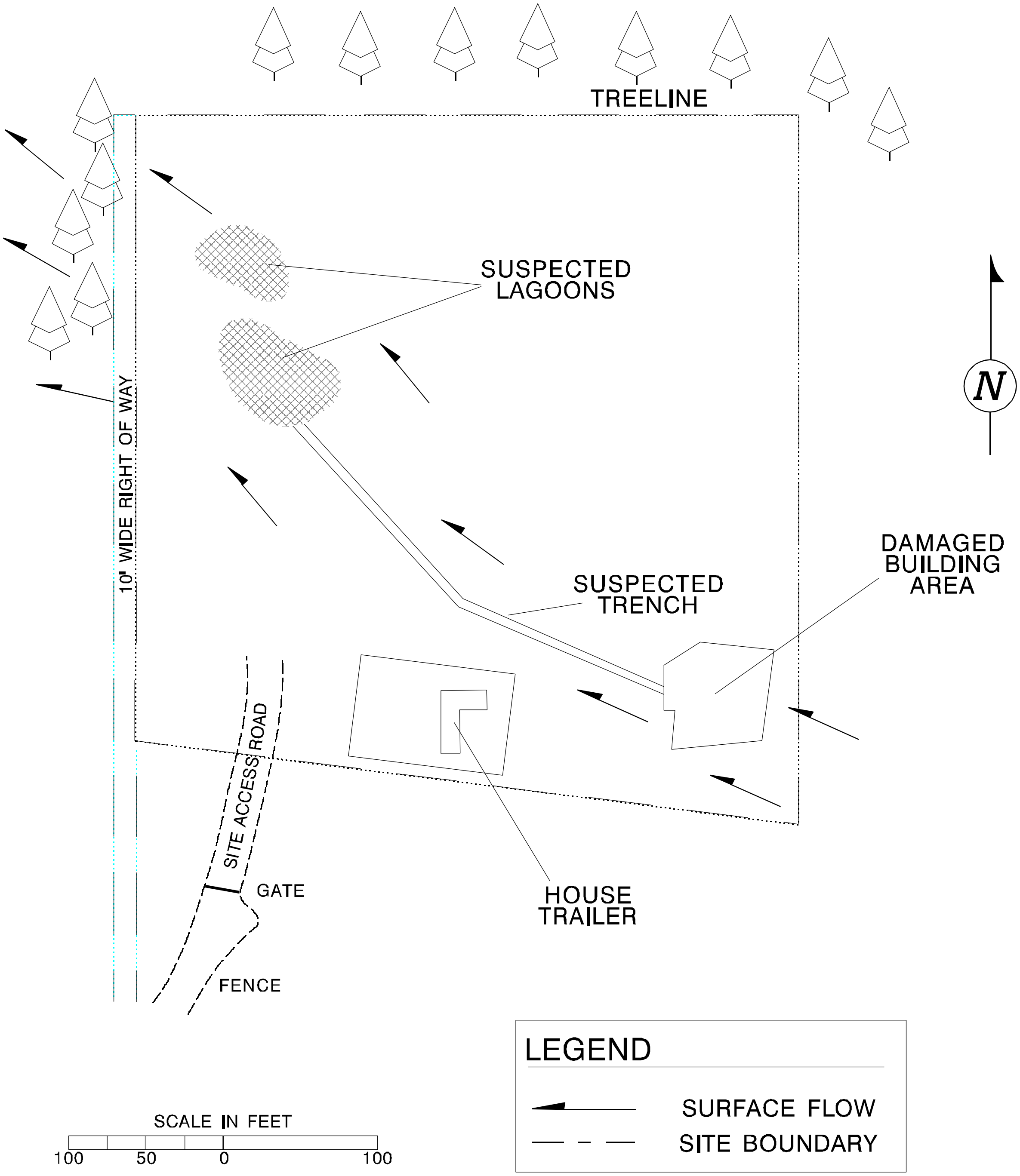
- Sample Order - Sampling order is from the least contaminated to the most contaminated wells or areas (if known).

2.5 EXAMPLE SITE

2.5.1 Background

The ABC Plating Site is located in northeastern Pennsylvania approximately 1.5 miles north of the town of Jonesville. Figure 2 provides a layout sketch of the site and surrounding area. The site covers approximately four acres and operated as a multi-purpose specialty electroplating facility from 1947 to 1982. During its years of operation, the company plated automobile and airplane parts with chromium, nickel, and copper. Cyanide solutions were used in the plating process. ABC Plating deposited electroplating wastes into two unlined shallow surface settling lagoons in the northwest portion of the site. Pennsylvania Department of Environmental Resources (PADER) personnel cited the owner/operator for the operation of an unpermitted treatment system and ordered the owner to submit a remediation plan for state approval. Before PADER could follow up on the order, the lagoons were partially backfilled with the wastes in place. The process building was later destroyed by a fire of suspicious origin. The owner abandoned the facility and could not be located by

Figure 2: Site Sketch
ABC Plating Site



enforcement and legal authorities. Several vats, drums, and containers were left unsecured and exposed to the elements. The state contacted EPA for an assessment of the site for a possible federally funded response action; an EPA On-Scene Coordinator (OSC) was assigned to the task.

2.5.2 Site History and Reconnaissance

The EPA OSC reviewed the PADER site file. In 1974 the owner was cited for violating the Clean Streams Act and for storing and treating industrial waste without a permit. The owner was ordered to file a site closure plan and to remediate the settling lagoons. The owner, however, continued operations and was then ordered to begin remediation in 90 days or be issued a cease and desist order. Soon after, a follow-The OSC obtained copies of aerial photographs of the site area from the local district office up inspection revealed that the lagoons had been backfilled without removing the waste.

The OSC and a sampling contractor (Team) arrived on site to interview local and county officials, fire department officers, neighboring residents (including a former facility employee), and PADER representatives regarding site operating practices and other site details. The former employee sketched facility process features on a map copied from state files. The features included two settling lagoons and a feeder trench which transported plating wastes from the process building to the lagoons. The OSC obtained copies of aerial photographs of the site area from the local district office of the U.S. Soil Conservation Service. The state provided the OSC with copies of all historical site and violation reports. These sources indicated the possible presence and locations of chromium, copper, and zinc plating process areas.

The Team mobilized to the site with all the equipment needed to perform multi-media sampling. The OSC and Team made a site entry, utilizing appropriate personal protective equipment and instrumentation, to survey the general site conditions. They observed 12 vats, likely containing plating solutions, on a concrete pad where the original facility process building once stood. Measurements of pH ranged from 1 to 11. Fifty drums and numerous smaller containers (some on the concrete pad, others sitting directly on the ground) were leaking and bulging because of the fire. Some rooms of the process building could not be entered due to unsafe structural conditions caused by the fire. The Team noted many areas of stained soil, which indicated container leakage, poor waste handling practices, and possible illegal dumping of wastes.

2.5.3 Identification of Parameters of Concern

During the site entry, the OSC and Team noted that several areas were devoid of vegetation, threatening wind erosion which could transport heavy metal- and cyanide-contaminated soil particulates off site. These particulates could be deposited on residential property downwind or be inhaled by nearby residents.

Erosion gullies located on site indicated surface soil erosion and stormwater transport. Surface drainage gradient was toward the west and northwest. The Team observed stressed, discolored, and necrotic vegetation immediately off site along the surface drainage route. Surface drainage of heavy metals and cyanide was a direct contact hazard to local residents. Surface water systems were also potentially affected. Further downgradient, site runoff entered an intermittent tributary of Little Creek, which in turn feeds Barker Reservoir. This reservoir is the primary water supply for the City of Jonesville and neighboring communities, which are located 2.5 miles downgradient of the site.

The site entry team observed that the site was not secure and there were signs of trespass (confirming a neighbor's claim that children play at the facility). These activities could lead to direct contact with cyanide and heavy metal contaminants, in addition to the potential for chemical burns from direct contact with strong acids and bases as might be found in leaking or unsecured drums or containers.

After interviewing residents, it was established that the homes located to the south and nearest to the site rely upon private wells for their primary drinking water supply. Ground water is also utilized by several small community production systems which have wells located within 2 miles of the site. The on-site settling lagoons were unlined and therefore posed a threat to ground water, as did precipitation percolating through contaminated soils. Contamination might have entered shallow or deeper aquifers and potentially migrated to off-site drinking water wells.

During Phase 1 sampling activities, full priority pollutant metals and total cyanide analyses were conducted on all soil and ground-water samples sent to the laboratory. These parameters were initially selected based on a study of plating chemistry:

plating facilities generally use either an acid or basic cyanide bath to achieve the desired coating on their metal products. Since Phase 1 samples were collected from the areas of highest suspected contaminant concentration (i.e., sources and drainage pathways), Phase 2 samples (all media types) were analyzed for total chromium, hexavalent chromium (in water only), and cyanide, the only analytes detected consistently during the Phase 1 analyses. During Phase 3, the samples sent to the laboratory for definitive analysis were analyzed for total chromium and cyanide.

2.5.4 Sampling Objectives

The OSC initiated an assessment with a specific sampling objective, as follows:

- Phase 1 -- Determine whether a threat to public health, welfare, and the environment exists. Identify sources of contamination to support an immediate CERCLA-funded activation for containment of contaminants and security fencing (site stabilization strategies) to reduce direct contact concerns on site. Sample the nearby drinking water wells for immediate human health concerns.

Once CERCLA funding was obtained and the site was stabilized:

- Phase 2 -- Define the extent of contamination at the site and adjacent residential properties. Estimate the costs for early action options and review any potential long-term remediation objectives. For example, install and sample soil borings and monitoring wells on site to evaluate potential impact on subsurface soils and ground water.

- Phase 3 -- After early actions are completed, document the attainment of goals. Assess that the response action was completed to the selected level and is suitable for long-term goals.

2.5.5 Selection of Sampling Approaches

The OSC, Team, and PADER reviewed all available information to formulate a sampling plan. The OSC selected a judgmental sampling approach for Phase 1. Judgmental sampling supports the immediate action process by best defining on-site contaminants in the worst-case scenario in order to evaluate the threat to human health, welfare, and the environment. Threat is typically established using a relatively small number of samples (fewer than 20) collected from source areas or suspected contaminated areas based on the historical data review and site reconnaissance. For this site, containerized wastes were screened to categorize the contents and to establish a worst-case waste volume, while soil samples were collected to demonstrate whether a release had already occurred, and nearby residential drinking water wells were sampled for immediate human health concerns.

For Phase 2, a stratified systematic grid design was selected to define the extent of contamination in soils. The grid could accommodate analytical screening and geophysical surveys. Based on search sampling conducted at sites similar to ABC Plating, a block grid with a 50-foot grid spacing was selected. This grid size ensured a 10 percent or less probability of missing a "hot spot" of 45 feet by 20 feet. The grid was extended to adjacent residential properties when contaminated soil was identified at grid points near the boundary of the site.

Based on the results of soil sampling and geophysical surveys, a judgmental approach was used to select locations for installation of 15 monitoring wells: at "hot spots"; along the perimeter of the suspected plume established from analytical results and geophysical survey plots; and at background ("clean") locations. Subsurface soil and ground- water samples were collected from each of the 15 monitoring well locations for laboratory analysis to establish the presence and, if applicable, the degree of contamination at depth.

2.5.6 Sampling Plan

During Phase 1, containerized wastes were evaluated using field analytical screening techniques. Phase 1 wastes-screening indicated the presence of strong acids and bases and the absence of volatile organic compounds. The Team collected a total of 12 surface soil samples (0-3 inches) and 3 ground-water samples during this phase and sent them to a laboratory for analysis. The soil sampling locations included stained soil areas, erosion channels, and soil adjacent to leaking containers. Background samples were not collected during Phase 1 because they were unnecessary for activating immediate action response funding. Ground-water samples were collected from three nearby residential wells. Based on Phase 1 analytical results, chromium was selected as the target compound for determination of extent of contamination in soil and ground water.

During Phase 2 sampling activities, the OSC used a transportable X-ray fluorescence (XRF) unit installed in an on-site trailer to screen soil samples for total chromium in order to limit the number of samples to be sent for laboratory analysis. Soil sampling was performed at all grid nodes at the surface (0-4 inches) and subsurface (36-40 inches). The 36-40 inch depth was selected based on information obtained from state reports and local interviews, which indicated that lagoon wastes were approximately 3 feet below ground surface. Once grid nodes with a contamination level greater than a selected target action level were located, composite samples were collected from each adjoining grid cell. Based on the XRF data, each adjoining grid cell was either identified as "clean" (below action level) or designated for response consideration (at or above action level).

Also during Phase 2, the OSC oversaw the performance of ground penetrating radar (GPR) and electromagnetic conductivity (EM) geophysical surveys to help delineate the buried trench and lagoon areas, any conductive ground-water plume, and any other waste burial areas. The GPR and comprehensive EM surveys were conducted over the original grid. Several structural discontinuities, defining possible disturbed areas, were detected. One GPR anomaly corresponded with the suspected location and orientation of the feeder trench. The EM survey identified several high conductivity anomalies: the suspected feeder trench location, part of the lagoon area, and a small area west of the process building, which may have been an illegal waste dumping area. (Field analytical screening and geophysical techniques are further discussed in Chapter 3.)

Using the data obtained during soil sampling and the geophysical surveys, a ground-water assessment plan for Phase 2 was prepared. The Team collected depth soundings and water level measurements of the nearby residential wells to assess aquifer usage and location (depth). With these data and the analytical results from Phase 1, a work plan for monitoring well installation and testing on site was developed. The plan consisted of:

- Installation of overburden, bedrock contact and bedrock (open borehole) monitoring wells in order to evaluate the shallow water table and aquifer conditions

- Analysis of subsurface soils retrieved during borehole/well drilling in order to evaluate the extent of contamination in overlying soils

- Collection of depth soundings and water level measurements of the newly installed monitoring wells to map aquifer and water table gradients

- Collection of ground-water samples from each monitoring well

- Performance of hydraulic tests in order to evaluate aquifer characteristics

The monitoring wells were located in areas shown, during soil sampling, to be heavily contaminated; along the outer perimeter of a contaminant plume based on soil XRF results and the geophysical surveys; and an apparent upgradient location for background conditions comparison. Fifteen wells were located at grid nodes corresponding to the above results. (Section 4.6.1 provides details on the performance of well installation (drilling), testing and surveying, and ground-water sampling procedures.)

Upon monitoring well installation and sampling, a hydraulic (pumping) test was completed of the bedrock monitoring wells to gather information about aquifer characteristics. These data characterize contaminant transport through the ground-water aquifer. The hydraulic test provided transmissibility, hydraulic conductivity, and storativity values. Utilizing these values with ground-water level data, the estimated vertical and horizontal ground-water gradient and velocity could be calculated. All monitoring wells installed were surveyed for elevation above mean sea level, needed to determine accurate depth to ground water (piezometric surface) and relative gradients.

Phase 3 activities are discussed in Section 6.8.

3.0 FIELD ANALYTICAL SCREENING, SAMPLING EQUIPMENT, AND GEOPHYSICAL TECHNIQUES

3.1 FIELD ANALYTICAL SCREENING

Field analytical screening techniques can provide valuable information in ground-water sampling. Field analytical screening for ground water is used primarily as a tool for siting monitoring wells and for on-site health and safety assessment during well drilling activities. When used correctly, screening techniques can help to limit the number of "non-detect" monitoring wells installed. Some of the commonly used screening methods for ground-water assessment are presented in this chapter in the general order that they would initially be used at a site, although site-specific conditions may mandate a different sequence. For more information on ground-water field screening devices, refer to the U.S. EPA *Compendium of ERT Field Analytical Procedures*, OSWER Directive 9360.4-04, and *Compendium of ERT Ground-Water Sampling Procedures*, OSWER Directive 9360.4-06. Refer to Standard Operating Safety Guides for each instrument, and the U.S. Department of Health and Human Services *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities* (NIOSH Pub. 85-115) for site entry information.

3.1.1 Flame Ionization Detector

The flame ionization detector (FID) detects and measures the level of total organic compounds (including methane) in the ambient air in proximity to a well or in a container headspace. The FID uses the principle of hydrogen flame ionization for detection and measurement. It is especially effective as an ethane/methane detector when used with an activated charcoal filter because most organic vapors are absorbed as the sample passes through the filter, leaving only ethane and methane to be measured.

The FID operates in one of two modes: the survey mode, or the gas chromatography (GC) mode. In the survey mode, the FID provides an approximate total concentration of all detectable organic vapors and gases measured relative to the calibration gas (usually methane). The GC mode identifies and measures specific components, some with detection limits as low as a few parts per million (ppm), using known standards analyzed concurrently in the field. Since the GC mode requires standards to identify classes of compounds, it is necessary to have an idea of which compounds might be present on site before sampling. Advantages of the FID are that it is portable, relatively rugged, and provides real-time results.

During a ground-water assessment, the FID is used in the survey mode for monitoring the borehole during drilling and in the survey or GC mode for health and safety screening.

The FID does not respond to inorganic substances. It has positive or negative response factors for each compound depending on the selected calibration gas standard. Ambient air temperatures of less than 40 degrees Fahrenheit will cause slower responses; relative humidity of greater than 95 percent can cause inaccurate and unstable responses. Interpretation of readings (especially in the GC mode) requires training and experience with the instrument.

3.1.2 Photoionization Detector

Another portable air monitoring instrument frequently used for field screening during ground-water assessments is the photoionization detector (PID). Like the FID, the PID provides data for real-time total organic vapor measurements, identifying potential sample locations and extent of contamination, and supporting health and safety decisions. The PID is useful in performing soil gas screening, health and safety monitoring during well drilling activities, and headspace screening analysis. The PID works on the principle of photoionization. Unlike the FID, the PID can be used to detect gross organic and some inorganic vapors, depending on the substance's ionization potential (IP) and the selected probe energy. It is portable and relatively easy to operate and maintain in the field.

The PID detects total concentrations and is not generally used to quantify specific substances. PIDs cannot detect methane; however, methane is an ultraviolet (UV) light absorber, and false negative instrument readings may register in methane-rich environments. The PID cannot detect substances with IPs greater than that of the UV light source. (Interchangeable UV lamps are available.) Readings can be affected by high wind speeds, humidity, condensation, dust, power lines, and portable radios. Dust particles and water droplets (humidity) in the sample may collect on the light source and absorb or deflect UV energy, causing erratic responses in PIDs not equipped with dust and moisture filters.

3.1.3 Gas Chromatograph

Although many FIDs are equipped with a GC mode, an independent, portable GC (gas chromatograph) can also be used on site to provide a chromatographic profile of the occurrence and intensity of unknown volatile organic compounds (VOCs) in ground water. The GC is useful as a soil gas screening tool to determine "hot spots" or plumes, potential interferences, and semi-quantitation of VOCs and semi-volatile organic compounds (semi-VOCs) in ground-water samples. For example, when installing a monitoring well, the GC might be used to screen water samples during drilling in order to indicate when a target contaminated aquifer zone is encountered.

Compounds with high response factors, such as benzene and toluene, produce large response peaks at low concentrations, and can mask the presence of compounds with lower response factors. However, recent improvements in GCs, such as pre-concentrator devices for lower concentrations, pre-column detection with back-flush capability for rapid analytical time, and the multi-detector (PID, FID, and electron capture detector (ECD)), all enable better compound detection. The GC is highly temperature-sensitive. It requires set-up time, many standards, and operation by trained personnel.

3.1.4 Hydraulic Probe

The hydraulic probe (Geoprobe® is one brand) is a truck-mounted device used to collect screening ground-water, soil, and soil gas samples at relatively shallow depths. The probe is mounted on the back of a small truck or van and is operated hydraulically using the vehicle's engine. Small diameter hardened steel probes are driven to depths of up to 40 feet or more, depending on soil conditions. Soil gas samples can then be collected using a vacuum pump. Soil or water samples can also be collected using a small-diameter shelby tube or slotted well point and foot valve pump.

The hydraulic probe can be used in ground-water investigations to assess vertical and horizontal extent of contamination. Shallow samples can be collected relatively quickly and easily. It is useful in a ground-water assessment to assist in siting monitoring wells and to install shallow wells if necessary. It can also collect undisturbed ground-water samples without installing wells. The hydraulic probe is only effective in unconsolidated geologic materials, however. In general, probing is possible under conditions amenable to hollow stem auger drilling.

3.1.5 Soil Gas Technique

Soil gas testing is a quick method of site evaluation. For ground-water assessments, soil gas testing is used to track contaminant plumes and determine appropriate locations for installing monitoring wells. For this technique, a thin stainless steel probe is inserted into a hole made in the soil with a special slam bar. The hole is sealed around the probe and a sampling pump is attached. Samples are then collected in Tedlar bags, sorbent cartridges, or SUMMA canisters. The samples are analyzed using an FID, PID, or GC. A disadvantage of the soil gas technique is that its ability to detect contaminants diminishes the further it is from the source (as contaminant concentration diminishes).

3.1.6 Field Parameter Instruments

Field parameters measured during ground-water sampling include pH, specific conductivity, temperature, salinity, and dissolved oxygen. Specific conductivity, pH, and temperature are often used as standard indicators of water quality. Instruments that measure these three indicators are used during ground-water assessments to determine if a well has been purged sufficiently (stabilized) prior to sampling (see Section 4.3).

3.1.7 X-Ray Fluorescence

Field analytical screening using X-ray fluorescence (XRF) is a cost-effective and time-saving method to detect and classify lead and other heavy metals in a sample. XRF screening provides immediate semi-quantitative results. The principle behind XRF is the detection and measurement of the X-rays released from an atom when it is excited by the absorption of source X-rays. The energy released (fluorescent X-rays) are characteristic of the atoms present.

Results of XRF analysis help determine the presence of metals and are often used to assess the extent of soil contamination at a site. For ground-water assessment, XRF may be used on subsurface soil samples collected during drilling or with surface soils when selecting locations for monitoring well installation. XRF use requires a trained operator and may require numerous site-specific calibration samples.

3.2 GROUND-WATER SAMPLING EQUIPMENT

Conducting representative ground-water sampling requires an understanding of the capabilities of the equipment used for sampling, since the use of inappropriate equipment may result in biased samples. Select appropriate sampling equipment based on the sampling objectives, the analytical parameters, the type of well being sampled (e.g., monitoring well or drinking water well), and other site-specific conditions. Follow SOPs for the proper use and decontamination of sampling equipment. This section presents various types of ground-water sampling equipment and information to assist in selecting appropriate materials.

The ground-water sampling devices discussed below are covered in greater detail in many SOPs and references on the various types of available ground-water sampling devices. Refer to U.S. EPA *A Compendium of Superfund Field Operations Methods*, OSWER Directive 9355.0-14, and *Compendium of ERT Ground-Water Sampling Procedures*, OSWER Directive 9360.4-06, for details on the equipment listed. Also refer to Driscoll, Fletcher G., *Ground-Water and Wells*, 2nd ed., and the 1985 "Proceedings of the Fifth National Symposium and Exposition on Aquifer Restoration and Ground-Water Monitoring," for additional comparisons of the various types of sampling equipment.

3.2.1 Bailer

A bailer is a simple purging device for collecting samples from monitoring wells. It usually consists of a rigid length of tube with a ball check-valve at the bottom. A line is used to mechanically lower the bailer into the well to retrieve a volume of water. Because bailers are portable and inexpensive, they can be dedicated to monitoring wells at a site, thus avoiding the need to use a bailer for sampling more than one well (and avoiding cross-contamination). Bailers are available in a variety of sizes and construction materials (e.g., polyvinyl chloride (PVC), Teflon®, and stainless steel).

Bailers are best suited for purging shallow or narrow diameter monitoring wells. Deeper, larger diameter, and water supply wells generally require mechanical pumps to evacuate a large volume of water.

For VOC analysis, a positive-displacement volatile sampling bailer is most effective. Bottom-fill bailers, which are more commonly used, are suitable provided that care is taken to preserve volatile constituents. Fill sample containers directly from the bailer, filling samples for VOC analysis first.

3.2.2 Hydraulic Probe

The hydraulic probe can be used to collect shallow (generally 40 feet or less) ground-water samples using a mill-slotted well point or retractable screen drive point. After the well point is driven to the desired depth, the probe rod is connected to a vacuum pump for purging. (Since ground water is sampled in situ and is not exposed to the atmosphere, extensive purging is not required.)

Water samples are collected using dedicated polypropylene tubing fitted with a small diameter foot-valve pump. Samples are collected in 40-ml vials or other containers for laboratory analysis. See Section 3.1.4 for more information on the hydraulic probe.

3.2.3 Air-Lift Pump

An air-lift pump operates by releasing compressed air via an air line lowered into the well. The air mixes with the water in the well to reduce the specific gravity of the water column and lift the water to the surface.

Air-lift pumping is used in well development and for preliminary testing. For sampling, air-lift pumping is less efficient than other pumping methods which follow; it may be selected for use when aeration is needed to remove gas or corrosive water which can be destructive to a well pump. Because an air-lift pump aerates the water, it is not applicable for VOC sample collection.

3.2.4 Bladder Pump

A bladder pump consists of a stainless steel or Teflon® housing that encloses a Teflon® bladder. The bladder pump is operated using a compressed gas source (bottled gas or an air compressor). Water enters the bladder through a lower check valve; compressed gas moves the water through an upper check valve and into a discharge line. The upper check valve prevents back flow into the bladder.

The bladder pump can be used to purge and sample to a depth of approximately 100 feet. It is recommended for VOC sampling because it causes minimal alteration of sample integrity as compared with other ground-water sample methods. The bladder pump requires a power supply and a compressed gas supply or air compressor. The pump is somewhat difficult to decontaminate and should thus be dedicated to a well (or dedicated tubing should be used).

3.2.5 Rotary Pump

A rotary pump is a positive displacement pump which discharges the same volume of water regardless of the water pressure. The rate of discharge is the same at both low and high pressure, but the input power varies in direct proportion to the pressure. The rotary pump consists of a housing with inlet and outlet ports and rotating gears or vanes. As water is discharged from the pump, a replacement supply of equal volume is taken in.

Rotary pumps are useful for well purging and general sample collection at shallow to deep sampling depths. Because of water agitation, they may not be suitable for sampling VOCs, and they are difficult to decontaminate between sampling stations.

3.2.6 Peristaltic Pump

A peristaltic pump is a suction lift pump consisting of a rotor with ball-bearing rollers. Dedicated Teflon® tubing is threaded around the rotor. Additional lengths of dedicated Teflon® tubing are attached to both ends of the rotor tubing: one end is inserted into the well; the other end is a discharge tube. The sample makes contact with the tubing only, not with the pump. The tubing should be equipped with a foot valve to avoid having aerated water from the tubing fall back into the well.

A peristaltic pump is suitable for sampling small diameter wells (e.g., 2 inches). Cross-contamination is not of concern because dedicated tubing is used and the sample does not come into contact with the pump or other equipment. The peristaltic pump has a depth limitation of 25 feet and its use can result in a potential loss of the volatile fraction due to sample aeration.

3.2.7 Packer Pump

A packer pump is used to isolate portions of a well or water column for sampling. The pump consists of two expandable parts that isolate a sampling unit between them. The parts deflate for vertical movement within the well and inflate when the desired sampling depth is reached. The packers are constructed of rubber and can be used with various types of pumps.

An advantage of the packer pump is it allows the isolation of a portion of the water column in order to sample at a discrete depth. Disadvantages relate to the rubber construction of the packers which may deteriorate over time allowing cross contamination. The rubber also poses potential contaminant compatibility concerns. A packer pump should not be used if the contaminants are unknown, or where well casing or contaminant characteristics interfere or interact with the pump construction materials.

3.2.8 Syringe Sampler

Syringe samplers are a relatively new and less commonly available sampling device. Syringe samplers were developed by research groups to obtain ground water samples over a period of time. The device consists of a syringe (15 to 1500 ml in volume) which is lowered into the well to the desired sampling depth. The syringe plunger is then pulled open by a remote method, either mechanical or pneumatic, allowing the syringe to fill.

The remote operation allows the collection of a sample at a discrete depth. In addition, the interior of the sampler (i.e., the syringe) is not exposed to the water column. Disadvantages to this device include the small volume of sample that can be collected, it cannot be adapted for evacuation/purging uses, and it is not readily commercially available.

3.2.9 Ground-Water Sampling Equipment Selection Factors

The following factors should be considered when selecting ground-water sampling equipment.

- Composition - Select the composition of the sampling equipment based on the sampling parameters and objectives. For example, use samplers made of Teflon®, glass, or stainless steel instead of PVC when sampling for VOCs. Consider well composition when selecting sampling equipment. For example, select a stainless steel bailer when bailing a well with stainless steel casing to avoid the introduction of organic constituents. When sampling a PVC-cased well, PVC, stainless steel, or Teflon® bailers may be used.

- Physical Constraints - Physical constraints of the monitoring well location, power availability, and topography are factors that affect selection of ground-water sampling equipment. For example, a small diameter or particularly deep well may require the use of different purging and sampling equipment than that used for other wells at the site. Site accessibility may hinder the use of large or vehicle-mounted equipment.

- Sample Analysis - Equipment should be chosen based on its impact on the samples. For example, sampling equipment selected for collecting VOCs should agitate the water as little as possible. This is not as critical for metals or other non-volatile analyses.

- Ease of Use - Generally, the more complicated the sampling equipment is, the greater the chance for some form of failure in the field. Utilize the simplest effective sampling devices available. Adequate training in equipment safety and use is critical to personnel safety as well as to sample representativeness. Consider ease of decontamination when using non-dedicated equipment.

3.3 GEOPHYSICAL METHODS

Geophysical methods can be useful in conjunction with screening and sampling activities to help delineate subsurface features and boundaries, contaminant plumes, and bedrock types. Geophysical data can be obtained relatively rapidly, often without disturbing the site. The data are helpful in selecting well locations and screen depths. The following sections discuss surface and borehole geophysics and preferable geophysical techniques for ground-water investigations.

3.3.1 Surface Geophysics

The following surface geophysical techniques may be useful in ground-water investigations. As implied by the name, these techniques are performed above ground. For more detailed information on each of these techniques (with the exception of gravimetric surveys), see ERT SOP #2159 and Driscoll, 1986. For more information on gravimetric surveys, see Driscoll, 1986.

- Ground Penetrating Radar (GPR) - Uses a high frequency transmitter that emits radar pulses into the subsurface. These waves are scattered at points of change in the dielectric permittivity of the subsurface material and are reflected back to an antenna. (Dielectric permittivity is a function of bulk density, clay content, and water content of the subsurface.) The returning energy wave is then plotted as a function of time on an analog plot. Interpretation of the analog plot identifies anomalies, clay layers, and water content in the substrate.

  GPR works best in dry, sandy soil above the water table, and at depths between 1 and 10 meters (although the full instrument depth range is less than one meter to tens of meters). When properly interpreted, GPR data can indicate changes in soil horizons, fractures, and other geological features, water-insoluble contaminants, man-made buried objects, and hydrologic features such as water table depth. Uneven ground surfaces or cultural noise affect GPR results.

- Electromagnetic Conductivity (EM) - Relies on the detection of induced electrical current flow through geologic strata. This method measures bulk conductivity (inverse of resistivity) of subsurface materials below the transmitter and receiver. EM is commonly used in the detection of ground-water pollution, as well as to locate pipes, utility lines, cables, trenches, buried steel drums, and other buried waste.

  EM has limited applications in areas of cultural noise, including above-ground power lines and metal fences, and lateral geologic variations which might be misinterpreted as contaminant plumes.

- Electrical Resistivity - Used to map subsurface structures through differences in their resistance to electrical current. Material resistivities are measured as functions of porosity, permeability, water solution, and concentrations of dissolved solids in pore fluids. Bulk resistivity is measured in the subsurface by measuring electrical currents injected through electrodes placed in the soil.

  Electrical resistivity surveys are limited by electrical noise, such as occur in industrial areas. Resistivity surveys should ideally be conducted in areas removed from pipelines and grounded metallic structures such as metal fences and railroad tracks. This requirement precludes use of electrical resistivity surveys on many sites. Resistivity can often be used off site to map area stratigraphy. Resistivity surveys are labor intensive, requiring ground setup and removal of electrodes for each station measurement. Use extreme care during rain or wet ground conditions.

- Seismic Investigations - Conducted by two methods: refractive and reflective. In the refractive method, the travel time of acoustic waves is measured as they move through and are refracted along an interface of the subsurface. The reflective method measures travel time of acoustic waves as they are reflected off an interface. Seismic refraction is typically used when bedrock is within 500 feet of the ground surface.

  Seismic refraction is useful for mapping discrete stratigraphic layers and therefore can help in selecting monitoring well locations and depths. A seismic refraction survey can provide subsurface stratigraphic and structural data in areas between existing wells or boreholes. Seismic reflection is used less often in ground-water investigations, but is more commonly used for deeper and larger-scale stratigraphic mapping (e.g., petroleum exploration).

- Magnetic Investigations - Rely on local variations in the earth's magnetic field to detect ferrous or magnetic objects. By mapping variations in the concentrations of the local magnetic fields, detection of buried objects such as drums or tanks may be accomplished. Magnetic surveys are limited by cultural noise such as power lines, utilities, and metal structures.

- Gravimetric Surveys - Measure small localized differences in the earth's gravity field caused by subsurface density variations, which may be produced by changes in rock type (porosity and grain type), saturation, fault zones, and varying thickness of unconsolidated sediments overlying bedrock. This method is useful in identifying buried valleys, particularly in glaciated areas.

  Gravimetric surveys use a portable gravity meter which can survey a large area relatively quickly. The accuracy of the readings is dependent upon the accuracy of the elevation determination of each station. (Most altimeters are accurate only to plus or minus 2 ft (0.6 m), so gravity stations should be surveyed.) A gravimetric survey can provide a quick preliminary screening of an area. Other geophysical methods or test drilling can then be used to help identify stratigraphy and aquifer characteristics.

Table 1 illustrates the applicability of various surface geophysical techniques to ground-water investigations. Table 2 lists some advantages and disadvantages of surface geophysical techniques to ground-water investigations.

3.3.2 Borehole Geophysics

The following borehole geophysical techniques may be useful in ground-water investigations. Borehole geophysics may be used alone or to supplement surface geophysical techniques. Site terrain is an important factor when conducting borehole geophysical surveys. Much of the equipment is mounted or housed inside a truck but can be carried to well locations if necessary. Some borehole logs can be run in a cased as well as open hole.

Often several of the following tests are run at the same time for comparative purposes. Borehole geophysical logs can be interpreted to determine the lithology, geometry, resistivity, formation factor, bulk density, porosity, permeability, moisture content, and specific yield of water-bearing formations as well as the chemical and physical characteristics of ground water. The operating principles of the various borehole geophysical techniques are similar. A sonde (a cylindrical tool containing one or more sensors) is lowered to the bottom of the borehole, activated, and slowly withdrawn. Signals or measurements at various depths are recorded at the surface. Instruments vary from hand-held portable gear to truck-mounted, power-driven equipment. For more detailed information on each of these techniques, see Driscoll, 1986.

- Resistance Logs - Electric logs measuring the apparent resistivity of the rock and fluid surrounding a well. They are good indicators of subsurface stratigraphy and water quality. Electric current is measured as it flows from electrodes in the probe to other electrodes in the probe or on the ground surface.

  Resistance logs have a small radius of investigation and are very sensitive to conductivity of borehole fluid and changes in borehole diameter. Increases in formation resistivity produce corresponding increases in resistance measurements on the log. Deflections on the log are interpreted as changes in lithology. Because of its excellent response to lithology changes, the resistance log is very useful for geological correlation. Formation fluids are perhaps the most important variable in interpreting resistance logs. For example, dry sands and clays have high resistivities, but their resistivities decrease with water saturation.

Dissolved minerals also affect resistivity. (Fresh water is a poor conductor whereas salt water is a good conductor; water in saturated clays contains dissolved minerals from the clay, which results in high conductivities.)

A limitation of resistance logs is that they can be run only in uncased boreholes that are filled with drilling fluid and water. Resistance logging is therefore most appropriately conducted before monitoring well completion.

- <u>Spontaneous Potential (SP) Logs</u> - Used in conjunction with resistivity logs to show the naturally occurring electric potentials of the chemical and physical changes at contacts between differing types of geologic materials. The electric current is measured between an electrode placed in an uncased borehole and one placed at the surface.

  SP response is due to small voltage differences caused by chemical and physical contacts between the borehole fluid and the surrounding formation. Voltage differences appear at lithology changes or bed boundaries and their response is used to quantitatively determine bed thickness or formation fluid resistivity. Qualitative interpretation of the data can be used to identify permeable beds.

  Buried cables, pipelines, magnetic storms, and the flow of ground water can all cause anomalous readings. Caution must be exercised when using SP data in a quantitative fashion. Mathematical formulas are structured for oil well logging and incorporate assumptions which may not apply to fresh water wells. As with resistance logs, SP logs can be run only in uncased, liquid-filled boreholes.

- <u>Gamma Logs</u> - Measure the naturally occurring gamma radiation emitted from the decay of radioisotopes normally found in the substrate. Elements that emit natural gamma radiation are potassium-40 and daughter products of the uranium and thorium decay series. Changes in radiation levels are commonly associated with differences in substrate composition.

  Gamma logs can be run in open or cased boreholes filled with water or air. The sensing device can be part of the same sonde that conducts SP and resistance logs. Gamma rays or photons are measured and plotted as counts per minute. This method is useful in identifying clay layers or other naturally radioactive geologic units.

  Gamma logging is used to identify the lithology of detrital sediments, where the finer-grained units have higher gamma intensity. (Fine-grained materials also tend to have lower permeability and effective porosity, important for evaluating aquifer zones.) A limitation with gamma and other nuclear logs is that they are affected by changes in borehole diameter and borehole media (e.g., air, water, or mud). Gamma logs record the sum of the radiation emitted from the formation and do not distinguish between radioactive elements. For use in stratigraphic correlation however, specific element identification is not critical. Interpretation of gamma logs is difficult where sandstone and other strata contain volcanic rock fragments with radioactive minerals (e.g., rhyolite). Interpretation is also difficult in sandstone containing a large proportion of feldspar (which contains radioactive potassium-40).

- <u>Gamma-Gamma Logs</u> - Similar to gamma logs except that a radioactive gamma source is attached to the gamma sonde and the gamma particles reflected back from the geologic formation are measured. Gamma-gamma logs measure the differing bulk densities of geologic materials. They can be used to identify lithology and also to calculate porosity when fluid and grain density are known.

- <u>Neutron Logs</u> - Also utilize a radiation source in the sonde. The neutron source is a europium-activated, lithium iodide crystal enriched in lithium-6. The neutron logging tool bombards the formation with neutrons and measures the returning radiation. Neutrons, when ejected from a nucleus, have great penetrating power and may travel through several feet of subsurface formation. All free neutrons are eventually captured by the nuclei of some element. Neutron logs respond primarily to hydrogen density. The high energy neutrons from the source are slowed by collision with hydrogen ions in the formation. This response to hydrogen ion content is then cross-calibrated to porosities for water-saturated rocks. Neutron logs respond to the hydrogen content in the borehole and surrounding formation and indicate the porosity of the various geologic units in the survey. Neutron logs can be run in cased or open holes which are dry or filled with fluid.

Neutron logs are typically used to determine moisture content above the water table and total porosity below the water table. Neutron logs are effective for identifying perched water tables. Neutron log information can also be used to determine lithology and conduct stratigraphic correlation of aquifers and associated formations as well as to help determine the effective porosity and specific yield of unconfined aquifers.

- Acoustic (Sonic) Logs - Measure the travel time and attenuation of an acoustic signal created by an electromechanical source in the borehole. A transmitter in the borehole converts the electrical energy to acoustic (sound) energy which travels through the formation as an acoustic pulse to one or more receivers. The acoustic energy is then converted back to electrical energy, which is measured at the surface. The acoustic wave velocity is affected by the type of material through which it passes (rock or sediment is more conductive than is pore fluid), hence it is useful in determining porosity.

  Acoustic logs can help determine fracture patterns within semiconsolidated and consolidated bedrock such as sandstone, conglomerate, and igneous rocks. Knowledge of fracture patterns in an aquifer is helpful in estimating ground-water flow, and thereby estimating the rate of plume movement. Acoustic logs can be used to locate the static water level and to detect perched water tables.

- Temperature Logs - Used to measure the thermal gradient of the borehole fluid. The sonde measures changes in temperature of the fluid surrounding it, and the log records resistivity as a function of temperature. Borehole fluid temperature is influenced by fluid movement in the borehole and adjacent strata. In general, the temperature gradient is greater in low permeability rocks than in high permeability rocks, likely due to ground-water flow. Temperature logs provide information regarding ground-water movement and water table elevation. Temperature logs are useful for detecting seasonal recharge and subsurface infiltration of irrigation and industrial wastewater runoff, and quantitative interpretation of resistivity logs.

  Temperature logs are designed to be operated from the top to the bottom of the borehole, in order to channel water past the sensor. Repeat temperature logs should be delayed until the borehole fluid has had time to reach thermal equilibrium.

Table 3 illustrates the applicability of various borehole geophysical techniques to ground-water investigations. Table 4 lists some advantages and disadvantages of borehole geophysical techniques to ground-water investigations.

3.3.3 Geophysical Techniques for Ground-Water Investigations

The following situations illustrate uses for geophysical techniques in ground-water assessment.

- To define the location, extent, and the movement of a contaminant plume, several geophysical techniques may be utilized, including EM, electrical resistivity, and possibly GPR. Resistivity and spontaneous potential (SP) logs could also be utilized as borehole geophysical methods.

- To locate faults and fracture systems, seismic refraction and reflection and EM are the preferred methods, but GPR, electrical resistivity and acoustic logs could also be used.

- The mapping of grain size distribution in unconsolidated sediments is not possible with any geophysical technique. It is possible, however, to identify different soil types of different grain sizes (e.g., sand, silt, and clay). Seismic reflection and refraction, GPR, and gravimetric surveys may be used to identify differing formations. Several borehole geophysical techniques could also be utilized in this type of analysis, including gamma, gamma-gamma, neutron porosity, resistivity, and SP logs.

- Definition of lithologic boundaries may be accomplished with seismic reflection and refraction and with GPR techniques. When using borehole geophysics, resistivity, SP, and acoustic logs are useful.

- For mapping water tables, GPR and electrical resistivity are preferred but seismic refraction and reflection and gravimetric surveys may also be used. If using borehole geophysics, direct measurement or temperature logs would be the method of choice. Resistivity and SP logs could also be used.

- To define the bedrock topography, seismic refraction and reflection, GPR and gravimetric surveys may be used.

- For delineating stratigraphic layers or subsurface features, such as buried stream channels and lenses, seismic refraction and reflection, electrical resistivity, gravimetric surveys, and possibly GPR could be used.

3.4 EXAMPLE SITE

3.4.1 Selection of Field Analytical Screening Techniques

Phase 1 sampling identified the sources and types of on-site contaminants in order to establish a threat. Hazard categorization techniques, organic vapor detecting instruments (FID and PID), and radiation and cyanide monitors were utilized to tentatively identify containerized liquid wastestreams in order to select initial judgmental soil sampling locations. During Phase 2 sampling, a portable XRF unit was used to determine the extent of soil contamination and to identify additional "hot spots." A FID and PID continued to be utilized throughout all field activities for health and safety monitoring during Phases 1 through 3.

The portable XRF for soil screening was also used during monitoring well installation. Continuous split spoon samples were collected during advancement of the boreholes. Each spoon was sampled and screened in the field using the XRF unit. Selected samples (one per borehole location) were submitted to the laboratory for confirmation analysis. One off-site sample was selected by the field geologist based on field observations and professional judgment.

Ground-water samples were screened in the field for pH, specific conductivity, and temperature using a three-in-one monitoring instrument. The instrument probe was placed into a clean glass jar containing an aliquot of the ground-water sample. The instrument was decontaminated prior to and after each sample screening.

3.4.2 Selection of Sampling Equipment

Dedicated plastic scoops were used for Phase 1 soil sampling. Phase 1 ground-water samples were collected directly from the residential taps into sample containers. For Phase 2, soils were collected from the near surface (0-4 inches) and at depth. Stainless steel trowels were used to retrieve shallow soil samples. Subsurface samples were collected by advancing boreholes using a hand-operated power auger to just above the sampling zone and then using a stainless steel split spoon to retrieve the soil. The split spoon was advanced with a manual hammer attachment.

Monitoring wells were installed using a dual-tube, air percussion drill rig. Borehole soil samples were retrieved using 2-foot stainless steel split spoon samplers. Soil from the split spoons was transferred to sample containers using disposable plastic scoops. Monitoring well installation is described further in Section 4.6.1.

Ground water was sampled in Phase 2 from the monitoring wells installed on site. First, monitoring wells were purged using a 1.5 gallon per minute (gpm) submersible rotary pump with flexible PVC outflow hose and safety cable. The pump and hose were decontaminated between well locations by pumping deionized water through the system. A similar pump and hose system was used to perform the hydraulic (pumping) test. The pumps are operated by a gas-powered generator placed near the well location.

The ground-water samples were obtained using dedicated bottom-fill Teflon® bailers. The bailer was attached to nylon rope, which was selected because less material would be adsorbed onto the nylon and brought out of the well. Residential ground-water samples were collected directly into the sample containers from the kitchen sink tap. Water level and depth measurements were obtained from monitoring wells using decontaminated electronic measuring equipment.

3.4.3 Selection of Geophysical Methods

The GPR instrument delineated buried trench and lagoon boundaries. The EM meter detected subsurface conductivity changes, thereby identifying buried metal containers and contaminants. The EM-31D, a shallower-surveying instrument than the EM-34, was selected because of the instrument's maneuverability and ease of use, and because the expected contaminant depth was less than 10 feet.

Table 1: Applicability of Surface Geophysical Techniques to Ground-Water Investigations

	Seismic Reflection	Seismic Refraction	Electromagnetic Conductivity	Magnetic Investigations	Ground Penetrating Radar	Electrical Resistivity	
Contaminant Plume Delineation			P		A	P	
Faults/Fracture Detection	P		P		A	A	A
Lithologic Boundary Delineation	P	P			A		
Bedrock Topography Delineation	P	P			A		A
Stratigraphic Mapping	P	P			A	P	P
Water Table Mapping	A	A			P	P	A
Soil Type of Unconsolidated Sediments	P	P			P		P
Metallic Detection			P	P	P	A	
Non-Metallic Detection						P	
Seepage Detection			A		P	A	
Buried Structure Detection				A	A		

P - Preferred Method

A - Applicable Method (in most cases)

Table 2: Advantages and Disadvantages of Surface Geophysical Techniques to Ground-Water Investigations

	Advantages	
Seismic Reflection	• Ability to discern discrete layers • Less offset space is required than for refraction	• Velocities 10-20% of true velocities • Data collection and interpretation are more labor intensive and complex than for refraction • Depth data not as precise as refraction • Signal enhancement needed to identify reflected waves
Seismic Refraction	• Relatively precise depth can be determined • Provide subsurface data between boreholes • Ability to map water table and top of bedrock	• Data collection can be labor intensive • Large geophone line lengths needed
Electromagnetic Conductivity	• Lightweight, portable equipment • Continuous or quick scan survey • Rapid data collection	• Interference from cultural noise and surface metal objects • Limited use where geology varies laterally
Magnetic Investigations	• Can survey large area quickly and cost effectively • Little site preparation needed	• Interference from cultural noise, and large metal objects • Unable to differentiate between steel anomalies
Ground Penetrating Radar	• Can survey large area quickly • Continuous real-time data display • Quick data processing	• Interference from cultural noise, uneven terrain, and vegetation • Clay content and shallow water table inhibit radar penetration
Gravimetric Surveys	• Can survey large area quickly • Little site preparation	• Accurate elevations require surveying • Should be used only as preliminary screening tool
Electrical Resistivity	• Quantitative modeling can estimate depth, thickness, and resistivity of subsurface layers	• Interference from cultural noise, surface metal objects, and industry • A minimum of two to three crew members is required • Surveys are labor intensive

Table 3: Applicability of Borehole Geophysical Techniques to Ground-Water Investigations

	Resistance Logs	Spontaneous Potential Logs	Gamma Logs	Gamma-Gamma Logs	Neutron Logs	Temperature Logs	
Contaminant Plume Delineation	P	P	P			P	
Faults/Fracture Detection							P
Lithologic Boundary Delineation	P	P	P	P	A		A
Bedrock Topography Delineation	P	P	P	P	A		P
Stratigraphic Mapping	P	P	P	P	P		P
Water Table Mapping	A	A			P	P	A
Soil Type of Unconsolidated Sediments	P	P	P	P	P		

P - Preferred Method A - Applicable Method (in most cases)

Table 4: Advantages and Disadvantages of Borehole Geophysical Techniques to Ground-Water Investigations

	Advantages	
Resistance Logs	• Indicates lithologic changes • Indicates amount and type of subsurface fluid (water quality)	• Can only be run in uncased borehole • Difficult to interpret lithology when using drilling fluid with clay additives
Spontaneous Potential Logs	• Can be run in conjunction with resistance log • Indicates lithologic changes and permeable beds	• Can only be run in uncased borehole • Interpretation for water well often more difficult than for oil well
Gamma Logs	• Easy to operate • Can be run in open or cased borehole • Qualitative guide for stratigraphic correlation and permeability	• Affected by changes in borehole diameter and borehole media • Feldspar and volcanic rock fragments make interpretation difficult
Gamma-Gamma Logs	• Can identify lithology and calculate porosity when fluid and grain density are known	• Porosity readings of low density materials can be erroneously high
Neutron Logs	• Can determine total porosity in saturated zone • Can determine moisture content in unsaturated zones • Can be run in open or cased borehole	• Radioactive source requires special handling by trained personnel • Logging can be somewhat complex
Acoustic Logs	• Useful for determining relative porosity • Indicates fracture patterns in aquifer • Can indicate static water level and perched water tables	• Clays may distort readings
Temperature Logs	• Can indirectly measure permeability • Provides information regarding ground-water movement and water table elevation	• Delay repeat logs until borehole fluid reaches thermal equilibrium

4.0 GROUND-WATER SAMPLE COLLECTION AND PREPARATION

4.1 INTRODUCTION

During a response action, proper field sample collection and preparation is as important as proper sampling equipment selection. Sample collection refers to the physical removal of an aliquot of ground water from its source (i.e., aquifer) for the purpose of either screening or laboratory analysis. Ground-water sample collection procedures should be selected so that the resultant sample is representative of the aquifer or particular water zone being sampled. Field sample preparation refers to all aspects of sample handling from collection to the time the sample is received by the laboratory. This chapter provides information on sample collection and preparation for ground water.

The representativeness of a ground-water sample is greatly influenced by the sampling device used and the manner in which the sample is collected. Proper training and use of SOPs will limit variables and enhance sample representativeness. Selection of ground-water sampling devices such as bailers and pumps should be site-specific and dependent on well diameter, yield, lift capacity, and the analytes being sampled. Excessive aeration should be minimized to preserve volatile constituents. Where possible, the bailer or pump used should be compatible with the analyte(s) of concern.

4.2 STATIC WATER LEVEL

Prior to sampling, the static water level elevation in each well should be measured. All measurements should be completed prior to the sampling event so that static water levels will not be affected. The water level measurements are necessary to establish well purging volumes. These measurements can also be used to construct water table or potentiometric surface maps and hence determine local ground-water flow gradient. Measure the depth to standing water and the total depth of the well to calculate volume of stagnant water in the well for purging. See ERT SOP #2151 for detail on collecting static water level measurements.

4.3 WELL PURGING

There is little or no vertical mixing of water in a nonpumping well, therefore stratification occurs. The well water in the screened section mixes with the ground water due to normal flow patterns, but the well water above the screened section will remain isolated and become stagnant. The stagnant water may contain foreign material inadvertently or deliberately introduced from the surface, resulting in unrepresentative data. Adequate well purging prior to sample withdrawal will safeguard against collecting nonrepresentative stagnant water samples.

Well purging techniques are specific to the following well types.

- <u>Residential, Commercial, and Public Supply Wells</u> - Sample residential, commercial, and public supply wells as near to the wellhead as possible and at a point before treatment, such as filtering and water softening units, whenever possible. Open the tap to a moderate flow and purge for approximately 15 minutes. If this is not possible, a 5-minute purge is considered a minimum. As an alternative to a minimum volume, purging can be conducted until the field parameters pH, temperature, and specific conductivity have stabilized (see Section 4.3.1).

- <u>Monitoring Wells</u> - To obtain a representative sample from a monitoring well, it is necessary to evacuate the standing water in the well casing prior to sampling. The minimum recommended amount that should be purged from a monitoring well is one casing volume, but three to five casing volumes of standing water should be evacuated where possible in order to obtain a ground-water sample representative of the aquifer. In a high yield aquifer where there is no standing water above the screened section of the well casing, purging three volumes is not as critical as in lower yield aquifers. (The faster recharge rate limits the amount of time that the water has to interact with the atmosphere and casing materials.) If the well is purged dry, it should be considered sufficiently purged for sampling (refer to Section 4.3.2 for additional information).

The amount of purging a well receives prior to sample collection depends on the intent of the sampling as well as the hydrogeologic conditions. When the sampling objective is to assess overall water resource quality, long pumping periods may be required to obtain a sample that is representative of a large volume of the aquifer. The pumped volume is determined prior to sampling, or the well is pumped until the stabilization of parameters such as temperature, specific conductivity, and pH has occurred.

Monitoring to define a contaminant plume requires a representative sample of a small volume of the aquifer. These circumstances require that the well be pumped enough to remove the stagnant water but not enough to induce flow from other areas. Generally, three well volumes are considered effective. Otherwise, the appropriate volume to be removed prior to sampling can be calculated, based on aquifer parameters and well dimensions.

Well purging devices include bailers, submersible pumps (rotary-type), non-gas contact bladder pumps, suction pumps, and hand pumps. See ERT SOP #2007 for specific guidelines on purging wells prior to sampling and for more detail on each purging device.

4.3.1 Stabilization Purging Technique

The stabilization technique is an alternative to volume purging. This method requires that several field parameters be continuously monitored during purging. When these parameters stabilize, begin sampling. The parameters used for this method are pH, temperature, and specific conductivity. Stabilization of these parameters indicates that the standing water in the monitoring well has been removed and that a representative sample of the aquifer water may now be collected. This method of purging is useful in situations where it is not feasible to evacuate three casing volumes from the well prior to sampling (e.g., large casing diameter, extremely deep, and active supply wells). See ERT SOP #2007 for specific volume and stabilization purging techniques.

4.3.2 Wells that Purge Dry

A well that is purged dry should be evacuated and allowed to recover prior to sample withdrawal. If the recovery rate is fairly rapid and time allows, evacuation of more than one volume of water is desirable. If the recovery rate is slow, the first recharge can be considered suitable for sample collection.

4.4 GROUND-WATER SAMPLE COLLECTION

In order to maintain sample representativeness, dedicated samplers should be used for each well whenever possible. When not possible, the sampler should be decontaminated after each sample collection and sufficient QA/QC blank samples should be collected to assess potential cross-contamination.

After well purging is complete, collect and containerize samples in the order of most volatile to least volatile, such as:

- Volatile organic analytes (VOAs)
- Purgeable organic carbon (POC)
- Purgeable organic halogens (POX)
- Total organic halogens (TOX)
- Total organic carbon (TOC)
- Extractable organic compounds
- Total metals
- Dissolved metals
- Phenols
- Cyanide
- Sulfate and chloride
- Turbidity
- Nitrate and ammonia
- Radionucliides

See ERT SOP #2007 for specific detail on filling sample containers, with special considerations for VOA sampling.

If the contaminants in the water column are stratified (e.g., DNAPLs, LNAPLs), be certain to use an appropriate sampling device. Modify, where possible, standard sampling procedures to collect the sample from the suspected depth for the contaminant layer. It may be necessary to lower the bailer used for sample collection to a particular depth in the well, or to use a point-source bailer or other discrete-depth sampling device.

After a monitoring well is initially constructed, it should be developed and purged to remove invaded water. The well should sit idle for at least two weeks to allow the water level to fully stabilize and the suspected stratified layers to settle out. Measurement of the thickness of a floating (LNAPL) layer may be accomplished in several ways. An indicator gel, chalk or paste may be applied to an incremented steel tape.

The indicator changes color in the presence of water or the immiscible layer, depending on the specific use of the indicator compound. For example, water-level indicator gel is used to determine the depth to the water surface. A weighted float is then used to determine the depth to the top of the LNAPL layer. The difference between these two readings is the thickness of the floating layer.

An electronic monitoring device called an interface probe is also available for the LNAPL layer measurement. This device, like an electric water-level sounder, is lowered into the well along an electronic wire/line. When the probe contacts the surface (the LNAPL layer) a sound is generated. As the sampler continues to lower the probe, a different electronic sound is emitted when the water surface, or water/oil interface, is reached. The line of the device is incremented, like a water-level sounder, so the layer thickness can be determined. Standard electric water-level sounding devices, however, will not work properly for these measurements. The interface probe is a specialized instrument which is commonly available and used at fuel oil/ground-water contamination sites.

A sample of a floating layer may be obtained using a bottom-fill bailer. Care should be taken to lower the bailer just through the floating layer, but not significantly down into the underlying ground water. (A clear bailer is preferable for this activity.)

For sampling sinking layers, a discrete-depth-capable sampling device, such as a packer pump or syringe sampler, is best suited. When these specialized devices are not available, depending on the sampling parameters, standard devices may be used. For example, samples at the bottom of the screen or at some intermediate location may also be obtained with a standard bailer and a second well casing. In order to avoid mixing the waters, a separate casing is temporarily lowered inside the permanent well casing. The temporary casing is equipped with an easily removed cap on the bottom so that no fluid enters the casing until it has reached the desired sampling depth. The cap is then freed from the bottom of the inner casing, allowing water to enter to be sampled by a bailer. At significant depths below the nonaqueous layer, several bailers full of water may need to be withdrawn and discarded before the sample is obtained from a fresh formation sample.

When a temporary casing and all other specialized equipment is unavailable, a standard bailer alone may be used. Collect a water sample from the well and transfer it to the sample container. Allow the sample to settle in the sample container into the separate stratified layers. The analytical laboratory may then decant, as appropriate, to obtain a sample of the desired layer. More commonly, the parameters of concern in the stratified layers are simply included in the laboratory analysis of the sample as a whole without the need to separate into unique layers. In this last example, care must be taken to allow the bailer to reach the desired depth in the water column to insure collecting any dense layers at the bottom of the well. (See Section 2.4 for additional discussion on sampling concerns and the physiochemical nature of contaminants.)

4.5 GROUND-WATER SAMPLE PREPARATION

This section addresses appropriate ground-water sample preparation and handling techniques. Proper sample preparation and handling maintain sample integrity. Improper handling can render samples nonrepresentative and unsuitable for analysis.

The analyses for which a sample is being collected determines the type of bottles, preservatives, holding times, and filtering requirements. Samples should be collected directly into appropriate containers that have been cleaned to EPA or other required standards. Check to see that a Teflon® liner is present in the sample bottle cap, if required.

Samples should be labeled, logged, and handled correctly, including appropriate chain-of-custody documentation. Place samples in coolers to be maintained at 4EC. Ship samples to arrive at the designated analytical laboratory well before their holding times are expired. It is preferable that samples be shipped or delivered daily to the analytical laboratory in order to maximize the time available for the laboratory to do the analysis.

Certain conditions may require special handling techniques. For example, treatment of a sample for VOAs with sodium thiosulfate preservative is required if there is residual chlorine in the water (e.g., a public water supply) that could cause free radical chlorination and change the identity of the original contaminants. (The preservative should not be used if there is no chlorine in the water.) All such special requirements must be determined prior to conducting fieldwork.

Sample preparation for ground water may include, but is not limited to:

- Filtering
- Homogenizing/Aliquotting
- Splitting
- Final Preparation

4.5.1 Filtering

Samples may require filtering, such as for total metals analysis. Samples collected for organic analyses should not be filtered. Two types of filters may be used, which must be decontaminated prior to use. A barrel filter works with a bicycle pump, which builds up positive pressure in the chamber containing the sample and then forces it through the filter into a container placed underneath. A vacuum filter has two chambers; the upper chamber contains the sample, and a filter divides the chambers. Using a hand pump or a Gilian®-type pressure pump, a vacuum is created in the upper chamber and the sample is filtered into the lower chamber. Preservation of the sample, if necessary, should be done after filtering.

See ERT SOP #2007, Section 2.7.5, for more detail on filtering ground-water samples.

4.5.2 Homogenizing/Aliquotting

Homogenizing, or aliquotting, is the mixing or blending of a grab sample to distribute contaminants uniformly. Ideally, proper homogenizing ensures that all portions of the sample are equal or identical in composition and are representative of the total sample collected. Incomplete homogenizing can introduce sampling error. Homogenizing disturbs the ground-water sample, so it is not appropriate for VOC sampling.

Homogenizing is done during only one sampling event per well location, and only after the VOC sample portions have first been filled. It may be utilized for wells with extremely low yield and potentially insufficient sample volume to fill all sample containers provided by the laboratory. In some low yielding wells, the percentage of suspended material in a bailer-full of sample will increase as sampling proceeds. Homogenizing ensures that at least a minimum volume is aliquotted per analytical parameter, and the percentage of suspended material is equitably divided among all containers (excluding VOCs).

4.5.3 Splitting

Split samples are created when the samples have to be separated into two or more equivalent parts and analyzed separately. Split samples are most often collected in enforcement actions to compare sample results obtained by EPA with those obtained by the potentially responsible party. Split samples also provide measures of sample variability and analytical error. Fill two sample collection jars simultaneously, alternating the sample stream or bailer full of sample between them.

4.5.4 Final Preparation

Final preparation includes preserving, packaging, and shipping samples.

Sample preservation is used to retard chemical breakdown of the sample. Preservation of ground-water samples includes controlling pH with chemical preservatives, refrigerating samples, and protecting samples from light.

Select sample containers on the basis of compatibility with the material being sampled, resistance to breakage, and capacity. Appropriate sample volumes and containers will vary according to the parameters being analyzed. Actual sample volumes, appropriate containers, and holding times are specified in the U.S. EPA *Compendium of ERT Ground-Water Sampling Procedures*, OSWER Directive 9360.4-06. Package all samples in compliance with current International Air Transport Association (IATA) or U.S. Department of Transportation (DOT) requirements, as applicable. Packaging should be performed by someone trained in current DOT shipping procedures.

See ERT SOP #2007, Section 2.3 for more detail on ground-water sample preparation.

4.6 EXAMPLE SITE

4.6.1 Sample Collection

During Phase 1 and Phase 2, surface soil samples were collected from shallow locations. The samples were collected as grab samples. The sample locations were cleared of surface debris, then samples were retrieved with disposable plastic scoops and placed directly into sample containers. During Phase 2, subsurface soil samples were collected at the soil boring/well installation locations, using stainless steel split spoon samplers. The split spoon samples were collected using a hand-held power auger to advance the hole. A 2-foot stainless steel split spoon sampler with hammer attachment was then pushed into the hole. The soil sample was retrieved from the split spoon sampler using a disposable plastic scoop to transfer the soil into a stainless steel bowl. Several scoopfuls were collected along the length of the split spoon sampler and composited in the bowl. The composite sample was then transferred directly into the sample container using the disposable plastic scoop.

Phase 1 and Phase 2 residential well ground-water samples were collected directly from the kitchen taps of homes using private wells near to the site. The configuration of the residential system was noted in the logbook prior to sampling. If present, water softeners were taken off line. Any screen or filter was first removed from the tap, which was allowed to run for a minimum of five minutes prior to sampling. The samples were collected directly into the sample containers.

Fifteen monitoring wells were installed at the site at locations described in Section 2.5.6. The wells were drilled with a dual-tube, air percussion rig. Each boring was completed to a 9.5-inch diameter. After completion of the boring, 4-inch Schedule 40 PVC casing and 0.010 slot screen were installed in lengths appropriate to each well. Shallow wells were drilled to approximately 40 feet below grade surface (BGS) and bedrock contact wells were drilled to approximately 55 to 60 feet BGS. Continuous split spoon sampling was performed at each well location from 4 feet BGS to well completion depth. The boreholes were grouted from the bottom to the top of the lower confining layer, then 10 feet of screen were set above the grouted portion. PVC casing was set above the screen to above the ground surface. Casing was extended to accommodate a 2-foot stick-up above grade, and then capped. A 6-inch diameter metal outer casing with locking cover was installed over the well casing stick-up and secured 2 feet BGS in concrete. A concrete spill pad was then constructed around each well outer casing to prevent re-infiltration at the well point. Upon completion, all monitoring wells were developed by purging using a decontaminated rotary pump and flexible PVC disposable hose.

A Team geologist supervising the monitoring well installation logged each borehole soil lithology from the retrieved split spoon samplers collected during drilling of the boreholes. The geologist scanned each sampler with a PID immediately upon opening (into halves) for health and safety monitoring. All logging was accomplished utilizing the Unified Soils Classification System standard method. Figure 3 provides an example of a soil boring and monitoring well completion log.

Soil samples were then collected in wide-mouth clear glass jars by transferring a portion of each lithologic unit in the split spoon with a disposable plastic scoop and compositing the sample in the jar. At the completion of each borehole, each sample was screened in the field using the XRF unit. Select samples (one per borehole location) were forwarded to the laboratory for confirmation analysis. Split spoon samplers were decontaminated after each use.

Upon completion and development, the 15 on-site monitoring wells were sampled for ground-water analysis. The well caps were brushed and cleaned off prior to opening. Immediately upon removing the well cap, a PID was operated over the opening to determine VOC levels, if any, in the breathing zone. The VOC monitoring was performed to establish if a higher level of respiratory protection was required. Depth to water level measurements were then taken of each well to the nearest 0.01 ft. The total depth of the well was obtained with a depth sounder. The volume of water in the well was then calculated using the formula below. For a four-inch well, well volume would equal 0.632 gallon/ft.:

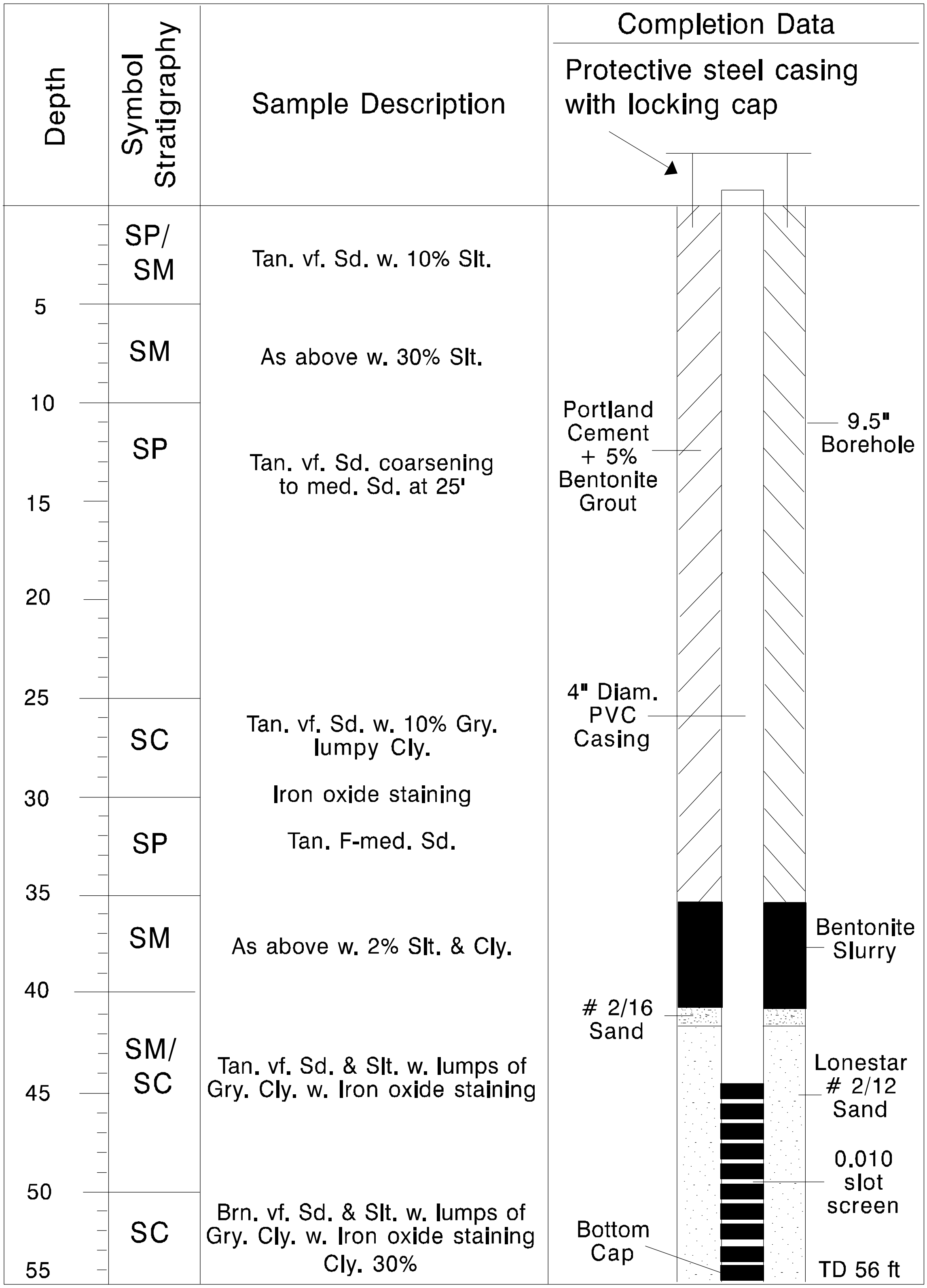
$$\text{Well volume} = \text{B} \times (\text{radius of well})^2 \times \text{height of water column} \times 7.48\ \text{gallon/ft}^3$$

(conversion factor for ft^3 to gallons)

Each monitoring well was purged prior to obtaining a representative sample. Wells with sufficient yield were purged three well volumes. Low-yielding wells were purged once to dryness. (Most wells on site are low-yielding.) Purging was completed using a 1.5 gpm decontaminated submersible (rotary-type) pump with flexible PVC outflow hose and safety cable. The pump was slowly lowered to a point approximately 3 feet above the bottom of the well. With the known flow rate, length of pumping required was calculated. Purge water was pumped into 55-gallon steel drums. (The drums were staged and later disposed of properly based on the results of analysis of their contents.) Low-yielding overburden wells were purged with a decontaminated stainless steel bottom-fill bailer and polypropylene rope until dry. All wells were allowed to recover overnightbefore sample collection, or until sufficient water was present to complete a sample set.

Each monitoring well was sampled after purging and recovery. Ground-water samples were collected using dedicated disposable Teflon® bailers. Each bailer was attached to a clean polypropylene rope and intro-

Figure 3: Soil Boring/Monitoring Well Completion Log



duced into the well. The bailer was lowered slowly to the approximate mid-point of the well. Once the sample was collected, care was taken not to agitate the water while pouring directly into the appropriate sample containers. An additional ground-water aliquot was placed into a large wide-mouth glass jar in order to obtain conductivity, temperature, and pH measurements. These measurements were recorded in the field logbook.

After well sampling, a hydraulic (pumping) test was performed to determine aquifer characteristics for mathematical modeling of potential contaminant plume migration. The hydraulic test was conducted using one well as a pumping well with three observation wells. The pumping well was purged at a rate of 22 gpm for 30 hours. All wells (observation and pumping) were monitored during pumping and for 4 hours after pumping ceased. Drawdown data from the wells were used to calculate the characteristics of the aquifer.

To generate accurate gradient and well location maps, the 15 newly installed monitoring wells were surveyed for vertical location using feet above mean sea level (MSL) units. Vertical elevations were taken at a mark on the top of the inner casing of each monitoring well, to establish a permanent location for all future water level measurements and elevations. A permanent benchmark was located near to the site by the survey team to determine all the well elevations. Elevations were then measured against the benchmark and mapped in MSL units.

All non-disposable equipment, including drill rig and equipment, stainless steel bailers, pumps, water level indicators, and depth sounders, were decontaminated between each location and prior to the first sampling event each day.

4.6.2 Sample Preparation

All sample containers were supplied by the contracted analytical laboratory. Chemical preservation was also provided by the laboratory through pre-preserved bottleware. Sample containers for ground-water samples consisted of:

- 1-liter polyethylene bottles for total chromium, pre-preserved with reagent-grade nitric acid lowering the pH to less than 2 after addition of the sample

- 1-liter polyethylene bottles for hexavalent chromium

- 1-liter polyethylene bottles for cyanide, pre-preserved with sodium hydroxide

Sample containers for soils consisted of 8-ounce glass jars with Teflon® caps for all parameters.

All samples were preserved to 4E C by placing them in coolers packed with "blue ice" immediately after collection and during shipment. (The laboratory was responsible for cooling and refrigeration of samples upon arrival.)

The samples were packaged in compliance with IATA requirements for environmental samples. Chain-of-custody paperwork was prepared for the samples. Laboratory paperwork was completed as appropriate and the samples were shipped to the predesignated laboratories for analysis. Holding times for total chromium and cyanide are less than six months, but hexavalent chromium has a holding time of less than 24 hours. This was coordinated in advance with the analytical laboratory and required daily ground delivery of samples to the laboratory.

Because many of the ground-water samples from the on-site wells were extremely turbid, the non-volatile portions of samples were filtered in the laboratory prior to analysis. Filtering was accomplished using a barrel filtering device with a minimum pore size of 0.45 microns. Samples for chromium analysis were split and filtered so that dissolved and particulate chromium could be differentiated. Dissolved chromium is of concern because of its ability to be transported in ground water.

5.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

5.1 INTRODUCTION

The goal of representative sampling is to obtain analytical results that accurately depict site conditions during a defined time interval. The goal of quality assurance/quality control (QA/QC) is to implement correct methodologies which limit the introduction of error into the sampling and analytical procedures, and ultimately into the analytical data.

QA/QC samples evaluate three types of information: 1) the magnitude of site variation; 2) whether samples were cross-contaminated during sampling and sample handling procedures; and 3) whether a discrepancy in sample results is a result of laboratory handling and analysis procedures.

5.2 DATA CATEGORIES

EPA has established data quality objectives (DQOs) which ensure that the precision, accuracy, representativeness, and quality of environmental data are appropriate for their intended application. Superfund DQO guidance defines two broad categories of analytical data: *screening* and *definitive*.

Screening data are generated by rapid, less precise methods of analysis with less rigorous sample preparation than definitive data. Sample preparation steps may be restricted to simple procedures such as dilution with a solvent, rather than elaborate extraction/digestion and cleanup. At least 10 percent of the screening data are confirmed using the analytical methods and QA/QC procedures and criteria associated with definitive data. Screening data without associated confirmation data are not considered to be data of known quality. To be acceptable, screening data must include the following: chain-of-custody, initial and continuing calibration, analyte identification, and analyte quantification. Streamlined QC requirements are the defining characteristic of screening data.

Definitive data are generated using rigorous analytical methods (e.g., approved EPA reference methods). These data are analyte-specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data (e.g., chromatograms, spectra, digital values) in the form of paper printouts or computer-generated electronic files. Data may be generated at the site or at an off-site location, as long as the QA/QC requirements are satisfied. For the data to be definitive, either analytical or total measurement error must be determined. QC measures for definitive data contain all of the elements associated with screening data, but also may include trip, method, and rinsate blanks; matrix spikes; performance evaluation samples; and replicate analyses for error determination.

For further information on these QA/QC objectives, please refer to U.S. EPA *Data Quality Objectives Process for Superfund*, pp. 42-44.

5.3 SOURCES OF ERROR

There are many potential sources of data error in ground-water sampling. The following is a list of some of the more common potential sources of error:

- Sampling design
- Sampling methodology
- Analytical procedures
- Seasonal variations

See U.S. EPA *Data Quality Objectives Process for Superfund*, pp. 29-36, for more information on error.

5.3.1 Sampling Design

The sampling design should utilize approved SOPs and previously approved sampling designs to ensure uniformity and comparability between samples. The actual sample collection process should be determined prior to sampling. Sampling equipment and techniques must be standardized for like sampling situations.

The sampling design should fulfill sampling and data quality objectives. The quality assurance objectives selected should be built into the sampling design, including all necessary QA/QC samples.

Sampling design errors for ground water include: well selection, well location, well construction and development, background sample location, and equipment (material and type).

5.3.2 Sampling Methodology

Sampling methodology and sample handling procedures have possible sources of error, including: cross-contamination from inappropriate use of sample collection equipment; unclean sample containers; improper sampling equipment decontamination; and improper shipment procedures. Procedures for collecting, handling, and shipping samples should be standardized to allow easier identification of any source(s) of error, and to minimize the potential for error. Use approved SOPs to ensure that all given sampling techniques are performed in the same manner, regardless of the sampling team, date, or location of sampling activity. Use field blanks, replicate samples, trip blanks, and rinsate blanks (discussed in Section 5.4) to identify errors due to improper sampling methodology and sample handling procedures. An example of a sampling methodology error for ground water is inappropriate purging.

5.3.3 Analytical Procedures

Analytical procedures may introduce errors from laboratory cross-contamination, inefficient extraction, and inappropriate methodology. Matrix spike, laboratory duplicate, performance evaluation, and laboratory control samples help to distinguish analytical error from sampling error.

5.3.4 Seasonal Variations

Seasonal variations are not controllable but must be taken into consideration as a source of error during ground-water assessments. Changes in flow direction or volume can redistribute contaminants throughout a site, making assessment difficult. Plan sampling events in order to minimize the effects of seasonal variations, if possible.

5.4 QA/QC SAMPLES

QA/QC samples are collected at the site or prepared for or by the laboratory. Analysis of the QA/QC samples provides information on the variability and usability of sampling data, indicates possible field sampling or laboratory error, and provides a basis for future validation and usability of the analytical data. The most common field QA/QC samples are field replicate, background, and rinsate, field, and trip blank samples. The most common laboratory QA/QC samples are performance evaluation (PE), matrix spike (MS), matrix spike duplicate (MSD), and laboratory duplicate samples. QA/QC results may suggest the need for modifying sample collection, preparation, handling, or analytical procedures if the resultant data do not meet site-specific quality assurance objectives.

Ground water is typically characterized by low or trace concentrations of contaminants, making precision and accuracy more important than for samples with higher concentrations (e.g., waste). Frequent field blanks are thus appropriate in ground-water sampling.

The following sections briefly describe the most common types of QA/QC samples appropriate for ground-water sampling.

5.4.1 Field Replicate Samples

Field replicates, also referred to as field duplicates and split samples, are field samples obtained from one sampling point, homogenized (where appropriate), divided into separate containers, and treated as separate samples throughout the remaining sample handling and analytical processes. Use replicate samples to assess error associated with sample methodology and analytical procedures. Field replicates can also be used when determining total error for critical samples with contamination concentrations near the action level. In such a case, a minimum of eight replicate samples is recommended for valid statistical analysis. Field replicates may be sent to two or more laboratories or to the same laboratory as unique samples. For total error determination, samples should be analyzed by the same laboratory. Generally, one field replicate per 20 samples per day is recommended.

5.4.2 Background Samples

Defining background conditions may be difficult because of natural variability and the physical characteristics of the site, but it is important in order to quantify true changes in contaminant concentrations due to a source or site. Defining background conditions is critical for avoiding false positives and for enforcement purposes in naming responsible parties. Background sampling is often required in ground-water sampling to verify plume direction, ambient conditions, and attribution of sources. A properly collected background sample serves as the baseline for the measure of contamination throughout the site. Ground-water background sample locations should be chosen carefully, usually upgradient from the suspected source of contamination where there is little or no chance of migration of contaminants of concern. Collect at least one background sample for comparison, although additional samples are often warranted by site-specific factors such as natural variability of local geology and multiple sources. Background samples may be collected to evaluate potential error associated with sampling design, sampling methodology, and analytical procedures. Refer to U.S. EPA "Establishing Background Levels" fact sheet, OSWER Directive 9285.7-19FS, for detailed discussion on the proper selection and considerations of a background sample location.

5.4.3 Rinsate Blank Samples

A rinsate blank, also referred to as an equipment blank, is used to assess cross-contamination from improper equipment decontamination procedures. Rinsate blanks are samples obtained by running analyte-free water over decontaminated sampling equipment. Any residual contamination should appear in the rinsate sample data. Analyze the rinsate blank for the same analytical parameters as the field samples collected that day. Handle and ship the rinsate like a routine field sample. Where dedicated sampling equipment is not utilized, collect one rinsate blank per type of sampling device per day.

5.4.4 Field Blank Samples

Field blanks are samples prepared in the field using certified clean water (HPLC-grade water (carbon-free) for organic analyses and deionized or distilled water for inorganic analyses) which are then submitted to the laboratory for analysis. A field blank is used to evaluate contamination or error associated with sampling methodology, preservation, handling/shipping, and laboratory procedures. Handle, ship, and analyze a field blank like a routine field sample. Submit one field blank per day.

5.4.5 Trip Blank Samples

Trip blanks are samples prepared prior to going into the field. They consist of certified clean water (HPLC-grade) and are not opened until they reach the laboratory. Utilize trip blanks for volatile organic analyses only. Handle, transport, and analyze trip blanks in the same manner as the other volatile organic samples collected that day. Trip blanks are used to evaluate error associated with shipping and handling and analytical procedures. A trip blank should be included with each shipment.

5.4.6 Performance Evaluation/ Laboratory Control Samples

A performance evaluation (PE) sample evaluates the overall error contributed by the analytical laboratory and detects any bias in the analytical method being used. PE samples contain known quantities of target analytes manufactured under strict quality control. They are usually prepared by a third party under an EPA certification program. The samples are usually submitted "blind" to analytical laboratories (the sampling team knows the contents of the samples, but the laboratory does not). Laboratory analytical error may be evaluated by the percent recoveries and correct identification of the components in the PE sample. *Note: Even though they are not available for all analytes, analyses of PE samples are recommended in order to obtain definitive data.*

A blind PE sample may be included in a set of split samples provided to the potentially responsible party (PRP). The PE sample will indicate PRP laboratory accuracy, which may be critical during enforcement litigation.

A laboratory control sample (LCS) also contains known quantities of target analytes in certified clean water. In this case, the laboratory knows the contents of the sample (the LCS is usually prepared by the laboratory). PE and LCS samples are not affected by matrix interference, and thus can provide a clear measure of laboratory error.

5.4.7 Matrix Spike/Matrix Spike Duplicate Samples

Matrix spike and matrix spike duplicate samples (MS/MSDs) are field samples that are spiked in the laboratory with a known concentration of a target analyte(s) in order to determine percent recoveries in sample extraction. The percent recovery from MS/MSDs indicates the degree to which matrix interferences will affect the identification of a substance. MS/MSDs can also be used to monitor laboratory performance. When four or more pairs of MS/MSDs are analyzed, the data obtained may be used to evaluate error due to laboratory bias and precision. Analyze one MS/MSD pair to assess bias for every 20 samples, and use the average percent recovery for the pair. To assess precision, analyze at least eight matrix spike replicates from the same sample, and determine the standard deviation and the coefficient of variation. MS/MSDs are recommended for screening data and are required as one of several methods for determining analytical error for definitive data. Since the MS/MSDs are spiked field samples, provide sufficient volume for three separate analyses (triple volume). When selecting a well for spiked samples, choose a well capable of providing steady volume.

5.4.8 Laboratory Duplicate Samples

A laboratory duplicate is a sample that undergoes preparation and analysis twice. The laboratory takes two aliquots of one sample and analyses them as separate samples. Comparison of data from the two analyses provides a measure of analytical reproducibility within a sample set. Discrepancies in duplicate analyses may indicate poor homogenization in the field or other sample preparation error, either in the field or in the laboratory.

5.5 EVALUATION OF ANALYTICAL ERROR

The acceptable level of error in sampling data is determined by the intended use of the data and the sampling objectives, including the degree of threat to public health, welfare, or the environment; response action levels; litigation concerns; and budgetary constraints.

Error may be determined with replicate samples. To evaluate the total error of samples with contaminant concentrations near the response action level, prepare and analyze a minimum of eight replicates of the same sample. Analytical data from replicate samples also serve as a quick check on errors associated with sample heterogeneity, sampling methodology, and analytical procedures. Different analytical results from two or more replicate samples could indicate improper sample preparation, or improper sample handling, shipment, or analysis.

Although a quantified confidence level may be desirable, it may not always be possible. A 95% confidence level (5 percent acceptable error) should be adequate for most Superfund activities. Note that the use of confidence levels is based on the assumption that a sample is homogeneous.

5.6 CORRELATION BETWEEN FIELD SCREENING RESULTS AND DEFINITIVE LABORATORY RESULTS

One cost-effective approach for delineating the extent of site contamination is to correlate inexpensive field screening data and other field measurements with definitive laboratory results. The relationship between the two methods can then be described by a regression analysis. The resulting equation can be used to predict laboratory results based on field screening measurements. In this manner, cost-effective field screening results may be used in conjunction with off-site laboratory analysis.

Statistical regression involves developing an equation that relates two or more variables at an acceptable level of correlation. In this case, the two variables are field screening results and definitive laboratory results. The regression equation can be used to predict a laboratory value based on the results of the screening device. The model can also be used to place confidence limits around predictions. Additional discussion of correlation and regression can be found in most introductory statistics textbooks. A simple linear regression equation can be developed on many calculators or computer databases. Consult a statistician to check the accuracy of more complex models.

Evaluation of the accuracy of a model relies in part on statistical correlation, which involves computing an index called the correlation coefficient (r) that indicates the degree and nature of the relationship between two or more sets of values. The correlation coefficient ranges from -1.0 (a perfect inverse or negative relationship), through 0 (no relationship), to +1.0 (a perfect, or positive, relationship). The square of the correlation coefficient, called the coefficient of determination, or simply R^2, is an estimate of the proportion of variance in the dependent variable. The value of an acceptable coefficient of variation depends on the sampling objectives and intended data uses. As a rule of thumb, statistical relationships should have an R^2 value of at least 0.6 to determine a reliable model. However, for health assessment purposes, the acceptable R^2 value may be more stringent (e.g., 0.8). Analytical calibration regressions have an R^2 value of 0.98 or greater.

Field screening data can be used to predict laboratory results if there is an acceptable correlation between them. The predicted values can be located on a base map and contoured. These maps can be examined to evaluate the estimated extent of contamination and the adequacy of the sampling program.

5.7 EXAMPLE SITE

5.7.1 Data Categories

Screening data which generate non-definitive, unconfirmed results were used to select analytical parameters and samples to be sent for laboratory confirmation analysis. Samples were sent to the analytical laboratory under protocols which provided definitive data. The rigorous laboratory analyses provided definitive identification and quantitation of contaminants.

5.7.2 Sources of Error

All direct reading instruments were maintained and calibrated in accordance with their instruction manuals. Many of these instruments are class-specific (e.g., volatile organic vapors) with relative response rates that are dependent on the calibration gas selected. Instrument response to ambient vapor concentrations may differ by an order of magnitude from response to calibration standards. If compounds of interest are known, site-specific standards may be prepared.

The number and location of initial field samples were based on observation and professional judgment (as outlined in Section 2.5.5). Field standard operating procedures, documented in the site sampling plan, established consistent screening and sampling procedures among all sampling personnel, reducing the chances for variability and error during sampling. Site briefings were conducted prior to all sampling and screening events to review the use of proper screening and sampling techniques.

Other steps taken to limit error included proper sample preparation, adherence to sample holding times, and the use of proper IATA shipment procedures. All off-site laboratory sample analyses were performed using approved EPA standard methods and protocols.

5.7.3 Field QA/QC Samples

Field QA/QC samples were collected during soil and ground-water sampling at the ABC Plating site. Two field replicate samples were collected for subsurface soils; two wells (one overburden and one bedrock) were selected for replicate collection and analysis of ground water. Rinsate blanks were collected from split spoon samplers, a bailer, and the submersible rotary pump after decontamination by pouring deionized water through the respective piece of equipment and then into a sample container. The field replicates and blanks were preserved and prepared as "regular" field samples. A trip blank for VOC analysis and a performance evaluation (PE) sample for metals were sent to the laboratory. (The PE sample is not affected by matrix interferences.) The trip blank was provided by the laboratory (pre-filled and preserved) and sent with the sample containers prior to sample collection. One trip blank per day was submitted to the laboratory. Additional volume was collected and provided to the laboratory for matrix spike/matrix spike duplicate analyses for one per 20 sample locations for each medium.

5.7.4 Laboratory QA/QC

Instructions on matrices, target compounds, and QA/QC criteria of particular interest were provided to the laboratory to help ensure that analytical results met the required quality assurance objectives. The laboratory analyzed for metals using the methods of inductively coupled plasma (ICP) spectrometry and atomic absorption (AA). Two SW-846 methods were employed for hexavalent chromium analysis: Method 7196, a colorimetric method, and Method 2185, a chelation method. These two methods were utilized in an attempt to better quantify hexavalent results. The presence of cyanide was confirmed in the laboratory using total and amenable cyanide analyses (colorimetric manual Method 9010).

6.0 DATA PRESENTATION AND ANALYSIS

6.1 INTRODUCTION

Data presentation and analysis techniques are performed with analytical, field screening, or geophysical results. The techniques discussed below can be used to compare analytical values, to evaluate numerical distribution of data, and to reveal the location of "hot spots," contaminant plumes, and the extent of contamination at a site. The appropriate methods to present and analyze sample data depend on the sampling objectives, the number of samples collected, the sampling approaches used, and other considerations.

6.2 DATA POSTING

Data posting involves placement of sample values on a site base map or cross-section. Data posting is useful for displaying the distribution of sample values, visually depicting the location of contamination with associated assessment data. Data posting requires each sample to have a specific location (e.g., *x*, *y*, and sometimes *z* coordinates). Ideally, the sample coordinates are surveyed values facilitating placement on a scaled map. Data posting is useful for depicting concentration values of ground-water and plume migration.

6.3 CROSS-SECTION/FENCE DIAGRAMS

Cross-section diagrams (two-dimensional) and fence diagrams (three-dimensional) depict subsurface features such as stratigraphic boundaries, aquifers, plumes, impermeable layers, etc. Two-dimensional cross-sections may be used to illustrate vertical profiles of ground-water concentrations on a site. Both cross-sections and fence diagrams can provide useful visual interpretations of contaminant concentrations and migration.

6.4 CONTOUR MAPPING

Contour maps are useful for depicting ground-water contaminant concentration values throughout a site. Contour mapping requires an accurate, to-scale basemap of the site. After data posting sample values on the basemap, insert contour lines (or isopleths) at a specified contour interval, interpolating values between sample points. Contour lines can be drawn manually or can be generated by computer using contouring software. Although the software makes the contouring process easier, computer programs have a limitation: as they interpolate between data points, they attempt to "smooth" the values by fitting contour intervals to the full range of data values. This can result in a contour map that does not accurately represent general site contaminant trends. If there is a big difference in concentration between a "hot spot" and the surrounding area, the computer contouring program, using a contour interval that attempts to smooth the "hot spots," may eliminate most of the subtle site features and general trends.

6.5 WELL LOCATION MAP

A well location map should be prepared using surveyed data for all features at the site. This map serves as a basemap onto which other data may be plotted (e.g., data posting, contaminant plume contours, water elevation contours). The map is drawn to scale and incorporates all wells located, installed, and sampled, including residential and monitoring wells. The surveyed coordinates for each monitoring well location could also be posted onto the map (in feet above mean sea level (msl)) to illustrate topography and surface gradient.

6.6 STATISTICAL GRAPHICS

The distribution or spread of the data set is important in determining which statistical techniques to use. Common statistical analyses, such as the t-test, rely on normally distributed data. The histogram is a statistical bar graph which displays the distribution of a data set. A normally distributed data set takes the shape of a bell curve, with the mean and median close together about halfway between the maximum and minimum values. A probability plot depicts cumulative percent against the concentration of the contaminant of concern. A normally distributed data set, when plotted as a probability plot, appears as a straight line. A histogram or probability plot can be used to see trends and anomalies in the data from a ground-water site prior to conducting more rigorous forms of statistical analysis.

6.7 RECOMMENDED DATA INTERPRETATION METHODS

The data interpretation methods chosen depend on project-specific considerations, such as the number of sampling locations and their associated range in values. Data which are dissimilar in composition should not be compared using statistical interpretation methods. Data posting, screening, and sampling data sheets, and cross-section/fence diagrams may be appropriate. A site feature showing extremely low data values (e.g., non-detects), with significantly higher values (e.g., 5,000 ppm) from neighboring "hot spots" and little or no concentration gradient in between, does not lend itself to contouring software.

6.8 EXAMPLE SITE

A water table contour map was generated with the water level data for the shallow overburden monitoring wells. This indicated a westward flow direction, which generally coincides with the surface topography. The deep bedrock wells lie nearly on a straight line, and therefore a confident determination of flow direction was not possible. A westward component of flow direction is evident in the data, however. The bedrock contact wells provided inconsistent water level data, most likely due to the presence of discontinuous perched water zones at the well locations.

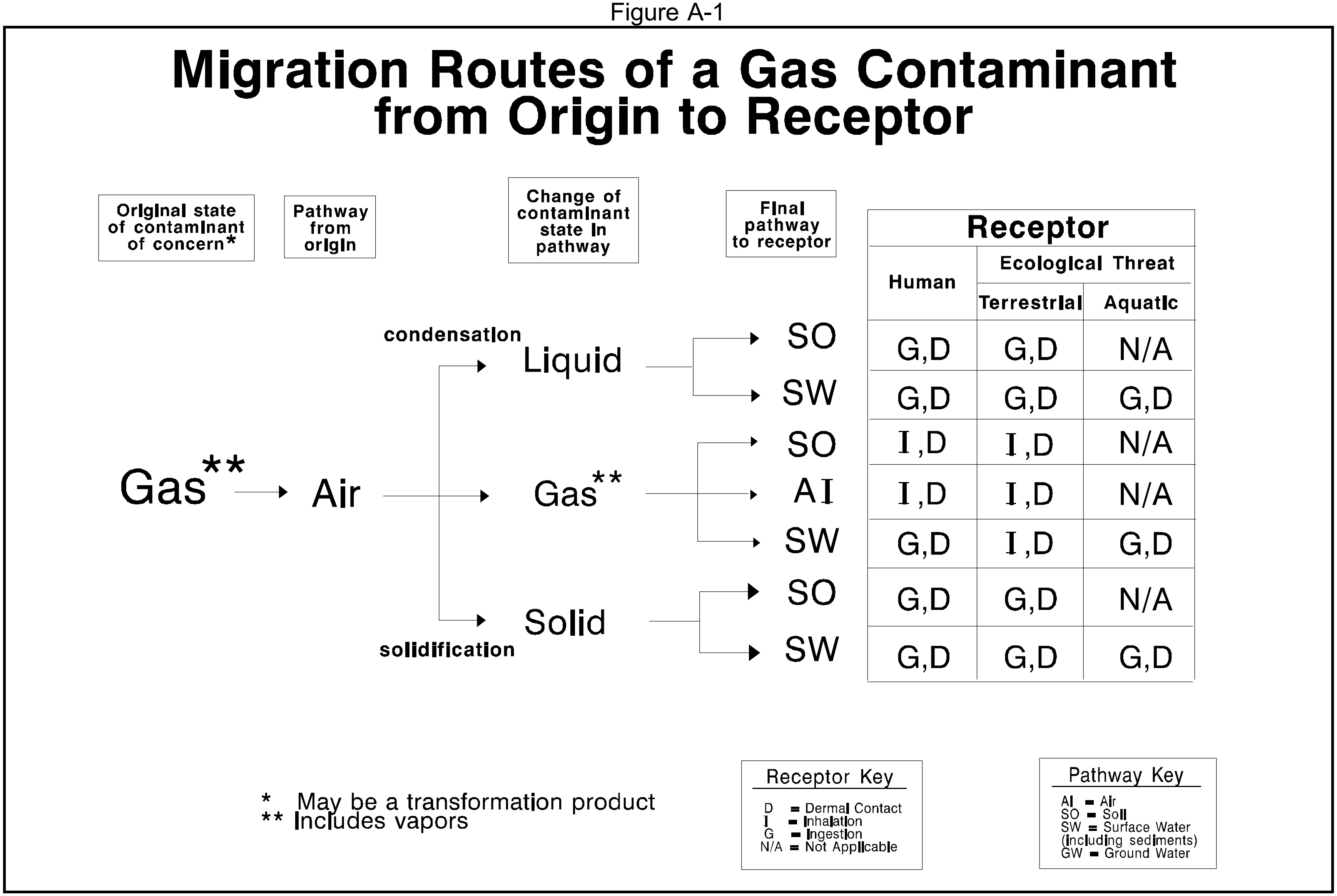
All ground-water samples were analyzed for total chromium and cyanide. Cyanide was not found in any of the samples above the 50 µg/l detection limit. Using a detection limit of 50 µg/l for chromium, three filtered samples were found to be contaminated at two locations (3OB, and 6OB/6AW). Five of the unfiltered ground-water samples (Wells 2SA, 3OB, 4SA, 6OB, and 6AW) exceeded the detection limit. These data were posted on a site/well location map to illustrate well proximities, as well as a map indicating the contours of contamination.

The rate of chromium contaminant migration in ground water and the potential long-term impact to nearby residential wells were estimated using a mathematical model which included worst case assumptions and evaluated attenuation of contaminants through soil and ground water. The OSC concluded that the potential for residential well contamination was minimal. Removal of soil, the source of contamination, was recommended. This decision met the Phase 2 objective of establishing early action options and consideration of long-term remediation requirements for ground water.

All containers of wastes were removed from the site. Soil treatment/disposal was completed using the existing grid design. Cells were sampled and designated as clean or excavated. Excavated material was stockpiled while treatment/disposal options were evaluated. Excavated cells were filled with stone and clean soil. Composite sampling in each cell verified cleanup, using an action level of 100 mg/kg chromium in the soil composite. (The clean-up level was established based on the earlier mathematical model and soil attenuation calculations.) The soil response served as an early action to meet the Phase 3 objective originally established for the site.

APPENDIX A -- Example of Flow Diagram For Conceptual Site Model

Figure A-1



Migration Routes of a Gas Contaminant from Origin to Receptor

Change of contaminant state in pathway	Final pathway to receptor	Human	Ecological Threat: Terrestrial	Ecological Threat: Aquatic
Liquid	SO	G,D	G,D	N/A
	SW	G,D	G,D	G,D
Gas**	SO	I,D	I,D	N/A
	AI	I,D	I,D	N/A
	SW	G,D	I,D	G,D
Solid	SO	G,D	G,D	N/A
	SW	G,D	G,D	G,D

* May be a transformation product
** Includes vapors

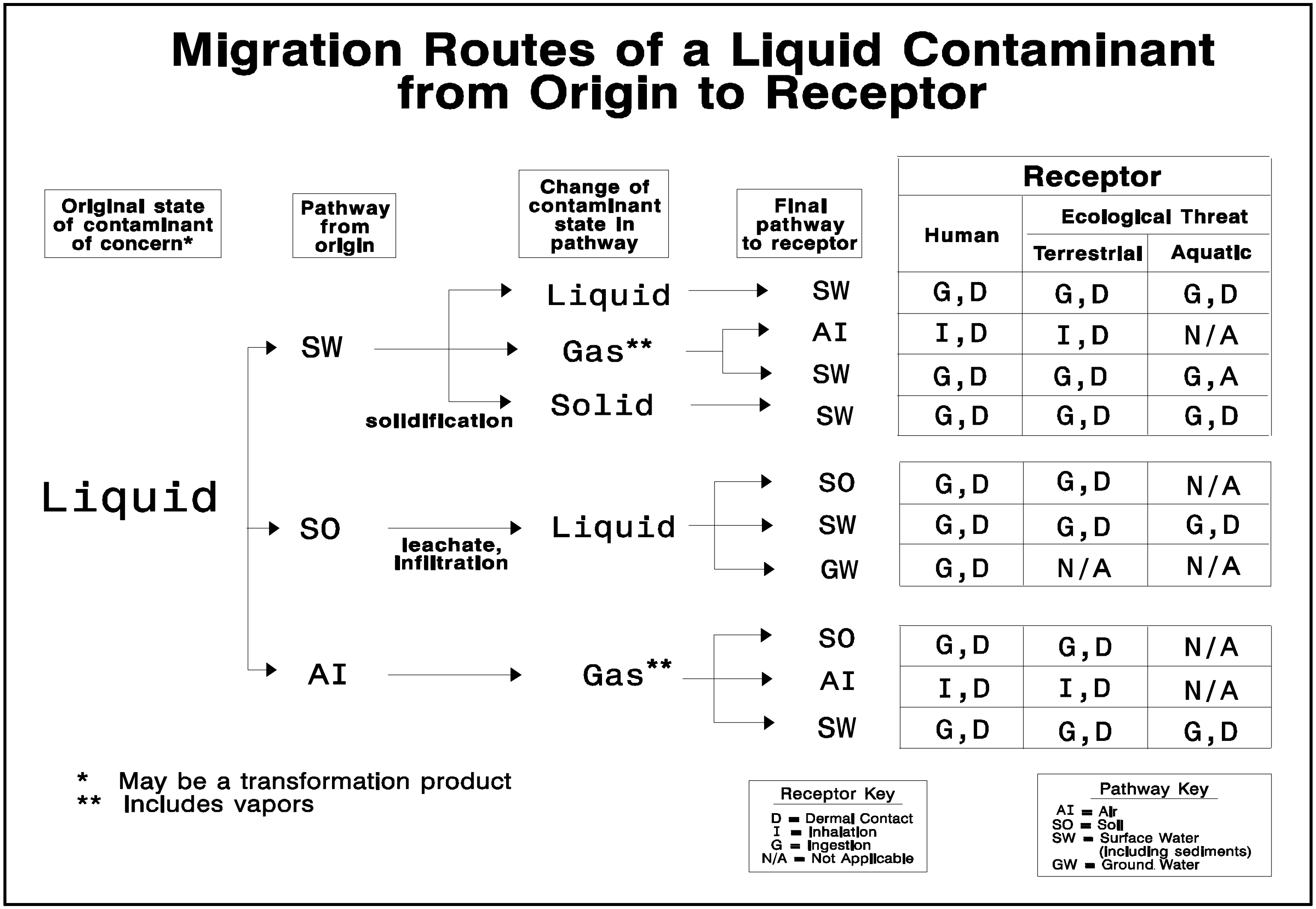
Receptor Key

D = Dermal Contact
I = Inhalation
G = Ingestion
N/A = Not Applicable

Pathway Key

AI = Air
SO = Soil
SW = Surface Water (including sediments)
GW = Ground Water

Figure A-2



Migration Routes of a Liquid Contaminant from Origin to Receptor

Original state of contaminant of concern*	Pathway from origin	Change of contaminant state in pathway	Final pathway to receptor	Receptor: Human	Receptor: Ecological Threat: Terrestrial	Receptor: Ecological Threat: Aquatic
Liquid	SW	Liquid	SW	G,D	G,D	G,D
		Gas**	AI	I,D	I,D	N/A
			SW	G,D	G,D	G,A
		Solid	SW	G,D	G,D	G,D
	SO	Liquid	SO	G,D	G,D	N/A
			SW	G,D	G,D	G,D
			GW	G,D	N/A	N/A
	AI	Gas**	SO	G,D	G,D	N/A
			AI	I,D	I,D	N/A
			SW	G,D	G,D	G,D

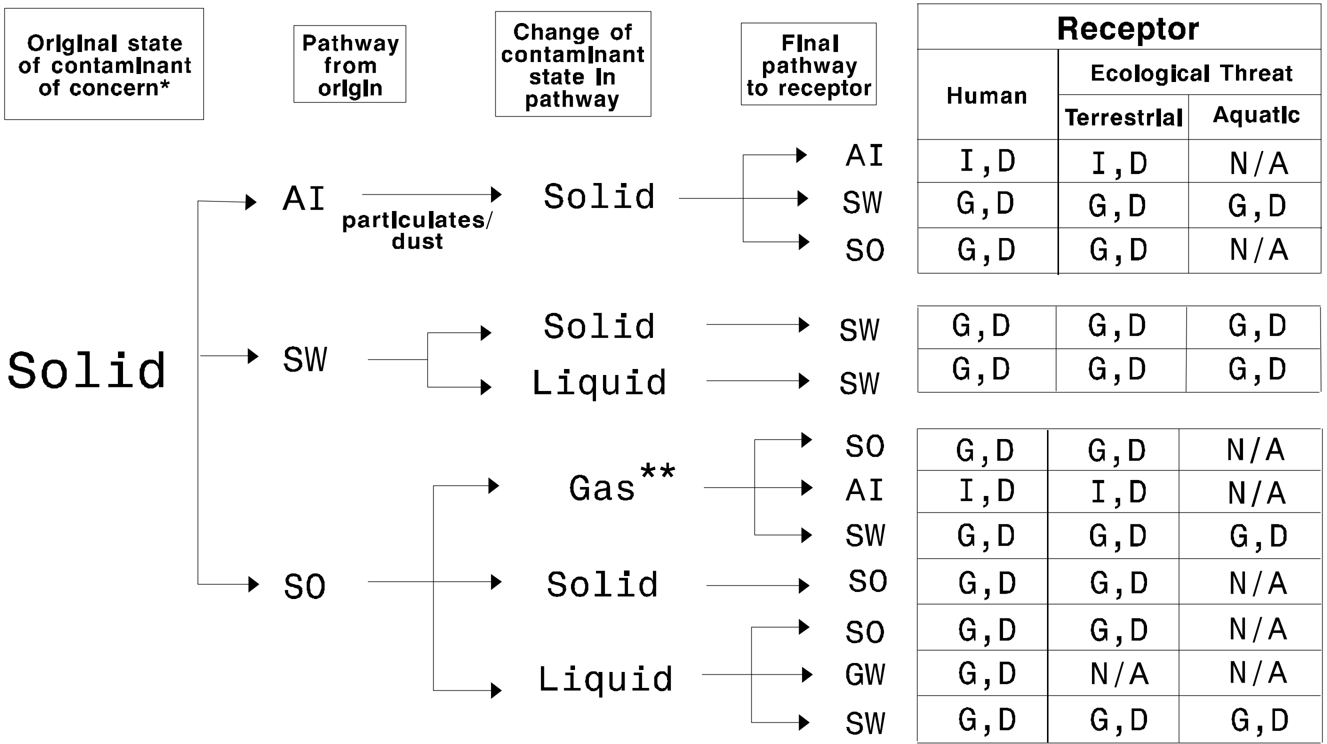
* May be a transformation product
** Includes vapors

Receptor Key
D = Dermal Contact
I = Inhalation
G = Ingestion
N/A = Not Applicable

Pathway Key
AI = Air
SO = Soil
SW = Surface Water (including sediments)
GW = Ground Water

Figure A-3

Migration Routes of a Solid Contaminant from Origin to Receptor



Original state of contaminant of concern*	Pathway from origin	Change of contaminant state in pathway	Final pathway to receptor	Receptor		
				Human	Ecological Threat	
					Terrestrial	Aquatic
Solid	AI	Solid (particulates/ dust)	AI	I,D	I,D	N/A
			SW	G,D	G,D	G,D
			SO	G,D	G,D	N/A
	SW	Solid	SW	G,D	G,D	G,D
		Liquid	SW	G,D	G,D	G,D
	SO	Gas**	SO	G,D	G,D	N/A
			AI	I,D	I,D	N/A
			SW	G,D	G,D	G,D
		Solid	SO	G,D	G,D	N/A
		Liquid	SO	G,D	G,D	N/A
			GW	G,D	N/A	N/A
			SW	G,D	G,D	G,D

* May be a transformation product
** Includes vapors

Receptor Key

D = Dermal Contact
I = Inhalation
G = Ingestion
N/A = Not Applicable

Pathway Key

AI = Air
SO = Soil
SW = Surface Water (including sediments)
GW = Ground Water

References

Aller, Bennett, Hackett, et al. 1989. *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*. National Water Well Association, Dublin, Ohio.

Code of Federal Regulations (CFR), Title 40 - Protection of Environment. Part 136 - Guidelines Establishing Test Procedures for the Analysis of Pollutants.

Custodio, Gurgui, Ferreira. 1987. *Ground-Water Flow and Quality Modelling*. D. Reidel Publishing Company, Dordrecht, Holland.

Driscoll, Fletcher G. 1986. *Ground Water and Wells* (2nd edition).

Fetter, C.W., Jr. 1980. *Applied Hydrogeology*. Charles E. Merrill Publishing Company, Columbus, Ohio.

Garrett, Peter. 1988. *How to Sample Ground Water and Soils*. National Water Well Association, Dublin, Ohio.

Keith, Lawrence, H. 1988. *Principles of Environmental Sampling*.

New Jersey Department of Environmental Protection. February 1988. *Field Sampling Procedures Manual*.

Palmer, Christopher, M. 1992. *Principles of Contaminant Hydrogeology*.

Proceedings of the Fifth National Symposium and Exposition on Aquifer Restoration and Ground-Water Monitoring. 1985.

U.S. Department of Health and Human Services. 1985. *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*. NIOSH Pub.85-115.

U.S. Environmental Protection Agency. 1995a. "Establishing Background Levels." Office of Solid Waste and Emergency Response Directive 9285.7-19FS.

U.S. Environmental Protection Agency. 1995b. *Superfund Program Representative Sampling Guidance*, Volume 1 -- *Soil*. Office of Solid Waste and Emergency Response Directive 9360.4-10.

U.S. Environmental Protection Agency. 1995c. *Superfund Program Representative Sampling Guidance*, Volume 4-- *Waste*. Office of Solid Waste and Emergency Response Directive 9360.4-14.

U.S. Environmental Protection Agency. September 1993. *Data Quality Objectives Process for Superfund*. Office of Solid Waste and Emergency Response Directive 9355.9-01.

U.S. Environmental Protection Agency. 1993. *Project Summary- Compilation of Ground-Water Models*. Office of Research and Development. EPA/600/SR-93/118.

U.S. Environmental Protection Agency. November 1992. *RCRA Ground-Water Monitoring: Draft Technical Guidance*. EPA/530-R-93-001.

U.S. Environmental Protection Agency. September 1992. *Guidance for Performing Site Inspections Under CERCLA*. Office of Solid Waste and Emergency Response Directive 9345.1-05

U.S. Environmental Protection Agency. February 1992. *Estimating the Potential for Occurrence of DNAPL at Superfund Sites*. Office of Solid Waste and Emergency Response Directive 9355.4-07.

U.S. Environmental Protection Agency. January 1992. *Statistical Training Course for Ground-Water Monitoring Data Analysis*. EPA/530-R-93-003.

U.S. Environmental Protection Agency. 1992. *Ground-Water Issue- Fundamentals of Ground-Water Modeling*. Office of Research and Development and Office of Solid Waste and Emergency Response. EPA/540/S-92/005.

U.S. Environmental Protection Agency. January 1991a. *Compendium of ERT Field Analytical Procedures*. Office of Solid Waste and Emergency Response Directive 9360.4-04.

U.S. Environmental Protection Agency. January 1991b. *Compendium of ERT Ground-Water Sampling Procedures*. Office of Solid Waste and Emergency Response Directive 9360.4-06.

U.S. Environmental Protection Agency. January 1991c. *Compendium of ERT Surface Water and Sediment Sampling Procedures*. Office of Solid Waste and Emergency Response Directive 9360.4-03.

U.S. Environmental Protection Agency. 1990. *Ground Water, Volume II: Methodology*. EPA/625/6-90/016b.

U.S. Environmental Protection Agency. April 1989. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance*. Office of Solid Waste and Emergency Response.

U.S. Environmental Protection Agency. September 1988. *Field Screening Methods Catalog -- User's Guide*. Office of Solid Waste and Emergency Response. EPA/540/2-88/005.

U.S. Environmental Protection Agency. December 1987. *A Compendium of Superfund Field Operations Methods*. Office of Solid Waste and Emergency Response Directive 9355.0-14.

U.S. Environmental Protection Agency. 1987. *Handbook, Ground Water*. EPA/625/6-87/016.

U.S. Environmental Protection Agency. September 1986. *RCRA Ground-Water Monitoring Technical Enforcement Guidance Document* (TEGD). Office of Solid Waste and Emergency Response Directive 9950.1.

U.S. Geological Survey. 1991. *Concepts and Modeling in Ground-Water Hydrology - A Self-Paced Training Course*. Open File Report 90-707.

CATEGORY 4: GROUNDWATER SAMPLING AND PURGING

Section 4.2

EPA Region 1: Low Stress (low flow) Purging and Sampling Procedure for the Collection of Groundwater Samples from Monitoring Wells

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION I

LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE FOR THE COLLECTION OF GROUND WATER SAMPLES FROM MONITORING WELLS

July 30, 1996
Revision 2

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION I

LOW STRESS (low flow) PURGING AND SAMPLING PROCEDURE FOR THE COLLECTION OF GROUND WATER SAMPLES FROM MONITORING WELLS

I. SCOPE & APPLICATION

This standard operating procedure (SOP) provides a general framework for collecting ground water samples that are indicative of mobile organic and inorganic loads at ambient flow conditions (both the dissolved fraction and the fraction associated with mobile particulates). The SOP emphasizes the need to minimize stress by low water-level drawdowns, and low pumping rates (usually less than 1 liter/min) in order to collect samples with minimal alterations to water chemistry. This SOP is aimed primarily at sampling monitoring wells that can accept a submersible pump and have a screen, or open interval length of 10 feet or less (this is the most common situation). However, this procedure is flexible and can be used in a variety of well construction and ground-water yield situations. Samples thus obtained are suitable for analyses of ground water contaminants (volatile and semi-volatile organic analytes, pesticides, PCBs, metals and other inorganics), or other naturally occurring analytes.

This procedure does not address the collection of samples from wells containing light or dense non-aqueous phase liquids (LNAPLs and DNAPLs). For this the reader may wish to check: Cohen, R.M. and J.W. Mercer, 1993, DNAPL Site Evaluation; C.K. Smoley (CRC Press), Boca Raton, Florida and U.S. Environmental Protection Agency, 1992, RCRA Ground-Water Monitoring: Draft Technical Guidance; Washington, DC (EPA/530-R-93-001).

The screen, or open interval of the monitoring well should be optimally located (both laterally and vertically) to intercept existing contaminant plume(s) or along flowpaths of potential contaminant releases. It is presumed that the analytes of interest move (or potentially move) primarily through the more permeable zones within the screen, or open interval.

Proper well construction and development cannot be overemphasized, since the use of installation techniques that are appropriate to the hydrogeologic setting often prevents "problem well" situations from occurring. It is also recommended that as part of development or redevelopment the well should be tested to determine the appropriate pumping rate to obtain stabilization of field indicator parameters with minimal drawdown in shortest amount of time. With this information field crews can then conduct purging and sampling in a more expeditious manner.

The mid-point of the saturated screen length (which should not exceed 10 feet) is used by convention as the location of the pump intake. However, significant chemical or permeability contrast(s) within the screen may require additional field work to determine the optimum vertical location(s) for the intake, and appropriate pumping rate(s) for purging and sampling more localized target zone(s). Primary flow zones (high(er) permealability and/or high(er) chemical concentrations) should be identified in wells with screen lengths longer than 10 feet, or in wells with open boreholes in bedrock. Targeting these zones for water sampling will help insure that the low stress procedure will not underestimate contaminant concentrations. The Sampling and Analysis Plan must provide clear instructions on how the pump intake depth(s) will be selected, and reason(s) for the depth(s) selected.

Stabilization of indicator field parameters is used to indicate that conditions are suitable for sampling to begin. Achievement of turbidity levels of less than 5 NTU and stable drawdowns of less than 0.3 feet, while desirable, are not mandatory. Sample collection may still take place provided the remaining criteria in this procedure are met. If after 4 hours of purging indicator field parameters have not stabilized, one of 3 optional courses of action may be taken: a) continue purging until stabilization is achieved, b) discontinue purging, do not collect any samples, and record in log book that stabilization could not be achieved (documentation must describe attempts to achieve stabilization) c) discontinue purging, collect samples and provide full explanation of attempts to achieve stabilization (note: there is a risk that the analytical data obtained, especially metals and strongly hydrophobic organic analytes, may not meet the sampling objectives).

Changes to this SOP should be proposed and discussed when the site Sampling and Analysis Plan is submitted for approval. Subsequent requests for modifications of an approved plan must include adequate technical justification for proposed changes. All changes and modifications must be approved before implementation in field.

II.EQUIPMENT

A. Extraction device

Adjustable rate, submersible pumps are preferred (for example, centrifugal or bladder pump constructed of stainless steel or

Teflon).

Adjustable rate, peristaltic pumps (suction) may be used with caution. Note that EPA guidance states: "Suction pumps are not recommended because they may cause degassing, pH modification, and loss of volatile compounds" (EPA/540/P-87/001, 1987, page 8.5-11).

The use of inertial pumps is discouraged. These devices frequently cause greater disturbance during purging and sampling and are less easily controlled than the pumps listed above. This can lead to sampling results that are adversely affected by purging and sampling operations, and a higher degree of data variability.

B. Tubing

Teflon or Teflon lined polyethylene tubing are preferred when sampling is to include VOCs, SVOCs, pesticides, PCBs and inorganics.

PVC, polypropylene or polyethylene tubing may be used when collecting samples for inorganics analyses. However, these materials should be used with caution when sampling for organics. If these materials are used, the equipment blank (which includes the tubing) data must show that these materials do not add contaminants to the sample.

Stainless steel tubing may be used when sampling for VOCs, SVOCs, pesticides, and PCBs. However, it should be used with caution when sampling for metals.

The use of 1/4 inch or 3/8 inch (inner diameter) tubing is preferred. This will help ensure the tubing remains liquid filled when operating at very low pumping rates.

Pharmaceutical grade (Pharmed) tubing should be used for the section around the rotor head of a peristaltic pump, to minimize gaseous diffusion.

C. Water level measuring device(s), capable of measuring to 0.01 foot accuracy (electronic “tape”, pressure transducer). Recording pressure transducers, mounted above the pump, are especially helpful in tracking water levels during pumping operations, but their use must include check measurements with a water level “tape” at the start and end of each record.

D. Flow measurement supplies (e.g., graduated cylinder and stop watch).

E. Interface probe, if needed.

F. Power source (generator, nitrogen tank, etc.). If a gasoline generator is used, it must be located downwind and at least 30 feet from the well so that the exhaust fumes do not contaminate the samples.

G. Indicator field parameter monitoring instruments - pH, Eh, dissolved oxygen (DO), turbidity, specific conductance, and temperature. Use of a flow-through-cell is required when measuring all listed parameters, except turbidity. Standards to perform field calibration of instruments. Analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846. For Eh measurements, follow manufacturer's instructions.

H. Decontamination supplies (for example, non-phosphate detergent, distilled/deionized water, isopropyl alcohol, etc.).

I. Logbook(s), and other forms (for example, well purging forms).

J. Sample Bottles.

K. Sample preservation supplies (as required by the analytical methods).

L. Sample tags or labels.

M. Well construction data, location map, field data from last sampling event.

N. Well keys.

O. Site specific Sample and Analysis Plan/Quality Assurance Project Plan.

P. PID or FID instrument (if appropriate) to detect VOCs for health and safety purposes, and provide qualitative field evaluations.

III.PRELIMINARY SITE ACTIVITIES

Check well for security damage or evidence of tampering, record pertinent observations.

Lay out sheet of clean polyethylene for monitoring and sampling equipment.

Remove well cap and immediately measure VOCs at the rim of the well with a PID or FID instrument and record the reading in the field logbook.

If the well casing does not have a reference point (usually a V-cut or indelible mark in the well casing), make one. Describe its location and record the date of the mark in the logbook.

A synoptic water level measurement round should be performed (in the shortest possible time) before any purging and sampling activities begin. It is recommended that water level depth (to 0.01 ft.) and total well depth (to 0.1 ft.) be measured the day before, in order to allow for re-settlement of any particulates in the water column. If measurement of total well depth is not made the day before, it should not be measured until after sampling of the well is complete. All measurements must be taken from the established referenced point. Care should be taken to minimize water column disturbance.

Check newly constructed wells for the presence of LNAPLs or DNAPLs before the initial sampling round. If none are encountered, subsequent check measurements with an interface probe are usually not needed unless analytical data or field head space information signal a worsening situation. Note: procedures for collection of LNAPL and DNAPL samples are not addressed in this SOP.

IV.PURGING AND SAMPLING PROCEDURE

Sampling wells in order of increasing chemical concentrations (known or anticipated) is preferred.

1. Install Pump

Lower pump, safety cable, tubing and electrical lines slowly (to minimize disturbance) into the well to the midpoint of the zone to be sampled. The Sampling and Analysis Plan should specify the sampling depth, or provide criteria for selection of intake depth for each well (see Section I). If possible keep the pump intake at least two feet above the bottom of the well, to minimize mobilization of particulates present in the bottom of the well. Collection of turbid free water samples may be especially difficult if there is two feet or less of standing water in the well.

2. Measure Water Level

Before starting pump, measure water level. If recording pressure transducer is used-initialize starting condition.

3. Purge Well

3a. Initial Low Stress Sampling Event

Start the pump at its lowest speed setting and slowly increase the speed until discharge occurs. Check water level. Adjust pump speed until there is little or no water level drawdown (less than 0.3 feet). If the minimal drawdown that can be achieved exceeds 0.3 feet but remains stable, continue purging until indicator field parameters stabilize.

Monitor and record water level and pumping rate every three to five minutes (or as appropriate) during purging. Record any pumping rate adjustments (both time and flow rate). Pumping rates should, as needed, be reduced to the minimum capabilities of the pump (for example, 0.1 - 0.4 l/min) to ensure stabilization of indicator parameters. Adjustments are best made in the first fifteen minutes of pumping in order to help minimize purging time. During pump start-up, drawdown may exceed the 0.3 feet target and then "recover" as pump flow adjustments are made. Purge volume calculations should utilize stabilized drawdown value, not the initial drawdown. Do not allow the water level to fall to the intake level (if the static water level is above the well screen, avoid lowering the water level into the screen). The final purge volume must be greater than the stabilized drawdown volume plus the extraction tubing volume.

Wells with low recharge rates may require the use of special pumps capable of attaining very low pumping rates (bladder, peristaltic), and/or the use of dedicated equipment. If the recharge rate of the well is lower than extraction rate capabilities of currently manufactured pumps and the well is essentially dewatered during purging, then the well should be sampled as soon as the water level has recovered sufficiently to collect the appropriate volume needed for all anticipated samples (ideally the intake should not be moved during this recovery period). Samples may then be collected even though the indicator field parameters have not stabilized.

3b. Subsequent Low Stress Sampling Events

After synoptic water level measurement round, check intake depth and drawdown information from previous sampling event(s) for each well. Duplicate, to the extent practicable, the intake depth and extraction rate (use final pump dial setting information) from previous event(s). Perform purging operations as above.

4. Monitor Indicator Field Parameters

During well purging, monitor indicator field parameters (turbidity, temperature, specific conductance, pH, Eh, DO) every three to five minutes (or less frequently, if appropriate). Note: during the early phase of purging emphasis should be put on minimizing and stabilizing pumping stress, and recording those adjustments. Purging is considered complete and sampling may begin when all the above indicator field parameters have stabilized. Stabilization is considered to be achieved when three consecutive readings, taken at three (3) to five (5) minute intervals, are within the following limits:

turbidity (10% for values greater than 1 NTU),
DO (10%),
specific conductance (3%),
temperature (3%),
pH (± 0.1 unit),
ORP/Eh (± 10 millivolts).

All measurements, except turbidity, must be obtained using a flow-through-cell. Transparent flow-through-cells are preferred, because they allow field personnel to watch for particulate build-up within the cell. This build-up may affect indicator field parameter values measured within the cell and may also cause an underestimation of turbidity values measured after the cell. If the cell needs to be cleaned during purging operations, continue pumping and disconnect cell for cleaning, then reconnect after cleaning and continue monitoring activities.

The flow-through-cell must be designed in a way that prevents air bubble entrapment in the cell. When the pump is turned off or cycling on/off (when using a bladder pump), water in the cell must not drain out. Monitoring probes must be submerged in water at all times. If two flow-through-cells are used in series, the one containing the dissolved oxygen probe should come first (this parameter is most susceptible to error if air leaks into the system).

5. Collect Water Samples

Water samples for laboratory analyses must be collected before water has passed through the flow-through-cell (use a by-pass assembly or disconnect cell to obtain sample).

VOC samples should be collected first and directly into pre-preserved sample containers. Fill all sample containers by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence.

During purging and sampling, the tubing should remain filled with water so as to minimize possible changes in water chemistry upon contact with the atmosphere. It is recommended that 1/4 inch or 3/8 inch (inside diameter) tubing be used to help insure that the sample tubing remains water filled. If the pump tubing is not completely filled to the sampling point, use one of the following procedures to collect samples: (1) add clamp, connector (Teflon or stainless steel) or valve to constrict sampling end of tubing; (2) insert small diameter Teflon tubing into water filled portion of pump tubing allowing the end to protrude beyond the end of the pump tubing, collect sample from small diameter tubing; (3) collect non-VOC samples first, then increase flow rate slightly until the water completely fills the tubing, collect sample and record new drawdown, flow rate and new indicator field parameter values.

Add preservative, as required by analytical methods, to samples immediately after they are collected if the sample containers are not pre-preserved. Check analytical methods (e.g. EPA SW-846, water supply, etc.) for additional information on preservation. Check pH for all samples requiring pH adjustment to assure proper pH value. For VOC samples, this will require that a test sample be collected during purging to determine the amount of preservative that needs to be added to the sample containers prior to sampling.

If determination of filtered metal concentrations is a sampling objective, collect filtered water samples using the same low flow procedures. The use of an in-line filter is required, and the filter size (0.45 um is commonly used) should be based on the sampling objective. Pre-rinse the filter with approximately 25 - 50 ml of ground water prior to sample collection. Preserve filtered water sample immediately. Note: filtered water samples are not an acceptable substitute for unfiltered samples when the monitoring objective is to obtain chemical concentrations of total mobile contaminants in ground water for human health risk calculations.

Label each sample as collected. Samples requiring cooling (volatile organics, cyanide, etc.) will be placed into a cooler with ice or refrigerant for delivery to the laboratory. Metal samples after acidification to a pH less than 2 do not need to be cooled.

6. Post Sampling Activities

If recording pressure transducer is used, remeasure water level with tape.

After collection of the samples, the pump tubing may either be dedicated to the well for resampling (by hanging the tubing inside the well), decontaminated, or properly discarded.

Before securing the well, measure and record the well depth (to 0.1 ft.), if not measured the day before purging began. Note: measurement of total well depth is optional after the initial low stress sampling event. However, it is recommended if the well has a “silting” problem or if confirmation of well identity is needed.

Secure the well.

V.DECONTAMINATION

Decontaminate sampling equipment prior to use in the first well and following sampling of each subsequent well. Pumps will not be removed between purging and sampling operations. The pump and tubing (including support cable and electrical wires which are in contact with the well) will be decontaminated by one of the procedures listed below.

Procedure 1

The decontaminating solutions can be pumped from either buckets or short PVC casing sections through the pump or the pump can be disassembled and flushed with the decontaminating solutions. It is recommended that detergent and isopropyl alcohol be used sparingly in the decontamination process and water flushing steps be extended to ensure that any sediment trapped in the pump is removed. The pump exterior and electrical wires must be rinsed with the decontaminating solutions, as well. The procedure is as follows:

Flush the equipment/pump with potable water.

Flush with non-phosphate detergent solution. If the solution is recycled, the solution must be changed periodically.

Flush with potable or distilled/deionized water to remove all of the detergent solution. If the water is recycled, the water must be changed periodically.

Flush with isopropyl alcohol (pesticide grade). If equipment blank data from the previous sampling event show that the level of contaminants is insignificant, then this step may be skipped.

Flush with distilled/deionized water. The final water rinse must not be recycled.

Procedure 2

Steam clean the outside of the submersible pump.

Pump hot potable water from the steam cleaner through the inside of the pump. This can be accomplished by placing the pump inside a three or four inch diameter PVC pipe with end cap. Hot water from the steam cleaner jet will be directed inside the PVC pipe and the pump exterior will be cleaned. The hot water from the steam cleaner will then be pumped from the PVC pipe through the pump and collected into another container. Note: additives or solutions should not be added to the steam cleaner.

Pump non-phosphate detergent solution through the inside of the pump. If the solution is recycled, the solution must be changed periodically.

Pump potable water through the inside of the pump to remove all of the detergent solution. If the solution is recycled, the solution must be changed periodically.

Pump distilled/deionized water through the pump. The final water rinse must not be recycled.

VI.FIELD QUALITY CONTROL

Quality control samples are required to verify that the sample collection and handling process has not compromised the quality of the ground water samples. All field quality control samples must be prepared the same as regular investigation samples with regard to sample volume, containers, and preservation. The following quality control samples shall be collected for each batch of samples (a batch may not exceed 20 samples). Trip blanks are required for the VOC samples at a frequency of one set per VOC sample cooler.

Field duplicate.

Matrix spike.

Matrix spike duplicate.

Equipment blank.

Trip blank (VOCs).

Temperature blank (one per sample cooler).

Equipment blank shall include the pump and the pump's tubing. If tubing is dedicated to the well, the equipment blank will only include the pump in subsequent sampling rounds.

Collect samples in order from wells with lowest contaminant concentration to highest concentration. Collect equipment blanks after sampling from contaminated wells and not after background wells.

Field duplicates are collected to determine precision of sampling procedure. For this procedure, collect duplicate for each analyte group in consecutive order (VOC original, VOC duplicate, SVOC original, SVOC duplicate, etc.).

If split samples are to be collected, collect split for each analyte group in consecutive order (VOC original, VOC split, etc.). Split sample should be as identical as possible to original sample.

All monitoring instrumentation shall be operated in accordance with EPA analytical methods and manufacturer's operating instructions. EPA analytical methods are listed in 40 CFR 136, 40 CFR 141, and SW-846 with exception of Eh, for which the manufacturer's instructions are to be followed. Instruments shall be calibrated at the beginning of each day. If a measurement falls outside the calibration range, the instrument should be re-calibrated so that all measurements fall within the calibration range. At the end of each day, check calibration to verify that instruments remained in calibration. Temperature measuring equipment, thermometers and thermistors, need not be calibrated to the above frequency. They should be checked for accuracy prior to field use according to EPA Methods and the manufacturer's instructions.

VII.FIELD LOGBOOK

A field log shall be kept to document all ground water field monitoring activities (see attached example matrix), and record all of the following:

Well identification.

Well depth, and measurement technique.

Static water level depth, date, time and measurement technique.

Presence and thickness of immiscible liquid (NAPL) layers and detection method.

Pumping rate, drawdown, indicator parameters values, and clock time, at the appropriate time intervals; calculated or measured total volume pumped.

Well sampling sequence and time of each sample collection.

Types of sample bottles used and sample identification numbers.

Preservatives used.

Parameters requested for analysis.

Field observations during sampling event.

Name of sample collector(s).

Weather conditions.

QA/QC data for field instruments.

Any problems encountered should be highlighted.

Description of all sampling equipment used, including trade names, model number, diameters, material composition, etc.

VIII. DATA REPORT

Data reports are to include laboratory analytical results, QA/QC information, and whatever field logbook information is needed to allow for a full evaluation of data useability.

EXAMPLE (Minimum Requirements) Page____of____

Well PURGING-FIELD WATER QUALITY MEASUREMENTS FORM

Location (Site/Facility Name)_________________________ Depth to _______/________ of screen
Well Number_________________Date_______________________ (below MP) top bottom
Field Personnel____ Pump Intake at (ft. below MP)_______________
Sampling Organization__________________________________ Purging Device; (pump type)_________________
Identify MP____

Clock Time 24 HR	Water Depth below MP ft	Pump Dial[1]	Purge Rate ml/min	Cum. Volume Purged liters	Temp. °C	Spec. Cond.[2] µS/cm	pH	ORP/ Eh[3] mv	DO mg/L	Turb- idity NTU	Comments

1. Pump dial setting (for example: hertz, cycles/min, etc).
2. µSiemens per cm(same as µmhos/cm)at 25 °C.
3. Oxidation reduction potential (stand in for Eh).

CATEGORY 4: GROUNDWATER SAMPLING AND PURGING

Section 4.3

Redi-Flow Performance Pump Operation

DOCUMENT TYPE: Standard Operating Procedure

TITLE: Redi-Flo Performance Pumps

PREPARED BY: Jeff Geraci, Environmental Scientist I __________________

REVISED BY: Kristina Davis, Environmental Scientist III __________________

REVIEWED BY: Jan Kilduff, Environmental Scientist V __________________

APPROVED BY: Marshall K. Cheung, Ph.D., Laboratory Director __________________

Table of Contents

Document No.:	***SP 0004 –001***
Copy provided to:	**Marshall K. Cheung**
Title:	Laboratory Director
	29 Palms Laboratory
	47-250 Dillon Road
	Coachella, CA 92236
Copy provided by:	**Alison Millar**
Title:	Environmental Technician II
Date:	July 28, 2004

1. Scope and Application

1.1. This procedure is to be followed when operating the Redi-Flo Variable Performance Pump.

2. Summary of Method

2.1. Start generator (See SOP #SP007 Generac EXL Generator Operation).
2.2. Connect Redi-Flo Variable Frequency Drive (RF-VFD) to pump and generator
2.3. Insert pump into water for cleaning in following order.
    2.3.1. Distilled water (TDS less than 5 mg/L=acceptable)
    2.3.2. Reagent water (TDS less than 2 mg/L=acceptable)
2.4. Start pump, RSR switch to Run, at slow rate and slowly increase pump rate.
2.5. Collect equipment blank samples
2.6. Stop pump by switching RSR switch to stop.
2.7. Repeat 2.1- 2.2 at sampling site.
2.8. Insert pump into monitoring well for sampling.
2.9. Start pump for sampling.
2.10. Stop pump
2.11. Insert pump into tap water for cleaning before storing.
2.12. Start pump
2.13. Stop pump

3. Equipment

3.1. Redi-Flo 2 Variable Performance Pump (RF2)
3.2. Motor lead (tubing and spool)
3.3. Discharge hose
3.4. Redi-Flo Variable Frequency Drive (RF-VFD)
3.5. Redi-Flo Pump Logbook
3.6. Generac EXL Generator
3.7. 55 gallon drum
3.8. Two (2) pipette baskets (a little under 5 gallons)
3.9. Cleaning rags
3.10. Tool box
    3.10.1. 2 ten inch wrenches
    3.10.2. Stop watch or timer
    3.10.3. Scissors
    3.10.4. Plumbers/Teflon tape
    3.10.5. Plastic bags
        3.10.5.1. 1 for garbage,
        3.10.5.2. 1 to cover pump after sampling and cleaning.
    3.10.6. Plastic-tie to secure bag around pump head after use.
    3.10.7. Pinch pliers to remove ring in pump head if necessary while cleaning.
    3.10.8. Alternative power source for Volt meter, either batteries or AC adapter
    3.10.9. Power surge protector
    3.10.10. Volt meter

4. Operating Conditions

- 4.1. The RF2 pump must be installed vertically with the discharge end pointed upwards.
- 4.2. The electrical voltage supply to the RF-VFD must always be between 103 and 126 VAC from 120v outlet (See SOP #SP007 Generac EXL Generator Operation).
- 4.3. The pump and motor must always be completely submerged in fluid to ensure lubrication and cooling of the motor.
- 4.4. Ensure that the pump remains at least 3 feet below the well water level through frequent depth sounding at the beginning of well purge (See SOP #SP006 Static Water Level Determination). Never let the pump run dry!
- 4.5. The pump is not recommended for continuous operation applications.
- 4.6. When the pump is used to purge wells, start the pump at minimum speed and then gradually increase to the desired speed.
- 4.7. Do not stop the pump until the pumped fluid contains no visible particles (to avoid blockage within the pump).

5. Reagents

- 5.1. Tap water (40 gallons)
- 5.2. Distilled water (Bottled) (5 gallons)
- 5.3. Reagent water (deionized/*Nanopure* water) (5 gallons)
- 5.4. 500 mL squirt bottle of reagent water

6. Procedure

- 6.1. Start pump
  - 6.1.1. Start the generator and allow it to warm up (See SOP # SP007 Generac EXL Generator Operation).
  - 6.1.2. Plug the RF-FD into the power surge protector that is plugged into generator.
  - 6.1.3. Select **RF2M** with the mode selection knob.
  - 6.1.4. Connect the motor lead to RF-VFD.
  - 6.1.5. The Frequency Display on the RF-VFD should read 0.0.
    - 6.1.5.1. If not, refer to Troubleshooting, pp 19-20 in manual.
    - 6.1.5.2. Let the RF-VFD stay on for 5 minutes before starting pump
  - 6.1.6. Submerge pump (RF2) must be placed in water source at least 3 feet below water level.
    - 6.1.6.1. If pre-sampling cleaning refer to section 6.3.
    - 6.1.6.2. If purging or sampling then refer to SOP SP 002 version 1.3.
    - 6.1.6.3. If post sampling cleaning refer to section 6.7.
  - 6.1.7. Switch RSR switch to Run.
  - 6.1.8. Turn the speed dial (10-turn potentiometer) slowly at first until the desired performance is attained (200 Hz = 2 gallons/minute for cleaning pump).
  - 6.1.9. Perform procedures
    - 6.1.9.1. If pre-sampling cleaning refer to section 6.3.
    - 6.1.9.2. If purging or sampling then refer to SOP SP 002 version 1.3.
- 6.2. Stop pump
  - 6.2.1. Turn speed dial all the way down until it reaches 25 Hz
  - 6.2.2. Switch RSR switch to Stop

6.2.3. Unplug the RF-VFD from the generator BEFORE removing the motor lead from the RF-VFD or turning off the generator.

6.2.4. Wipe down RF-VFD and put away.

6.3. Pre-sampling pump cleaning

6.3.1. Place pump in clean pipette basket and fill to top with distilled water (about 5 gallons).

6.3.2. Turn pump on according to 6.1 and again pump at 200 Hz (2 gallons/min), allowing the first gallon pumped to exit the basket and then allowing the remaining 4 gallons to re-circulate through pump, hose, and basket for 15 minutes.

6.3.2.1. Take a sample every 5 minutes to test for conductivity and TDS.

6.3.2.1.1. If TDS is less than 5 mg/L then proceed with next step, otherwise repeat 6.3.5. with fresh distilled water (< 5mg/l = acceptable). Record results in Conductivity Log.

6.3.3. Turn pump off (Section 6.2).

6.3.4. Place pump in clean pipette basket and fill with 5 gallons of deionized water.

6.3.5. Start pump according to section 6.1 and pump rate to 200 Hz or 2 gallons/minute.

6.3.6. Check temperature, conductivity and TDS every 5 minutes for 15 minutes. Record results in Conductivity Log.

6.3.6.1. If after 15 minutes the TDS is not less than 2mg/l then repeat 6.3.8 with new deionized water.

6.3.7. Turn pump off (Section 6.2).

6.3.8. Use remaining distilled and deionized water from steps 6.3.5 and 6.3.8 to rinse hose and hose reel.

6.3.9. Gently clean RF-VFD housing and case with damp rag.

6.4. Purging monitoring well and Sampling

6.4.1. Place pump at desired depth

6.4.2. Refer to section 6.1 for starting pump operation

6.4.3. Purge well at "high speed".

6.4.4. Sample monitoring well at "low speed".

6.4.5. Section 6.2 for turning off pump

6.4.6. Cover pump with plastic bag and tie to protect clean pump head.

6.5. Post sampling pump cleaning back at office

6.5.1. Set pump in clean 55-gallon drum filled with clean tap water.

6.5.2. Start pump according to section 6.1 and run at an approximate 2 gallons per minute rate (RF-VFD setting of 200 Hz).

6.5.3. Pump tap water to ground or recycle it back into drum for 15 minutes.

6.5.3.1. Take sample every 5 minutes and test for conductivity and TDS, record in Conductivity log (SOP # PP002)

6.5.4. Turn off pump (Section 6.2)

6.5.5. Dissemble pump motor head for cleaning.

6.5.5.1. Use pinch ring pliers to remove ring inside top of casing.

6.5.5.2. Use ten-inch wrench to remove from encasing

6.5.5.3. Use ten-inch wrench to remove tubing from pump.

6.5.5.4. Clean all items with rag and water

6.5.6. Assemble pump to lead to reuse again

6.5.6.1. Wrap screws with Teflon tape before assembling.

        - 6.5.6.2. insert diagram**
    - 6.5.7. Cover pump with plastic bag and tie up for storage in sample receiving room.
    - 6.5.8. Gently clean RF-VFD housing and case with damp rag.

7. Bibliography

7.1. Redi-Flo Variable Performance Pump Installation and Operation Instruction Manual. Customer service center: phone (800) 333-1366; fax (800) 333-1363.

CATEGORY 4: GROUNDWATER SAMPLING AND PURGING

Section 4.4

Standard Guide for Sampling Groundwater-Water Monitoring Wells

Designation: D 4448 – 01 (Reapproved 2007)

Standard Guide for Sampling Ground-Water Monitoring Wells[1]

1. Scope

1.1 This guide covers sampling equipment and procedures and "in the field" preservation, and it does not include well location, depth, well development, design and construction, screening, or analytical procedures that also have a significant bearing on sampling results.This guide is intended to assist a knowledgeable professional in the selection of equipment for obtaining representative samples from ground-water monitoring wells that are compatible with the formations being sampled, the site hydrogeology, and the end use of the data.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for collecting ground-water quality samples from monitoring wells and is not intended to serve as a ground-water monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information only.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)

D 5088 Practices for Decontamination of Field Equipment Used at Waste Sites

D 5792 Practice for Generation of Environmental Data Related to Waste Management Activities: Development of Data Quality Objectives

D 5903 Guide for Planning and Preparing for a Groundwater Sampling Event

D 6089 Guide for Documenting a Ground-Water Sampling Event

D 6452 Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations

D 6517 Guide for Field Preservation of Ground-Water Samples

2.2 *EPA Standards:*

EPA Method 9020A

EPA Method 9022

3. Terminology

3.1 *Definitions:*

3.1.1 *low-flow sampling*—a ground water sampling technique where the purge and sampling rates do not result in significant changes in formation seepage velocity.

3.1.2 *minimal purge sampling*—the collection of ground water that is representative of the formation by purging only the volume of water contained by the sampling equipment (that is, tubing, pump bladder).

3.1.2.1 *Discussion*—This sampling method should be considered in situations where very low yield is a consideration and results from this sampling method should be scrutinized to confirm that they meet data quality objectives (DQOs) and the work plan objectives.

3.1.3 *passive sampling*—the collection of ground-water quality data so as to induce no hydraulic stress on the aquifer.

3.1.4 *water quality indicator parameters*—refer to field monitoring parameters that include but are not limited to pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature, and turbidity that are used to monitor the completeness of purging.

4. Summary of Guide

4.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to: the design and construction of the well, rate of ground-water flow, and the chemical species of interest.

---

[1] This guide is under the jurisdiction of ASTM Committee D34 on Waste Management and is the direct responsibility of Subcommittee D34.01.02 on Sampling Techniques.

Current edition approved Oct. 15, 2007. Published October 2007. Originally approved in 1985. Last previous edition approved in 2001 as D 4448–01.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

Sampling procedures may be different if analyses for trace organics, volatiles, oxidizable species, or trace metals are needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well purging, sample withdrawal, and field preparation of samples. Certain sampling protocols eliminate the first step.

4.2 The sampling must be well planned and all sample containers must be prepared prior to going to the field. These procedures should be incorporated in the approved work plan that should accompany the sampling crew so that they may refer to it for guidance on sampling procedures and analytes to be sampled (see Guide D 5903).

4.3 Monitoring wells must be either purged to remove stagnant water in the well casing or steps must be taken to ensure that only water meeting the DQOs and the work plan objectives is withdrawn during sampling (see Practice D 5792). When well purging is performed, it is accomplished by either removing a predetermined number of well volumes or by the removal of ground water until stable water quality parameters have been obtained. Ideally this purging is performed with minimal well drawdown and minimal mixing of the formation water with the stagnant water above the screened interval in the casing. Passive sampling and the minimal purge methods do not attempt to purge the water present in the monitoring well prior to sampling **(1)**.[3] The minimal purge method attempts to purge only the sampling equipment. Each of these methods is discussed in greater detail in Section 6.

4.4 The types of chemical species that are to be sampled as well as the reporting limits are prime factors for selecting sampling devices **(2, 3)**. The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analytes of concern in any way. Material compatibility is further discussed in Section 8.

4.5 The method of sample collection can vary with the parameters of interest. The ideal sampling scheme employs a completely inert material, does not subject the sample to pressure change, does not expose the sample to the atmosphere, or any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis. Since these ideals are not always obtainable, compromises must be made by the knowledgeable individual designing the sampling program. These concerns should be documented in the data quality objectives (DQOs) of the sampling plan (see Practice D 5792) **(4)**.

4.6 The degree and type of effort and care that goes into a sampling program is always dependent on the chemicals of concern and their reporting levels as documented in the project's DQOs. As the reporting level of the chemical species of analytical interest decreases, the precautions necessary for sampling generally increase. Therefore, the sampling objective must clearly be defined ahead of time in the DQOs. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. A draft U.S. EPA guidance document **(5)** concerning monitoring well sampling, including considerations for trace organics, is available to provide additional guidance.

4.7 Care must be taken not to contaminate samples or monitoring wells. All samples, sampling devices, and containers must be protected from possible sources of contamination when not in use. Water level measurements should be made according to Test Method D 4750 before placing, purging, or sampling equipment in the well. Redox potential, turbidity, pH, specific conductance, DO (dissolved oxygen), and temperature measurements should all be performed on the sample in the field, if possible, since these parameters change too rapidly to be conducted by a fixed laboratory under most circumstances. Field meter(s) or sondes equipped with flow-through cells are available that are capable of continuously monitoring these parameters during purging if they are being used as water quality indicator parameters. These devices prevent the mixing of oxygen with the sample and provide a means of determining when the parameters have stabilized. Certain measurements that are used as indicators of biological activity, such as ferrous iron, nitrite, and sulfite, may also be conducted in the field since they rapidly oxidize. All temperature measurements must be done prior to any significant atmospheric exposure.

5. Significance and Use

5.1 The quality of ground water has become an issue of national concern. Ground-water monitoring wells are one of the more important tools for evaluating the quality of ground water, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

5.2 The goal in sampling ground-water monitoring wells is to obtain samples that meet the DQOs. This guide discusses the advantages and disadvantages of various well sampling methods, equipment, and sample preservation techniques. It reviews the variables that need to be considered in developing a valid sampling plan.

6. Well Purging

6.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may alter water quality or because the formation water quality may change over time (see Guide D 6452). Even if it is unchanged from the time it entered the well, the stagnant water may not be representative of formation water at the time of sampling. There are two approaches to purging that reflect two differing viewpoints: to purge a large volume of ground water and to purge a minimum of, or no ground water before collecting a sample. The approach most often applied is to purge a sufficient volume of standing water from the casing, along with sufficient formation water to ensure that the water being withdrawn at the time of sampling is representative of the formation water. Typically, three to five well volumes are used. An alternative method that is gaining acceptance is to minimize purging and to conduct purging at a low flow rate or to eliminate purging entirely.

6.2 In any purging approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be

---

[3] The boldface numbers in parentheses refer to a list of references at the end of this guide.

used. Excessive drawdown distorts the natural flow patterns around the well. Two potential negative effects are the introduction of ground water that is not representative of water quality immediately around the monitoring well and artificially high velocities entering the well resulting in elevated turbidity and analytical data that reflects the absorption of contaminants to physical particles rather than soluble concentrations in ground water. It may also result in cascading water from the top of the screen that can result in changes in dissolved gasses, redox state, and ultimately affect the concentration of the analytes of interest through the oxidation of dissolved metals and possible loss of volatile organic compounds (VOCs). There may also be a lingering effect on the dissolved gas levels and redox state from air being introduced and trapped in the sandpack. In no instance shall a well be purged dry. If available, the field notes or purge logs generated during previous sampling or development of the well as well as construction logs should be reviewed to assist in the selection of the most appropriate sampling method.

6.3 The most often applied purging method has an objective to remove a predetermined volume of stagnant water from the casing prior to sampling. The volume of stagnant water can either be defined as the volume of water contained within the casing and screen, or to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out. Research with a tracer in a full scale model 2-in. polyvinyl chloride (PVC) well **(6)** indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stagnant water in the casing. This approach (with three to five casing volumes purged) was suggested by the U.S. EPA **(7)**.

6.4 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stagnant water **(6, 8)**. Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stagnant water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer may flow into the purged zone through the well's gravel/sand pack.

6.5 An alternate method is based on research by Barcelona, Wehrmann, and Varlien **(1)** and Puls and Powell **(2)**. Their research suggests that purging at rates less than 1 L/min (approximately 0.25 gal/min) provides more reproducible VOCs and metals analytical results than purging at high rates. This method is based on the premise that at very low pumping rates, there is little mixing of the water column and laminar ground-water flow through the screen provides a more consistent sample. This sampling method also produces less turbid samples that may eliminate the need for filtration when collecting metals. This method is commonly referred to as low-flow sampling.

6.6 The low-flow sampling approach is most applicable to wells capable of sustaining a yield approximately equal to the pumping rate. A monitoring well with a very low yield may not be applicable to this technique since it may be difficult to reduce the pumping rate sufficiently to prevent mixing of the water column in the well casing in such a well. The water level in the well being sampled should be continuously monitored using an electronic water-level indicator during low-flow sampling. Such a water-level indicator could be set below the water surface after sufficient water has been withdrawn to fill the pump, tubing, and flow cell. The water-level indicator would then produce a continuous signal indicating submersion. When the well is purged, if the water level falls below the water-level indicator probe, the signal indicates that the water level has fallen below the maximum allowable drawdown and the pumping rate should be decreased. Pumping is started at approximately 100 mL/min discharge rate and gradually adjusted to match the well's recharge rate. The selection of the type of pump is dependent on site-specific conditions and DQOs. The bladder pump design is most commonly used in this sampling method, however, the depth limitation of this pump may necessitate the use of a gas-driven piston pump in some instances.

6.7 A variation on the above purging approaches is to monitor one or more indicator parameters until stabilization of the selected parameter(s) has been achieved. Stabilization is considered achieved when measurements are within a predefined range. This range has been suggested to be approximately 10 % over two successive measurements made 3 min apart by the U.S. EPA **(4)**. More recent documents **(9)** have suggested ranges ±0.2°C for temperature, ±0.1 standard units for pH, ±3 % for specific conductance, ±10 % for DO, and ±10 mV for redox potential. A disadvantage of the stabilization approach is that there is no assurance in all situations that the stabilized parameters represent formation water. These criteria should therefore be set on a site by site basis since if set too stringent, large volumes of contaminated purge water may be generated without ensuring that the samples are any more representative. In a low yielding formation, this could result in the well being emptied before the parameters stabilize. Also, if significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. If these criteria are properly selected, the volume of investigative derived waste water may be reduced.

6.8 The indicator parameters that may be monitored include pH, temperature, specific conductance, turbidity, redox potential, and DO. A combination of a pump and field meter(s) or sondes equipped with a flow-through cell is ideal for this purpose since it allows the monitoring of one or more of these parameters on a continuous basis without exposure to the atmosphere. A typical flow-through cell application is shown in Fig. 1. The pump used in this technique may be any pump capable of producing a steady flow such as a peristaltic or bladder pump. If a submersible pump is used, the hydraulic pressure developed in the flow-through cell may be sufficient to force the probes out of their position. This problem may be eliminated by installing a tee connector in the discharge line to allow only a portion of the flow to enter the flow-through cell. Another concern with the low-flow sampling method is sorption onto the tubing. Studies have indicated that at flow rates of

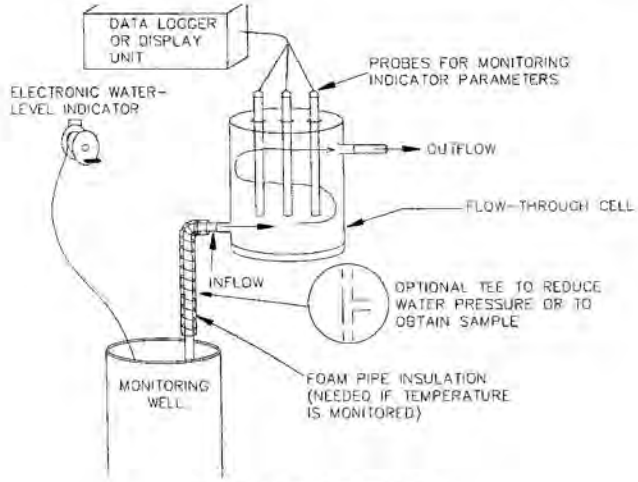


FIG. 1 Flow-Through Cell

0.1 L/min (0.026 gal/min), low-density polyethylene (LDPE) and plasticized polypropylene tubings are prone to sorption and TFE-fluorocarbon should be used. This is especially a concern if tubing lengths of 15 m (50 ft) or longer are used **(10)**.

6.9 Gibb and Schuller **(11)** have described a time-drawdown approach using knowledge of the well hydraulics to predict the percentage of stagnant water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are collected when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect on the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stagnant water due to effects other than drawdown (for example, density differences) is not accounted for in this approach.

6.10 An alternative to purging a well before sampling is to collect a water sample within the screened zone without purging. These techniques are based on studies that under certain conditions, natural ground-water flow is laminar and horizontal with little or no mixing within the well screen **(12, 13)**. To properly use these sampling techniques, a water sample must be collected within the screened interval with little or no mixing of the water column within the casing. Examples of these techniques include minimal purge sampling which uses a dedicated sampling pump capable of pumping rates of less than 0.1 L/min, discrete depth sampling using a bailer that allows ground water entry at a controlled depth, (for example, differential pressure bailer **(14)**), or diffusion sampling. These sampling techniques are discussed in 8.1.10.

7. Materials and Manufacture

7.1 The choice of materials used in the construction of sampling devices should be based upon knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. A second concern is that corrosion or degradation may compromise the structural integrity of the sampling device. In some situations, PVC or other plastic may be sufficient. In others, an all TFE-fluorocarbon apparatus may be necessary. The potential presence of nonaqueous phase liquid (NAPL) should also be a consideration since its presence would expose the sampling equipment to high concentrations of potential solvents. No one material is ideal in that each material will, to some degree absorb or leach chemicals or may degrade on exposure to a chemical.

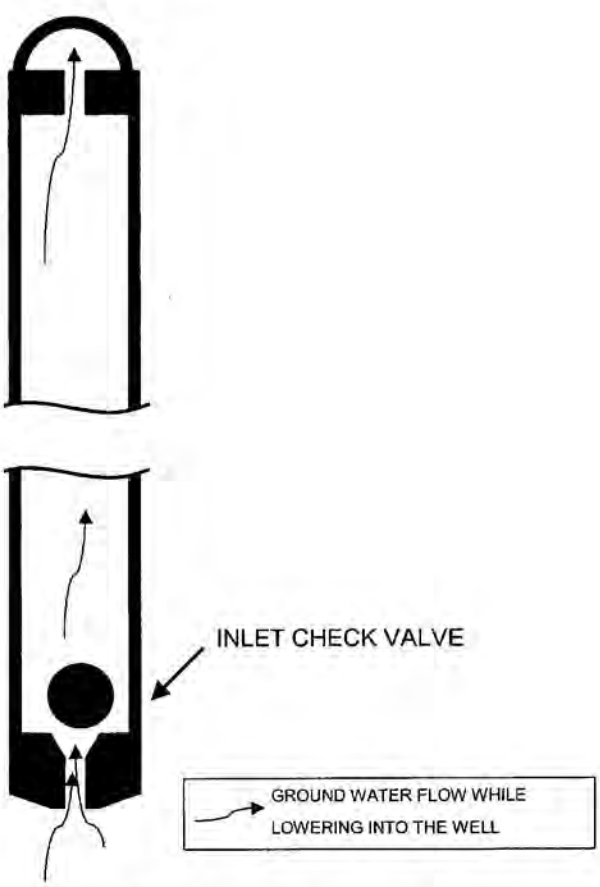


FIG. 2 Single Check Valve Bailer

7.2 The advantages and disadvantages of these materials for sampling equipment are summarized in Table 1.

7.3 *PVC*:

7.3.1 If adhesives are avoided, PVC is acceptable in many cases although their use may still lead to some problems if trace organics are of concern or NAPL is present **(15)**. At present, interactions occurring between PVC and ground water are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC **(16)**.

7.3.2 The structural integrity concerns with PVC increase with the concentration of PVC solvents in ground water. As such, NAPLs that are PVC solvents are a primary concern. Potential NAPLs that are of a concern for PVC and other commonly used plastics are listed in Table 2. Degradation of these materials is primarily by solvation, which is the penetration of the material by the solvent that ultimately causes softening and swelling that can lead to failure. Even in lower concentrations, however, PVC solvents may deteriorate PVC. Methylene chloride, which is a very effective PVC solvent, will

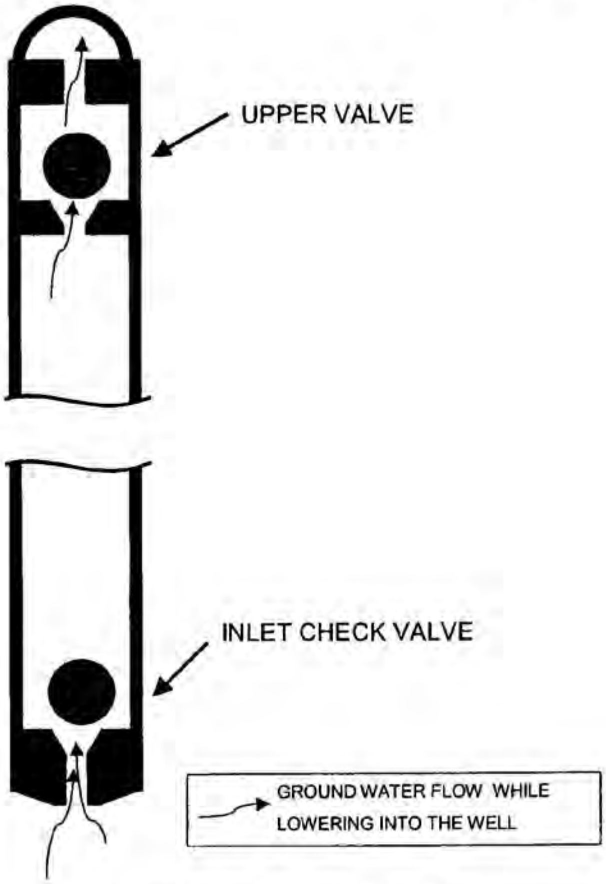


FIG. 3 Double Check Valve Bailer

soften PVC at one tenth its solubility limit while trichloroethylene, which is a less effective solvent, will begin to soften PVC at six tenths its solubility limit **(17)**.

7.4 *TFE-Fluorocarbon Resins*:

7.4.1 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices. Molded parts are exposed to high temperature during fabrication that destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point. Relative to PVC and stainless steel, TFE-fluorocarbon is less sorptive of cations **(18)**.

7.4.2 Extruded TFE-fluorocarbon tubing may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once removed by flushing, should not affect the sample. TFE-fluorocarbon fluorinated ethylene propylene (FEP) and TFE-fluorocarbon perfluoroalkoxy (PFA) resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

7.5 *Glass and Stainless Steel*:

7.5.1 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is generally not used, however, because of difficulties in handling and fabrication. Stainless steel is strong and easily machined to fabricate equipment. It is, however, not totally immune to corrosion that could release metallic contaminants (see Table 1). Stainless steel contains various alloying metals, some of these (that is, Nickel) may catalyze reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on ground-water quality and the constituents of interest.

7.5.2 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be able to be cleaned of trace organics, and must be cleaned between each monitoring well use to avoid cross-contamination of wells and samples. Decontamination of equipment PVC and stainless steel constructed sampling equipment exposed to organic chemicals, pesticides or nitroaromatic compounds generally can be successfully accomplished using a hot detergent solution followed by a hot water rinse. Equipment constructed of LDPE and TFE-fluorocarbon should also be hot air dried or oven dried at approximately 105°C to remove residual pesticides and organic contaminants, respectively **(19, 20)**. A common method to verify that the device is "clean" and acceptable is to analyze a sample (equipment blank) that has been soaked in or passed through the sampling device, or both, to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples that represent the sampling equipment blank, in addition to other blanks (field blank and trip blank). Decontamination procedures are further discussed in Practice D 5088.

7.6 Additional samples are often collected in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chemical Society's committee on environmental improvement has published guidelines for data acquisition and data evaluation, which should be useful in such environmental evaluations **(21)**.

8. Sampling Equipment

8.1 The choice of sampling technique must be based on an understanding of the hydrogeology of the site under investigation and the end use of the data. Since each technique has its advantages and disadvantages, no one technique can be chosen as the best overall technique. Since different techniques will likely yield different results, it is best to be consistent throughout an investigation to facilitate the comparison of data values over time. There is a fairly large choice of equipment presently available for ground-water sampling. The sampling devices can be categorized into the following nine basic types as described in the following sections:

8.1.1 *Down-Hole Collection Devices*:

8.1.1.1 Bailers, messenger bailers, or thief **(22, 23)** are examples of down-hole collection devices. They are not practical for removal of large volumes of water but are relatively inexpensive permitting their dedicated use and are widely used. These devices can be constructed in various shapes and sizes from a variety of materials. They do not subject the sample to pressure extremes.

TABLE 1 Material Considerations In Selection Of Sampling Equipment **(76)**

Material	Considerations
Polytetrafluoroethylene	• Virgin PTFE readily sorbs some organic solutes **(17)** • Ideal material in corrosive environments where inorganic compounds are of interest • Useful where pure product (organic compound) or high concentrations of PVC solvents exist • Potential structural problems because of its low tensile and compressive strengths, low wear resistance, and the extreme flexibility of the casing string as compared to other engineering plastics **(40, 70, 71)** • Potential problems with obtaining a seal between the casing and the annular sealant because of PTFEs low coefficient of friction and antistick properties as compared to other plastics **(71)** • Maximum string length of 2-in. (~5-cm) diameter schedule PTFE casing should not exceed about 375 ft (~115 m) **(72)** • Expensive
Polyvinylchloride	• Leaching of compounds of tin or antimony, which are contained in original heat stabilizers during polymer formulation, could occur after long exposure • When used in conjunction with glued joints, leaching of volatile organic compounds from PVC primer and glues, such as THF (tetrahydrofuran), MEK (methylethylketone), MIBK (methylisobutylketone) and cyclohexanone could leach into ground water. Therefore, threaded joints below the water table, sealed with O-rings or Teflon tape, are preferred • Cannot be used where pure product or high concentrations of a PVC solvent exist • There is conflicting data regarding the resistance of PVC to deterioration in the presence of gasoline **(73)** • Maximum string length of 2-in. (~5-cm) diameter threaded PVC casing should not exceed 2000 ft (~610 m) **(72)** • PVC can warp and melt if neat cement (cement and water) is used as an annular or surface seal because of heat of hydration **(74, 40)** • PVC can volatilize CFCs into the atmosphere within the unsaturated zone, which can be a potential problem for studies of gas and moisture transport through the unsaturated zone • Easy to cut, assemble, and place in the borehole • Inexpensive
Stainless steel	• Generally has high corrosion resistance, which differs with type • Corrosion can occur under acidic and oxidizing conditions • Corrosion products are mostly iron compounds, with some trace elements • Primarily two common types: (*1*) Type 304 Stainless Steel: Iron alloyed with the following elements (percentages): Chromium (18-20 %), Nickel (8-11 %), Manganese (2 %), Silicon (0.75 %), Carbon (0.08 %), Phosphorus (0.04 %), Sulfur (0.03 %) (*2*) SS 316: Iron alloyed with the following elements (in percentages): Chromium (16-18 %), Nickel (11-14 %), Manganese (2 %), Molybdenum (2-3 %), Silicon (0.75 %), Carbon (0.08 %), Phosphorus (0.04 %), Sulfur (0.03 %) • Corrosion resistance is good for Type 304 stainless steel under aerobic conditions. Type 316 stainless steel has improved corrosion resistance over Type 304 under reducing conditions **(75)** • Expensive
Galvanized steel	• Less corrosion resistance than stainless steel and more resistance to corrosion than carbon steel (see Carbon steel entry) • Oxide coating could dissolve under chemically reduced conditions and release zinc and cadmium, and raise pH • Weathered or corroded surfaces present active adsorption sites for organic and inorganic constituents • Inexpensive
Carbon steel	• Corrosion products can occur (for example, iron and manganese oxides, metal sulfides, and dissolved metal species) • Sorption of organic compounds onto metal corrosion products is possible • Weathered surfaces present active adsorption sites for organic and inorganic constituents • Inexpensive

8.1.1.2 A schematic of a single check valve unit is illustrated in Fig. 2. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon, stainless steel, and PVC are the most common materials used for construction **(24)**.

8.1.1.3 In operation, the single check valve bailer is gently lowered into the well to a depth just below the water surface, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without sample loss through the check valve.

8.1.1.4 A double check valve bailer allows point source sampling at a specific depth **(25, 26)**. The double check valve bailer is also effective at collecting dense, non-aqueous phase liquid (DNAPL) from the bottom of a monitoring well. An example is shown in Fig. 3. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes through the unit with limited restriction. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation.

8.1.1.5 A top-filling bailer is a closed bottom tubular device, opened on top and provided with a loop or other fixture to attach to the drop line. The top-filling bailer is gently lowered below the water surface in the well and water pours into the bailer from the top. Although this variation on the bailer design

TABLE 2 Chemical Compatibility Table For Selected NAPL (78)

Chemical	PTFE (Teflon)	PP (Polypropylene)	PVC (Type I)	PVC (Type II)	304 Stainless	316 Stainless	Carbon Steel
Benzene	R	X	U	U	G	G	G
Carbon Tetrachloride	R	U	X	U	E	E	G
Dichlorobenzene	R	R	U	U	. . .	G	. . .
Dichloroethane (DCA)	R	X	U	U	G	G	G
Dichloroethylene (DCE)	R	R	U	U	G	G	. . .
Diesel Fuel	R	R	R	. . .	E	E	G
Ethyl Benzene	R	U	U	U	S	G	U
Gasoline	R	X	R	. . .	G	G	G
Hydraulic Oil (petro.)	R	X	R	. . .	R	R	. . .
Hydraulic Oil (synthetic)	R	X	R	. . .	R	R	. . .
Jet Fuels	R	X	R	R	G	G	G
Kerosene	R	R	R	R	G	G	G
Motor Oil	R	X	R	R	G	G	G
Napthalene	R	R	U	U	E	E	G
Tetrachloroethylene (PCE)	R	U	U	U	E	E	G
Toluene	R	R	U	U	E	E	E
Trichloroethylene (TEC)	R	R	U	U	G	G	G
Xylenes	R	R	U	U	G	G	G

For Metals
E < 2 mills Penetration/Year
G < 20 mills Penetration/Year
S < 50 mills Penetration/Year
U > 50 mills Penetration/Year
(1 mill = 0.001 in.)
R = Resistant (No corrosion rate reported)

For All Non-Metals
R = Resistant
U = Unsatisfactory
X = Conflicting Data, at least one reference reported unsatisfactory

results in greater agitation of the sample, it may be used to collect a sample of light, non-aqueous phase liquid (LNAPL) by lowering it just below the surface of the LNAPL and allowing the bailer to skim the LNAPL from the surface of the water column.

8.1.1.6 The differential pressure bailer is a sealed canister body with two small diameter tubes of different heights built into its removable top **(14)**. The bailer is usually constructed of stainless steel to provide sufficient weight to allow it to sink relatively quickly to the desired sampling depth. Once the bailer's downward progress is stopped, differences in hydrostatic pressure between the two tubes allows the bailer to fill through the lower tube as air is displaced through the upper tube. This type of bailer minimizes the exposure of the sample to air especially if fitted with internal 40 mL vials for direct sample bottle filling.

8.1.1.7 Special care must be taken to minimize exposing the sample to the atmosphere during the transfer of the sample from the bailer to the sample bottle. There are several approaches to overcome this issue. Bottom-emptying bailers used for sampling of VOCs, for example, should have an insertable sample cock or draft valve cock (often referred to as a bottom or bailer emptying device) in or near the bottom of the sampler allowing withdrawal of a sample from the bailer with minimal atmosphere exposure.

8.1.1.8 Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. A plastic sheet may be spread out on the ground around the monitoring well for this purpose. Disposable TFE-fluorocarbon, PVC, polyethylene, and polypropylene bailers are available which offer time savings and all but eliminates the potential for cross contamination during sampling.

8.1.1.9 Sample oxidation is a concern with single check valve and top filling bailers. Sample oxidation might occur during the extended time it takes to bail a sample if water levels are a great depth below the ground surface or if there is a delay in the transfer of the sample from the bailer to the sample bottles. Using point source bailers, however, minimizes the oxidation problem.

8.1.1.10 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber **(27)**. Foerst, Kemmerer, and Bacon samplers are of this variety **(23, 24, 26)**. A number of thief or messenger devices are available in various materials and shapes. Differential pressure bailers **(14)** also provide a point source sample but do not require manual tripping.

8.1.2 *Bladder Pumps*:

8.1.2.1 Bladder pumps consist of a flexible membrane enclosed by a rigid housing. Water enters the pump cavity through an inlet, usually located on the bottom of the pump. Compressed gas either from a compressor or air cylinder is injected into a bladder within the pump cavity forcing the check valve on the inlet to close and the sample up through a second check valve at the top of the pump and into a discharge line (Fig. 4). Water is prevented from re-entering the bladder by the top check valve. The bladder is then depressurized, allowing the pump to refill. The process is repeated to cycle the water to the surface. Samples taken from depths of 122 m (400 ft) have been reported.

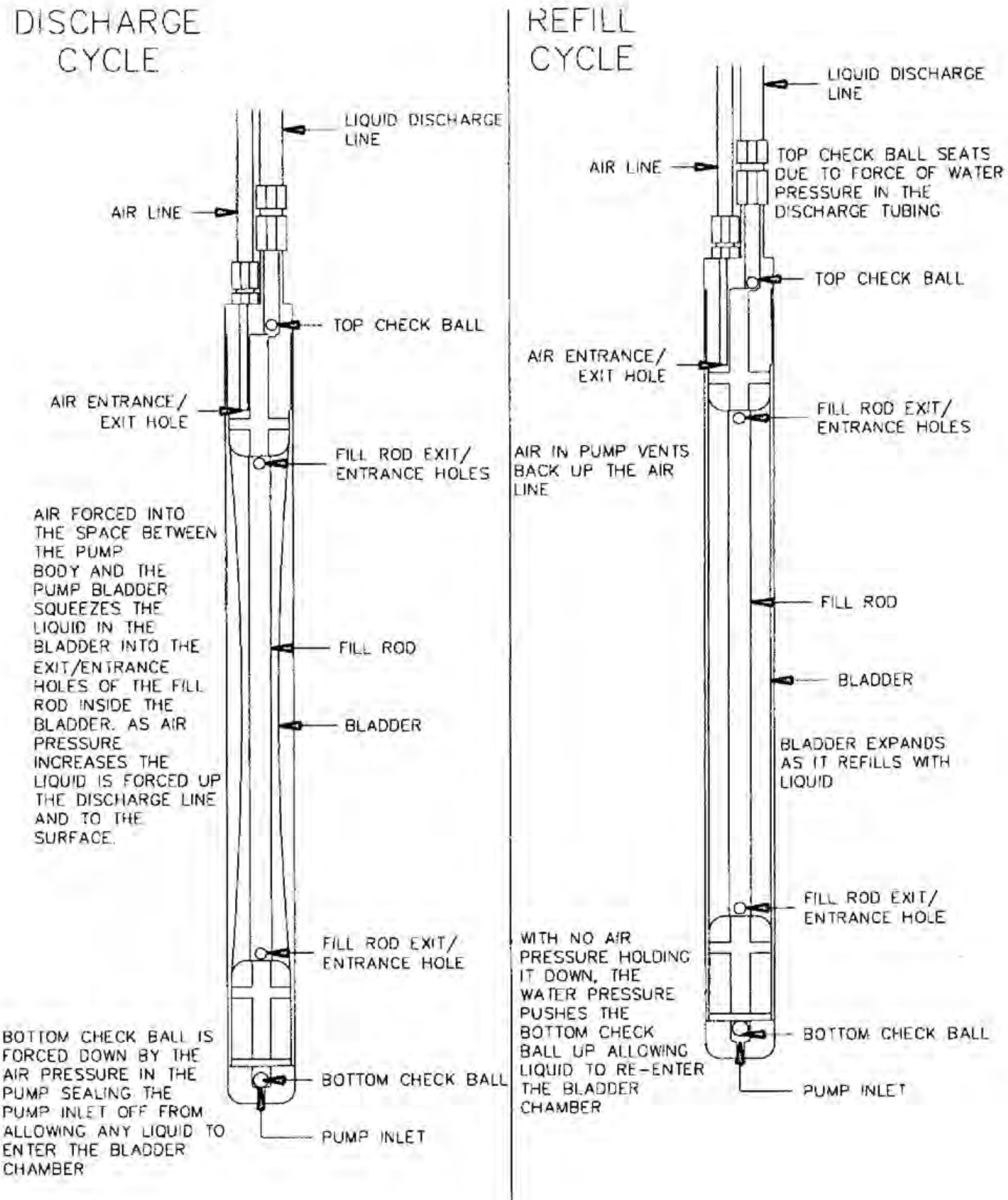


FIG. 4 Squeeze Type Bladder Pump

8.1.2.2 A variety of design modifications and materials are available **(29, 30)** however, TFE-fluorocarbon bladders, either PVC, TFE-fluorocarbon resin or stainless steel bodies and fittings are most common. An automated controller system is used to control the time between pressurization cycles and regulate pressure.

8.1.2.3 Bladder pumps have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volumes required, and difficulty in decontaminating the pump. This pump design is most applicable to dedicated well installations and where low pump rate or flow rate (less than 0.5 L/min) are required. The flow rate from a bladder pump is dependent on the dimensions of the bladder pump, controller settings, gas pressure, and total dynamic head.

8.1.3 *Suction Lift Pumps*:

8.1.3.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. The theoretical suction limit is about 10.4 m (34 ft), but most suction pumps are capable of maintaining a water lift of only 7.6 m (25 ft) **(31)**.

8.1.3.2 Many suction pumps draw water through a volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of non-inert materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or potentially cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps may be acceptable for purging of wells, but should not generally be used for sampling.

8.1.3.3 An exception to the above statements is a peristaltic pump (also known as a rotary peristaltic pump). A peristaltic pump is a self-priming, low-volume suction pump that consists of a rotor with rollers **(32)**. Flexible tubing is inserted around the pump rotor and squeezed by rollers as they rotate. One end of the tubing is placed into the well (a weighted end may be used) while the other is connected directly to a receiving vessel. As the rotor moves, reduced pressure is created in the well tubing and an increased pressure on the tube leaving the rotor head. Pumping rates may be controlled by varying the speed of the rotor or by changing the size of the pump head, which contains the pump rotor.

8.1.3.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may be degassed (cavitation is unlikely), but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pump head itself. A section of silicone tubing is commonly used within the peristaltic pump head, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement **(33)** recommends using medical grade silicone tubing for VOC sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton[4] for use with their pumps. Plasticized polypropylene tubings and LDPE should be avoided if flow rates less than 0.1 L/min (0.025 g/min) are used **(10)**. The extraction rate with this method can range from 0.04 to 30 L/min (0.01 to 8 gal/min) **(34)**.

8.1.3.5 There is disagreement on the applicability of peristaltic pumps for the collection of groundwater samples. Research by Tai, et al **(35)** has shown that peristaltic pumps provide adequate recovery of VOCs. The U.S. EPA **(4)** does not recommend its use because of studies that suggest that VOCs may be lost during sampling **(36)**.

8.1.3.6 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two-way stopper bottle and a hand held or mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism **(37, 38)**.

8.1.3.7 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement **(37, 38, 39)**.

8.1.3.8 Suction pump approaches offer a simple sample retrieval method for shallow monitoring wells. The direct line method is portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 L/min (5 to 40 gal/min) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps, as discussed in 8.1.3.4.

8.1.3.9 All three systems can be specially designed so that the water sample contacts only the TFE-fluorocarbon or silicone tubing prior to sample bottle entry. Dedicated tubing is recommended for each well or piezometer sampled. Each of these methods that relay on suction can change solution chemistry by causing degassing which may result in loss of volatile compounds and dissolved gasses and this should be a consideration in their application **(34)**.

8.1.4 *Electric Submersible Pumps*:

8.1.4.1 A submersible pump consists of a sealed electric motor that powers a piston, impeller, or helical single thread worm. Water is brought to the surface through a discharge tube. Similar pumps are commonly used in the water well industry and many designs exist **(40)**.

8.1.4.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 L/min (1.2 gal/min) flow rate at 33.5 m (110 ft) has been developed **(41)**. Another submersible pump has an

---

[4] Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.

outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 L/min (14 gal/min) depending upon the depth of the total dynamic head **(42)**.

8.1.4.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the discharge tube during sampling. The possibility of introducing trace metals into the sample from pump materials also exists; however, submersible pumps designed specifically for environmental work do exist. These pumps are constructed of relatively inert materials such as stainless steel, TFE-fluorocarbons and Viton. Decontamination procedures are discussed in Practice D 5088. Recent research, however, has suggested that steam cleaning followed by rinsing with unchlorinated, deionized water should be used between samplings when analysis for VOCs is required **(43)**. Complete decontamination of submersible pumps is difficult and should be confirmed by the collection of equipment blanks.

8.1.4.4 Submersible pumps have several disadvantages that should be considered. The silt and fine sand commonly present in monitoring wells may cause excessive wear to internal impellers and staters. These pumps also commonly require a high-amperage 120/220-V power source and a reel and winch system that limit their mobility. Submersible pumps may also not be suitable for collecting liquids containing VOCs or dissolved gasses because of their potential to degas the sample.

8.1.5 *Gas-Lift Pumps*:

8.1.5.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water **(44, 45)**.

8.1.5.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing **(45)**. In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping **(40)**. A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.

8.1.5.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, and pressurized air cylinders have been used. When air compressors are used, an air-oil filter must be installed to minimize the introduction of oil to the well.

8.1.5.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for VOCs or dissolved gasses (for example, DO, methane). The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb **(11)** expressed concerns in sampling for inorganics. These concerns were attributed to changes in redox, pH, and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

8.1.6 *Gas Displacement Pumps*:

8.1.6.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig. 5. Water fills the chamber. A positive pressure is applied to the gas line closing the sampler check valve and forcing water up the sample line. The cycle is repeated by removing the pressure. Vacuum can also be used in conjunction with the gas **(46)**. The device can be permanently installed in the well **(47, 48, 49)** or lowered into the well **(50, 51)**.

8.1.6.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed **(52, 53)**. The unit was designed specifically for sample testing for trace level organics. Continuous flow rates of up to 38 L/min (10 gal/min) are possible.

8.1.6.3 Gas displacement pumps offer reasonable potential for preserving sample integrity because little driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses and contamination from the driving gas and the housing materials.

8.1.7 *Gas Driven Piston Pumps*:

8.1.7.1 A double piston pump powered by compressed air is illustrated in Fig. 6. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston that allows water entry during the suction stroke of the piston and forces the sample to the surface during

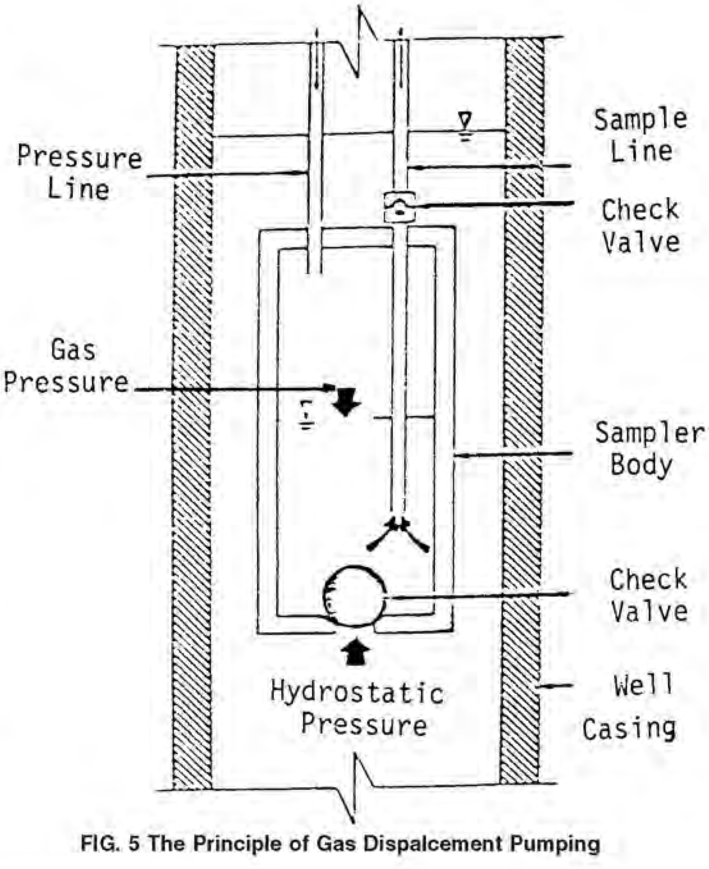


FIG. 5 The Principle of Gas Dispalcement Pumping

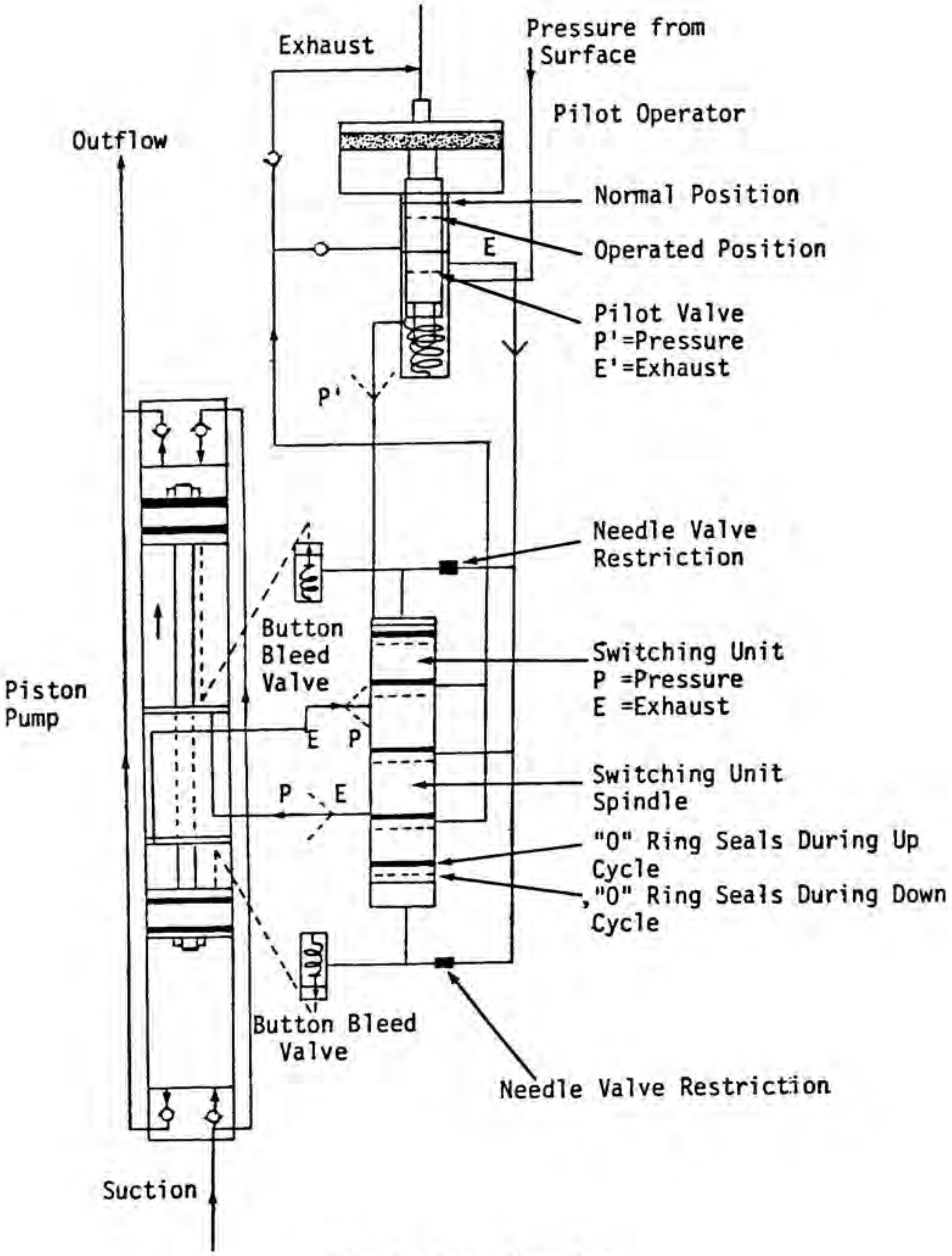


FIG. 6 Gas-Driven Piston Pump

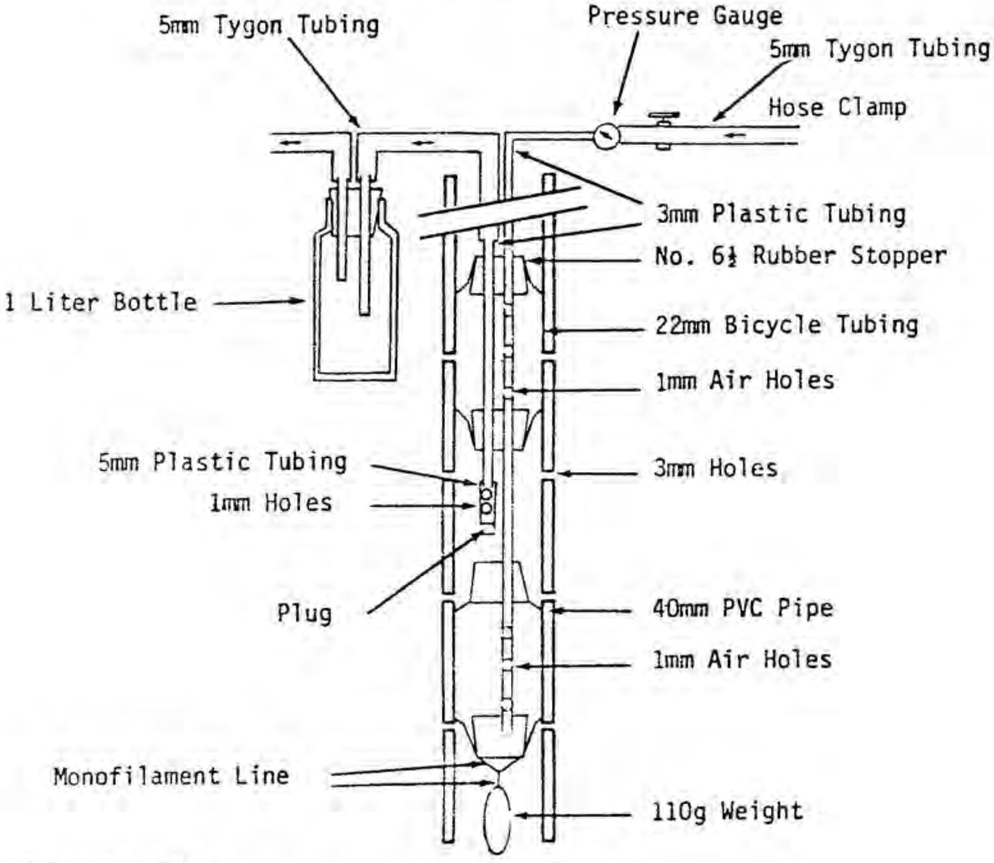
the pressure stroke (**54**). Pumping rates between 0.16 and 0.51 L/min (0.04 and 0.13 gal/min) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

8.1.7.2 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

8.1.8 *Packer Pump Arrangement*:

8.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between packers within a well. Since the hydraulic or pneumatic activated packers are pressed against the casing wall, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed of a rubber compound (**54-57**). A packer pump unit consisting of a vacuum sampler positioned between packers is illustrated in Fig. 7 (**58**).

8.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Because access to



Taken from Ref **(79)**

FIG. 7 Packer Pump Arrangement

the interval between packers is blocked once the packers are inflated, the selection of sampling devices is limited to sampling pumps. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

8.1.9 *Inertial-Lift Pumps*:

8.1.9.1 The inertial-lift pump consists of a foot valve at the end of a flexible tube. The tube and foot valve is inserted into the well with one end of the tube remaining at the surface. The tube is then rapidly moved in a continuous up-and-down motion. Each upward stroke lifts the water column in the tubing a distance equal to the stroke length. At the end of the upstroke, the water continues to move slightly upward by inertia. On the down stroke, the foot valve opens allowing fresh water to enter the tube. This process continues resulting in a flow to the surface.

8.1.9.2 The inertial-lift pump is capable of operating efficiently at depths to 30 m (100 ft). It is effective in small diameter wells or direct-push technology probes which are typically 12.5 mm (½-in.) diameter. The pumping rate ranges from 0 to 7.6 L/min (0 to 2 gal/min) **(34)**, depending on the rate of the up and down pumping stroke and the tube diameter. The equipment used in this pump is inexpensive enough to be dedicated to a well with the exception of the pump handle or motor drive that do not contact the sample.

8.1.9.3 The inertial-lift pump, however, has several disadvantages. It is difficult to operate in deep, large diameter wells. Although a motor drive can overcome this limitation, the incorporation of a motor drive limits the portability of the equipment. The foot valve must be selected to match the casing material since it will tend to ride against the casing and potentially will either damage the casing or wear out. The discharge tubing must be stiff for the pump to operate properly. This makes the tubing awkward to install and remove from a monitoring well.

8.1.10 *Minimal Purge, Discrete Depth, and Passive Sampling*—Sampling techniques that do not rely on, or require only minimal purging may be used if a particular zone within a screened interval is to be sampled or if a well is not capable of yielding sufficient ground water for purging. These techniques include minimal purge, discrete depth sampling, and passive sampling.

8.1.10.1 A dedicated pump is used for minimal purge sampling so that only enough water is purged through the pump so that the volume of water contained by the pump and discharge tube is removed before sampling. No attempt is made to purge the casing, screen, or formation. This volume should be minimized by the selection of small diameter tubing and the smallest possible pump chamber. This initial volume of discharged water is discarded since it had prolonged contact with the sampling device.

8.1.10.2 The discrete depth sampler is often non-dedicated. It is lowered very slowly to the depth of the screen where a water sample is drawn into the sampling chamber. This is accomplished either manually by using a triggering mechanism such as a cable or automatically such as with a differential pressure bailer **(14)**. Discrete depth samplers, however, must be used with great caution because of the potential of mixing of the water column in the well casing while lowering the sampler to its sampling depth.

8.1.10.3 Passive sampling, using diffusion samplers (a water-filled membrane), is based on the principle of molecular diffusion of VOCs from the ground water into the sampler. (Research is currently being conducted by the U. S. Geological Survey to evaluate diffusion samplers for the collection of non-VOC parameters, however, study results have not been published.) The samplers must remain in the borehole for an adequate time for the water initially within the sampler to equilibrate with that in the borehole. The diffusion sampler typically consists of water-filled, low-density polyethylene tubing, which acts as a semi-permeable membrane. The sampler is attached to a weighted line, and lowered to a predetermined depth within the screened interval. Since the sample is depth specific, multiple samplers may be strung together to provide samples from different depths within the well. After adequate residence time has elapsed, the sampler(s) are removed from the well, punctured and the sample transferred into sample bottles. The samples are preserved and submitted to the laboratory for analysis. In a study of this technique, a minimum of 11 days was required to achieve equilibration **(59, 60)**. Concerns about the applicability of this sampling method to specific VOCs have been raised, however, no detailed evaluation of this issue has been published. In a comparison of sampling techniques, samples collected by the diffusion method were found to be biased lower than samples collected using a low-flow method **(61)**, however, this difference was attributed to issues with the laboratory or to the depth-specific nature of diffusion samplers.

9. Sample Containers and Preservation

9.1 The order of sample container filling, method of filling, selection of sample container type, and preservation method should be provided in the sampling and analysis plan. Generally, the order of sample container filling should proceed from most volatile to least volatile compound.

9.2 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard chemical reactions and complexes, and reduce the volatilization of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and freezing. For water samples, immediate refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include the temperature to which the samples were exposed. Inexpensive devices for this purpose, such as a recording thermometer, are available for this purpose. A water-filled bottle may be included in the sample-shipping container for temperature measurement by the laboratory receiving the samples.

9.3 All bottles and containers must be specially pre-cleaned, and organized in ice chests (isolating samples and sampling equipment from the environment) before one goes into the field. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labeling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Examples of detailed plans and documentation procedures have been published **(23, 62,** see Guide D 6089).

9.4 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, the individual laboratory protocols, and the required QC samples. Since a well may not be capable of yielding adequate sample volume, a minimum required sample volume should be provided to the sample crew. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

9.5 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils **(22, 23, 29, 58, 63-65)**. Some of this information is summarized in Table X1.1 and Guide D 6517, however, different regulatory programs have specific requirements that must be met.

9.6 Sample containers for VOC samples require special cleaning and handling considerations **(66)**. The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-fluorocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring a sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independently preserved samples. The sampling program for VOCs should include at a minimum trip blanks. Trip blanks and field spikes should also be considered for low level analysis.

9.7 The laboratory must analyze the purgeable samples within 14 days after collection. For samples for solvent extractions (extractable organics-base neutrals, acids, pesticides, herbicides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note 1). Samples for organic extraction must be extracted within 7 days and analyzed within 40 days after extraction.

NOTE 1—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

9.8 For a number of ground-water parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well (see Test Method D 4750) and parameters that can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication **(67)** and detailed procedures are outlined in a U.S. Geological Survey publication **(68, 69)**. Although a discussion of water level measuring techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made either before a well is purged or after it has had sufficient time to recover. Parameters that can change rapidly with storage include pH, turbidity, redox potential, DO, and temperature. Specific conductance, although most accurately determined in a laboratory setting, often is measured in the field where it is used as an indicator parameter to determine the completeness of purging. For some of the other parameters, the emphasis in ground-water monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 µm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include metals, radioactivity parameters, dissolved organic carbon, dissolved orthophosphate, and total dissolved phosphorous **(22, 23)**. If metals are to be analyzed, filter the sample prior to acid preservation. If concerns related to the loss of mobile colloidal material by filtering is a consideration, sampling protocol should be modified to limit sample turbidity during collection so that filtering is not necessary. This is often done by using very low purge and sample flow rates. For total organic carbon (TOC), the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well determined. However, if results of metal, TOC or other parameters that could be affected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

9.9 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit or weekend delivery receipt. All samples for organic analysis (and many other parameters), should be maintained at 4°C (±2°C) **(65)** during storage and shipping and should arrive at the laboratory within one day after shipment. Sample receipt should be verified to provide an opportunity to trace a lost shipment or to resample if breakage occurs during shipment.

9.10 A commonly used shipping container is an insulated ice chest (cooler) equipped with bottle dividers. An overnight courier service is recommended, if personal delivery service is not practical. Care must be taken in packaging the ice so that no leakage occurs. Such leakage may damage sample labels or, if it escapes the sample cooler, may be misconstrued to be hazardous liquid by the courier. Sample paperwork, including the chain-of-custody, should be enclosed in a sealed plastic bag and taped to the inside lid of the shipping container to protect it from water. Sample containers may be sealed in plastic bags to protect sample labels from water damage from melting ice or sample leakage from other bottles.

9.11 Many courier services have strict shipping requirements for samples that are "hazardous." The courier service should be contacted prior to field activities if there is a concern about how to ship a sample.

10. Keywords

10.1 diffusion sampling; ground water; low flow; low stress; minimal purge; monitoring; purge; sampling; stabilization; well

APPENDIX

(Nonmandatory Information)

X1. SAMPLE HANDLING PROCEDURES FOR GROUND WATER MONITORING PARAMETERS

X1.1 See Table X1.1 for procedures for handling samples.

TABLE X1.1 Sample Handling Procedures For Ground Water Monitoring Parameters (77)

Parameter[A]	Bottle Type[A]	Preservative	Volume Required for Analysis, min (mL)[B]	Storage Time[C] (with Preservation, where applicable), max
pH	P,G	None, analyze immediately for field measurement	25	ASAP (≤48 h) for lab measurement
Specific Conductance	P,G	Cool (4°C)	100	28 days
Alkalinity and Bicarbonate	P,G	Cool (4°C)	100	14 days
COD	P,G	Analyze ASAP (≤48h) or add H_2SO_4 to pH<2; cool (4°C)	100	28 days
TDS	P,G	Cool (4°C)	100	7 days
TSS	P,G	Cool (4°C)	100	7 days
Chloride	P,G	None	50	28 days
Fluoride	P	None	300	28 days
Nitrate	P,G	Analyze ASAP (≤48h) or add H_2SO_4 to pH<2; cool (4°C)	100	28 days
Sulfate	P,G	Cool (4°C)	50	28 days
Ammonia	P,G	Analyze ASAP (≤48h) or add H_2SO_4 to pH<2; cool (4°C)	500	28 days
Mercury	P,G	HNO_3 to pH<2	100	28 days
Metals, Dissolved (Including Ca, Mg, K, Na)	P,G	Filter on site; HNO_3 to pH<2	200	6 months
Metals, Total (Including Ca, Mg, K, Na)	P,G	HNO_3 to pH<2	100	6 months
Phenols	P,G	Add H_2SO_4 pH<2; cool (4°C)	500	28 days
Hardness	P,G	HNO_3 to pH<2	100	6 months
Volatile Organic Compounds (VOC)	G, TFE-lined cap	Add HCL to pH<2; cool (4°C)	2 × 40 ml	14 days
Total Organic Carbon (TOC)	G, TFE-lined cap	Add H_2SO_4 or HCL to pH<2; cool (4°C)	40	28 days
Total Organic Halogen (TOH)	Amber glass, TFE-lined cap	H_2SO_4 to pH<2 and cool (4°C) for EPA 9020A; cool (4°C) for EPA 9022	250	28 days
Turbidity	P, borosilicate glass	Cool (4°C)	100	48 h

[A] P = Plastic (polyethylene or equivalent); G = Glass; G, TFE-lined cap = Glass screw-cap vials sealed with Teflon-faced silicone septa.

[B] Individual laboratories may request more than the minimum volume.

[C] ASAP = As soon as possible.

REFERENCES

(1) Barcelona, Michael J., Wehrmann, H. Allen, and Varljen, Mark D., "Reproducible Well-Purging Procedures and VOC Stabilization Criteria for Ground-water Sampling," *Ground Water*, Vol 32, No. 1, 1994, pp. 12-22.

(2) Puls, Robert W., and Powell, R. M., "Acquisition of Representative Ground Water Quality Samples for Metals," *Ground Water Monitoring Review*, 1992, pp. 16-176.

(3) Gibb, J. P., Schuller, R. M., and Griffin, R. A., *Monitoring Well Sampling and Preservation Techniques*, EPA-600/9-80-101, 1980.

(4) *Data Quality Objectives Process for Hazardous Waste Site Investigations*, EPA QA/G-4HW, EPA/600/R-00/007, U.S. EPA, January 2000.

(5) *RCRA Ground-Water Monitoring Draft Technical Guidance*, Office of Solid Waste, U.S. EPA, 1992.

(6) Humenick, M. J., Turk, L. J., Coldrin, M.,"Methodology for Monitoring Ground Water at Uranium Solution Mines," *Ground Water*, Vol 18 (3), May–June 1980, p. 262.

(7) *RCRA Technical Enforcement Guidance Document*, OSWER-9950.1, 1985.

(8) Marsh, J. M., and Lloyd, J. W., "Details of Hydrochemical Variations in Flowing Wells," *Ground Water*, Vol 18 (4), July-August 1980, p. 366.

(9) Nielsen, David M., Nielsen, Gillian L., "Technical Guidance on Low-flow Purging & Sampling and Passive Sampling," *NEFS-TG001-99*, Nielsen Environmental Field School, Galena, OH, 1999.

(10) Parker, Louise V., and Ranney, Thomas A., "Sampling Trace-Level Organics with Polymaric Tubing," *Dynamic Studies Special Report*, 97-2, 1997.

(11) Gibb, J. P., Schuller, R. M., and Griffin, R. A., "Collection of Representative Water Quality Data from Monitoring Wells," *Proceeding of the Municipal Solid Waste Resource Recovery Symposium*, EPA-600/9-81-002A, March 1981.

(12) Powell, R. M., and Puls, R. W., "Passive Sampling of Ground Water Monitoring Wells without Purging: Multilevel Well Chemistry and Tracer Disappearance," *Journal Contam. Hydrol.*, 12, 1993, pp. 51-77.

(13) Kearl, P., Korte, N., and Cronk, T., "Suggested Modifications to Ground Water Sampling Procedures based on Observations from the Colloidal Borescope," *Ground Water Monitoring Review* Vol 12, No. 2, 1992, pp. 155-166.

(14) Smyth, R. E., and Wayne, T., "New Sampling Device Provides Laboratory Verification," Part 1 of 2, Publication of Sibak Industries, Limited, Inc., presented at the Waste Testing and Quality Assurance Symposium, Arlington, VA, August 1999.

(15) McCaulou, Douglas R., Jewett, D. G., Huling, S., "Compatibility of NAPLs and Other Organic Compounds with Materials used in Well Construction, Sampling, and Remediation," *Ground Water Monitoring and Remediation*, 1996, pp. 125-131.

(16) Boettner, E. A., Gwendolyn, L. B., Zand, H., and Aquino, R., *Organic and Organotin Compounds Leached from PVC and CPVC Pipe*, NTIS P8 82-108 333, 1982.

(17) Parker, Louise V. , and Ranney, Thomas A., "Effect of Concentration on Sorption of Dissolved Organics by PVC, PTFE, and Stainless Steel Well Casings," *Ground Water Monitoring Review*, Vol 14, No. 3, 1994, pp. 139-149.

(18) Ranney, Thomas A., and Parker, Louise V., "Sorption and Leaching of Trace Level Metals by Polymeric Well Casings," Special Report 96-2, 1996.

(19) Parker, Louise V., and Ranney, Thomas A., "Decontaminating Materials Used in Groundwater Sampling Devices," Special Report 97-25, 1997.

(20) Parker, Louise V., and Ranney, Thomas A., "Decontaminating Groundwater Sampling Devices," Special Report 97-25, 1997.

(21) ASC Committee on Environmental Improvement, "Guidelines for Data Acquisition and Data Quality Evaluation in Environmental Chemistry." *Analytical Chemistry*, Vol 52, 1980, pp. 2242–2249.

(22) *Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities*, EPA/530/SW-611, August 1977.

(23) *Handbook for Sampling and Sample Preservation of Water and Wastewater*, U.S. Dept. of Commerce NTIS PB-259 946, September 1976.

(24) Timco Manufacturing Co., Inc., "Variable Capacity Bailer," *Timco Geotechnical Catalogue*, Prairie du Sac, WI, 1982.

(25) deVera, E., Simmons, B., Stephens, R., and Storm, D., *Samplers and Sampling Procedures for Hazardous Waste Streams*, Environmental Protection Agency, EPA-600/2-80-018, 1980, p. 51.

(26) Morrison, R., *Ground Water Monitoring Technology*, Timco Manufacturing Co., 1982, p. 276.

(27) Eijelkamp, "Equipment for Soil Research," *General Catalogue*, Geisbeek, The Netherlands, 1979, pp. 82–83.

(28) Wood, W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, 1976, p. 24.

(29) Gilham, R. W., "Syringe Devices for Groundwater Monitoring," *Ground Water Monitoring Review*, Vol 2 (2), Spring 1982, p. 36.

(30) *Remote Sampler Model 200*, Markland Specialty Engineering, Ltd., Etobicoke, Ontario, Bulletin 200/78, 1978.

(31) Herzog, B., Pennino, J., and Nielsen, G., "Ground-Water Sampling," *Practical Handbook of Ground-Water Monitoring*, Nielsen, D. M., ed., Lewis Publishers, Chelsea, MI, 1991, pp. 449-499.

(32) Masterflex, *Masterflex Pump Catalogue*, Barnant Corp., Barrington, IL, 1981.

(33) "Guidelines for Contracting Sampling and Analyses for Priority Pollutants in Pulp and Paper Industry Effluents," *NCASI Stream Improvement Technical Bulletin*, No. 335, August 1980.

(34) Federal Remediation Technologies Roundtable, Field Sampling and Analysis Technologies Matrix Version 1.0, http://www.frtr.gov/site/, revised February 6, 1999.

(35) Tai, D. Y., Turner, K. S., and Garcia, L. A., "The Use of a Standpipe to Evaluate Ground Water Samplers," *Ground-Water Monitoring Review*, Winter, 1991, pp. 125-132.

(36) Imbrigiotta, T. E., Gibs, J., Fusillo, T. V., Kish, G. R., and Hochreiter, J. J., "Field Evaluation of Seven Sampling Devices for Purgeable Organic Compounds," *Ground-Water Contamination: Field Methods*, Collins, A. G. and Johnson, A. J., eds., ASTM STP 963, ASTM, Philadelphia, 1988, pp. 258-273.

(37) Allison, L., "A Simple Device for Sampling Ground Water in Auger Holes," *Soil Science Society of America Proceedings*, No. 35, 1971, pp. 844–845.

(38) Willardson, L., Meek, B., and Huber, M., "A Flow Path Ground Water Sampler," *Soil Science Society of America Proceedings*, No. 36, 1972, pp. 965–966.

(39) Wilson, L., *Monitoring in the Vadose Zone: A Review of Technical Elements and Methods*, U.S. Environmental Protection Agency, EPA-60017-80-134, 1980, p. 180.

(40) Driscoll, F. G., *Ground Water and Wells*, Johnson, Filtration Systems, Inc., St. Paul, MN, 1986, p. 1189, Table 21.6, and p. 324.

(41) Keck, W. G., and Associates, *New "Keck" Submersible Water Sampling Pump for Groundwater Monitoring*, Keck, W. G. and Associates, East Lansing, MI, 1981.

(42) McMillion, L., and Keeley, J. W., "Sampling Equipment for Ground-Water Investigation," *Ground Water*, Vol 6, 1968, pp. 9–11.

(43) Industrial and Environmental Analysts, Inc., *Procedures and Equipment for Groundwater Monitoring*, Industrial and Environmental Analysts, Inc., Essex Junction, VT, 1981.

(44) Sommerfeldt, T., and Campbell, D., "A Pneumatic System to Pump Water From Piezometers," *Ground Water*, Vol 13, 1975, p. 293.

(45) Smith, A., "Water Sampling Made Easier with New Device," *The Johnson Drillers Journal*, July-August 1976, pp. 1-2.

(46) Trescott, P., and Pinder, G., "Air Pump for Small-Diameter Piezometers," *Ground Water*, Vol 8, 1970, pp. 10–15.

(47) Morrison, R., and Ross, D., "Monitoring for Groundwater Contamination at Hazardous Waste Disposal Sites," *Proceedings of 1978 National Conference on Control of Hazardous Material Spills*, Miami Beach, FL, April 13, 1968, pp. 281–286.

(48) Morrison, R., and Brewer, P. "Air-Lift Samplers for Zone-of-Saturation Monitoring," *Ground Water Monitoring Review*, Spring 1981, pp. 52–54.

(49) Morrison, R., and Timmons, R., "Groundwater Monitoring II," *Groundwater Digest*, Vol 4, 1981, pp. 21–24.

(50) Bianchi, W. C., Johnson, C., Haskell, E., "A Positive Action Pump for Sampling Small Bore Holes," *Soil Science Society of America Proceedings*, Vol 26, 1961, pp. 86–87.

(51) Timmons, R., Discussion of "An All-Teflon Bailer and an Air-Driven Pump for Evacuating Small-Diameter Ground-Water Wells," by Buss, D., and Bandt, K., *Ground Water*, Vol 19, 1981, pp. 666–667.

(52) Timco Manufacturing Co., Inc., "Gas Lift Teflon Pump," *Timco Geotechnical Catalogue*, Prairie du Sac, WI, 1982.

(53) Tomson, M., King, K., and Ward, C., "A Nitrogen Powered Continuous Delivery, All Glass Teflon Pumping System for Groundwater Sampling from Below 10 Meters," *Ground Water*, Vol 18, 1980, pp. 444–446.

(54) Signor, D., "Gas-Driven Pump for Ground-Water Samples," *U.S. Geological Survey, Water Resources Investigation 78–72*, Open File Report, 1978.

(55) *Tigre Tierra HX Pneumatic Packer*, Tigre Tierra, Inc., Puyallup, WA, 1981.

(56) Cherry, R., "A Portable Sampler for Collecting Water Samples from Specific Zones in Uncased or Screened Wells," *U.S. Geological Survey*, Prof. Paper 25-C, 1965, pp. 214–216.

(57) Grisak, G., Merritt, W., and Williams, D., "Fluoride Borehole Dilution Apparatus for Groundwater Velocity Measurements," *Canadian Geotechnical Journal*, Vol 14, 1977, pp. 554–561.

(58) Galgowski, C., and Wright, W., "A Variable-Depth Ground-Water Sampler," *Soil Science Society of America Proceedings*, Vol 44, 1980, pp. 1120–1121.

(59) Vroblesky, D. A., and Hyder, W. T., "Diffusion Samplers as an Inexpensive Approach to Monitoring VOCs in Ground Water," *Ground Water Monitoring Review* 12, No. 3, 1992, pp. 177-184.

(60) Gefell, M. J., Hamilton, L. A., and Stout, D. J., "Comparison between Low-flow and Passive-diffusion Bag Sampling Results for Dissolved Volatile Organics in Fracture Sedimentary Bedrock," Proceedings of the Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Remediation Conference and Exposition, Nov. 17-19, 1999, Houston, TX, pp. 304-315.

(61) Parsons Engineering Science, Inc., "Technical Report for the Evaluation of Groundwater Diffusion Samplers," prepared for the Air Force Center for Environmental Excellence, Technology Transfer Division, 1999.

(62) *Samplers and Sampling Procedures for Hazardous Waste Streams*, U.S. EPA MERL Laboratory, Cincinnati, OH, EPA-600/2-80-018, January 1980.

(63) *Methods for Chemical Analysis of Water and Wastes*, EPA-600/4-79-020, U.S. EPA EMSL Laboratory, Cincinnati, OH, March 1979.

(64) *Standard Methods for the Examination of Water and Wastewater*, APAA, 14th ed., Washington, DC, 1976, pp. 38–45.

(65) U.S. EPA, "Test Methods for Evaluation Solid Wastes, Physical/Chemical Methods (SW846)," Third Edition, September 1986; Final Update I, July 1992; Final Update IIA, August 1993; Final Update II, September 1994; Final Update IIB, January 1995, and Final Update III, December 1996.

(66) *Handbook for Analytical Quality Control in Water and Wastewater Laboratories*, EPA-600/4-79-019, U.S. EPA EMSL Laboratory, Cincinnati, OH, March 1979.

(67) "A Guide to Groundwater Sampling," *NCASI Technical Bulletin*, No. 362, National Council for Stream and Air Improvement, Research Triangle Park, NC, January 1982.

(68) U.S. Department of Interior, "Groundwater," Chapter II, *National Handbook of Recommended Methods for Water Data Acquisition*, 1980.

(69) *Subsurface Characteristics and Monitoring Techniques*, Desk Reference Guide, EPA/1625/R-93/0036, 1993.

(70) Dablow, J. F. III, Persico, Daniel, and Walker, G. R., "Design Considerations and Installation Techniques for Monitoring Wells Cased with "Teflon" PTFE," in *Ground-water Contamination-Field Methods*, Collins, A. G., and Johnson, A. I., eds., American Society for Testing and Materials, *Special Technical Publication 963*, Philadelphia,1988, pp. 199-205.

(71) Aller, Linda, Bennett, T. W., Hackett, Glen, Petty, R. J., Lehr, J. H., Sedoris, Helen, Nielson, D. M., and Denne, J. E., *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, National Water Well Association, Dublin, OH, 1989, p. 398.

(72) Nielsen, D. M., and Schalla, Ronald, "Design and Installation of Ground-Water Monitoring Wells," in *Practical Handbook of Ground-Water Monitoring*, Nielsen, D. M., ed., Lewis Publishers, Chelsea, MI, 1991, pp. 239-331.

(73) Schmidt, G. W., "The Use of PVC Casing and Screen in the Presence of Gasoline on the Ground Water Table," *Ground Water Monitoring Review*, 7, No. 2, 1987, p. 94.

(74) Johnson, R. C., Jr., Kurt, C. E., and Dunham, G. F., Jr., "Well Grouting and Casing Temperature Increases," *Ground Water*, Vol 18, No. 1, 1980, pp. 7-13.

(75) Parker, L. V., "Suggested Guidelines for the use of PTFE, PVC and Stainless Steel in Samplers and Well Casings," in *Current Practices in Ground Water and Vadose Zone Investigations*, Nielsen, D. M., and Sara, M. N., eds., Special Technical Publication 1118, American Society for Testing and Materials, Philadelphia, 1992, pp. 217-229.

(76) Adapted from Lapham, Wayne W., Wilde, Franceska D., Koterba, Michael T., *Guidelines and Standard Procedures for Studies of Ground-Water Quality*, U.S. Geological Survey Water-Resources Investigations Report 96-4233, 1997.

(77) From Standard Methods for the Examination of Water and Wastewater, 18th Edition, 1992, p. 1-22, Methods for Chemical Analysis of Water and Wastes, March 1983 Revision, p. xvi-xx, or EPA Test Methods for Evaluating Solid Waste, SW-846, 3rd Edition.

(78) Adapted from McCaulou, Douglas R., Jewett, David G., and Huling, Scott G., "Compatibility of NAPLs and Other Organic Compounds with Materials Used in Well Construction, Sampling, and Remediation," *Ground Water Monitoring Review*, Fall 1996, Vol 16, No. 4, pp. 125-131.

(79) *Samplers and Sampling Procedures for Hazardous Waste Streams*, U.S. EPA, MERL Laboratory, Cincinnati, OH, EPA–600/2–80–018, January 1980.

CATEGORY 4: GROUNDWATER SAMPLING AND PURGING

Section 4.5

Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers

Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers[1]

This standard is issued under the fixed designation D 5521; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers the development of screened wells installed for the purpose of obtaining representative groundwater information and water quality samples from granular aquifers, though the methods described herein could also be applied to wells used for other purposes. Other well-development methods that are used exclusively in open-borehole bedrock wells are not described in this guide.

1.2 The applications and limitations of the methods described in this guide are based on the assumption that the primary objective of the monitoring wells to which the methods are applied is to obtain representative water quality samples from aquifers. Screened monitoring wells developed using the methods described in this guide should yield relatively sediment-free samples from granular aquifer materials, ranging from gravels to silty sands. While many monitoring wells are considered "small-diameter" wells (that is, less than four inches in inside diameter), some of the techniques described in this guide will be more easily applied to large-diameter wells (that is, four-inches or greater in inside diameter).

1.3 The values stated in inch-pound units are to be regarded as standard. All other units in parentheses are provided for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites

D 5092 Practice for Design and Installation of Ground-Water Monitoring Wells in Aquifers

3. Terminology

3.1 *Definitions:*

3.1.1 Many of the terms discussed in this guide are contained in Terminology D 653. The reader should refer to this for definitions of selected terms.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *air entrapment*—trapping of air or other gas in pore spaces of the formation or filter pack during development with compressed air.

3.2.2 *air lift pump*—a device consisting of two pipes, with one (the air line) inside the other (the eductor pipe), used to withdraw water from a well. The lower ends of the pipes are submerged, and compressed air is delivered through the inner pipe to form a mixture of air and water. This mixture rises in the outer pipe to the surface because the specific gravity of this mixture is less than that of the water column.

3.2.3 *air line*—a small vertical air pipe used in air-lift pumping. It usually extends from the ground surface to near the submerged lower end of the eductor pipe. The length of the air line below the static water level is used in calculating the air pressure required to start air-lift pumping.

3.2.4 *annular seal*—material used to provide a seal between the borehole and the casing of a well. The annular seal should

---

[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

Current edition approved Nov. 1, 2005. Published December 2005. Originally approved in 1994. Discontinued in 2002 and reinstated as D 5521–05. Last previous edition approved in 1994 as D 5521–94$^{\epsilon 1}$.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

have a hydraulic conductivity less than that of the surrounding geologic materials and be resistant to chemical or physical deterioration.

3.2.5 *backwashing*—the reversal of water flow caused by the addition of water to a well that is designed to loosen bridges and facilitate the removal of fine-grained materials from the formation surrounding the borehole.

3.2.6 *bailer*—a long, narrow tubular device with an open top and a check valve at the bottom that is used to remove water and sediment from a borehole or well.

3.2.7 *bailing (development)*—a development technique using a bailer which is raised and lowered in the well to create a strong inward and outward movement of water from the formation to break sand bridges and to remove fine materials from the well.

3.2.8 *borehole wall*—the face of an open borehole.

3.2.9 *bridge*—an obstruction to fluid and sediment movement in the filter pack or formation adjacent to the well due to the arching of fine sand grains across pore spaces. This condition is caused by one-directional movement of water into the well during development, as might occur during overpumping.

3.2.10 *bridging (development)*—the creation of obstructions to fluid and sediment movement in filter pack or formation materials during well development.

3.2.11 *cable tool drilling*—a drilling technique in which a drill bit attached to the bottom of a weighted drill stem is raised and dropped to crush and grind formation materials. In unconsolidated formations, casing is usually driven as drilling proceeds to prevent collapse of noncohesive materials into the borehole.

3.2.12 *cathead*—a rotating power unit on a drilling rig employing either a plain spool or an automatic spool used to hoist drill pipe, casing, small tools, or other drilling equipment.

3.2.13 *centrifugal pump (submersible)*—a downhole pump consisting of a sealed electric motor that drives impellers through a rotating shaft and seal arrangement at high revolutions per minute.

3.2.14 *centrifugal pump (surface)*—a pump that moves a liquid by accelerating it radially outward from within a rotating impeller to a surrounding circular-shaped chamber.

3.2.15 *development*—see *well development.*

3.2.16 *drilling fluid*—a water- or air-based fluid used in the well drilling operation to remove cuttings from the borehole, to clean and cool the bit, to reduce friction between the drill string and the sides of the borehole and to hold the borehole open during the drilling operation.

3.2.17 *eductor pipe*—the vertical discharge pipe used in air-lift pumping, submerged at least one third but usually two thirds of its length below the pumping water level in the well.

3.2.18 *filter cake*—the solids from a drilling fluid that are deposited on the walls of a borehole in a geologic formation during the process of drilling. Also called mudcake.

3.2.19 *filter-packed well*—a well in which the natural formation materials adjacent to the well screen has been replaced by a filter pack material.

3.2.20 *formation damage*—reduction of formation hydraulic conductivity at the borehole wall caused by the drilling process. May consist of compaction, clay smearing, clogging of pores with drilling mud filtrate, or other drilling-related damage.

3.2.21 *hydraulic jetting*—a well-development method that employs a jetting tool with nozzles and a high-pressure pump to force water outwardly through the well screen, the filter pack, and sometimes into the adjacent geologic unit, for the purpose of dislodging fine sediment and correcting formation damage done during drilling.

3.2.22 *indicator parameters*—chemical parameters, including pH, specific conductance, temperature and dissolved oxygen content, which are used to determine when formation water is entering a monitoring well.

3.2.23 *jetting*—see *hydraulic jetting.*

3.2.24 *monitoring well*—a well that is constructed by one of a variety of techniques that may serve a variety of purposes: (*1*) extracting ground water for physical, chemical, or biological testing; (*2*) measuring water levels; (*3*) measuring formation hydraulic parameters; or (*4*) measuring formation fluid chemical or physical parameters.

3.2.25 *naturally developed well*—a well in which the formation materials collapse around the well screen, and fine formation materials are removed using standard development techniques.

3.2.26 *overpumping*—a well-development technique that involves pumping the well at a rate that exceeds the design capacity of the well.

3.2.27 *rawhiding*—starting and stopping a pump intermittently to produce rapid changes in the pressure head in the well.

3.2.28 *sandlocking*—refers to the accumulation of sand and other sediment on development tools while they are working in the well screen, resulting in the tools becoming lodged in the screen. Also refers to the accumulation of sand and other sediment in the impeller section of a submersible pump, resulting in the impellers binding.

3.2.29 *sloughing*—caving of formation materials into an unstabilized open borehole.

3.2.30 *spudding*—the operation, in cable-tool drilling, of drilling a collar hole and advancing a casing through overburden. Also a general term in rotary or diamond core drilling applied to drilling through overburden.

3.2.31 *sump*—a blank extension of casing beneath the well screen that provides a space for sediment brought into the well during development to accumulate.

3.2.32 *surge block*—a plunger-like tool consisting of disks of flexible material (for example, neoprene) sandwiched between rigid (for example, metal) disks that may be solid or valved, and that is used in well development. See *surging.*

3.2.33 *surging*—a well-development technique in which a surge block is alternately raised and lowered within the well casing or screen, or both, to create a strong inward and outward movement of water through the well screen.

3.2.34 *tool string*—the drill pipe or drill rod and all attached drilling or development tools used in the borehole or well.

3.2.35 *turbidity*—cloudiness in water due to suspended and colloidal material.

3.2.36 *well casing*—a durable pipe placed in a borehole to prevent the walls of the borehole from caving, and to seal off surface drainage or undesirable water, gas, or other fluids and prevent their entrance into the well.

3.2.37 *well development*—the act of repairing damage to the borehole caused by the drilling process and removing fine-grained materials or drilling fluids, or both, from formation materials so that natural hydraulic conditions are restored and well yields are enhanced.

3.2.38 *well screen*—a filtering device that allows ground water to flow freely into a well from the adjacent formation, while minimizing or eliminating the entrance of fine-grained material into the well.

4. Significance and Use

4.1 A properly designed, installed, and developed ground-water monitoring well, constructed in accordance with Practice D 5092 should provide the following: representative samples of ground water that can be analyzed to determine physical properties and water-quality parameters of the sample or potentiometric levels that are representative of the total hydraulic head of that portion of the aquifer screened by the well, or both. Such a well may also be utilized for conducting aquifer tests used for the purpose of determining the hydraulic properties of the geologic materials in which the well has been completed.

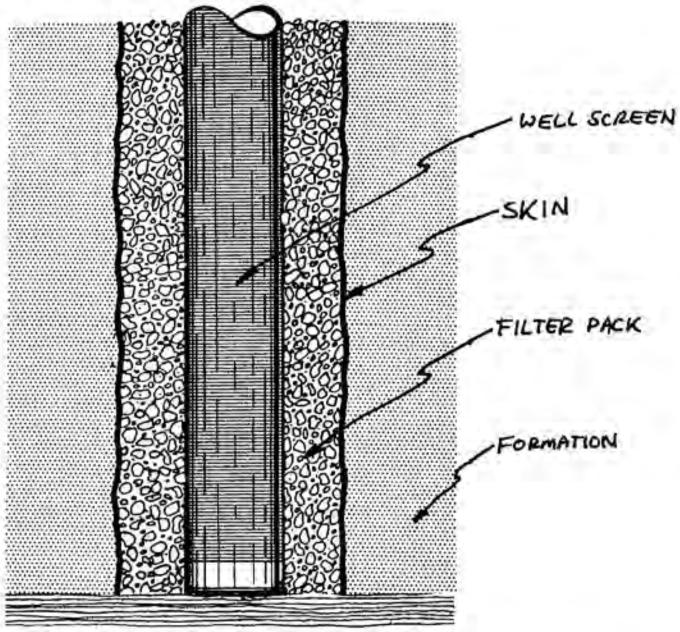
4.2 Well development is an important component of monitoring well completion. Monitoring wells installed in aquifers should be sufficiently developed to ensure that they serve their intended objectives. Well development methods vary with the physical characteristics of the geologic formation in which the monitoring well is screened, the construction details of the well, the drilling method used during the construction of the borehole in which the well is installed, and the quality of the water. The development method for each individual monitoring well should be selected from among the several methods described in this guide and should be employed by the well construction contractor or the person responsible for monitoring well completion.

4.3 The importance of well development in monitoring wells cannot be overestimated; all too often development is not performed or is carried out inadequately. Proper and careful well development will improve the ability of most monitoring wells to provide representative, unbiased chemical and hydraulic data. The additional time and money spent performing this important step in monitoring well completion will minimize the potential for damaging pumping equipment and in-situ sensors, and increase the probability that ground-water samples are representative of water contained in the monitored formation.

5. Purposes of Monitoring Well Development

5.1 Monitoring wells are developed primarily for the following reasons:

5.1.1 To rectify damage done during drilling to the borehole wall and the adjacent formation (that is, clogging, smearing, or compaction of formation materials) that may result in a localized reduction in hydraulic conductivity of the formation near the borehole (see Fig. 1);



NOTE 1—One of the purposes of development is to rectify the damage done to the borehole wall during drilling, such as the "skin" of fine-grained materials that accumulates on the borehole wall during mud-rotary drilling.

FIG. 1 Example of Rectifying Damage Done During Drilling

5.1.2 To remove fine-grained materials from the formation and filter pack (where applicable) that may result in the acquisition of turbid, sediment-laden samples;

5.1.3 To stabilize formation and artificial filter pack materials (where applicable) adjacent to the well screen (see Fig. 2[3]);

5.1.4 To retrieve lost drilling fluid (if drilling fluid was used in the borehole installation process) that may alter the quality of water in the vicinity of the well and interfere with water quality analysis (see Fig. 3); and

5.1.5 To maximize well efficiency and hydraulic communication between the well and the adjacent formation to provide for the acquisition of representative ground-water samples and formation hydraulic test data.

6. Conducting a Monitoring Well-Development Program

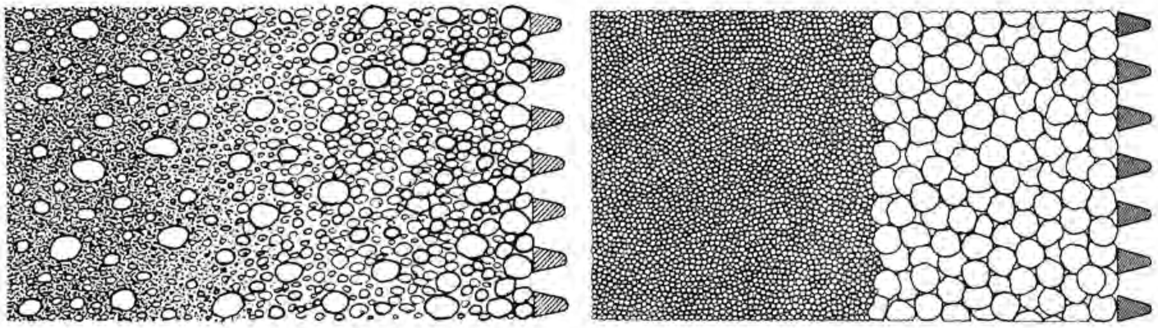
6.1 *Well Development Process*—The well development process consists of three phases: predevelopment, preliminary development, and final development.

6.1.1 Predevelopment refers to techniques used to mitigate formation damage during well construction. This is particularly important when using direct or reverse rotary drilling systems that depend on drilling fluid to carry cuttings to the surface and support an open borehole. Control of drilling fluid properties, during the drilling operation and immediately prior to the installation of screen, casing, and filter pack, is very important.

6.1.2 Preliminary development takes place after the screen, casing, and filter pack have been installed. Methods used to accomplish this task include surging, bailing, hydraulic jetting,

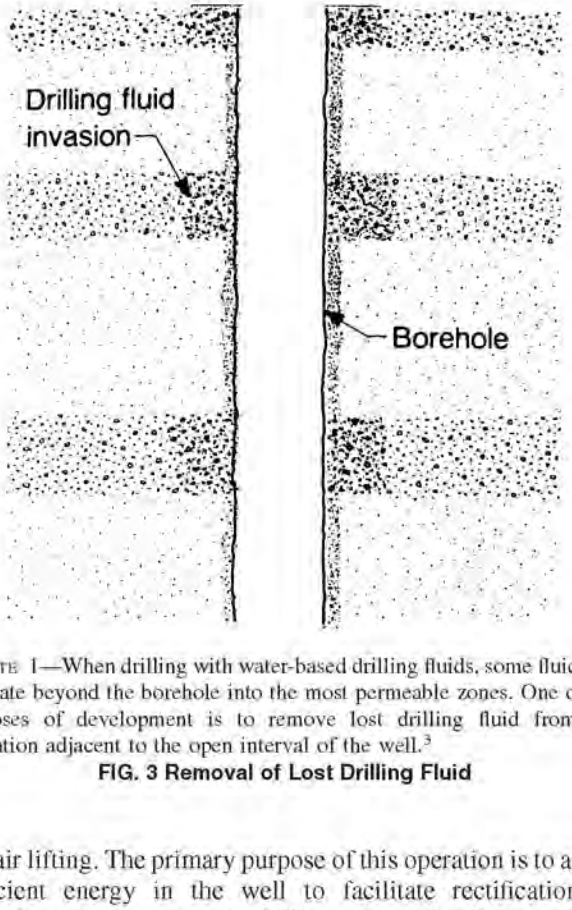
---

[3] Figure adapted from *Ground Water and Wells*, Second Edition, 1986.



NOTE 1—After well development, formation materials in "naturally developed" wells (left) and filter packed wells (right) should be stabilized so that entry of fine-grained materials into the well is minimized and no settlement occurs.[3]

FIG. 2 Formation Materials in Wells



NOTE 1—When drilling with water-based drilling fluids, some fluid will infiltrate beyond the borehole into the most permeable zones. One of the purposes of development is to remove lost drilling fluid from the formation adjacent to the open interval of the well.[3]

FIG. 3 Removal of Lost Drilling Fluid

and air lifting. The primary purpose of this operation is to apply sufficient energy in the well to facilitate rectification of formation damage due to drilling; removal of fine-grained materials from the screen, filter pack, and formation; stabilization and consolidation of the filter pack; retrieval of drilling fluid (if used); and creation of an effective hydraulic interface between the filter pack and the formation.

6.1.3 During this phase of well development, the preferred technique is to gradually apply the selected method, increasing intensity as long as the well responds to treatment. Response generally is indicated by increased yields of water and sediment. Intensive development of a well that appears to be plugged should not be attempted because damage and destruction of the well may result.

6.1.4 Final development refers to procedures performed with a pump, such as pumping and surging, and backwashing. These techniques are used as the final step in achieving the objectives of well development. If preliminary development methods have been effective, the time required for final development should be relatively short. However, if the preliminary methods have not been successful, or if conditions preclude the use of the preliminary techniques listed, the final development phase should be continued until the development completion criteria (described below) are satisfied.

6.2 *Factors Affecting the Selection of a Well-Development Method*—A variety of factors must be considered in selecting the method(s) used for developing any given monitoring well; these include: the construction of the well (that is, material used for well casing and screen, type and open area of well screen, type of joint between casing sections, screen length and slot size, casing and screen diameter, whether or not a filter pack was used in the well and the thickness of the filter pack); characteristics and hydraulic conductivity of the formation materials adjacent to the well screen; water quality in the aquifer in which the well is installed (that is, whether or not it may be contaminated, requiring special safety or handling considerations, or both, such as containment or treatment upon removal from the well); consequences of introducing foreign fluids (that is, air, water, or chemical solutions) into the well and aquifer; drilling method used during borehole installation; depth to static water level and height of the water column in the well; type and portability of available equipment (that is, whether or not a drilling rig is required); time available for development; and cost effectiveness of the method.

6.3 *Timing of Well Development: When and How Long to Develop*—The point in time at which a monitoring well is developed is a decision that is generally based on design and construction of the well. For example, if the well is installed with the intent of using natural formation material as the filter pack (that is, a "naturally developed" well), development is generally performed after the screen and casing have been installed and the formation material has collapsed against the screen (to at least 5 feet above the screen), but before the annular seal is installed. Because this type of well design is based on the assumption that well development will remove a significant fraction of the formation materials adjacent to the well screen (therefore causing some sloughing in the borehole), developing the well after installing the annular seal may result in portions of the annular seal collapsing into the vicinity of the well screen. On the other hand, properly designed and constructed filter-packed wells may be developed after the annular seal materials have been installed and given sufficient time to set or cure, because the well screen is designed to retain at least 90 % and preferably 99 % of filter pack materials and little or no sloughing should occur.

6.3.1 The duration of well development is based on the primary purpose(s) of the development process. For example, if the primary purpose for development is to remove drilling fluid lost to the formation during borehole installation, the time required for completion of development may be based on the time it takes to remove from the well some multiple of the estimated volume lost. If the primary purpose of development is to rectify damage done during drilling to the borehole wall and the adjacent formation, the time for development may be based on the response of the well to pumping. An improvement in recovery rate of the well indicates that the localized reduction in hydraulic conductivity has been effectively rectified by development. If the primary purpose of development is to remove fine-grained materials, development may continue until visibly clear water is discharged from the well, or until the turbidity of water removed from the well is at some specified level. These criteria may be difficult or impossible to satisfy in formations with a significant fraction of fine-grained material. Another criterion used for determining when development is complete is the stabilization of certain indicator parameters (that is, temperature, specific conductance, pH, redox potential, dissolved oxygen) that are easily measured in the field. While this criterion may be an indicator of when native formation water is being produced, it does not necessarily indicate that well development is complete.

6.4 *Decontamination of Well Development Equipment*—Any equipment or materials used to develop a monitoring well should be thoroughly cleaned in accordance with Practice D 5088. Cleaning should take place prior to the use of any equipment in any monitoring well, and between uses in either the same well or in other wells.

7. Limitations of Well Development

7.1 Well development should be applied with great care to wells installed in predominantly fine-grained formation materials (that is, in formations dominated by fine sand, silt or clay). If vigorous development is attempted in such wells, the turbidity of water removed from the well may actually increase many times over. In some fine-grained formation materials, no amount of development will measurably improve formation hydraulic conductivity or the hydraulic efficiency of the well.

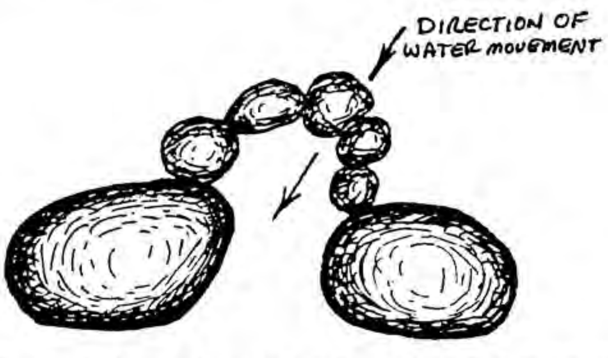
7.2 While development methods which require the addition of a foreign fluid to a well may be applied to ground-water monitoring wells, such methods should be used with an understanding of the negative effects that added fluids may have on the ability of the well to yield representative ground-water quality samples. Only in very extreme or special cases should fluids other than clean water or filtered air be considered for use in a well during development. Fluids other than water, including deflocculating or dispersing agents (that is, polyphosphates), acids (that is, hydrochloric or hydrofluoric acid), surfactants, and disinfectants (that is, sodium hypochlorite), may produce severe and persistent chemical alterations of water quality in the immediate vicinity of the well. The use of chemicals for well development is not discussed further for these reasons.

7.2.1 Any water added to a monitoring well for the purpose of development should be of known and acceptable chemistry. The impact of added water on in situ water quality should be evaluated and, to the extent possible, this water should be removed by pumping after development is complete. One possible means of reducing potential problems related to the addition of water to the well is to obtain water-quality samples from the well only after natural ground-water flow in the aquifer has had time to flush the remnants of well-development fluids beyond the well. Another means may be to use water that has been taken from the formation itself (that is, water pumped from the formation either prior to or during development) for the development process.

7.3 Development methods using compressed air (that is, air-lift pumping) should be attempted only after great care has been taken to remove any compressor oil or other foreign substances from the air stream prior to introduction into the well. Air should not be forced into the formation or allowed to be released directly into the well without the use of a containment device (that is, an eductor pipe). The injection of air into the formation may cause air entrapment and result in a dramatic reduction in formation hydraulic conductivity. An uncontrolled release of air into the well may cause significant chemical changes in the water in the well and the adjacent formation.

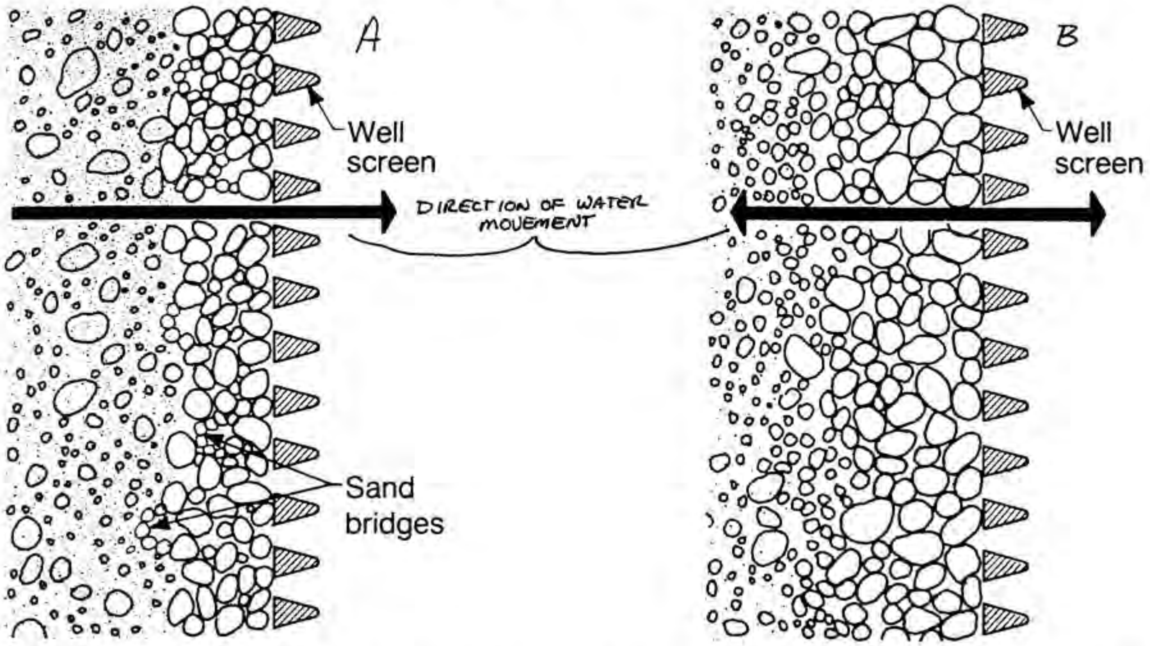
7.4 Development methods that rely only on pumping ("passive"development), especially at low-flow rates, do not sufficiently stabilize formation or filter pack material and do not effectively remove fine-grained material or rectify formation damage done during drilling (see Fig. 4). Effective development action requires movement of water in both directions through the well screen openings (see Fig. 5). Although visibly clear water may eventually be discharged as a result of such pumping, any subsequent activity that agitates the water column in the well (that is, conducting a formation hydraulic test, purging prior to sampling, or sampling, especially with bailers) can cause considerable turbidity in the well.

7.5 Development should be applied very cautiously to wells that are known or suspected to be contaminated with hazardous chemical constituents, particularly constituents which pose a



NOTE 1—Bridging in formation and filter pack materials is caused by movement of water in one direction only during well development.[3]

FIG. 4 Bridging in Formation and Filter Pack Materials



NOTE 1—Effective development action requires movement of water in both directions through the well screen openings. (*B*) Reversing flow helps to minimize bridging in the formation and filter pack (if used). (*A*) Movement of water in only one direction, as when overpumping the well, does not produce the proper development effect.[3]

FIG. 5 Movement of Water in Both Directions

hazard through inhalation or dermal contact. Appropriate safety precautions should be taken to protect field personnel. It should be noted that contaminated water and sediment removed from monitoring wells during development may also have to be contained in drums, tanks, or other storage vessels until the water and sediment have been tested and evaluated to determine an appropriate disposal or treatment method. This could significantly increase the cost of development.

8. Methods and Processes Available for Monitoring Well Development

8.1 *General*—Of the various methods available for use in developing wells in general, mechanical surging, overpumping and backwashing, and high-velocity hydraulic jetting with pumping (or combinations of two or more of these methods) are best suited for use in developing ground-water monitoring wells. The method most appropriate for use in a given situation depends on a variety of factors discussed in 6.2. The user should evaluate the methods described herein and select the method that is most appropriate for the situation at hand.

8.2 *Mechanical Surging*—Mechanical surging is accomplished by using a close-fitting surge block (sometimes referred to as a surge plunger or swab) affixed to the end of a length of drill pipe, a solid rod, or a cable, operating like a piston in the well casing or screen. The up-and-down plunging action alternately forces water to flow into (on the upstroke) and out of (on the downstroke) the well, similar to a piston in a cylinder (see Fig. 6). The downstroke causes a backwash action to loosen bridges in the formation or filter pack and the upstroke then pulls dislodged fine-grained material into the well. This method is equally applicable to small-diameter and large-diameter wells and is the most effective method for small-diameter wells.

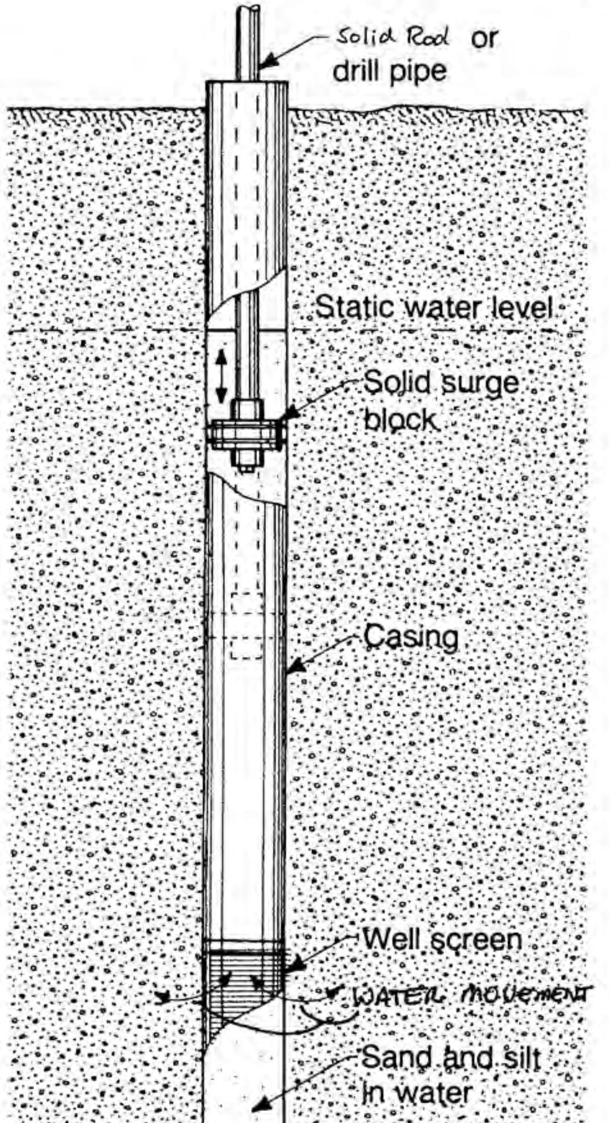
8.2.1 Several designs for surge blocks, including a solid surge block, a valved or vented surge block, a spring-loaded surge block, and a multiple-flange surge block (see Fig. 7[4]) can be utilized. A heavy bailer or a pump (such as a gas-drive pump or an inertial lift pump) fitted with flexible disks similar to those on a surge block (see Fig. 8[5]) may also be used to produce the surging action, but these are not as effective as a close-fitting surge block.

8.2.2 The proper procedure for mechanical surging is to bail or pump the well first to make sure that the well will yield water. If the screen is completely plugged and water does not enter the well upon bailing or pumping, surging should not be attempted, as the strong negative pressure created on the upstroke of the surge block may cause the screen to collapse. When it is determined that the well will yield water, the surge block is lowered until it is below the static water level but above the screen, and a relatively slow, gentle surging action is started. This surging action should allow any material blocking the screen to break up, go into suspension, and move into the well. The surge block should be operated with particular care if the formation above the screen consists mainly of fine sand, silt or clay which may slump into the screened interval. The water column should effectively transmit the action of the surge block to the screened section of the well. As water begins to move easily in and out of the well, the surge block is lowered (in steps) farther into the well and the speed (and, therefore, the force) of the surging movement is increased. If initial development is too vigorous, particularly in fine-grained formations,

---

[4] Figures *a* and *b* adapted from *Ground Water Wells*, Second Edition, 1986, and Figs. *c* and *d* adapted from *Handbook of Ground Water Development*, 1990.

[5] Figure adapted from *Handbook of Ground Water Development*, 1990.



NOTE 1—For certain types of formations, a surge block is an effective tool for well development. On the downstroke, water is forced outward into the formation; water, silt, and fine sand are then pulled into the well screen during the upstroke.[3]

FIG. 6 Mechanical Surging

surging can harm a well rather than improve it. Because significant pressure differentials can occur during mechanical surging, great care must be taken to avoid damaging (that is, collapsing) the casing or screen by overzealous development.

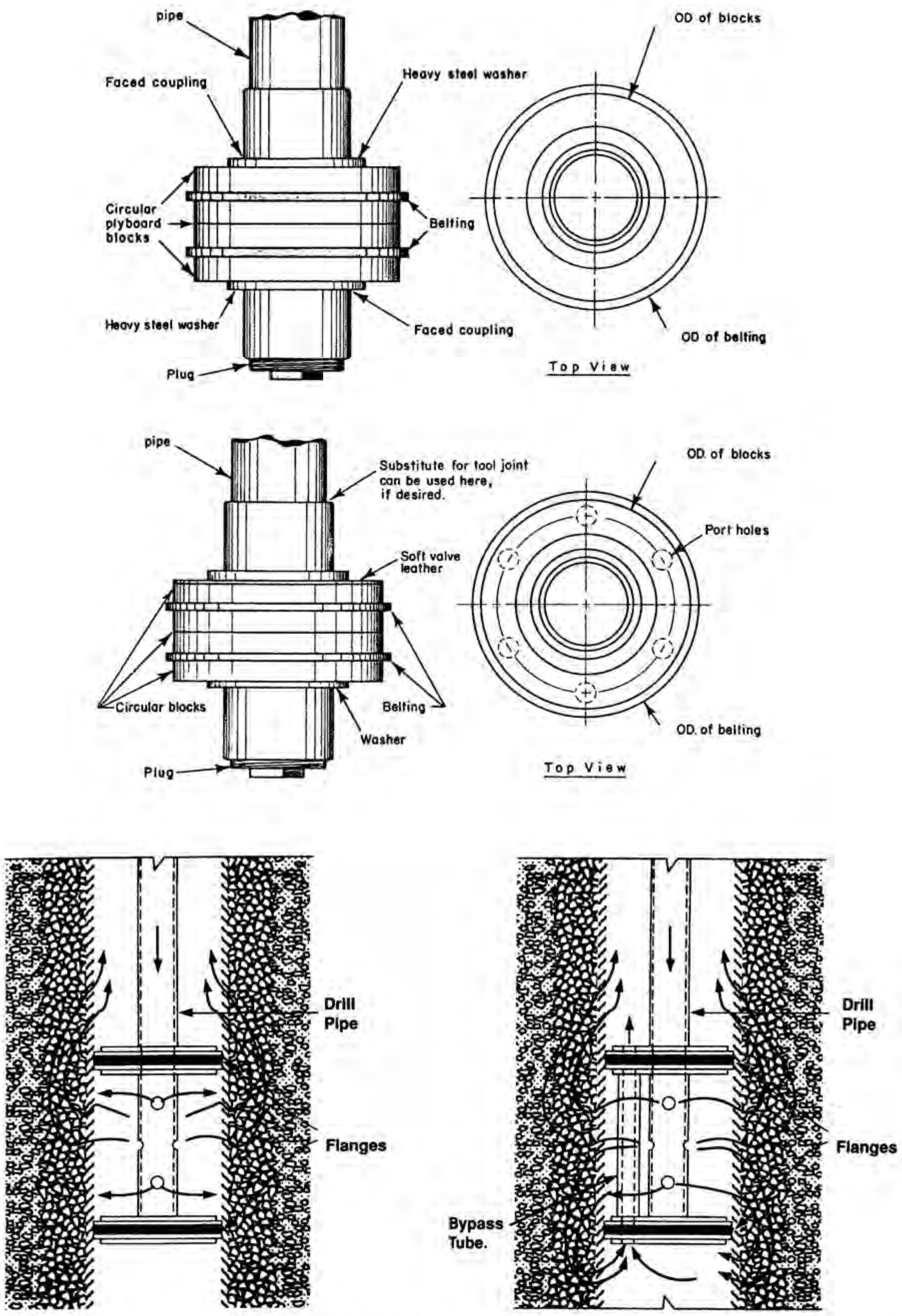
8.2.3 In wells with short (that is, less than five feet) screens, it may not be necessary to operate the surge block within the screen to develop the entire screened interval; in wells with longer (that is, ten feet or more) screens, it may prove more effective to operate the surge block within the screen to concentrate its action at various levels. Surging should always begin above the screen and move progressively downward to prevent the surge block from becoming sand locked and to prevent damage to the screen. The surge block should be lowered in intervals equal to the length of the stroke until the entire screen has been surged. If surging of long screened wells is done exclusively in the casing, especially in situations in which the formation adjacent to the screen is highly variable, surging may preferentially develop only the material adjacent to the top of the screen or the most permeable zones of material adjacent to the screen.

8.2.4 The force exerted on the formation depends in part on the length of the stroke and the vertical velocity of the surge block. The length of the stroke depends on the mechanism used to operate the surge block. For cable-tool rigs, that are ideally suited to the surging operation, the length of the stroke is determined by the spudding motion. For rigs using a cathead to surge, the length of the stroke can be varied by varying the length of time that the rope is tightened on the spool. For manual surging, the length of the stroke is generally limited to the range of motion of the operator's arms. Generally, a 2 to 3 ft (0.61 to 0.91 m) stroke is sufficient to achieve proper well development with mechanical surging.

8.2.5 The vertical velocity of the surge block depends on the weight exerted on the block and the retraction speed. Generally, a vertical velocity of between 3 and 5 ft/s (0.91 to 1.52 m/s) is most effective. On the downward stroke, the surge block assembly must be of sufficient weight to free-fall through the water column in the well and create a vigorous outward surge. The surge block assembly should not be permitted to fall out of plumb because of the hazard of the assembly falling against and possibly damaging the screen. When used with a cable-tool rig, a surge block may be weighted using the drilling tool string so it will fall at the desired rate, with the spudding motion controlled to vary the retraction speed. If a rotary rig is used, the weight on the surge block can be provided by drill pipe, with the retraction speed controlled by the rate of response of the hydraulic system. For rigs using a cathead to assist in surging, weight must be supplied to the surge block through either drill rod or the addition of weights above or below the surge block; the speed of retraction can be varied by the tension of the rope on the spool. For manual surging, only a limited amount of weight can be added to the surge block assembly because of the difficulty of working by hand with a heavy tool string in a well. Down force may be applied more easily manually by pushing the surge block into the well. The speed of manual retraction is controlled by the rate at which the individual is capable of pulling the surge block assembly back out of the well.

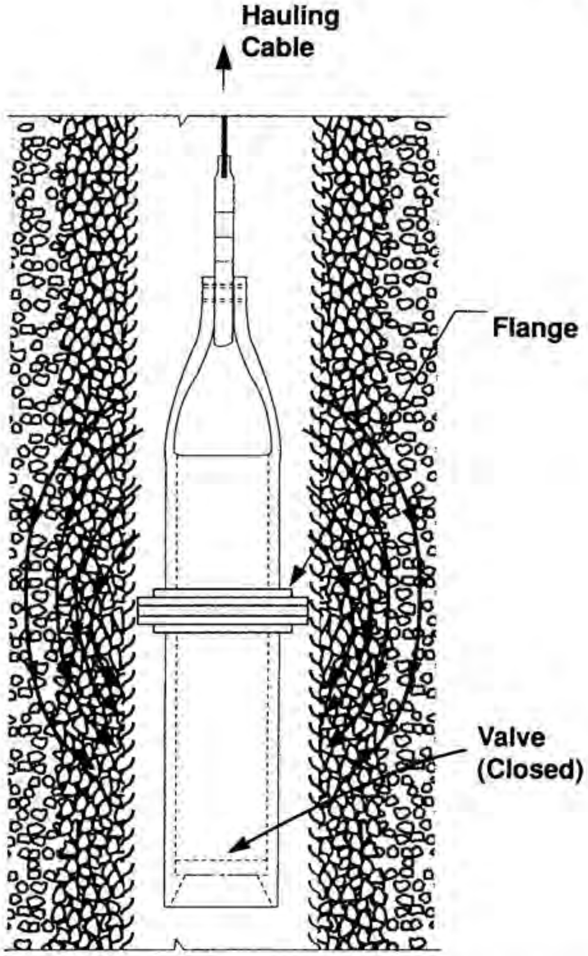
NOTE 1—Manual surging is a very tiring and laborious procedure that commonly exhausts field personnel long before development is complete.

8.2.6 The effectiveness of mechanical surging is also governed in part by how tightly the surge block fits into the well casing or screen. If surging is to be performed only in the casing, the outside diameter of the surge block should be sized to be within ⅛ to ¼ in. (0.32 to 0.64 mm) of the inside diameter of the casing. (Care should be taken during casing assembly to ensure a smooth inner surface, especially at joints;



NOTE 1—Various configurations of surge blocks: (*a*) solid surge block; (*b*) valved surge block; (*c*) double-flanged surge block; and (*d*) valved double-flanged surge block.[3,4]

FIG. 7 Various Configurations of Surge Blocks



NOTE 1—A heavy (steel) bailer fitted with a flange to serve as a surging tool. Arrows indicate the direction of water movement during retraction of the bailer.[5]

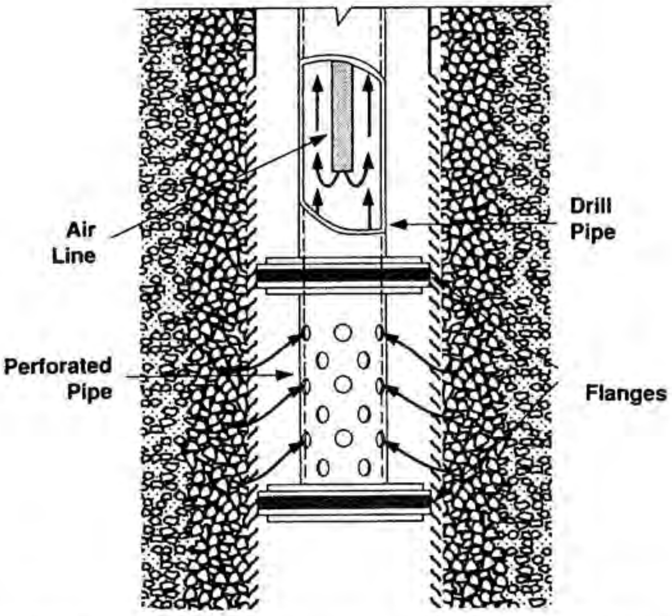
FIG. 8 Bailer

shoddy assembly or irregular surfaces at casing joints could result in damage to the surge block or the casing, or both.) If surging is to be performed within the screen, care should be taken to avoid "sandlocking" the surge block. If sandlocking is a concern, the surge block can be sized to be slightly smaller. This reduction in size reduces the pressure exerted on the screen by allowing some water to flow past the surge block on both the upstroke and the downstroke, and it allows fine sediment to flow around the block rather than lodging between the block and the screen. A valved or vented surge block creates the same effect. Prior to the surging operation, the surge block or a dummy pipe of equivalent diameter and length should be tested to be certain that it will fit into the casing or screen, or both, without becoming lodged.

8.2.7 The first surging run should be very short so that the operator can judge the amount of sediment entering the screen. Surging should continue for several minutes, and the surge block should be removed from the well and the accumulation of sediment measured. Subsequent surging runs should be done over short to increasingly longer periods, keeping records of how quickly sediment enters the screen. When the sediment accumulated at the bottom of the screen begins to block off a portion of the screen, the sediment should be removed by pumping or bailing. Alternately, it may be possible to surge and pump simultaneously, using a specially designed surging tool (see Fig. 9) or a surge block affixed to an open pipe with a swivel for attachment to a pump and alternating surging without pumping with surging and pumping. Because development is more effective if the amount of sediment in the screen is kept to a minimum, accumulated sediment should be removed as often as possible. A "sump" or length of blank casing installed beneath the screen may help to keep the screen free of sediment. Surging should not be attempted when the screen is full of sediment because the force of surging may cause the casing above the screen to collapse. The rate and volume of sediment accumulation should be recorded to provide data on the progress of development. Surging and cleaning should be continued until little or no sediment is measured after surging. The time required to properly surge a well depends on the character of the aquifer material and its apparent response to development, and may vary widely from well to well.

8.2.8 Manual mechanical surging can be accomplished effectively only in relatively shallow small-diameter wells (that is, wells less than 4 in. in diameter that are less than 50 ft (15.2.4 m) deep). Development of larger diameter or (10.16 cm) deeper wells will require either mechanical assistance (that is, by means of a block and tackle or pulley system used with a tripod assembled atop the well) or the use of a drilling rig or pump-pulling rig.

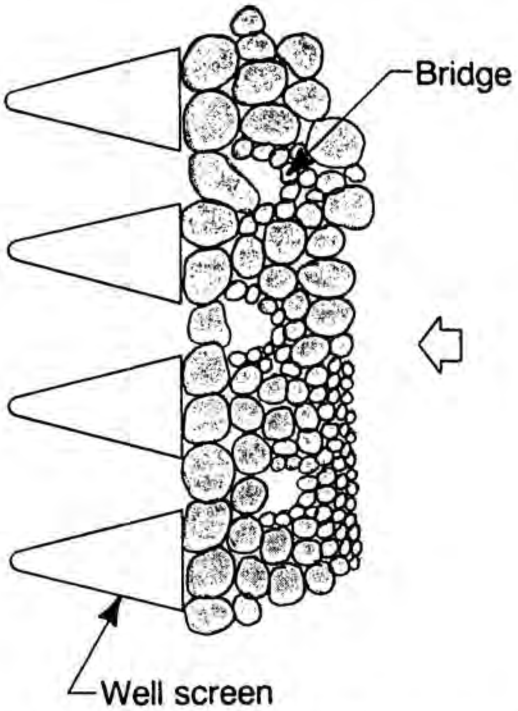
8.3 *Overpumping and Backwashing*—The simplest of method removing formation fines is by overpumping, or pumping at a higher rate then the well will be pumped when it is purged and sampled. Theoretically, increasing the drawdown



NOTE 1—A specially designed surging tool combining a double-flanged surge block with an air-lift pumping system to allow simultaneous surging and pumping. Arrows indicate the direction of water movement during pumping.[5]

FIG. 9 Specially Designed Surging Tool

to the lowest possible level results in increased flow velocities toward the well, resulting in the movement of fine-grained materials into the well (that is, any monitoring well that can be pumped sediment-free at a high pumping rate can then be pumped sediment-free at a lower rate). However, five important limitations to overpumping include: overpumping by itself will not adequately develop a well because water flow is in only one direction; it may cause bridges to form in the formation or filter pack, or both, resulting in only partial stabilization of these materials (see Fig. 10); it often requires the use of larger pumping equipment than will fit into the small-diameter casings that are used in many monitoring wells; it subjects the pump used in the operation to abrasion, excessive wear, and loss of efficiency, as well as the possibility of sandlocking; and it results in the production of potentially large volumes of water that may require containment or treatment. Furthermore, because the pump is normally set above the top of the well screen, most of the development that takes place during overpumping occurs in the zones of highest hydraulic conductivity closest to the top of the screen. For a given pumping rate, the longer the screen, the less development will take place in the lower part of the screen. After fine-grained material has been removed from the high hydraulic conductivity zones near the top of the screen, water entering the screen moves preferentially through these zones, leaving the rest of the well poorly developed. Overpumping may be effective in filter-packed wells or in non-stratified sands in which flow toward the well is more or less uniform. Overpumping is also useful for removing drilling fluid lost to the formation, but it is not an adequate development method if used alone. Overpumping is best used in combination with backwashing. Backwashing is the term applied to the method of well development in which water is added to the well to create a flow reversal.



NOTE 1—During development by overpumping, sand grains can bridge openings because flow occurs in only one direction. Once the well is placed into service, agitation by normal pump cycling can break down the bridges, causing sand pumping.[3]

FIG. 10 Overpumping

8.3.1 A commonly used backwashing procedure is to pump water into the well in a sufficient volume to maintain a head greater than that in the formation. This requires a high-capacity water source. Water can be obtained by diverting part of the water pumped from the well during overpumping into a large tank. After the well is pumped, the stored water is pumped back down the well, either through the pump column or through a separate pipe. This method of backwashing should not be used in cases in which the water pumped from the well is potentially contaminated.

NOTE 2—There may be regulatory or legal constraints on returning potentially contaminated fluids to a monitoring well.

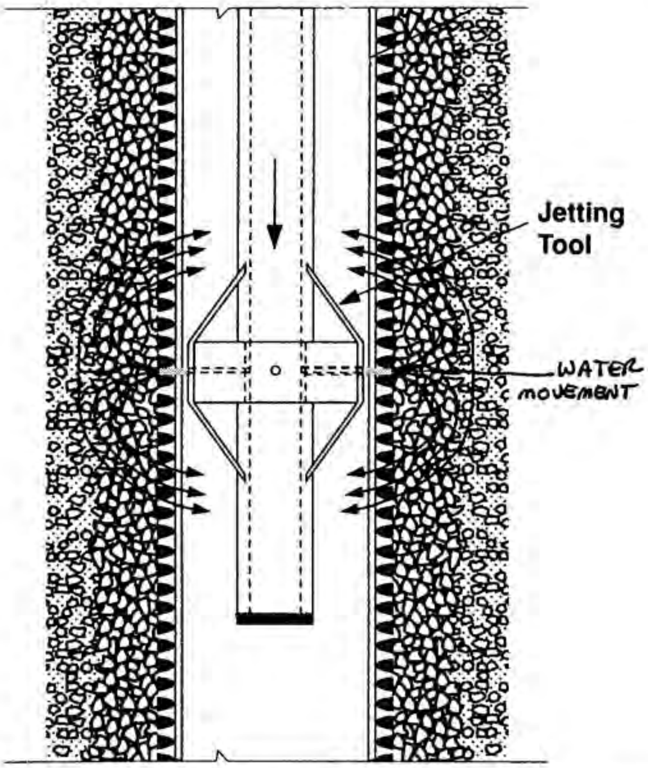
8.3.2 "Rawhiding" consists of starting and stopping a pump intermittently to produce rapid changes in the pressure head within the well. The alternate lifting and dropping of a column of water in the pump discharge pipe creates a surging action in the well. During a surge, the amount of water contained in the discharge pipe, combined with the well's natural recovery, may not be sufficient to cause the water level in the well to rise above the static water level. In this situation, supplemental water is generally added to the well when pumping is stopped for a surge. Judgment should be exercised concerning the duration of the backwash and the quantity of water added, because to some extent the success of this method depends on the frequency of flow reversals rather than the magnitude of water level change in the well.

8.3.3 Before beginning the rawhiding procedure, the pump should be started at reduced capacity and gradually increased to full capacity to minimize the danger of sandlocking the pump. When the pump discharge is clear of sediment, the pump is shut off and the water in the pump discharge or column pipe falls back into the well; the pump is then repeatedly started and stopped as rapidly as the power unit and starting equipment will permit. The pump used must not be equipped with a check valve or other backflow prevention device. To avoid damaging submersible pumps, the control box should be equipped with a starter lockout so the pump cannot be started when it is back spinning. During the rawhiding procedure, the well should be pumped occasionally to remove the sediment that has been brought in by the surging action.

8.3.4 Some wells respond satisfactorily to rawhiding, but in some cases the surging effect is not vigorous enough to obtain optimum results. Also, rawhiding is very hard on pumping equipment.

8.3.5 Various types of pumps can be used to rawhide a monitoring well. To be effective for development by rawhiding, a pump must be capable of pumping at a rate of at least 5 to 10 gal/min (18.93 to 37.85 L/mm) (gpm). Surface centrifugal or diaphragm pumps are capable of these rates, but can only be used if the depth to static water level in the well is less than about 20 ft (6.1 m) below ground surface. Submersible centrifugal pumps with these pumping capacities are available for small-diameter monitoring wells, but the impellers in these pumps are relatively easily damaged by sand because of the very high speed at which they operate. Air-lift pumps can be constructed to easily fit into a small-diameter monitoring well and these pumps are capable of pumping in excess of 10 gpm. However, air-lift pumping and backwashing results in mixing of aerated water with water in the well and adjacent formation, temporarily altering groundwater quality.

8.4 *High-Velocity Hydraulic Jetting*—Where conditions permit, another effective method available for use in developing monitoring wells, is high-velocity hydraulic jetting. Because of the size of the equipment required, this method is more easily applied to wells of four inches or greater diameter. Development by high-velocity hydraulic jetting employs several horizontal jets of water operated from inside the well screen so that high-velocity streams of water exit through the screen and loosen fine-grained material and drilling mud residue from the formation (Fig. 11). The loosened material moves inside the well screen and can be removed from the well by concurrent pumping or by bailing. Jetting is particularly successful in developing highly stratified unconsolidated formations, consolidated bedrock wells, large-diameter wells, and naturally developed wells. Jetting can also be useful in filter-packed wells provided that filter pack material is carefully chosen to provide some, but not excessive, loss through the well screen, and that the filter pack is not too thick (that is, not greater than 2 or 3 in. (5.1 or 7.6 cm)).



NOTE 1—Development by high-velocity hydraulic jetting employs a tool using several horizontal jets of water operated from inside the well screen. High-velocity streams of water are directed through the screen into the formation or filter pack to loosed fine-grained material and drilling mud residue and bring it into the well, where it can be pumped out.[5]

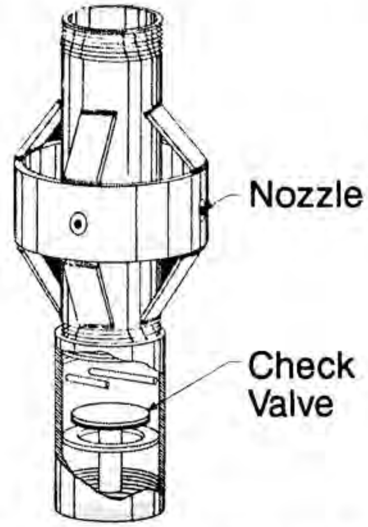
FIG. 11 High-Velocity Hydraulic Jetting

8.4.1 The equipment required for jetting includes a jetting tool with two or more equally spaced nozzles; a high-pressure pump, hose, and connectors; a string of pipe; and a water tank or other high-volume water supply. The high-velocity jets direct water through the screen openings, and agitate and rearrange the particles of the formation surrounding the screen. The filter cake that is formed on the borehole wall during mud rotary drilling is broken down and dispersed, allowing easy removal by pumping. Jetting is also useful in correcting other damage done during drilling.

8.4.2 Fig. 12 shows a jetting tool with four nozzles. Nozzles should be equally spaced around the circumference of the jetting tool, and generally range from 5⁄32- to 3⁄8-in. (0.4 to 0.95 cm). The jetting tool should be constructed so that the nozzle outlets or holes are as close to the inside diameter of the screen as practical (generally within ½ in (1.27 cm)), with the bottom end of the tool capped and the top end threaded so it can be screwed on to the lower end of the pipe string. If the outside diameter of the jetting tool is too small in relation to the inside diameter of the screen, much of the energy of the jet is dissipated by the turbulence created within the well.

8.4.3 Every effort should be made to limit sediment concentrations in the water used for jetting. Sediment-laden water that is recirculated through the jetting tool, causes erosion of the nozzle bores and may produce a pronounced pressure reduction at the nozzle face. Sediment in water used for jetting can also damage screens if the jets are directed at one area for a prolonged period of time.

8.4.4 A nozzle velocity of as low as 100 ft/s (30.5 m/s) can produce effective jetting results, though much better results can be expected when the nozzle velocities are between 150 and 300 ft/s (m/s). Velocities greater than 300 ft/s may not result in sufficient additional benefit to justify the additional cost. In general, 200 psi (45.7 and 91.4 kPa) at the nozzle is the preferred operating pressure for jetting in wells constructed



NOTE 1—A jetting tool with four nozzles spaced 90° apart around the circumference of the tool. The check valve at the bottom of the tool closes when water pressure is introduced from the surface, and opens to allow pumping through the drop pipe after jetting is completed.[3]

FIG. 12 Jetting Tool With Four Nozzles

with metallic screens. However, great care must be exercised in jetting screens constructed of PVC or other less-abrasion-resistant materials. All jetting of PVC screens should be done only with clean, sediment-free water to minimize abrasion, and the pressure used should not exceed 100 psi. In general, pressures higher than 100 psi are required when working in predominantly fine-grained formations or filter-packed wells.

8.4.5 The energy that agitates formation particles outside the well screen is a function of both the velocity and the diameter of the water stream. The energy of the jetting stream will depend on the capacity of the pump (maximum pressure output and flow rate at that pressure) and the orifice size of the discharge nozzle. The nozzle size should be the largest possible diameter that will maintain a minimum line pressure of 100 psi at the minimum anticipated flow rate of the pump. For a given nozzle size (water stream diameter), greater pressures will result in greater energy to penetrate formation materials. The pipe that is attached to the jetting tool should be large enough to minimize friction losses so that the velocity at the nozzle is as high as possible.

8.4.6 Although jetting can be accomplished without a drilling rig, it is usually done with a rig such as a rotary rig or another type of rig with rotating capability that is equipped with a mud pump that can supply the required down-hole pressure. When using a drilling rig, the jetting tool is attached to the lower end of the drill string and tool rotation is controlled by the rig. The jetting tool is placed near the bottom of the well screen and rotated slowly while being pulled upward at a rate of 5 to 15 min/ft (1.57 to 4.57 min/m) of screen. Material loosened from the formation is brought into the well by the turbulence created above and below the jets, and accumulates at the bottom of the screen (or in a sump if one is used) as the jetting tool is raised. This material must be removed concurrently or periodically. Slowly rotating and gradually raising the tool exposes the entire surface of the screen to the vigorous action of the jets. Several passes up and down the screen are made until the amount of additional material removed from the formation becomes negligible. To avoid erosion of the screen and to expedite development, the jetting tool should never be operated in a stationary position; it should always be slowly rotated and slowly raised or lowered.

8.4.7 In general, the effectiveness of the jetting process is controlled by the ratio of the filter-pack thickness to the jet radius, the velocity of the jet, the distance from the jet to its impact point on the screen, and the ratio of the hydraulic conductivity of formation materials to that of the filter pack materials.

8.4.8 Optimal removal of sediment by jetting will depend on the time allotted to the process. Because the jetting energy can focus on only a small part of the formation at a given moment, more time may be necessary for jetting than for other methods that affect a larger portion of the formation. Less satisfactory results from jetting almost inevitably occur when not enough time is allowed for a thorough job.

8.5 *High-Velocity Hydraulic Jetting Combined with Simultaneous Pumping*—Although jetting is effective in dislodging material from the formation, maximum development efficiency is achieved when jetting is combined with simultaneous pumping. This combination of development techniques is particularly successful for wells in unconsolidated sands and gravels. It is not always practicable, but should be considered where permitted by the size of the well, the available equipment, and the position of the static water level with respect to the screen.

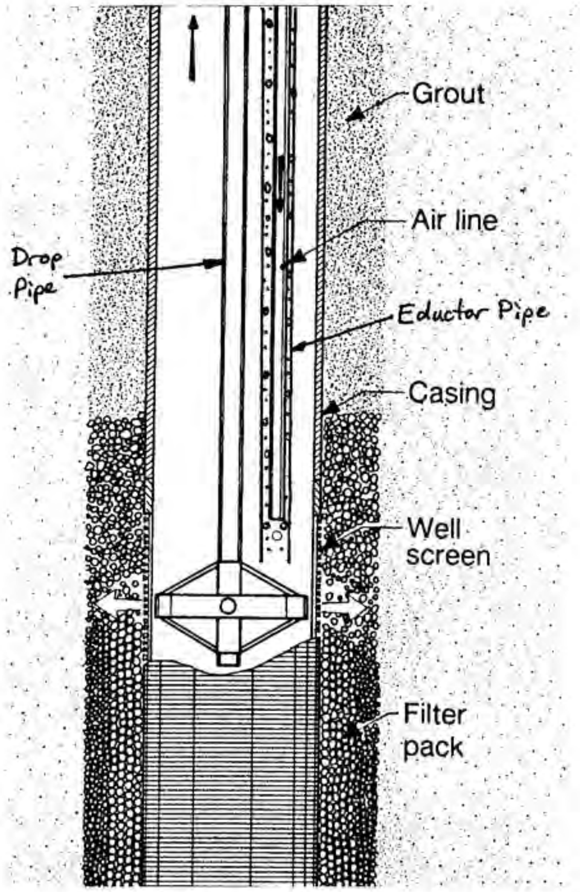
8.5.1 In jetting, water is added to the well at a rate governed by the nozzle size and the pump pressure. The volume of water simultaneously pumped from the well should always exceed the volume pumped in during jetting, by as much as 1.5 to 2 times, so that a gradient is created toward the well. The movement of water into the well helps to remove some of the formation material loosened by jetting. The pump then delivers the sediment from the well before it can settle in the screen. This procedure also serves to immediately remove most of the water added to the well during jetting, which may be a concern in some monitoring wells.

8.5.2 An added advantage of pumping is that water removed from the well provides a continuous supply that can be recirculated through the pump and jetting equipment after the sediment has settled out in a tank (to avoid damaging the high-pressure pump, jetting nozzles, or screen). This partially alleviates concerns regarding the quality of water added to the well during jetting, because the water used in this situation is water from the well being pumped. This water may be altered chemically during pumping, particularly if the equipment is not cleaned prior to use. Pumping while developing also permits an appraisal of the effectiveness of the jetting, based on the size and volume of the sediment collected at the bottom of the holding tank.

8.5.3 An air-lift pump (see Fig. 13) is the most common type of pump employed in this development operation, because of its small diameter and efficiency in removing sediment without damage to the pumping mechanism. Occasionally, the size of the air line and eductor pipe may have to be decreased somewhat so that the air line and eductor pipe will both fit into the annulus between the jetting pipe and the well casing. The air-lift system operates best when the air line is at least 40 % submerged (see Fig. 14) and when the bottom of the eductor pipe is placed just above the jetting tool allowing more suspended sediment to be pumped out of the well.

8.5.4 Compressed air used for development must be filtered to ensure that oil from the air compressor is not introduced into the well. In theory, this could be accomplished relatively easily with high-volume carbon filters. In practice, however, the effectiveness of air/oil filters in removing entrained oil is questionable. It is difficult to ensure that the air used has a non-detectable oil content. Thus, development with compressed air may actually introduce oil into the well, albeit at very low levels. This oil may have the effect of confusing water quality analytical results. Alternately, oilless or oil-free compressors may be used to obviate the problems inherent with common oil-lubricated air compressors.

8.5.5 When air-lift pumping is impractical or undesirable, a submersible pump can be used, but this is only possible in large-diameter wells. Usually, the pump must be placed above the jetting tool so that the amount of sediment passing through the pump is minimized to avoid damaging the pump. Thus, the



NOTE 1—In this configuration, the jetting tool and drop pipe are separate from an air-lift pumping system so that jetting and air-lift pumping can be done simultaneously.[3]

FIG. 13 Air-Lift Pump

pump causes material temporarily placed in suspension by the jetting action to move into the well, but much of the sediment falls to the bottom. This sediment must be removed periodically during the jetting and pumping operation so that the entire screen can be effectively developed.

8.6 *Developing with Air*—Developing with air is not recommended for monitoring wells. Air development may force air into contact with the formation, which may alter the oxidation-reduction potential of the formation water and change the chemistry of the water in the vicinity of the well. The effects of this type of chemical disturbance may persist for several weeks or more after well development.

8.6.1 Blowing air into the well during the process of air development may cause air to become entrapped in the narrow slots of some monitoring well screens, the pores of the filter pack or formation materials immediately adjacent to the borehole. Entrapped air is difficult to remove and it may significantly reduce formation hydraulic conductivity and effectively reduce the amount of open area of the well screen.

8.6.2 In situations in which the well is installed in an area of contaminated groundwater, development with air may potentially result in the exposure of field personnel to hazardous materials. Though precautions can be taken to minimize personnel exposure, other development methods, which may also be more effective, can be used without such exposure problems and are, therefore, generally preferable.

8.6.3 For these reasons, compressed air alone should not be used to develop monitoring wells. Air-lift pumping, in which the air stream is not released directly into the well but instead is confined within an eductor pipe (see Fig. 15), should not produce the deleterious effects of air surging, and can thus be used in conjunction with other development processes.

9. Report

9.1 Keep records of the various operations performed during development and the progress and results of the development procedure. Report the following information: recorded:

9.1.1 Baseline turbidity (to be compared with turbidity levels obtained later in the life of the well);

9.1.2 Chemical quality, physical characteristics (that is, color, odor, etc.) volume, and sediment content of water added to the well or removed from the well;

9.1.3 Amount and particle size of sediment that accumulates in the well between phases of development;

9.1.4 Type(s) of equipment used during development;

9.1.5 Well construction details;

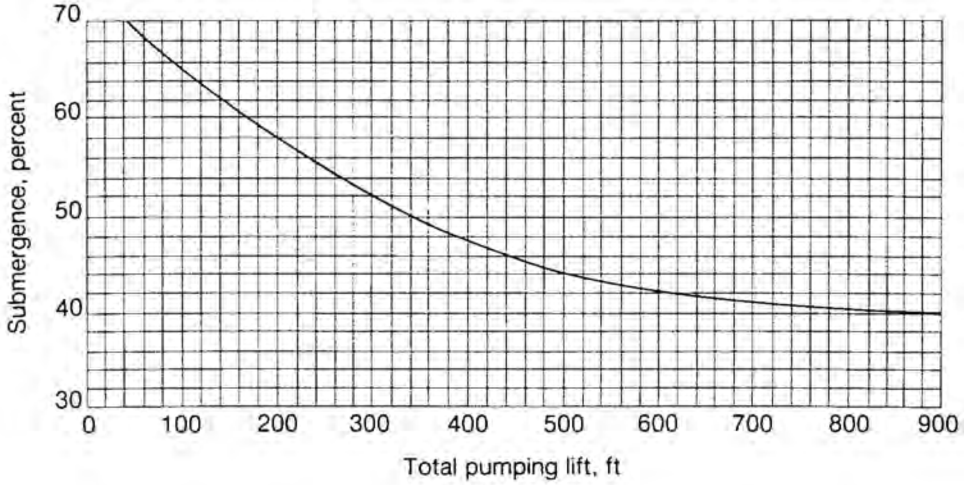
9.1.6 Static water level prior to, during, and after development;

9.1.7 Time spent during development and

9.1.8 Other details pertinent to the development process and the objectives of development. A well development data form, such as that illustrated in Fig. 16, can be used for this purpose.

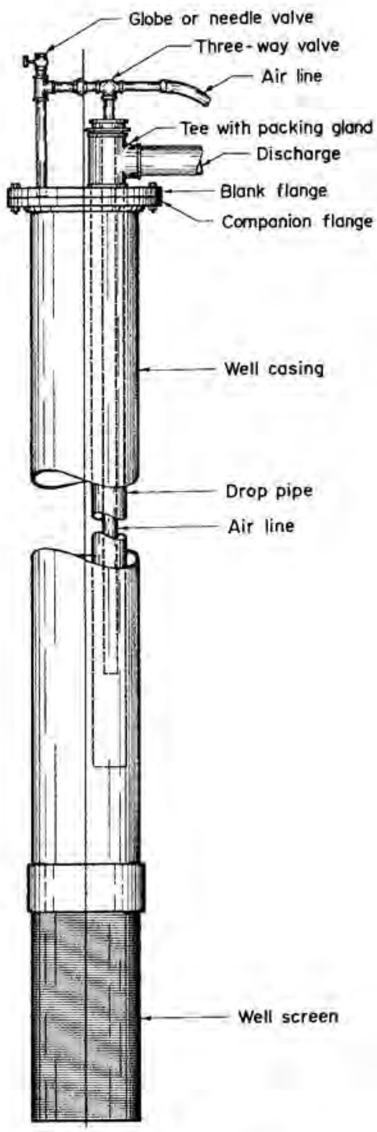
10. Keywords

10.1 aquifer; ground water; high-velocity; hydraulic jetting; jetting; mechanical surging; monitoring well; over-pumping and backwashing; representative sample; well development



NOTE 1—Approximate percent pumping submergence for optimum air-lift efficiency. In general, development proceeds most efficiently when the discharge is maximized. Therefore, the submergence should always be as great as possible within practical limits.[3]

FIG. 14 Submerged Air Line



NOTE 1—See Footnote 3.

FIG. 15 A Typical Air-Lift Pumping Configuration

WELL DEVELOPMENT DATA

SITE TYPE	SITE ID
WELL	

DEPTH TO BOTTOM (INITIAL) ______

(FINAL) ______

STATIC WATER LEVEL (INITIAL) ______

(FINAL) ______

MEASURING POINT ______

CASING I.D. ______

Responsible Professional ______

DRILLER ______

PROJECT NO. ______

DATE(S) INSTALLED ______

DATE(S) DEVELOPED ______

PUMP (TYPE) ______

(CAPACITY) ______

BAILER (TYPE) ______

(CAPACITY) ______

TIME	VOLUME OF WATER REMOVED	pH	SPECIFIC CONDUCTANCE AT 25°C	TEMP	SAND CONTENT	OTHER PHYSICAL CHARACTERISTICS (CLARITY, ODOR, PARTICULATES, COLOR)

FOPM14 / SEPT 87

FIG. 16 Example of a Well Development Data Form

CATEGORY 4: GROUNDWATER SAMPLING AND PURGING

Section 4.6

Sampling Procedures

Sampling Procedures

Most samples received by 29 Palms Laboratory will have been taken by the cllient.
29 Palms Laboratory will provide to the client:

1. Appropriate certified clean sample containers that are traceable by lot to sources
2. Labels
3. Shipping containers
4. Chain-of-Custody forms
5. Method specific sampling instructions that include handling, preservation, and storage procedures

All samples should be handled and preserved in accordance with the method of analysis (See table I).
Samples known to be highly contaminated should be shipped according to DOT regulations for the . transport of hazardous materials.
Due to extreme weather conditions in the Coachella Valley where 29 Palms Laboratory is located, all samples requiring preservation should be immediately kept on ice in an ice chest at time of sampling. ***Care should be taken to ensure that samples remain on ice during delivery to the laboratory.***

TABLE I - CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

EPA METHOD	METHOD NAME	CONTAINER	SAMPLE AMOUNT	PRESERVATION	MAXIMUM HOLDING TIME
100-Series	Physical Properties				
120.1	Conductance	Polyethylene, Glass	100 ml	Cool, $4^{o}C$	28 Days
150.1	pH	Polyethylene, Glass	25 ml	None	Analyze Immediately
160.1	Residue, Filterable	Polyethylene, Glass	100 ml	Cool, $4^{o}C$	7 Days
200-Series	Total Metals	Polyethylene, Glass	100 ml	HNO_3 to pH <2	6 Months
300-Series	Non-Metallics				
325.3	Chloride	Polyethylene, Glass	50 ml	None	28 Days
340.1	Fluoride	Polyethylene, Glass	300 ml	None	28 Days
352.1	Nitrate	Polyethylene, Glass	100 ml	Cool, $4^{o}C$	48 Hrs.
365.3	Orthophosphate	Polyethylene, Glass	50 ml	Filter on site, Cool, $4^{o}C$	48 Hrs.
365.3	Total Phosphate	Polyethylene, Glass	50 ml	Cool, $4^{o}C$, H2SO4 to pH <2	28 Days
375.4	Sulfate	Polyethylene, Glass	50 ml	Cool, $4^{o}C$	28 Days
600-Series	Organics				
608	Organochlorine Pesticides	Amber Glass with Teflon-Lined Caps	1 liter	Cool, $4^{o}C$ 0.008% Sodium Thiosulfate	Extracted by 7 Days Analyzed by 40 Days
632	Carbamate Pesticides	Amber Glass with Teflon-Lined Caps	1 liter	Cool, $4^{o}C$ 0.008% Sodium Thiosulfate	Extracted by 7 Days Analyzed by 40 Days
8000-Series	Organics				
8081A	Organochlorine				
	Pesticides Solid -	8 oz. Glass	50 grams	Cool, $4^{o}C$	14 Days
	Liquid -	Amber Glass with Teflon-Lined Caps	1 liter	Cool, $4^{o}C$ 0.008% Sodium Thiosulfate	Extracted by 7 Days Analyzed by 40 Days
8141A	Organophosphorus				
	Pesticides Solid -	8 oz. Glass	50 grams	Cool, $4^{o}C$	14 Days
	Liquid -	Amber Glass with Teflon-Lined Caps	1 liter	Cool, $4^{o}C$ 0.008% Sodium Thiosulfate pH to 5-8 with NaOH or H_2SO_4	Extracted by 7 Days Analyzed by 40 Days
8318	Carbamate				
	Pesticides Solid -	8 oz. Glass	50 grams	Cool, $4^{o}C$	14 Days
	Liquid -	Amber Glass with Teflon-Lined Caps	1 liter	Cool, $4^{o}C$ 0.008% Sodium Thiosulfate pH to 4-5 with 0.1 N Chloroacetic Acid	Extracted by 7 Days Analyzed by 40 Days

CATEGORY 5: HYDRAULIC PROFILING TOOL (HPT)

Section 5.1

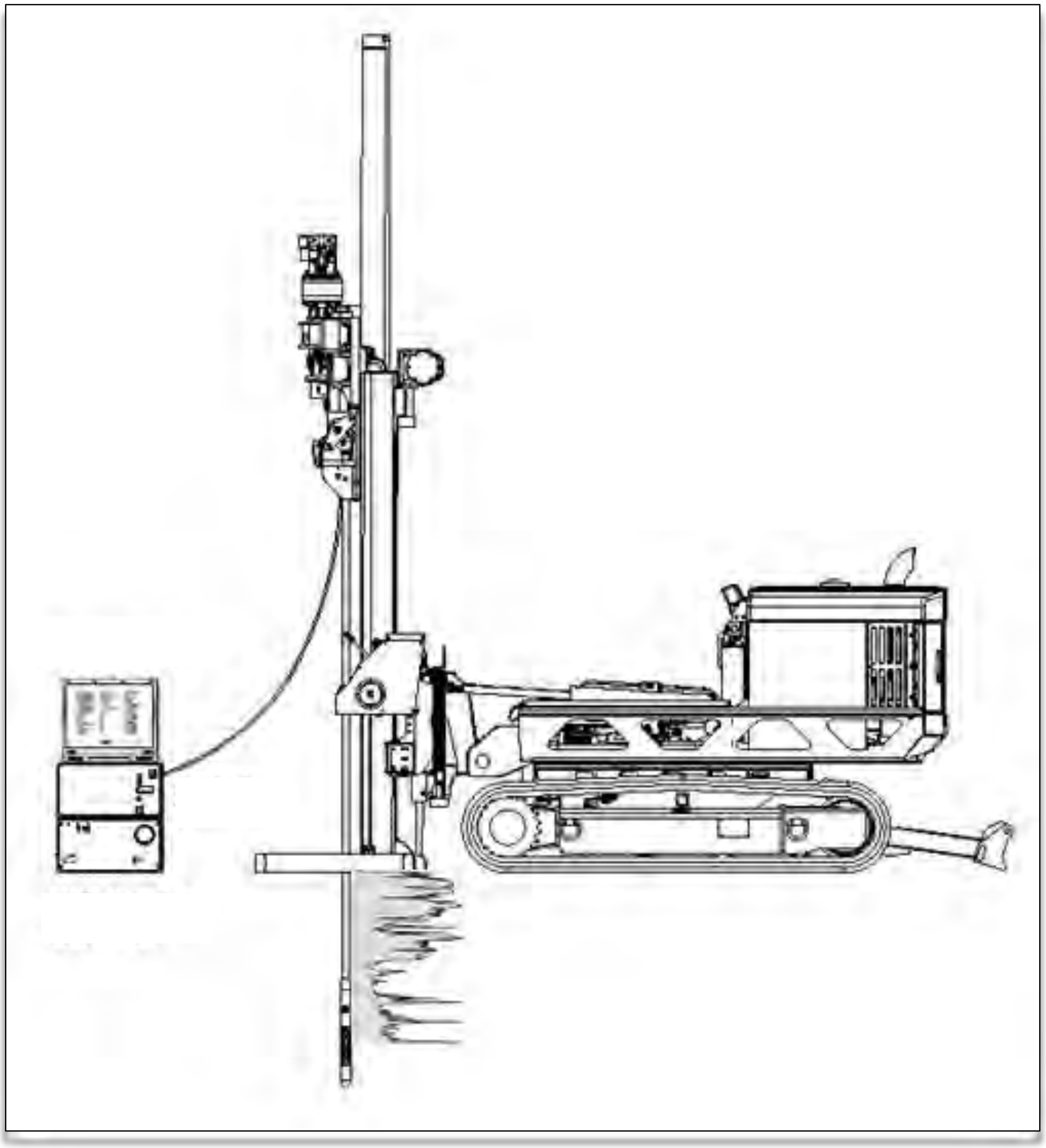
Standard Operating Procedure for Geoprobe Hydraulic Profiling Tool (HPT) System

Geoprobe® Hydraulic Profiling Tool (HPT) System

Standard Operating Procedure

Technical Bulletin No. MK3137

Prepared February 6, 2013



1.0 Objective

This document serves as the standard operating procedure for the Geoprobe® Hydraulic Profiling Tool (HPT) system. In this procedure, the HPT system is used to measure the pressure response of soil to injected water for identifying potential flow paths and to assist with characterization of soil type. This document has been updated from Geoprobe Systems® Technical Bulletin No. MK3137 (March 2007) to show the use of an FI6000 field instrument for HPT system control and data acquisition.

2.0 Background

2.1 Definitions

Geoprobe®*: A brand of high quality, hydraulically-powered machines that utilize both static force and percussion to advance sampling and logging tools into the subsurface. The Geoprobe® brand name refers to both machines and tools manufactured by Geoprobe Systems®, Salina, Kansas. Geoprobe® tools are used to perform soil core and soil gas sampling, groundwater sampling and testing, electrical conductivity and contaminant logging, grouting, and materials injection.

**Geoprobe® and Geoprobe Systems® are registered trademarks of Kejr, Inc., Salina, Kansas.*

Hydraulic Profiling Tool (HPT) System: A system manufactured by Geoprobe Systems® to evaluate the hydraulic behavior of subsurface soil. The tool is advanced through the subsurface at a constant rate while water is injected through a screen on the side of the probe. An in-line pressure sensor measures the pressure response of the soil to water injection. The pressure response identifies the relative ability of a soil to transmit water. Both pressure and flow rate are logged versus depth.

2.2 Introduction

The HPT system has been developed by Geoprobe Systems® for the geohydrologic characterization of soils. The HPT probe and logging system is able to quickly provide logs that are easily interpreted. HPT logs are used to indicate hydraulic conductivity, EC, hydrostatic profile, and areas of EC/permeability anomalies.

The HPT system is designed to evaluate the hydraulic behavior of unconsolidated materials. As the probe is pushed or hammered at 2 cm/s, clean water is pumped through a screen on the side of the HPT probe at a low flow rate, usually less than 300 mL/min. Injection pressure, which is monitored and plotted with depth, is an indication of the hydraulic properties of the soil. That is, a low pressure response would indicate a relatively large grain size, and the ability to easily transmit water. Conversely, a high HPT pressure response would indicate a relatively small grain size and the lack of ability to transmit water.

An electrical conductivity measurement array is built into the HPT probe. This allows the user to collect soil electrical conductivity (EC) data for lithologic interpretation. In general, the higher the electrical conductivity value, the smaller the grain size, and vice versa. However, other factors can affect EC, such as mineralogy and pore water chemistry (brines, extreme pH, contaminants). In contrast, HPT pressure response is independent of these chemical and mineralogical factors.

There are four primary components of the HPT system: the probe assembly, trunkline, HPT Flow Module (K6300 Series), and Field Instrument (FI6000 series). These primary components are shown in Figure 2.1.

The probe assembly consists of the HPT probe and connection section. This assembly houses the downhole HPT pressure transducer, water and electrical connections, and the probe body with the injection screen and electrical conductivity array.

Injecting water at a constant rate is integral to system operation. The HPT Flow Module houses the pump and associated hand crank mechanism used for adjusting the output flow of the HPT pump. The flow module also contains the HPT flow measurement and injection line pressure transducers. HPT flow can be adjusted from approximately 50 to 500 ml/min. The HPT pump is a positive displacement pumping device with minimal decrease in flow over the HPT operating pressure range. The flow module is equipped with an internal bypass that is factory set to open and return flow to the supply reservoir at a pressure of 120 psi. When the soil resistance to water injection becomes sufficiently great, the HPT Flow Module bypass will open, returning some or all of the pumped flow to the supply reservoir. The flow meter only measures flow leaving the module to the HPT probe. The HPT Flow Module is connected to the Field Instrument via a data cable.

Water and power are transmitted from the controller to the probe assembly via the HPT trunkline. The probe rods must be pre-strung with the trunkline before advancing the probe.

Data collection occurs in real time by connecting the controller to the field instrument. The field instrument collects, stores and displays transducer pressure, flow rate and electrical conductivity, line pressure, probe rate, and diagnostic parameters, with depth.

Since the HPT pressure response is analogous to the soil’s ability to transmit water (and therefore the to the soil’s dominant grain size), the HPT system can be used to identify potential contaminant migration pathways. Similarly, it can help identify zones for remedial material injection or provide qualitative guidance on how difficult injection may be in different zones of the formation.

The HPT system may be used to direct other investigation methods, such as soil and groundwater sampling and slug testing. HPT pressure response and EC data can help target zones of geologic and hydraulic interest, minimizing the number of soil and groundwater samples required to adequately develop a site conceptual model. When hydraulic conductivity values are required, the HPT system can also help the user identify zones to slug test, as well as the length of the screen required to adequately test the zone.

The HPT system also can be used to collect static water pressure data at discrete intervals during the logging process. These static pressure data can be used to calculate static water levels or to create a hydrostatic profile for the log.

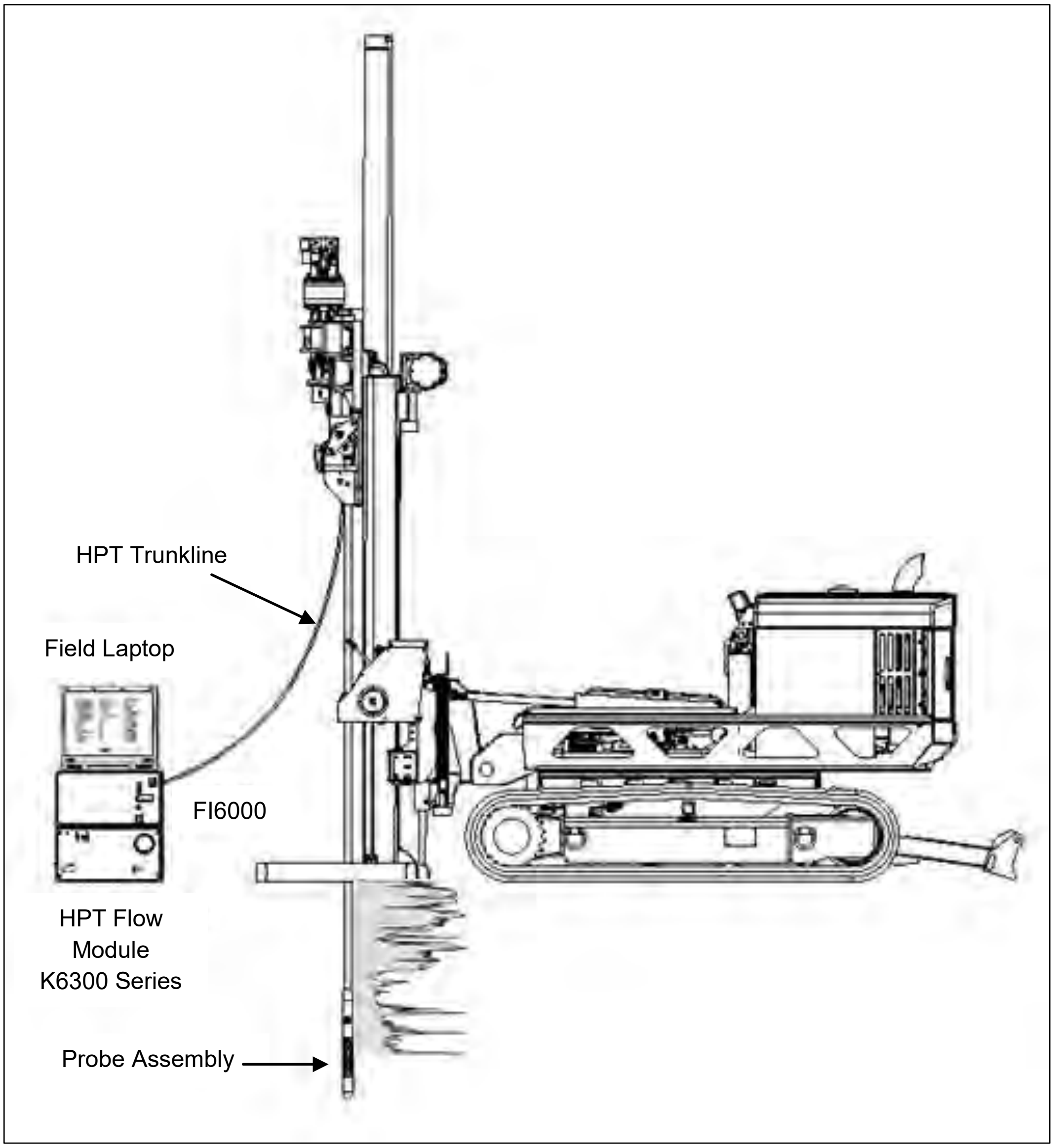


Figure 2.1: HPT Components

3.0 Tools and Equipment

The following equipment is required to perform and record an HPT log using a Geoprobe® 66- or 78-Series Direct Push Machine. Refer to Figures 3.1, 3.2, and 3.3 for identification of the specified parts.

Basic HPT System Components	Quantity	Part Number
Field Instrument, 120V	-1-	FI6000
Field Instrument, 220V	*	FI6003
HPT Acquisition Software	-1-	K6020
HPT Flow Module, 120V	-1-	K6300
HPT Flow Module, 220V	*	K6303
HPT Probe, 1.75 inch	-1-	K6050
MIP/HPT Connection Tube	-1-	31641
MIP/HPT Adapter 1.5 Pin x LB Box	-1-	20712
HPT Probe, 2.25 inch	**	K8050
2.25 Probe Rod, 24 inch	**	32656
2.25 Inch Water Seal Adapter	**	45170
2.25 Inch Water Seal Drive Head	**	48866
HPT Reference Tube 1.75 in HPT Probe	-1-	50344
HPT Reference Tube 2.25 in HPT Probe	**	50344
HPT Trunkline 150 ft.	-1-	K6415
HPT Trunkline 200 ft.	(optional)	K6420
HPT Service Kit *(contains the following)*	-1-	29028
O-Ring Pick	*-1-*	*AT102*
Term Block 4 POS Green	*-4-*	*7700*
Electrical Tape, 0.75-in. x 60-ft.	*-1-*	*6167*
Membrane Ratchet Wrench Asm	*-1-*	*48877*
Coupling 1/8 to 1/8 Tube	*-5-*	*48842*
Oetiker #7 Band Clamp 5.8 x 7mm	*-10-*	*48724*
HPT Sensor Module	*-2-*	*43327*
Silicone Dielectric Compound	*-1-*	*41274*
Butt Connector Red (10 pak)	*-2-*	*39807*
HPT Trunkline Seal Asm.	*-4-*	*37031*
Trunkline Seal Spacer (1 pair)	*-2-*	*36378*
O-Ring 120 BUNA 70	*-10-*	*3537*
HPT Screen Asm	*-4-*	*28895*
HPT Spring Washer (pkg 10)	*-1-*	*52399*
Tube Nylon 0.25 OD x 0.04 W Flexible	*-1-*	*20727*
Tubing 0.125 ID x 0.25 OD Polyur Yellow	*-1-*	*17957*
EC Probe Test Jig	-1-	SC563
EC Test Load	-1-	37785
Stringpot, 100-inch	-1-	SC160-100
Stringpot Cordset, 65-feet (19.8 m)	-1-	16401

*Use in place of 120V components if desired.

**Use in place of 1.75 inch probe and components if desired.

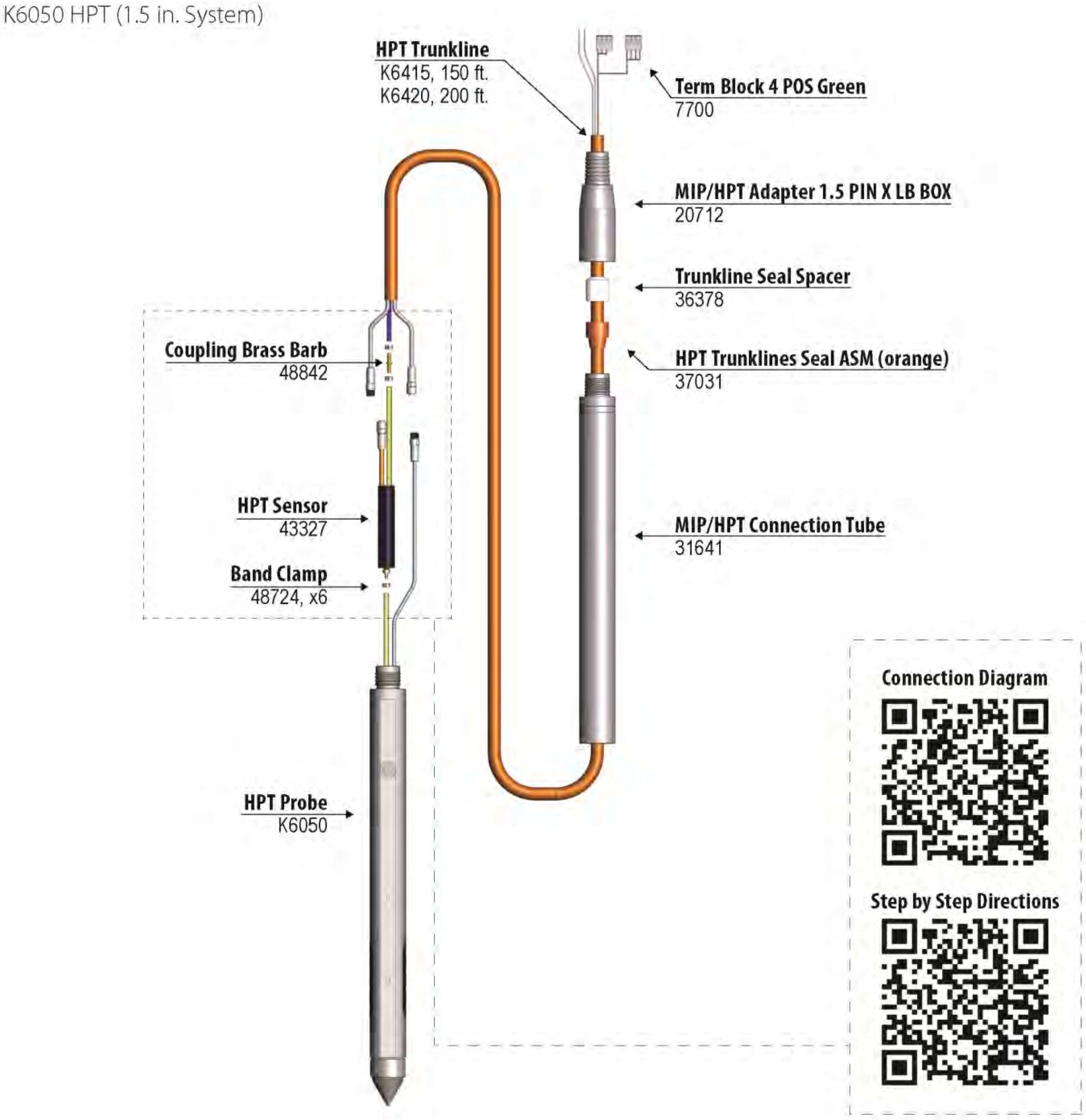


Figure 3.1 PN K6050 1.75 inch HPT Probe and components

http://geoprobe.com/tool-string-diagrams/k6050-hpt

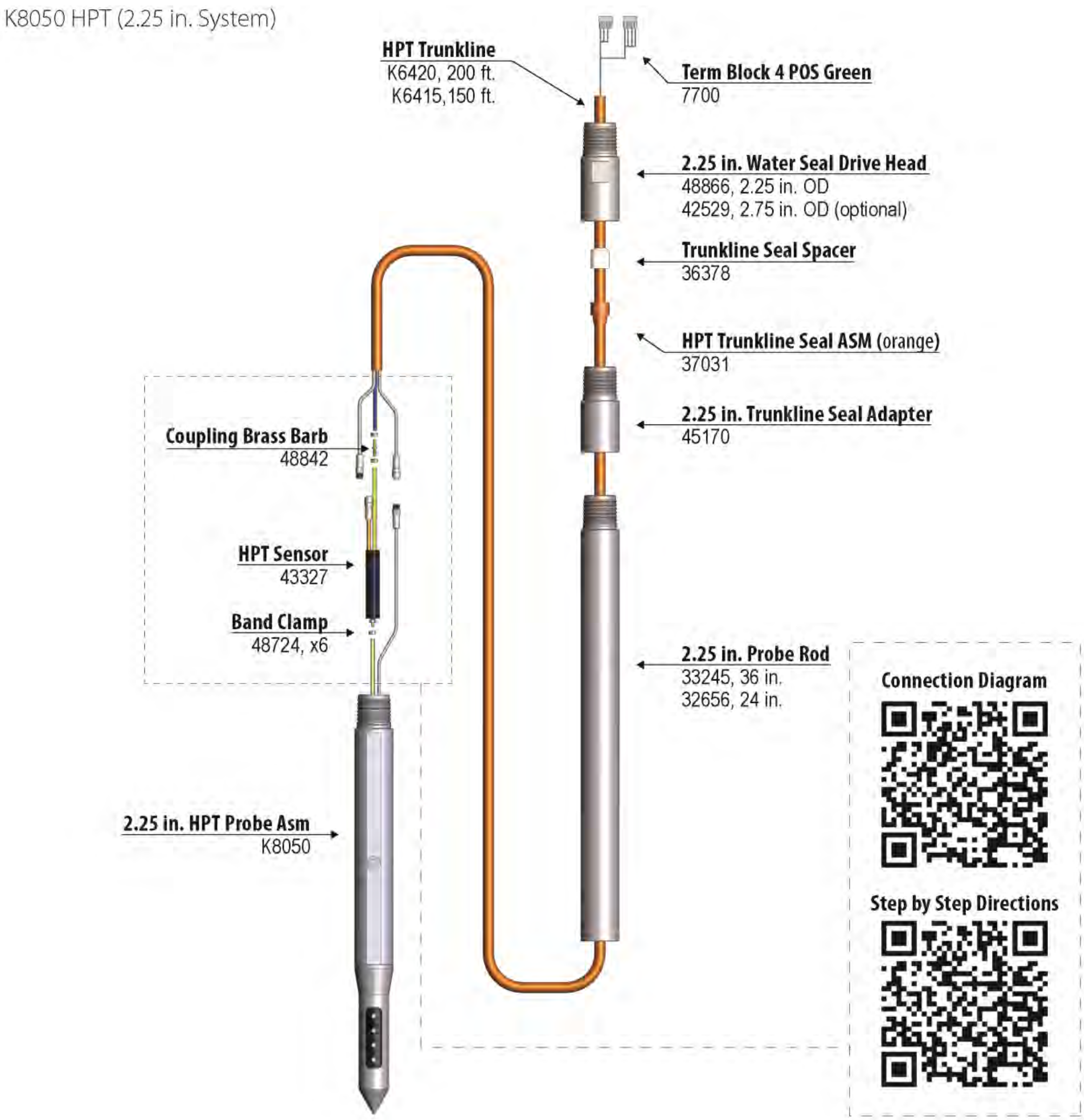
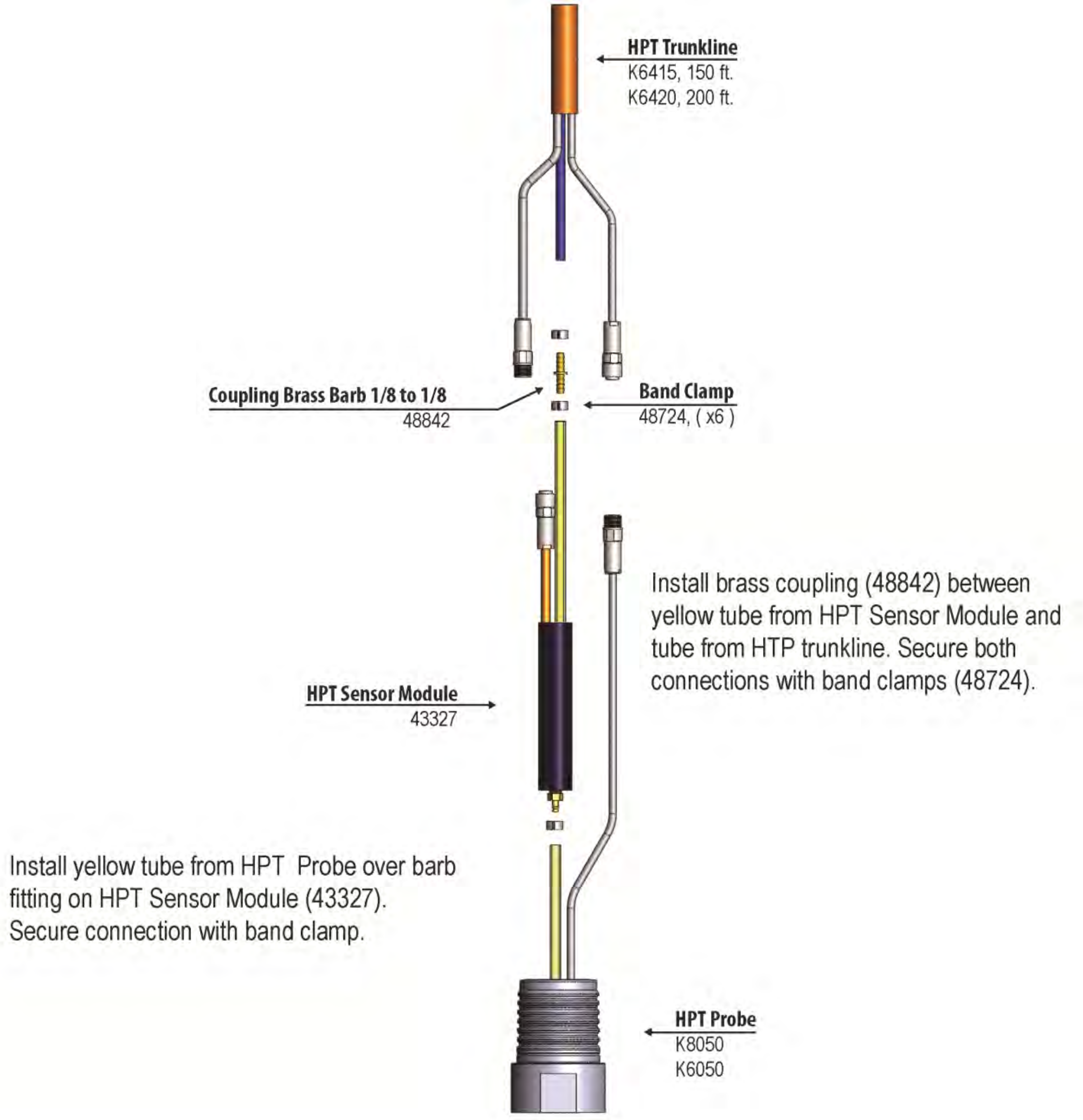


Figure 3.2 PN-K8050 2.25 inch HPT Probe and components

http://geoprobe.com/tool-string-diagrams/k8050-hpt

HPT Sensor Connection Diagram



Install brass coupling (48842) between yellow tube from HPT Sensor Module and tube from HTP trunkline. Secure both connections with band clamps (48724).

Install yellow tube from HPT Probe over barb fitting on HPT Sensor Module (43327). Secure connection with band clamp.

Figure 3.3 PN 43327 HPT Sensor Module Connection Diagram

http://geoprobe.com/tool-string-diagrams/hpt-sensor-connection-diagram

4.0 HPT Assembly

Refer to Appendix A

Threading the Rods

- Protect the end to be threaded through the rods with electrical tape or shrink tubing.
- Probe rods must alternate directions prior to threading the trunkline.
- The end of the HPT trunkline with chrome connectors is the downhole or probe end.
- The probe end of the trunkline will always enter the male end and exit the female end of the probe rods.
- The instrument end (no chrome connectors) will always enter the female end and exit the male end of the probe rods.
- After the trunkline is through the probe rods make sure the downhole end is threaded through the male end of the drive head and connection tube prior to connecting to the probe.
- The trunkline is now ready to connect to the instrument and HPT pressure sensor and probe.

5.0 Field Operation

5.1 Instrument Setup

1. Connect the HPT Controller (K6300), Field Instrument (FI6000) and laptop (Fig. 5.1) to an appropriate power source.

2. Connect the FI6000 to the K6300 using the 62-pin serial cable inserted into the acquisition port of each instrument.

3. Secure the EC wires into the Green terminal block connector and insert into the FI6000. The wires match to the EC dipoles in the following top down order when the probe tip is on the ground – white, black, yellow and blue (Fig 5.2).

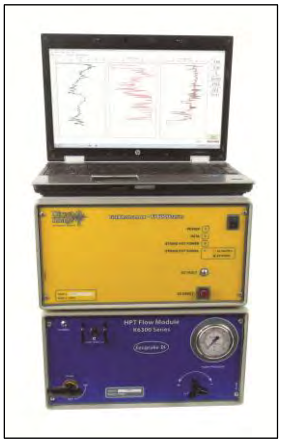


Figure 5.1: HPT Instrument Setup

4. Secure the HPT sensor wires to the appropriate inputs on the green terminal block connector and connect to the rear of the K6300. The top down order of the wires which is listed on the back of the instrument is: brown, orange, red and reserved (open).

5. Insert the nylon water line tubing from the trunkline into the water output connector on the back of the K6300.

6. Connect the HPT water supply hose into the input port on the rear of the K6300 and insert the filtered end of the supply line into a water supply tank. The bypass line connects to the bypass port and will follow the supply line back to the supply tank.

Figure 5.2: EC Wire Connections

7. Connect the USB cable between the USB interface port on the rear of the FI6000 to USB input on the field laptop computer.

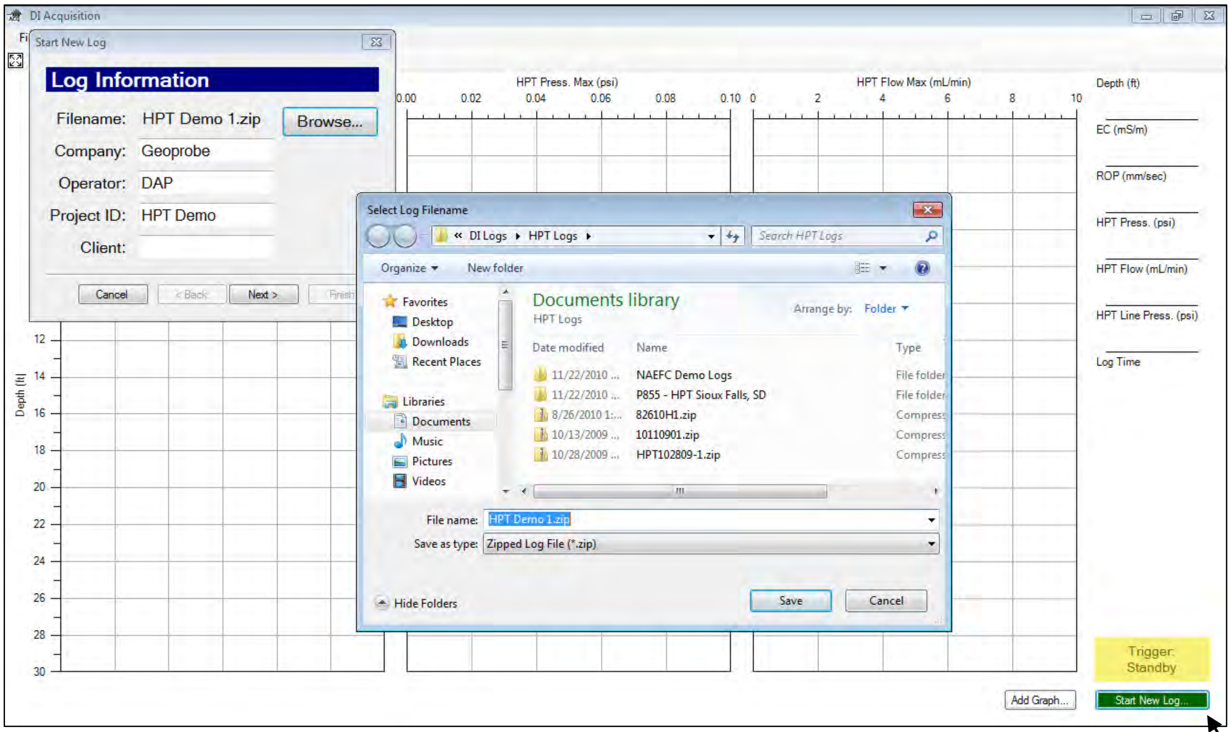
8. A stringpot is required to measure depth. Bolt the stringpot onto the machine and the stringpot onto the bracket. Connect the plastic connector end of the stringpot cable to the "Stringpot" connector on the back of the Field Instrument and the metal connector to the stringpot. Pull the stringpot cable and attach to the stringpot piston weight which should be mounted to the probe machine foot and pull the keeper pin so the weight is free to move.

5.2 Starting the Software

1. Make sure the FI6000 and K6300 are connected together with the 62 pin cable, powered on and connected to the computer by the USB cable for the software to load properly.

2. Start the DI Acquisition Software which should open in HPT mode.

3. Select "Start New Log". The software will request log information and have you browse for a storage location and create and save a file name for the log (Fig. 5.3).



Log Information

Filename: HPT Demo 1.zip

Company: Geoprobe

Operator: DAP

Project ID: HPT Demo

Client:

File name: HPT Demo 1.zip

Save as type: Zipped Log File (*.zip)

Figure 5.3: DI Acquisition Software – Start New Log Sequence

4. Select "Next". If the software has been run before it will show a list of previous settings including Probe Type, EC Configuration, Stringpot length, rod length and HPT Transducer. If any of these have changed or you are unsure select "No" but if they are all the same select "yes". If you select "No" the software will have you select the proper settings after the EC Load Test, if you selected "Yes" the selection of these settings will be bypassed.

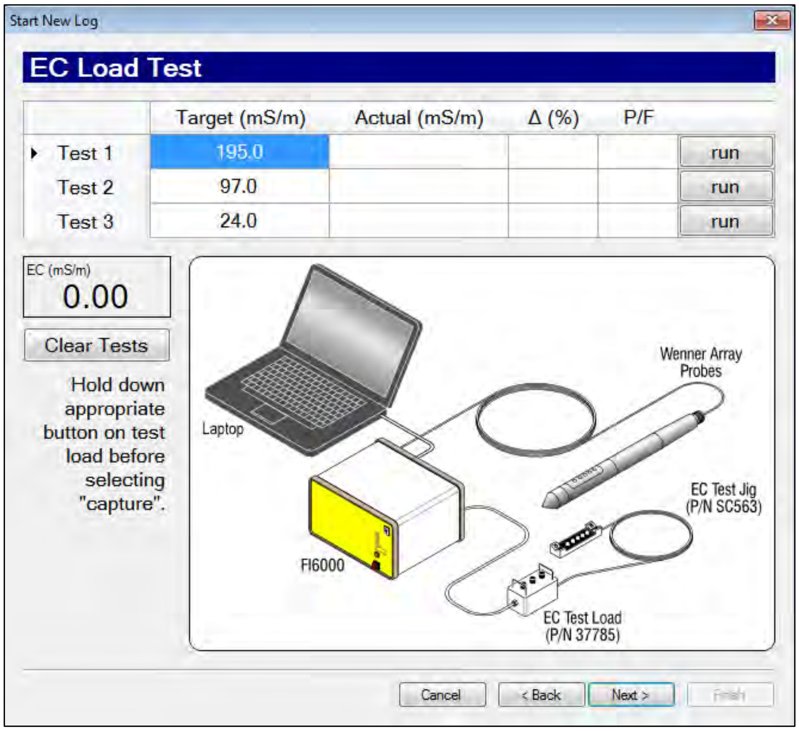
5.3 QA Testing the EC and HPT Systems

Both the EC and HPT components must be tested before and after each log. This is required to ensure that the equipment is working properly and capable of generating good data before and after the log.

A. Electrical Conductivity Load Test

1. Secure the EC 3 position test load connector (37785) to the test input jack on the back of the Field Instrument.

2. Secure the EC Probe Test Jig into the input on the EC 3 position test load.



Start New Log

EC Load Test

	Target (mS/m)	Actual (mS/m)	Δ (%)	P/F	
Test 1	195.0				run
Test 2	97.0				run
Test 3	24.0				run

EC (mS/m) 0.00

Hold down appropriate button on test load before selecting "capture".

Figure 5.4: EC Load Test Screen

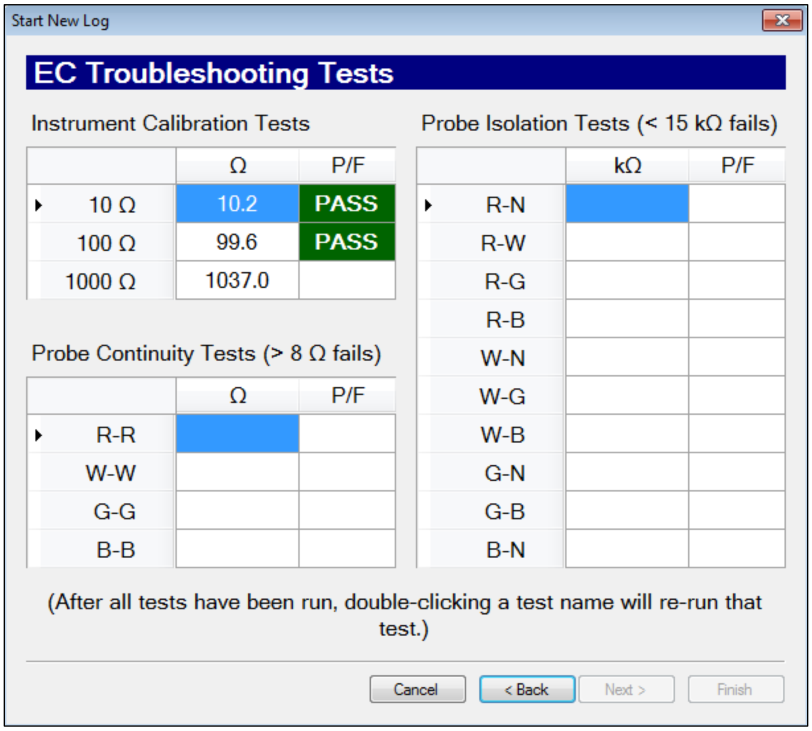
3. Clean and dry the EC dipoles as well as several inches of the probe body above the pins.

4. Place the EC Test Jig (SC563) so that the four springs on the test jig touch the four dipoles of the Wenner EC array (Fig. 5.4). Make sure the trunkline and test jig wires go in the same direction. The other spring on the test jig will ground the probe body above the Wenner array. Make sure the springs are pulled out far enough to make a solid contact on the dipoles.

5. When you get to the EC Load Test Screen and the EC test load and test jig are in place on the probe press down on the test 1 button on the test load and select “run” of Test 1 (Fig. 5.4). After 5 seconds the actual value will acquire and will pass if within 10% of the target value. Continue on with Test 2 and 3.

6. If any of the EC load tests fail do not pass within the allowed 10% acceptance range you can make adjustments on the test jig and rerun the test by just re-clicking the “run” button for an individual test.

7. If the tests continue to fail, select “Next” and the software will conduct the “EC Troubleshooting Tests.” The Instrument Calibration Tests (Fig. 5.5) checks of the calibration within the FI6000. If these are far out of range it will influence the EC Test load values and will need to return to Geoprobe® for repair. The “Probe Continuity and Isolation Tests” confirm each of the wires is a complete circuit and is fully isolated from one another. If a probe continuity test fails just outside the target range of <8ohms this is typically a contact issue with the test jig and the dipoles. If the continuity is in the thousands of ohms this is a break in the EC wire circuit – either in the probe, the trunkline or the connection between them.



EC Troubleshooting Tests

Instrument Calibration Tests

	Ω	P/F
10 Ω	10.2	PASS
100 Ω	99.6	PASS
1000 Ω	1037.0	

Probe Continuity Tests (> 8 Ω fails)

	Ω	P/F
R-R		
W-W		
G-G		
B-B		

Probe Isolation Tests (< 15 kΩ fails)

	kΩ	P/F
R-N		
R-W		
R-G		
R-B		
W-N		
W-G		
W-B		
G-N		
G-B		
B-N		

(After all tests have been run, double-clicking a test name will re-run that test.)

Figure 5.5: EC Troubleshooting Test Screen

8. When these tests are complete select next. In the next screen, the software will provide an EC option, if one is available. The EC Load Test will only work if EC can be operated in Wenner array meaning all of the EC wires in the continuity test pass with results <8ohms on the individual circuits. EC can be operated and collect good data in one odf the dipole areas: top, middle or bottom dipole. If the R-R test fails but the others pass the software will provide the option in the next screen to run either middle dipole or bottom dipole arrays. If R-R and G-G are both an incomplete circuit then no EC array is available to run and a new probe must be connected or the problem fixed. In the Wenner configuration it requires 2 adjacent dipoles to operate in dipole mode. If an EC array is chosen and run in this last manner then all of the EC information collected will be bad data.

B. HPT Reference Testing

Reference testing is done to ensure that the HPT pressure sensor is in working order and to evaluate the condition of the HPT injection screen. The HPT reference test calculates atmospheric pressure which is required to obtain static water level readings and to determine the estimated K values for the log in our post log processing software the DI Viewer.

Reference Test Procedure

1. Connect a clean water source to the HPT controller and turn on the pump.

2. Allow water to flow through the system long enough so that no air remains in the trunkline or probe (air in the system can cause inaccurate flow and pressure measurements).

3. Insert the probe into the HPT reference tube and allow the water to flow out the valve adjusting the flow rate to between 250-300ml/min (Fig. 5.5). Ensure that the reference tube is close to vertical.

4. With a stable pressure reading and the water flowing out of the valve select “capture” - bottom with flow (Fig. 5.6)

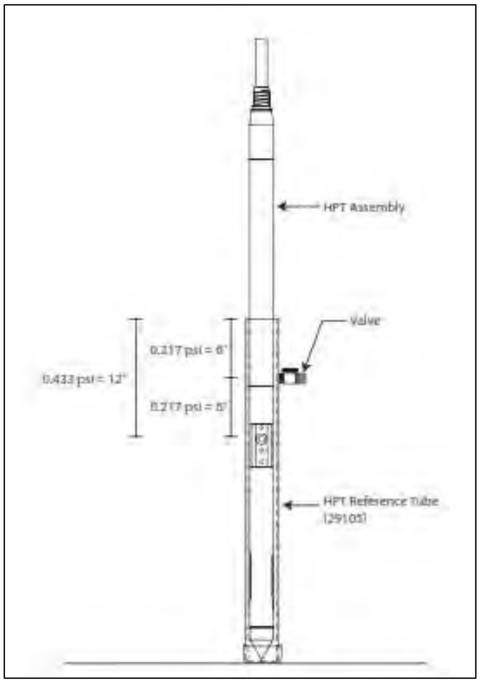
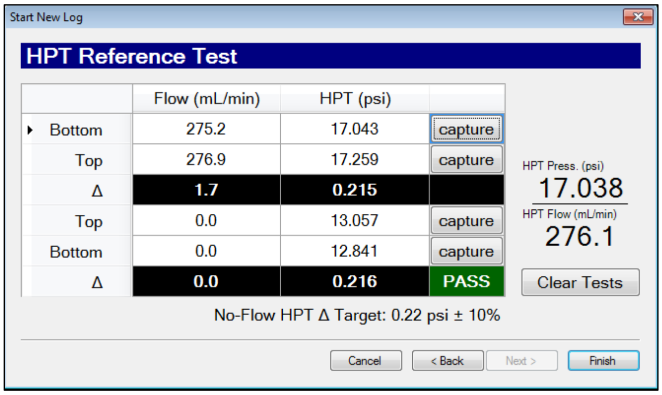


Figure 5.5: HPT Reference Test Setup

5. Close the valve and allow the water to overflow the top of the tube. When the pressure stabilizes select “capture” - top with flow.

6. Shut off the water flow. When the pressure stabilizes select “capture” - top flow = 0.

7. Open the valve and allow the water to drain out. When the pressure stabilizes select “capture” - bottom flow = 0.



HPT Reference Test

	Flow (mL/min)	HPT (psi)	
Bottom	275.2	17.043	capture
Top	276.9	17.259	capture
Δ	1.7	0.215	
Top	0.0	13.057	capture
Bottom	0.0	12.841	capture
Δ	0.0	0.216	PASS

HPT Press. (psi) 17.038

HPT Flow (mL/min) 276.1

No-Flow HPT Δ Target: 0.22 psi ± 10%

Figure 5.6: HPT Reference Test Screen

The HPT reference test reading flow = 0 is the true test of the condition of the pressure sensor and is the only sensor test to have a pass/fail reading on it. Ideally, the pressure difference between the top and bottom values will be 0.22 psi (1.52kPa). Typical pressure readings of the sensor will be in the 12PSI-15PSI (83kPa-104kPa) range.

5.4 Running an HPT Log

1. Place the rod wiper on the ground over the probing location and install the drive cushion in place of the anvil of the probing machine.

2. Place the probe tip in the center of the rod wiper, and place the slotted drive cap on top of the HPT probe.

3. Start the HPT water flow. **Note**: It is important that there is always water flowing when the probe is advanced to avoid soil particles from moving through the screen and causing problems with the pressure readings or causing a blockage behind the screen.

4. Adjust the probe so that it is vertical and advance the probe until the HPT screen is at the ground surface.

5. Click the trigger button in the lower right hand corner of computer screen. (The Trigger label will flash and the background will change from yellow to green).

9. Advance the probe at a rate of 2 cm/s. If necessary, feather the hammer to maintain this advance rate.

10. Perform a dissipation test (Section 5.4) in a zone of higher permeability indicated by lower HPT pressure.

11. After completing the log, press the trigger button again and select “Stop Log”.

12. Pull the rod string using either the rod grip pull system or a slotted pull cap. Run a post-log EC test and HPT response test (Section 5.2).

5.5 Performing a Dissipation Test

At least one dissipation test must be performed in order to calculate the static water level and estimated K readings from the log. Dissipation tests need to be performed below the water table and are best in zones of high permeability where the injection pressure can dissipate off quickly once the flow is shut off.

1. Stop in a zone of higher permeability which is indicated by lower HPT inject pressure.

2. Switch the DI Acquisition display view from the depth screen to the time screen by pressing the F10 key (F9 and F10 toggle between the depth and time screen of the acquisition software).

3. The screen will be grayed out which means that the data up to that point has not been saved. Select “Start Dissipation Test” which will turn the screen from gray to a white background indicating that you are now saving the time data.

4. Now shut the pump switch off and when the line pressure reaches zero, turn the flow valve off.

5. The HPT Pressure will begin to drop (dissipate the hydrostatic increase) and allow it to stabilize so very little visible drop in pressure is seen. When the pressure has fully dissipated turn the flow valve and the pump switch back on. When the flow and pressure are reestablished select “End Dissipation test.”

6. Select F9 to return to the depth screen and advancing the tool into the ground.

   Note: Performing a dissipation test in zones of higher permeability may only take 30 seconds or so but if the HPT pressure was higher to start with it may take a long time up to several hours to dissipate off to equilibrium. This is why targeting the most permeable zone to perform the dissipation tests is most desirable.

6.0 HPT Log Interpretation

Below is a typical HPT log, which consists of both the HPT pressure response and electrical conductivity. In general, both HPT pressure and EC values increase with decreasing grain size, and decrease with increasing grain size. The log in Figure 6.1 shows good consistency between EC and HPT pressure for the majority of the log. It is only between 32’-42’bgs that we see some divergence of the graphs with higher HPT pressure while the EC readings remained low. This can happen for reasons such as poor mineralogy of the soil. Refusal was encountered in a shale layer beginning at 75’bgs and it can be noted that as we enter this layer the HPT flow gets suppressed as the pressure reaches a maximum value of 100PSI (690kPa). The second graph of the log shows the hydrostatic profile on the secondary series of the graph. The hydrostatic profile has 2 black triangles which indicate where dissipation tests were run and used to calculate the profile. The red circle indicates the calculated water table based upon where the hydrostatic profile intersects atmospheric pressure. The fourth graph is the estimate K or groundwater flow graph. This is calculated based upon HPT pressure and HPT flow relationships. Less permeable soil will have less groundwater flow.

It is fairly common to see zones where EC readings and HPT pressure contradict one another. In cases where EC readings are low and HPT pressure trends higher as in the log in Figure 6.1 the following are possible reasons:

- Poor mineralogy of the soil particles resulting in silt and clay soils with very low EC readings. This is seen in many locations along the east coast of the United States.
- Silts intermixed with sand particles.
- Weathered bedrock may have low EC but would have low permeability.

Where we have cases of higher EC and lower HPT pressure typically is due to an ionic influence in the soil or groundwater. These higher EC readings can range from very slight to higher than typical soil readings. Very high EC readings can occur when the probe contacts metallic objects in the soil which will ground them out and typically will cause hard sharp spikes in the EC data.

- Chloride or other ionic contaminant (sea water, injection materials)
- Sea Water intrusion
- Wire, metal objects or Slag

In cases where HPT and EC do not confirm one another it is important to take confirmation soil and/or groundwater samples to help understand the difference between the two graphs.

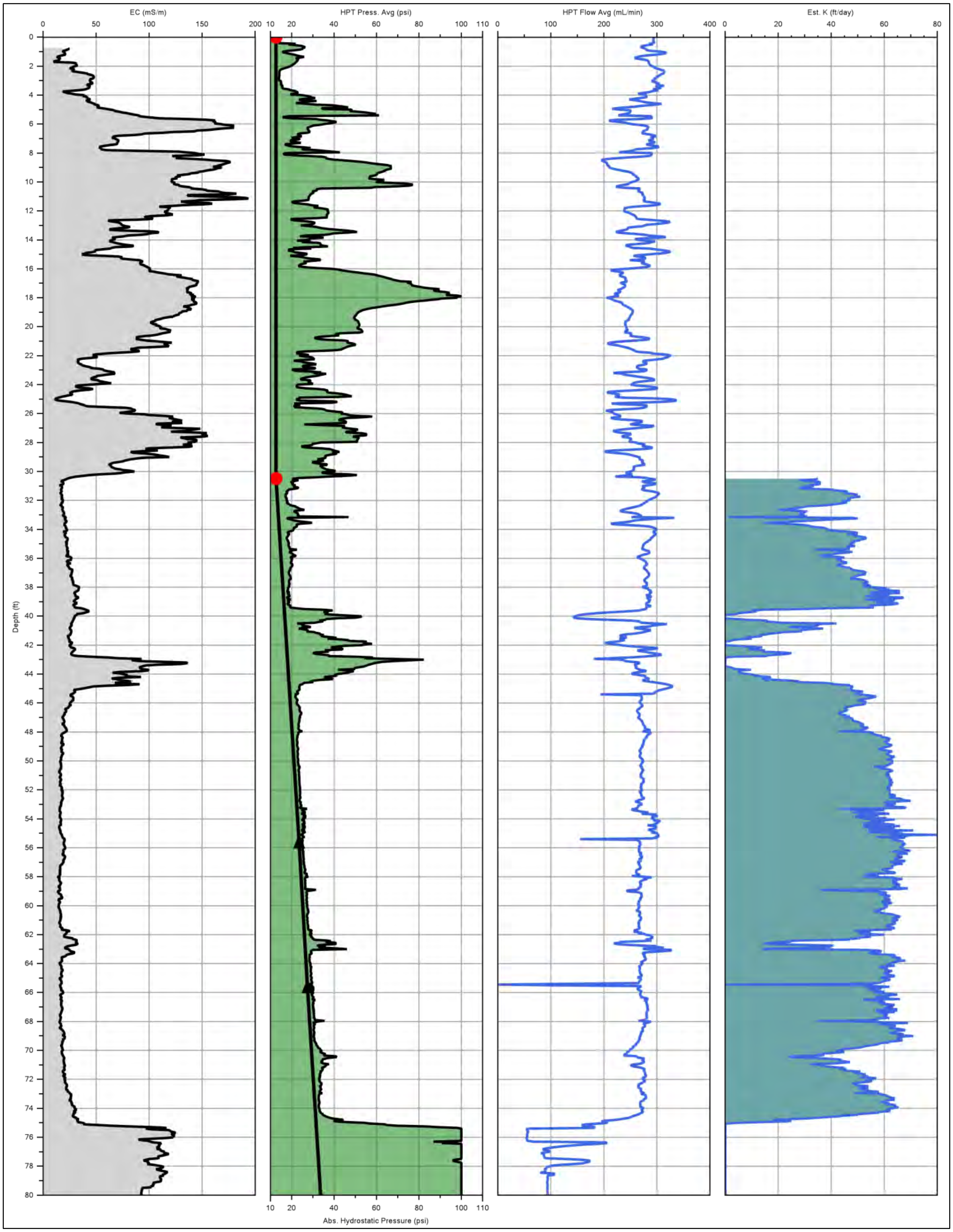


Figure 6.1: HPT Log file showing (left to right):
Electrical Conductivity (EC), HPT Injection Pressure with Hydrostatic Profile, HPT Flow, and Estimated K

7.0 Troubleshooting

7.1 Using the HPT Controller Test Load

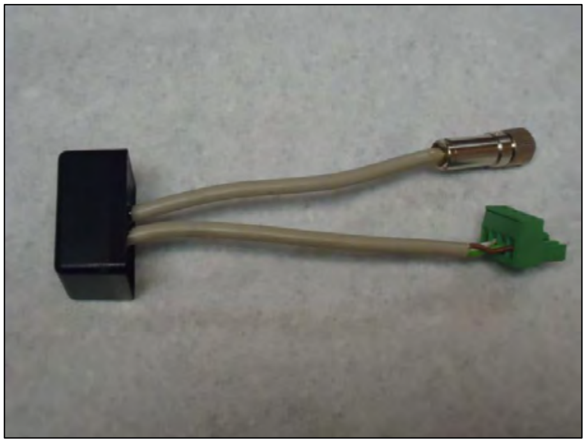


Figure 7.1: HPT Test Load PN32441

The HPT Controller Test Load (32441) is included with the HPT Controller to help troubleshoot the HPT pressure sensor, trunkline, and controller. If there is a major problem with the HPT pressure sensor or the system wiring the system will not read anywhere close to atmospheric pressure with the probe at the surface. Commonly if the HPT sensor has broken the software will read either a maximum or minimum value which would be 100PSI or 0PSI (690kPa or 0KPa). If there is damaged wiring or nothing is connected to the controller the system typically reads 50PSI (345kPa).

When connected to either the trunkline (in place of the pressure sensor), or the controller (in place of the trunkline and pressure sensor), the test load will cause the pressure sensor value to read a pressure ranging from approximately 25PSI-35PSI (172kPa – 241kPa).

To use the test load, set up the system as previously described. Turn on both the field instrument and HPT controller and start the HPT software. Plug the green wire connector of the test load into the HPT sensor connector on the back of the HPT controller. If the pressure sensor value reads somewhere around 30PSI (207kPa), the controller is able to properly read pressures so the problem is in the trunkline or the HPT sensor. If HPT controller has not moved from what it was reading or is way out from the expected value of the load test the HPT controller may require servicing. Contact Geoprobe Systems® for service.

Next, connect the HPT sensor wires of the trunkline to the controller with the green connector and then connect the test load to the female chrome connector on the downhole end of the trunkline in place of the pressure sensor. Again, the pressure value displayed on the field instrument should be somewhere around 30PSI (207kPa) and should be the same as what was seen with the load test connected into the controller. If the load test through the trunkline is around 30PSI (207kPa), then both the trunkline and the controller are working properly and the problem is in the HPT sensor. If it is not, the trunkline may be defective and should be replaced. Before restringing another HPT trunkline, first connect the new trunkline sensor wires into the HPT controller and the downhole end into the test load. If the system now reads in the expected test load range the trunkline needs replacing.

Finally, connect the pressure sensor to the trunkline. If it reads atmospheric pressure, approximately 12PSI-15PSI (83kPa-104kPa), then the pressure transducer is functioning properly. However, if it does not, replace the sensor with a new one and re-check the pressure reading. Be sure to enter the new sensor calibration values into the software prior to starting the new log. Additional pressure sensors purchased from Geoprobe®.

7.2 Common Problems

Problem: The pressure transducer is hooked up to the trunkline, but the software is reporting a reading of ~ 50PSI (345kPa).
Solution: Make sure that the trunkline wires are secured to the green terminal blocks and plugged in to the back of the HPT controller. Check components using the HPT Controller Test Load (Section 7.1).

Problem: The pressure transducer is hooked up to the trunkline, but the software is reporting a reading of 100PSI or 0PSI (690kPa or 0KPa).
Solution: Make sure all of the connections are good and recheck the pressure reading. If still bad connect a new HPT pressure sensor onto the trunkline and see if it reads atmospheric pressure. If not check all the components using the HPT Controller Test Load (Section 7.1).

Problem: The pressure with flow values keep drifting when water is flowing out the port or over the top of the reference tube.
Solution 1: If the trunkline was just connected and flow was just started air may still be in the lines. Allow the water to continue to flow through system which will purge out the remaining air. When it appears that most of the air is out of the lines pressing your finger over the injection screen for a few seconds can help to drive out any remaining air from the trunkline.
Solution 2: There may be debris behind the screen. Remove the HPT injection screen with the membrane wrench and turn the water flow on, place your finger over the open port to drive out debris. Replace the screen and retry the reference test with flow.
Solution 3: If the with flow pressure values continue to not settle down and provide close to the expected difference for a 6” water column then the problem may be inside the HPT control box. When you remove the cover of the HPT controller there will be a brass filter located on the left side when viewing from the front of the instrument (Fig 7.2). Particulates and precipitates can collect inside this filter causing problems with HPT pressure stability. Remove this filter and open up using appropriate wrenches. The filter can be easily cleaned by rinsing water over the screen. Reassemble and return to its proper location inside the control box. Resume reference testing the system.

Figure 7.2: Location of Inline Filter in K6300 and buildup of particulates in filter.

Problem: EC won’t pass the QA tests.

Solution: Check the trunkline to probe EC connections ensuring they are tight. Run the troubleshooting tests (Section 4.3A), test EC on a new probe.

APPENDIX A

Making HPT Probe, Sensor and Trunkline Connections

http://geoprobe.com/literature/hpt-sensor-connection-tutorial

A DIVISION OF KEJR, INC.
-Corporate Offices-
601 N. Broadway • Salina, KS 67401
1-800-436-7762 • Fax 785-825-2097
www.geoprobe-DI.com

CATEGORY 6: LABORATORY ANALYSIS TABLE

Section 6.1

Laboratory Analysis Table

Table 1
Soil Parameters, Methods, Containers, Holding Times, Reporting Limits Summary

Parameters	Analytical Method	Sampling Container	Holding Time	Target Method Reporting Limit (mg/kg)[1]
GENERAL CHEMISTRY (DRY WEIGHT)				
Chloride	EPA 9056	(A) 4 oz. glass jar, cool, 4°C[a]	28 days	10
Fluoride	EPA 9056		28 days	10
Nitrate (as N)	EPA 9056		28 days	2
Nitrite (as N)	EPA 9056		28 days	5
pH	EPA 9045D		ASAP	0.1 units
Phosphorus, Total	SM 4500 PE		28 days	1
Sulfate	EPA 9056		28 days	50
Sulfide	EPA 9034	(B) 4 oz. glass jar, cool, 4°C[a]; Zn acetate preserved (Containerized immediately, no headspace) or undisturbed tube with Zn preserved ends	7 days	10
Sulfite	SM 4560-S03B	(C) 4 oz. glass jar, cool, 4°C[a]	ASAP	20
TOC	EPA 9060A	(D) 4 oz. glass jar, cool, 4°C[a]	28 days	1700
METALS (DRY WEIGHT)				
Antimony	EPA 6020B	(E) 4 oz. glass jar, cool, 4°C[a]	6 months	0.25
Arsenic	EPA 6020B*		6 months	0.0159
Barium	EPA 6010B		6 months	5
Beryllium	EPA 6010B		6 months	3
Boron	EPA 6010B		6 months	12
Cadmium	EPA 6020		6 months	0.25
Calcium	EPA 6010B*		6 months	10
Chromium (total)	EPA 6010B		6 months	2
Copper	EPA 6010B		6 months	5
Iron	EPA 6010B*		6 months	10
Lead	EPA 6010B		6 months	1
Magnesium	EPA 6010B		6 months	25
Manganese	EPA 6010B		6 months	2
Mercury	EPA 7471B*		28 days	0.078
Molybdenum	EPA 6010B		6 months	2
Potassium	EPA 6010B		6 months	30
Selenium	EPA 6020B		6 months	0.2
Sodium	EPA 6010B*		6 months	20
Thallium	EPA 6020B*		6 months	0.0061
PETROLEUM: Only if identified during sampling: organic vapors >100 ppm, petroleum odor, or discolored soil				
VOCs	EPA 8260B	(F) 4 oz. glass jar cool, 4°C[a]	14 days/ 40 days[b]	varies
PAHs	EPA 8270C - SIM	(G) 4 oz. glass jar cool, 4°C[a]	14 days/ 40 days[b]	varies
GRO (C6-10)	EPA 8015B	(H) 4 oz. glass jar cool, 4°C[a]	14 days/ 40 days[b]	20
DRO (C10-C22)	EPA 8015B	(I) 4 oz. glass jar cool, 4°C[a]	14 days	25
ORO (C22-C32)	EPA 8015B		14 days	75

SOIL LEACHING POTENTIAL (SPLP)				
Antimony	1312/ 6010B	(J) 8 oz. glass jar, cool, 4°C[a]	6 months to leach/6 months to analyze	0.5 mg/L
Arsenic	1312/ 6020*		6 months to leach/6 months to analyze	0.09 ug/L
Boron	1312/ 6010B		6 months to leach/6 months to analyze	1.0 mg/L
Cadmium	1312/ 6020*		6 months to leach/6 months to analyze	0.05 ug/L
Chloride	1312/ 9056		28 days to leach/28 days to analyze	2.0 mg/L
Chromium	1312/ 6020		6 months to leach/6 months to analyze	2.0 ug/L
Chromium VI	1312/ 7199		24 hours to leach / 24 hours to analyze	2.0 ug/L
Fluoride	1312/ 9056		28 days to leach/28 days to analyze	0.40 mg/L
Molybdenum	1312/ 6010B		6 months to leach/6 months to analyze	0.05 mg/L
pH	1312/ EPA9045D		ASAP	1 SU
Phosphorus, Total	1312/SM 4500		28 days to leach/28 days to analyze	0.1 mg/L
Selenium	1312/ 6020		6 months to leach/6 months to analyze	0.5 ug/L
Sulfate	1312/ 9056		6 months to leach/6 months to analyze	10 mg/L
Thallium	1312/6010B		28 days to leach/28 days to analyze	2.0 mg/L
TDS	1312/SM 2540		6 months to leach/6 months to analyze	0.5 mg/L
Arsenic Species: 5 sample minimum, TA to hold and send as 5 sample batches				
Speciation: Arsenic III and V	EPA 1632	8 oz. (Undisturbed tube #1)	6 months	0.05 (ug/kg)
Speciation: Selenium 0, -II, IV, and VI	HPLC-ICP-MS		6 months	0.11
Soil Geochemical				
Iron (II)	SM 3500	4 oz (Undisturbed tube #1)	6 months	1
Iron (III)	SM 3500		6 months	5
Chromium (VI)	EPA 7196A/7199		6 months	1
XRD Soil Minerology	SEM	8 oz. (Undisturbed tube #2)	NA	<1%-5%
XRF Indicator Parameters	SEM		NA	NA
Mineral Adsorption Potential	EPA 6010/6020	8 oz. (Undisturbed tube #2)	NA	NA
Mineralogy of Parameters	ICP-AEC, ICP-MS	8 oz. (Undisturbed tube #2)	NA	NA
Scanning Electron Microscopy (SEM)	SEM		NA	NA
Soil Physical				
Atterberg Limits	ASTM D4318	Double zip-lock bag, all air should be removed.	NA	0.01
Bulk Density	ASTM D6683		NA	1 g/mL
Grain Size	ASTM D422/D6913		NA	0.001
Moisture Content	ASTM D2216		NA	0.001
Permeability	ASTM D5084	Undisturbed tube #3	NA	0.001

Notes:

[1] Reported in mg/kg unless otherwise noted; target MRL assume that laboratory dilution will not be required.

[a] Cool to 4° C ± 2° C

[b] 14 days to extract, 40 days after extraction
*Report to method detection limit (MDL)
NA—not applicable

Table 2
Direct Push Groundwater Parameters, Methods, Containers, Holding Times, Reporting Limits Summary

Parameters (field filtered in priority order)	Analytical Method	Sampling Container	Holding Time	Target Method Reporting Limit (mg/L)[1]
FIELD PARAMETERS				
pH	EPA 150.1	100 mL field container	NA	NA
Dissolved Oxygen	ASTM Method D888-09 (C)		NA	NA
Specific Conductance	EPA 120.1		NA	NA
Temperature	SM 2550 B		NA	NA
GENERAL CHEMISTRY				
Alkalinity (bicarbonate)	EPA SM-2320B	(A) one 500 mL HDPE unpreserved, Cool, 4^{o}C (fill to top) Collect a 2nd 500 mL HDPE if possible	14 Days	20
Alkalinity (carbonate)	EPA SM-2320B		14 Days	20
Alkalinity (total)	EPA SM-2320B		14 Days	20
Chloride	EPA 300.0		28 Days	25
Fluoride	EPA 9056		28 Days	0.8
Nitrate (as N)	EPA 9056		48 Hours	0.1
Nitrite (as N)	EPA 9056		48 Hours	0.1
Sulfate	EPA 300.0		28 Days	2
TDS	SM-2540		7 Days	15
METALS				
Antimony, Dissolved	EPA 6020	(B) one 500 mL HDPE HNO3 Preserved	6 Months	0.006
Arsenic, Dissolved	EPA 6020B*		6 Months	0.001
Barium, Dissolved	EPA 6010B		6 Months	2
Beryllium, Dissolved	EPA 6020		6 Months	0.004
Boron, Dissolved	EPA 6010B		6 Months	0.05
Cadmium, Dissolved	EPA 6020*		6 Months	0.0005
Calcium, Dissolved	EPA 6010B		6 Months	2
Chromium, Dissolved	EPA 6020		6 Months	0.0005
Copper, Dissolved	EPA 6010B		6 Months	0.023
Iron, Dissolved	EPA 6010B		6 Months	0.1
Lead, Dissolved	EPA 6020		6 Months	0.008
Magnesium, Dissolved	EPA 6010B		6 Months	2
Manganese, Dissolved	EPA 6010B		6 Months	0.002
Mercury, Dissolved	EPA 7470A		6 Months	0.00005
Molybdenum, Dissolved	EPA 6010B		6 Months	0.002
Potassium, Dissolved	EPA 6010B		6 Months	0.5
Selenium, Dissolved	EPA 6020		6 Months	0.0005
Sodium, Dissolved	EPA 6010B		6 Months	0.5
Thallium, Dissolved	EPA 6020		6 Months	0.0005
WATER FORENSICS				
δ34S and δ18O sulfate	EA-IRMS	(C) one 1L HDPE unpreserved; Cool, 4°C[a]	4 weeks after extraction	5 % (per mil)
δD- and δ^{18}O-water	EA-IRMS	(D) one 500 mL HDPE unpreserved; Cool, 4°C[a]	4 weeks after extraction	5 % (per mil)
GENERAL CHEMISTRY -Other				
Density	ASTM D1429-13	(E) one 250 mL HDPE unpreserved; Cool, 4°C[a]	NA	1
Phosphorus, dissolved	EPA 365.4	(F) one 250 mL HDPE H_2SO_4 preserved	28 Days	0.1
Dissolved Organic Carbon (DOC)	SM 5310B	(G) four 40 mL amber glass vials with septa Lid, HCL preserved	28 Days	5 (µg/L)
Total Organic Carbon (TOC)	SM 5310B		28 Days	2 (µg/L)
Sulfide	SM 4500-S2-D	(H) one 500 mL NaOH HDPE with Zinc Acetate	7 Days	0.002

Sulfite	SM 4500-S03B	(I) one 250 mL EDTA HDPE	ASAP	2
ARSENIC SPECIES: Field Filter, 5 sample minimum, TA to hold and send as 5 sample batches				
Arsenic (III)	EPA 1632	(J) one 500 mL HDPE HCL preserved	6 months	0.0032
Arsenic (V)	EPA 1632			0.0032
PETROLEUM: Only if identified during sampling: petroleum odor or discolored water/sheen				
VOCs	EPA 8260B	(K) three 40 mL clear glass vials HCL preserved (no headspace)	14 days	varies (µg/L)
PAHs	EPA 8270C - SIM	(L) one 1L amber glass unpreserved[b]	7 days	varies (µg/L)
GRO (C6-10)	EPA 8015B	(M) three 40 mL clear glass vials HCL preserved (no headspace)	14 days	0.2 (µg/L)
DRO (C10-C22)	EPA 8015B	(N) one 1-L amber glass jar[b]	14 days	0.5 (µg/L)
ORO (C22-C32)	EPA 8015B		14 days	0.5 (µg/L)

Notes:

All discrete groundwater samples will be field filtered.

[1] Reported in mg/L unless otherwise noted; target Method Reporting Limits assume that laboratory dilution will not be required.

[a] Cool to 4° C ± 2° C

[b] A second 1L jar will be collected as a back-up container if water quantity allows

*Report to method detection limit (MDL)

NA—not applicable

HDPE—high-density polyethylene

HNO3—nitric acid

Table 3
Monitoring Well Groundwater Parameters, Methods, Containers, Holding Times, Reporting Limits Summary

Parameters (non-field filtered in priority order)	Analytical Method	Sampling Container	Holding Time	Target Method Reporting Limit (mg/L)[1]
FIELD PARAMETERS				
Depth to Water (DTW)	Field Probe	NA	NA	NA
Dissolved Oxygen	ASTM Method D888-09 (C)	100 mL field container	NA	NA
Oxidation Reduction Potential (ORP)	APHA SM2580		NA	NA
pH	EPA 150.1		NA	NA
Specific Conductance	EPA 120.1		NA	NA
Temperature	SM 2550 B		NA	NA
Turbidity	EPA 180.1			
GENERAL CHEMISTRY				
TDS	SM-2540	(A) one 500 mL HDPE unpreserved; Cool, 4°C[a]	7 Days	15
Alkalinity (bicarbonate)	EPA SM-2320B	(B) one 500 mL HDPE unpreserved; Cool, 4°C[a]	14 Days	20
Alkalinity (carbonate)	EPA SM-2320B		14 Days	20
Alkalinity (total)	EPA SM-2320B		14 Days	20
Chloride	EPA 300.0		28 Days	25
Fluoride	EPA 9056		28 Days	0.8
Nitrate (as N)	EPA 9056		48 Hours	0.1
Nitrite (as N)	EPA 9056		48 Hours	0.1
Phosphorus, dissolved	SM 4500		28 Days	0.1
Sulfate	EPA 300.0		28 Days	2
Sulfide	SM 4500	(C) one 500 mL HDPE NaOH	7 Days	0.002
Sulfite	SM 4500	(D) one 250 mL HDPE EDTA	ASAP	2
Density	ASTM D1429-13	(E) one 250 mL HDPE unpreserved; Cool, 4°C[a]	NA	1
Dissolved Organic Carbon (DOC)	SM 5310B	(G) four 40 mL amber glass vials, unpreserved	28 Days	2 (µg/L)
Total Organic Carbon (TOC)	SM 5310B	(F) four 40 mL amber glass vials, HCL preserved	28 Days	5 (µg/L)
METALS				
Antimony, Dissolved	EPA 6020	(H) one 500 mL unpreserved, Cool, 4^{O}C	6 Months	0.006
Arsenic, Dissolved	EPA 6020B*		6 Months	0.00025
Barium, Dissolved	EPA 6010B		6 Months	2
Beryllium, Dissolved	EPA 6020		6 Months	0.004
Boron, Dissolved	EPA 6010B		6 Months	0.05
Cadmium, Dissolved	EPA 6020*		6 Months	0.0005
Calcium, Dissolved	EPA 6010B		6 Months	2
Chromium, Dissolved	EPA 6020		6 Months	0.0005
Copper, Dissolved	EPA 6010B		6 Months	0.023
Iron, Dissolved	EPA 6010B		6 Months	0.1
Lead, Dissolved	EPA 6020		6 Months	0.008
Magnesium, Dissolved	EPA 6010B		6 Months	2
Manganese, Dissolved	EPA 6010B		6 Months	0.002
Mercury, Dissolved	EPA 7470A		6 Months	0.00005
Molybdenum, Dissolved	EPA 6010B		6 Months	0.002
Potassium, Dissolved	EPA 6010B		6 Months	0.5
Selenium, Dissolved	EPA 6020		6 Months	0.0005
Sodium, Dissolved	EPA 6010B		6 Months	0.5
Thallium, Dissolved	EPA 6020		6 Months	0.0005
WATER FORENSICS				
δ34S and δ18O sulfate	EA-IRMS	(I) one 1L HDPE unpreserved; Cool, 4°Ca	4 weeks after extraction	5 % (per mil)
δD- and δ^{18}O-water	EA-IRMS		4 weeks after extraction	5 % (per mil)
Arsenic Species: Field Filter, 5 sample minimum, TA to hold and send as 5 sample batches				

Arsenic (III)	EPA 1632	(J) one 500 mL HDPE HCL preserved	6 months	0.0032
Arsenic (V)	EPA 1632			0.0032
VOCs	EPA 8260B	(K) three 40 mL clear glass vials HCL preserved (no headspace)	14 days	varies (µg/L)
PAHs	EPA 8270C - SIM	(L) one 1L amber glass unpreserved[b]	7 days	varies (µg/L)
GRO (C6-10)	EPA 8015B	(M) three 40 mL clear glass vials HCL preserved (no headspace)	14 days	0.2 (µg/L)
DRO (C10-C22)	EPA 8015B	(N) one 1-L amber glass jar[b]	14 days	0.5 (µg/L)
ORO (C22-C32)	EPA 8015B		14 days	0.5 (µg/L)

Notes:

[1] Reported in mg/L unless otherwise noted; target MRL assume that laboratory dilution will not be required.

[a] Cool to 4° C ± 2° C

[b] One 500 ml bottle is the minimum sample volume required. Two 500 ml bottles is preferred by the laboratory.

*Report to method detection limit (MDL)

Target Method Reporting Limits assume that laboratory dilution will not be required.

NA—not applicable

HDPE—high-density polyethylene

HNO3—nitric acid

CATEGORY 7: MONITORING WELL INSTALLATION AND ABANDONMENT

Section 7.1

Standard Operating Procedures for Groundwater Monitoring Well Installation Using the Geoprobe

STANDARD OPERATING PROCEDURES FOR GROUNDWATER MONITORING WELL INSTALLATION USING THE GEOPROBE®

The Office of Environmental Measurement and Evaluation
EPA New England - Region 1
11 Technology Dr
North Chelmsford, MA 01863

Prepared by: ______________________ ________
Name & Title Date

Reviewed by: ______________________ ________
Jerry Keefe Date

Approved by: ______________________ ________
Robert Maxfield Date

Revision Page

Date	**Rev#**	**Summary of Changes**	**Sections**
	1	**Initial Approval**	

Table of Contents

1.0 Scope & Application:

1.1 This Standard Operating Procedure (SOP) is applicable to the installation of permanent groundwater monitoring wells using the Geoprobe® machine.

1.2 A separate SOP applies to soil core sampling using the Geoprobe® machine.

2.0 Summary of Method:

2.1 The method employed utilizes a Geoprobe® machine (owned by EPA New England) to drive soil probing equipment into the subsurface so monitoring wells can be installed for groundwater sampling. The machine drives steel probe rods (with inner diameter openings) into the ground, which collectively serve as a protective casing through which well screens and risers are installed. The sampler uses the correct number of probe rods based on the desired well depth for a groundwater sampling event. Next, the sampler carefully inserts pre-connected PVC screens/risers, or another monitoring well device, into the inner opening of the probe rods, (ensuring the well riser will be sufficiently above ground when the well casing is removed). After retracting the probe rods and grouting the surrounding hole, the sampler may use the well for groundwater monitoring purposes.

3.0 Definitions:

3.1 Geoprobe®: The brand name of a hydraulically-powered machine which utilizes static force and percussion to drive small diameter sampling tools into the subsurface for the purpose of sample collection, such as groundwater. Also referred to as “direct push” machines, they rely on the compression of soil and rearrangement of soil particles, (rather than traditional drilling methods), for subsurface penetration of sampling tools.
(Note: The Geoprobe brand name is a registered trademark of Kejr, Inc., Salina, Kansas).

3.2 Probe Rod: Constructed of steel, they are used as outer casings through which PVC or other type of wells are installed. They are removed during the well installation process, once the well screen/risers have been positioned in the probe hole.

3.3 Grout: A binding material with low permeability, such as bentonite, used for sealing probe holes (such as surrounding a groundwater monitoring well). This prevents contamination of the subsurface and ensures groundwater sampling integrity.

3.4 Trip Blanks: A sample of the proper preservative from the laboratory, in the appropriate sample container, taken out to the field, and returned to the laboratory for analysis without being opened. Trip blanks are generally for volatile organic compounds, low level metals, and gasoline range hydrocarbon samples. Used to assess contamination introduced during sample transport.

3.5 Laboratory Quality Samples: Additional samples will be collected for the laboratory's quality control: matrix spike, matrix spike duplicate, laboratory duplicates, etc.

4.0 Health and Safety Warnings:

4.1 Prior to initiating any Geoprobe work in Massachusetts, Maine, New Hampshire, Rhode Island, or Vermont, EPA staff is required to notify the Dig Safe System, Inc. at the following number: 1-888-Dig-Safe (1-888-344-7233). Additional information is available on their website, http://www.digsafe.com/. In Connecticut, EPA staff is required to notify 'Call Before You Dig' (CBYD) at 1-800-922-4455 at least two days prior to the proposed work. Additional information is available on their website: http://www.occ.state.ct.us/Consumerinformation/cbyd.htm

4.2 Prior to using Geoprobe equipment on a site, scan the proposed probing area with EPA New England's hand-held metal detector device in advance, to avoid any metal or electrical interference which could damage the machine or cause injury to samplers.

4.3 When working with potentially hazardous materials or situations, follow EPA, OSHA, and specific health or safety procedures. Please refer to Section 6.0 - Personnel Qualifications, of this SOP for additional information.

4.4 All proper personal protection gear must be worn when operating the Geoprobe machine, including: eye protection (e.g. safety goggles), ear protection, hard hat, steel-toed work boots, and durable work gloves.

4.5 When handling the steel probe rods, the use of durable gloves (leather or canvas) is recommended due to small burrs on rods which could cause injury to unprotected skin.

4.6 At least two field personnel should collectively remove the Geoprobe machine from the trailer. This will help to control any sudden acceleration of the machine's wheels when moved down the inclined trailer ramp.

4.7 Samples which contain chemical hazards should be handled with suitable protection to skin, eyes, etc. and established decontamination procedures should be followed for both work and personal protection equipment clean-up.

5.0 Interferences:

5.1 Geoprobe equipment should not be operated during precipitation (e.g. rain, snow, hail), thunderstorms, and other unfavorable weather events.

5.2 During the well installation process a subsurface boulder(s) may impede the path of the probe rods in a desired well location. It is recommended that one first perform a test probe of 4' to 8' into the subsurface. Therefore, prior to driving in well casing rods, one can ensure the path is clear of interferences.

5.3 If groundwater monitoring wells must be installed on private property, EPA sampling staff must ensure permission for access is granted prior to initiating work.

6.0 Personnel Qualifications:

6.1 All field samplers working at Superfund sites are required to take a 40-hour OSHA health and safety training course, and a yearly 8-hour refresher course, prior to engaging in any field activities.

6.2 The field sampler should be properly trained by experienced staff before operating the Geoprobe machine.

6.3 All personnel shall be responsible for complying with all quality assurance/quality control requirements that pertain to their organizational/technical function.

7.0 Equipment and Supplies:

7.1 Geoprobe® Soil Probing Machine (owned by EPA New England)

7.2 Mobile dual circuit power unit, with electric start engine operating on unleaded gasoline.

7.3 Hand-held metal detector device.

7.4 Probe Rods - [Large]: diameter: 2.125", length: 48"; [Small]: diameter: 1"; length: 48"

7.5 Expendable Drive Point, and Expendable Point Holder (48").

7.6 Drive Cap and Puller Cap

7.7 Rod Grip Pull System with detachable handle, (for retracting probe rods).

7.8 Well screens - 5 ft. each, Well risers - 5 ft. each (PVC or other material); and PVC top caps, or other plastic type screws.

7.9 Sampling tubing (small diameter for low-flow groundwater pumping)

7.10 Tape measure, electrical/duct tape, cutting tools

7.11 Water level sounder

7.12 Geotech "Geopump 2" peristaltic or similar water pump; (car) battery power source.

7.13 Groundwater sampling containers

7.14 Sampling Preservative (if necessary)

7.15 Coolers with ice or laboratory-approved ice packs

7.16 Site logbook, custody seals, and chain of custody form

7.17 Cleaning brushes of assorted sizes, including: small nylon bristle (for scrubbing rod threads) and a long-handle brush (for cleaning rod interiors).

7.18 Soap for cleaning probing tools, (should be environmentally safe for on-site disposal).

7.19 EPA-approved plastic gasoline refill container

7.20 Decontamination equipment and reagents:
- Decon sprayers with attached pump: distilled water; (soapy) de-ionized water
- Decon transport sled
- Larger plastic bags (for storing contaminated work boots, gloves, etc.)
- Buckets, brushes

7.21 PID - Photo Ionization Detector/Analyzer

7.22 Miscellaneous: Zip lock plastic bags, plastic containers of tap water and distilled water, paper towels, permanent or waterproof pen/markers for labeling purposes.

8.0 Groundwater Monitoring Well Installation:

8.1. Identify the proposed location of the monitoring well. Perform a brief site survey, which includes using a metal detector to scan the proposed probe location for any metal obstacles or electrical hazards.

8.2 Determine the desired depth of the proposed monitoring well, and the corresponding number of probe rods which will be needed to meet the criteria.

8.3 Remove the Geoprobe machine and accompanying mobile power unit from the trailer, using caution when moving it down the ramp. Fill the gas tank if needed.

8.4 Move the Geoprobe machine into position over the proposed monitoring well location. After connecting the power cables, unfold the probe, and place in the proper probing position (see Owner's Manual for details).

8.5 Lay out all Geoprobe accessory equipment near the work site beforehand, such as probe rods, caps, etc. that will be used in the survey.

8.6 Perform an initial test probe*****. Attach a 1" drive point to the threaded end of a point holder. Add a drive cap to the holder, and place under the probe hammer in the driving position (see Owner's Manual), and turn on the Geoprobe power source. Drive the point holder into the ground, until the drive cap is a few inches above the surface. Remove the drive cap, thread a 1" probe rod onto the holder, and drive once again. Thread successive rods in a similar manner until reaching desired well depth.

[*****Note: Each Geoprobe operator must wear the required personal protection gear before operating the machine. Please refer to Health and Safety Warnings, Section 4.2, for details].

8.7 Remove the probe rods using the Rod Grip Puller, attaching a puller cap to the top probe rod, retracting upward with the machine, and detaching each successive rod.

8.8 Attach an 2.125" expendable drive point to the threaded end of a 2.125" point holder. Add a drive cap to the holder, and place under the probe hammer in the driving position. Drive the point holder into the ground, until the drive cap is a few inches above the surface. Remove the drive cap, and thread successive 2.125" probe rods in the same manner as described in step 8.6 above. <u>Make sure that your probe rod assembly is straight as its being driven into the ground</u>. After reaching the desired well depth, the well can now be installed.

8.9 For PVC Caps: Attach a cap to the end of a screen(s). Thread one or two 5 ft. risers to the top of screen assembly. With the assistance of a second person, <u>firmly</u> grasp and lower the assembly through the circular opening in the top probe rod, without releasing and dropping the assembly to the well bottom. Attach additional 5 ft. riser sections until the assembly reaches the bottom of the probe rods (the well bottom). [Note: at least one foot of riser should extend past the top probe rod above the ground surface].

8.10 To retract the probe rods surrounding the monitoring well, reposition the probe machine so the Rod Grip Puller can be attached to the lower portion of the top probe rod. One person should operate the Geoprobe machine while a second person grasps and firmly presses down on the PVC screen/riser assembly. Observe whether the risers stay in place or move up with the rods.

- If risers stay in place, stable formation conditions are present. Continue retracting and detaching each successive probe rod.
- If risers move up with the probe rods, the drive point is likely located in heavy sands. If they continue to rise, place a piece of spare PVC riser over the top of the well riser, and carefully hammer the assembly back into the ground as rods are retracted. (Do not hammer directly on the well riser; this could damage or contaminate the opening).

8.11 Create a sand barrier around the well screen by pouring special “well screen sand” into the opening around the well riser to the top of the well screen. (Note: some sand may already be present due to collapse of the natural formations). The sand forms a barrier which prevents the grout from penetrating into the screened portion of the well.

8.12 Next, grout the well. EPA-EIA uses medium-sized bentonite chips (such as Pure Gold™) which are poured on the top of the sand layer surrounding the riser. Sufficiently hydrate the bentonite by pouring tap water on top of it, which initiates the sealing process.

8.13 If not immediately sampling from the well, label the riser with permanent ink, add a surface cover (preferably water resistant) and secure cover with electrical/duct tape.

8.14 If necessary, thoroughly clean and scrub all Geoprobe equipment (probe rods, caps, etc.) with soap and water. Then complete a final rinse of equipment with distilled water. Be sure to wear thick rubber gloves while cleaning.

9.0 General Groundwater Sampling Procedure: (*Note*: for more detailed information, please refer to the separate Groundwater Sampling SOP)

9.1 Using a water level sounder with tape measure, determine the depth to the water table, and depth to the well bottom.

9.2 Measure out the correct length of small diameter tubing based on measured depths. At least 12" of additional tubing should protrude above the well riser. Lower the tubing into the well opening until it reaches the mid point of the well screen.

9.3 Purge at least three well volumes of water before sampling begins, using a water pumping device, such as a peristaltic pump.

9.4 Label appropriate sampling containers with sampling details and custody information**.**

9.5 To collect sample, hold the sample container in a slightly tilted position under the well tubing dispenser, and fill to desired amount.

9.6 Repeat step 9.6 until the appropriate number of samples is obtained.

9.7 After sampling is complete: disconnect the pump, remove the tubing from the well, label the well riser, and securely cover and tape the riser opening.

10.0 Handling, Preservation, and Storage:

10.1 After retrieving groundwater samples from the monitoring well, deliver to the assigned on-site preserver (if applicable). Label the sampling container(s) with sampling details and custody information

10.2 Preserve the sample with the appropriate preservative, (unless using approved pre-preserved sample vials).

10.3 Cap the containers, and use a custody seal if sample is for enforcement.

10.4 Load all samples into a cooler(s), ensuring that the bottles are in the ice but *not* totally immersed in water.

10.5 Record all pertinent data in the site logbook and on the field data sheet.

10.6 Complete the chain of custody form. Attach the custody seals to the cooler prior to delivering to the EPA regional laboratory.

10.7 Upon arriving at the EPA regional laboratory, contact assigned Chemistry staff to log in the samples. If after hours, place in the samples in the approved refrigerated storage area.

11.0 Data and Records Management:

11.1 All data and information is to follow the Field Data Management SOP.

11.2 The chain of custody form is signed over to the laboratory. A copy is kept with the sampling records.

11.3 The sampling data is to be stored at US EPA - NE, 11 Technology Dr, North Chelmsford, MA for at least 3 years.

12.0 Quality Control and Quality Assurance:

12.1 Representative samples are required. The sampler will evaluate the site specific conditions to assure the sample will be representative.

12.2 All sampling equipment must be decontaminated prior to use and after each discrete sample following the General Field Equipment - Cleaning, Preparation, and Decontamination SOP.

12.3 All field QC samples requirements in the SAP or QAPP must be followed. These may involve trip blanks, equipment blanks, field duplicates and the collection of extra samples for the laboratory’s quality control.

13.0 Waste Management and Pollution Prevention:

13.1 During field sampling and analysis events there may be hazardous waste produced from the sample collection. The waste must be handled and disposed of in accordance with federal, state, and municipal regulations. Dispose of the hazardous waste produced at the site where the work was performed, if the operating site has proper disposal available. If there is no disposal that meets regulatory requirements, the waste must be transported back to EPA-NE and transferred to the hazardous waste manager for disposal. The sample volume should be minimized to reduce unnecessary waste.

14.0 References:

14.1 U.S. Environmental Protection Agency, (EPA) 1997. Expedited Site Assessment Tools For Underground Storage Tank Sites: A Guide for Regulators. (EPA 510-B-97-001). March, 1997.

14.2 Geoprobe Systems, 1997. 1998-99 Tools and Equipment Catalog

14.3 American Society for Testing and Materials (ASTM), 1992. ASTM D 5092 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers: *1993 Annual Book of ASTM Standards, Vol. 0408.* Philadelphia, PA.

CATEGORY 7: MONITORING WELL INSTALLATION AND ABANDONMENT

Section 7.2

Standard Practice for Design and Installation of Ground Water Monitoring Wells

Designation: D 5092 – 04$^{\epsilon 1}$

Standard Practice for Design and Installation of Ground Water Monitoring Wells[1]

This standard is issued under the fixed designation D 5092; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ϵ^1 NOTE—Editorial changes were made throughout in June 2004.

1. Scope

1.1 This practice describes a methodology for designing and installing conventional (screened and filter-packed) ground-water monitoring wells suitable for formations ranging from unconsolidated aquifers (i.e., sands and gravels) to granular materials having grain-size distributions with up to 50 % passing a #200 sieve and as much as 20 % clay-sized material (i.e., silty fine sands with some clay). Formations finer than this (i.e., silts, clays, silty clays, clayey silts) should not be monitored using conventional monitoring wells, as representative ground-water samples, free of artifactual turbidity, cannot be assured using currently available technology. Alternative monitoring technologies (not described in this practice) should be used in these formations

1.2 The recommended monitoring well design and installation procedures presented in this practice are based on the assumption that the objectives of the program are to obtain representative ground-water samples and other representative ground-water data from a targeted zone of interest in the subsurface defined by site characterization.

1.3 This practice, in combination with proper well development (D 5521), proper ground-water sampling procedures (D 4448), and proper well maintenance and rehabilitation (D 5978), will permit acquisition of ground-water samples free of artifactual turbidity, eliminate siltation of wells between sampling events, and permit acquisition of accurate ground-water levels and hydraulic conductivity test data from the zone screened by the well. For wells installed in fine-grained formation materials (up to 50 % passing a #200 sieve), it is generally necessary to use low-flow purging and sampling techniques (D 6771) in combination with proper well design to collect turbidity-free samples.

1.4 This practice applies primarily to well design and installation methods used in drilled boreholes. Other Standards, including Guide D 6724 and Practice D 6725, cover installation of monitoring wells using direct-push methods.

1.5 The values stated in inch-pound units are to be regarded as standard. The values in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Nat all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 150 Specification for Portland Cement

C 294 Descriptive Nomenclature of Constituents of Natural Mineral Aggregates

D 421 Practice for Dry Preparation of Soil Samples for Particle Size Analysis and Determination of Soil Constants

D 422 Test Method for Particle Size Analysis of Soils

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 1452 Practice for Soil Investigation and Sampling by Auger Borings

D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils

D 1587 Practice for Thin-Walled Tube Sampling of Soils

D 2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

D 2217 Practice for Wet Preparation of Soil Samples for Particle Size Analysis and Determination of Soil Constants

---

[1] This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21.05 on Design and Installation of Ground-Water Monitoring Wells.

Current edition approved Jan. 1, 2004. Published March 2004. Originally approved in 1990. Last previous edition approved in 2002 as D 5092 – 02.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

D 2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D 3282 Practice for Classification of Soils and Soil Aggregate Mixtures for Highway Construction Purposes
D 3441 Test Method for Deep, Quasi-Static, Cone and Friction Cone Penetration Tests of Soil
D 3550 Practice for Ring Lined Barrel Sampling of Soils
D 4220 Practice for Preserving and Transporting Soil Samples
D 4700 Guide for Soil Sampling from the Vadose Zone
D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
D 5079 Practices for Preserving and Transporting Rock Core Samples
D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites
D 5254 Practice for Minimum Set of Data Elements to Identify a Ground-Water Site
D 5299 Guide for Decommissioning of Ground-Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities
D 5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D 5518 Guide for Acquisition of File Aerial Photography and Imagery for Establishing Historic Site Use and Surficial Conditions
D 5521 Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers
D 5608 Practice for Decontamination of Field Equipment Used at Low-Level Radioactive Waste Sites
D 5730 Guide to Site Characterization for Environmental Purposes with Emphasis on Soil, Rock, the Vadose Zone, and Ground Water
D 5753 Guide for Planning and Conducting Borehole Geophysical Logging
D 5777 Guide for Using the Seismic Refraction Method for Subsurface Investigation
D 5781 Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D 5782 Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D 5783 Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D 5784 Guide for Use of Hollow Stem Augers for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D 5787 Practice for Monitoring Well Protection
D 5872 Guide for the Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D 5875 Guide for the Use of Cable Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D 5876 Guide for the Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D 5978 Guide for Maintenance and Rehabilitation of Ground-Water Monitoring Wells
D 5979 Guide for Conceptualization and Characterization of Ground-Water Systems
D 6001 Guide for Direct-Push Water Sampling for Geoenvironmental Investigations
D 6067 Guide for Using the Electronic Cone Penetrometer for Environmental Site Characterization
D 6167 Guide for Conducting Borehole Geophysical Logging
D 6169 Guide to the Selection of Soil and Rock Sampling Devices Used With Drilling Rigs for Environmental Investigations
D 6235 Practice for Expedited Site Characterization of Vadose Zone and Ground-Water Contamination at Hazardous Waste Contaminated Sites
D 6274 Guide for Conducting Borehole Geophysical Logging—Gamma
D 6282 Guide for Direct-Push Soil Sampling for Environmental Site Characterization
D 6286 Guide to the Selection of Drilling Methods for Environmental Site Characterization
D 6429 Guide for Selecting Surface Geophysical Methods
D 6430 Guide for Using the Gravity Method for Subsurface Investigation
D 6431 Guide for Using the Direct Current Resistivity Method for Subsurface Investigation
D 6432 Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation
D 6519 Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler
D 6639 Guide for Using the Frequency Domain Electromagnetic Method for Subsurface Investigations
D 6640 Guide for Collection and Handling of Soils Obtained in Core Barrel Samplers for Environmental Investigations
D 6724 Guide for the Installation of Direct-Push Ground-Water Monitoring Wells
D 6725 Practice for the Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers
D 6771 Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations
F 480 Specification for Thermoplastic Well Casing and Couplings Made in Standard Dimension Ratios (SDR), Schedule 40 and Schedule 80

3. Terminology

3.1 *Definitions:*

3.1.1 *annular space; annulus*—the space between two concentric strings of casing, or between the casing and the borehole wall. This includes the space(s) between multiple strings of casing in a borehole installed either concentrically or adjacent to one another.

3.1.2 *artifactual turbidity*—particulate matter that is not naturally mobile in the ground-water system and that is produced in some way by the ground-water sampling process. May consist of particles introduced to the subsurface during drilling or well construction, sheared from the target monitoring zone during pumping or bailing the well, or produced by exposure of ground water to atmospheric conditions.

3.1.3 *assessment monitoring*—an investigative monitoring program that is initiated after the presence of a contaminant in ground water has been detected. The objective of this program is to determine the concentration of constituents that have contaminated the ground water and to quantify the rate and extent of migration of these constituents.

3.1.4 *ballast*—materials used to provide stability to a buoyant object (such as casing within a water-filled borehole).

3.1.5 *borehole*—an open or uncased subsurface hole, generally circular in plan view, created by drilling.

3.1.6 *borehole log*—the record of geologic units penetrated, drilling progress, depth, water level, sample recovery, volumes, and types of materials used, and other significant facts regarding the drilling and/or installation of an exploratory borehole or well.

3.1.7 *bridge*—an obstruction within the annulus that may prevent circulation or proper placement of annular fill materials.

3.1.8 *casing*—pipe, finished in sections with either threaded connections or beveled edges to be field welded, which is installed temporarily or permanently either to counteract caving, to advance the borehole, or to isolate the zone being monitored, or any combination of these.

3.1.9 *casing, protective*—a section of larger diameter pipe that is placed over the upper end of a smaller diameter monitoring well riser or casing to provide structural protection to the well, to prevent damage to the well, and to restrict unauthorized access into the well.

3.1.10 *casing, surface*—pipe used to stabilize a borehole near the surface during the drilling of a borehole that may be left in place or removed once drilling is completed.

3.1.11 *caving; sloughing*—the inflow of unconsolidated material into a borehole that occurs when the borehole walls lose their cohesiveness.

3.1.12 *cement*—commonly known as Portland cement. A mixture that consists of calcareous, argillaceous, or other silica-, alumina-, and iron-oxide-bearing materials that is manufactured and formulated to produce various types which are defined in Specification C 150. Portland cement is considered a hydraulic cement because it must be mixed with water to form a cement-water paste that has the ability to harden and develop strength even if cured under water.

3.1.13 *centralizer*—a device that assists in the centering of a casing or riser within a borehole or another casing.

3.1.14 *confining unit*—a body of relatively low hydraulic conductivity formation material stratigraphically adjacent to one or more aquifers. Synonymous with "aquiclude," "aquitard," and "aquifuge."

3.1.15 *detection monitoring*—a program of monitoring for the express purpose of determining whether or not there has been a contaminant release to ground water.

3.1.16 *d-10*—the diameter of a soil particle (preferably in mm) at which 10 % by weight (dry) of the particles of a particular sample are finer. Synonymous with the effective size or effective grain size.

3.1.17 *d-60*—the diameter of a soil particle (preferably in mm) at which 60 % by weight (dry) of the particles of a particular sample are finer.

3.1.18 *flush joint or flush coupled*—casing or riser with ends threaded such that a consistent inside and outside diameter is maintained across the threaded joints or couplings.

3.1.19 *gravel pack*—common term used to refer to the primary filter pack of a well (see *primary filter pack*).

3.1.20 *grout (monitoring wells)*—a low-permeability material placed in the annulus between the well casing or riser and the borehole wall (in a single-cased monitoring well), or between the riser and casing (in a multi-cased monitoring well), to prevent movement of ground water or surface water within the annular space.

3.1.21 *hydrologic unit*—geologic strata that can be distinguished on the basis of capacity to yield and transmit fluids. Aquifers and confining units are types of hydrologic units. Boundaries of a hydrologic unit may not necessarily correspond either laterally or vertically to lithostratigraphic formations.

3.1.22 *multi-cased well*—a well constructed by using successively smaller diameter casings with depth.

3.1.23 *neat cement*—a mixture of Portland cement (Specification C 150) and water.

3.1.24 *packer (monitoring wells)*—a transient or dedicated device placed in a well that isolates or seals a portion of the well, annulus, or borehole at a specific level.

3.1.25 *piezometer*—a small-diameter well with a very short screen that is used to measure changes in hydraulic head, usually in response to pumping a nearby well. Synonymous with observation well.

3.1.26 *primary filter pack*—a clean silica sand or sand and gravel mixture of selected grain size and gradation that is installed in the annular space between the borehole wall and the well screen, extending an appropriate distance above the screen, for the purpose of retaining and stabilizing the particles from the adjacent formation(s). The term is used in place of *gravel pack*.

3.1.27 *PTFE tape*—joint sealing tape composed of polytetrafluoroethylene.

3.1.28 *riser*—the pipe or well casing extending from the well screen to just above or below the ground surface.

3.1.29 *secondary filter pack*—a clean, uniformly graded sand that is placed in the annulus between the primary filter pack and the overlying seal, or between the seal and overlying grout backfill, or both, to prevent intrusion of the seal or grout, or both, into the primary filter pack.

3.1.30 *sediment sump*—a blank extension of pipe or well casing, closed at the bottom, beneath the well screen used to collect fine-grained material from the filter pack and adjacent formation materials during the process of well development. Synonymous with rat trap or tail pipe.

3.1.31 *single-cased well*—a monitoring well constructed with a riser but without an exterior casing.

3.1.32 *static water level*—the elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, or hydraulic testing.

3.1.33 *tamper*—a heavy cylindrical metal section of tubing that is operated on a wire rope or cable. It either slips over the riser and fits inside the casing or borehole annulus, or fits between the riser and annulus. It is generally used to tamp annular sealants or filter pack materials into place and to prevent bridging or break bridges that form in the annular space.

3.1.34 *target monitoring zone*—the ground-water flow path from a particular area or facility in which monitoring wells will be screened. The target monitoring zone should be an interval in subsurface materials in which there is a reasonable expectation that a monitoring well will intercept ground water moving beneath an area or facility and any migrating contaminants that may be present.

3.1.35 *tremie pipe*—a small-diameter pipe or tube that is used to transport filter pack materials and annular seal materials from the ground surface into an annular space.

3.1.36 *uniformity coefficient*—the ratio of d-60/d-10, where d-60 and d-10 are particle diameters corresponding to 60 % and 10 % finer on the cumulative particle size curve, respectively.

3.1.37 *uniformly graded*—a quantitative definition of the particle size distribution of a soil that consists of a majority of particles being of approximately the same diameter. A granular material is considered uniformly graded when the uniformity coefficient is less than about five (Test Method D 2487). Comparable to the geologic term *well sorted*.

3.1.38 *vented cap*—a cap with a small hole that is installed on top of the riser.

3.1.39 *weep hole*—a small-diameter hole (usually ¼ in.) drilled into the protective casing above the ground surface that serves to drain out water that may enter the annulus between the riser and the protective casing.

3.1.40 *well completion diagram*—a record that illustrates the details of a well installation.

3.1.41 *well screen*—a device used to retain the primary or natural filter pack; usually a cylindrical pipe with openings of a uniform width, orientation, and spacing.

4. Significance and Use

4.1 This practice for the design and installation of ground-water monitoring wells will promote *(1)* efficient and effective site hydrogeological characterization; *(2)* durable and reliable well construction; and *(3)* acquisition of representative ground-water quality samples, ground-water levels, and hydraulic conductivity testing data from monitoring wells. The practices established herein are affected by governmental regulations and by site-specific geological, hydrogeological, climatological, topographical, and subsurface geochemical conditions. To meet these geoenvironmental challenges, this practice promotes the development of a conceptual hydrogeologic model prior to monitoring well design and installation.

4.2 A properly designed and installed ground water monitoring well provides essential information on one or more of the following subjects:

4.2.1 Formation geologic and hydraulic properties;

4.2.2 Potentiometric surface of a particular hydrologic unit(s);

4.2.3 Water quality with respect to various indicator parameters; and

4.2.4 Water chemistry with respect to a contaminant release.

5. Site Characterization

5.1 *General*—A thorough knowledge of site-specific geologic, hydrologic and geochemical conditions is necessary to properly apply the monitoring well design and installation procedures contained within this practice. Development of a conceptual site model, that identifies potential flow paths and the target monitoring zone(s), and generates a 3-D picture of contaminant distribution and contaminant movement pathways, is recommended prior to monitoring well design and installation. Development of the conceptual site model is accomplished in two phases -- an initial reconnaissance, after which a preliminary conceptual model is created, and a field investigation, after which a revised conceptual model is formulated. When the hydrogeology of a project area is relatively uncomplicated and well documented in the literature, the initial reconnaissance may provide sufficient information to identify flow paths and the target monitoring zone(s). However, where limited or no background data are available or where the geology is complex, a field investigation will be required to develop the necessary conceptual site model.

5.2 *Initial Reconnaissance of Project Area*—The goal of the initial reconnaissance of the project area is to identify and locate those zones or preferential flow pathways with the greatest potential to transmit fluids from the project area. Identifying these flow pathways is the first step in selecting the target ground-water monitoring zone(s).

5.2.1 *Literature Search*—Every effort should be made to collect and review all applicable field and laboratory data from previous investigations of the project area. Information such as, but not limited to, topographic maps, aerial imagery (see Guide D 5518), site ownership and utilization records, geologic and hydrogeologic maps and reports, mineral resource surveys, water well logs, information from local well drillers, agricultural soil reports, geotechnical engineering reports, and other engineering maps and reports related to the project area should be reviewed to locate relevant site information.

5.2.2 *Field Reconnaissance*—Early in the investigation, the soil and rocks in open cut areas (e.g., roadcuts, streamcuts) in the vicinity of the project should be studied, and various soil and rock profiles noted. Special consideration should be given to soil color and textural changes, landslides, seeps, and springs within or near the project area.

5.2.3 *Preliminary Conceptual Model*—The distribution of the predominant soil and rock units likely to be found during subsurface exploration may be hypothesized at this time in a preliminary conceptual site model using information obtained in the literature search and field reconnaissance. In areas where the geology is relatively uniform, well documented in the literature, and substantiated by the field reconnaissance, further refinement of the conceptual model may not be necessary unless anomalies are discovered in the well drilling stage.

5.3 *Field Investigation*—The goal of the field investigation is to refine the preliminary conceptual site model so that the target monitoring zone(s) is (are) identified prior to monitoring well installation.

5.3.1 *Exploratory Borings and Direct-Push Methods*—Characterization of the flow paths conceptualized in the initial reconnaissance involves defining the porosity (type and amount), hydraulic conductivity, stratigraphy, lithology, gradation and structure of each hydrologic unit encountered beneath the site. These characteristics are defined by conducting an exploratory program which may include drilled soil borings (see Guide D 6286 for selection of drilling methods) and direct-push methods (e.g., cone penetrometers [see Test Method D 3441 or Guide D 6067] or direct-push machines using soil sampling, ground-water sampling and/or electrical conductivity measurement tools [see Guides D 6282 and D 6001]). Exploratory soil borings and direct-push holes should be deep enough to develop the required engineering and hydrogeologic data for determining the preferential flow pathway(s), target monitoring zone(s), or both.

5.3.1.1 *Sampling*—Soil and rock properties should not be predicted wholly on field description or classification, but should be confirmed by laboratory and/or field tests made on samples or in boreholes or wells. Representative soil or rock samples of each material that is significant to the design of the monitoring well system should be obtained and evaluated by a geologist, hydrogeologist, soil scientist or engineer trained and experienced in soil and rock analysis. Soil sample collection should be conducted according to Practice D 1452, Test Method D 1586, Practice D 3550, Practice D 6519 or Practice D 1587, whichever is appropriate given the anticipated characteristics of the soil samples (see Guide D 6169 for selection of soil sampling methods). Rock samples should be collected according to Practice D 2113. Soil samples obtained for evaluation of hydraulic properties should be containerized and identified for shipment to a laboratory. Special measures to preserve either the continuity of the sample or the natural moisture are not usually required. However, soil and rock samples obtained for evaluation of chemical properties often require special field preparation and preservation to prevent significant alteration of the chemical constituents during transportation to a laboratory (see Practice D 6640). Rock samples for evaluation of hydraulic properties are usually obtained using a split-inner-tube core barrel. Evaluation and logging of the core samples is usually done in the field before the core is removed from the core barrel.

5.3.1.2 *Boring Logs*—Care should be taken to prepare and retain a complete boring log and sampling record for each exploratory soil boring or direct-push hole (see Guide D 5434).

NOTE 1—Site investigations conducted for the purpose of generating data for the installation of ground-water monitoring wells can vary greatly due to the availability of reliable site data or the lack thereof. The general procedure would be as follows: *(1)* gather factual data regarding the surficial and subsurface conditions, *(2)* analyze the data, *(3)* develop a conceptual model of the site conditions, *(4)* locate the monitoring wells based on the first three steps. Monitoring wells should only be installed with sufficient understanding of the geologic, and hydrologic and geochemical conditions present at the site. Monitoring wells often serve as part of an overall site investigation for a specific purpose, such as determining the extent of contamination present, or for predicting the effectiveness of aquifer remediation. In these cases, extensive additional geotechnical and hydrogeologic information may be required that would go beyond the Section 5 Site Characterization description.

Boring logs should include the location, geotechnical data (that is, penetration rates or blow counts), and sample description information for each material identified in the borehole either by symbol or word description, or both. Description and identification of soils should be in accordance with Practice D 2488; classification of soils should be in accordance with either Practice D 2487 or Practice D 3282. Identification of rock material should be based on Nomenclature C 294 or by an appropriate geologic classification system. Observations of seepage, free water, and water levels should also be noted. The boring logs should be accompanied by a report that includes a description of the area investigated; a map illustrating the vertical and horizontal location (with reference to either North American Vertical Datum of 1988 [NAVD 88] or to a standardized survey grid) of each exploratory soil boring or test pit, or both; and color photographs of rock cores, soil samples, and exposed strata labeled with a date and identification.

5.3.2 *Geophysical Exploration*—Geophysical surveys may be used to supplement soil boring and outcrop observation data and to aid in interpretation between soil borings. Appropriate surface and borehole geophysical methods for meeting site-specific project objectives can be selected by consulting Guides D 6429 and D 5753 respectively. Surface geophysical methods such as seismic (Guide D 5777), electrical-resistivity (Guide D 6431), ground-penetrating radar (Guide D 6432), gravity (Guide D 6430) and electromagnetic conductance surveys (Guide D 6639) can be particularly valuable when distinct differences in the properties of contiguous subsurface materials are indicated. Borehole methods such as resistivity, gamma, gamma-gamma, neutron, and caliper logs (see Guide D 6167) can be useful to confirm specific subsurface geologic conditions. Gamma logs (Guide D 6274) are particularly useful in existing cased wells.

5.3.3 *Ground-Water Flow Direction*—Ground-water flow direction is generally determined by measuring the vertical and horizontal hydraulic gradient within each conceptualized flow pathway. However, because water will flow along the pathways of least resistance (within the highest hydraulic conductivity formation materials at the site), actual flow direction may be oblique to the hydraulic gradient (within buried stream channels or glacial valleys, for example). Flow direction is determined by first installing piezometers in the exploratory soil borings that penetrate the zone(s) of interest at the site. The depth and location of the piezometers will depend upon anticipated hydraulic connections between conceptualized flow pathways and their respective lateral direction of flow. Following careful evaluation, it may be possible to utilize existing private or public wells to obtain water-level data. The construction integrity of such wells should be verified to ensure that the water levels obtained from the wells are representative only of the zone(s) of interest. Following water-level data acquisition, a potentiometric surface map should be prepared. Flow pathways are ordinarily determined to be at right angles, or nearly so, to the equipotential lines, though consideration of complex geology can result in more complex interpretations of flow

5.4 *Completing the Conceptual Model*—A series of geologic and hydrogeologic cross sections should be developed to refine the conceptual model. This is accomplished by first plotting logs of soil and rock observed in the exploratory soil borings or test pits, and interpreting between these logs using the geologic and engineering interrelationships between other soil and rock data observed in the initial reconnaissance or with geophysical techniques. Extrapolation of data into adjacent areas should be done only where geologically uniform subsurface conditions are known to exist. The next step is to integrate the geologic profile data with the potentiometric data for both vertical and horizontal hydraulic gradients. Plan view and cross-sectional flow nets should be constructed. Following the analysis of these data, conclusions can be made as to which flow pathway(s) is (are) the appropriate target monitoring zone(s).

NOTE 2—UUse of ground-water monitoring wells is difficult and may not be a reliable technology in fine-grained, low hydraulic conductivity formation materials with primary porosity because of *(1)* the disproportionate influence that microstratigraphy has on ground-water flow in fine-grained strata; *(2)* the proportionally higher vertical flow component in low hydraulic conductivity strata; and *(3)* the presence of indigenous metallic and inorganic constituents in the matrix that make water-quality data evaluation difficult.

6. Monitoring Well Construction Materials

6.1 *General*—The materials that are used in the construction of a monitoring well that come in contact with water samples should not alter the chemical quality of the sample for the constituents being examined. The riser, well screen, and annular seal installation equipment should be cleaned immediately prior to well installation (see either Practice D 5088 or D 5608) or certified clean from the manufacturer and delivered to the site in a protective wrapping. Samples of the riser and screen material, cleaning water, filter pack, annular seal, bentonite, and mixed grout should be retained to serve as quality control until the completion of at least one round of ground- water quality sampling and analysis has been completed.

6.2 *Water*—Water used in the drilling process, to prepare grout mixtures and to decontaminate the well screen, riser, and annular sealant injection equipment, should be obtained from a source of known chemistry that does not contain constituents that could compromise the integrity of the well installation.

6.3 *Primary Filter Pack*:

6.3.1 *General*—The purposes of the primary filter pack are to act as a filter that retains formation material while allowing ground water to enter the well, and to stabilize the formation to keep it from collapsing on the well. The design of the primary filter pack is based on the grain-size distribution of the formation material (as determined by sieve analysis—see Test Method D 422) to be retained. The grain size distribution of the primary filter pack must be fine enough to retain the formation, but coarse enough to allow for unrestricted movement of ground water into and through the monitoring well. The design of the well screen (see 6.4.3) must be done in concert with the design of the filter pack. After development, a monitoring well with a correctly designed and installed filter pack and screen combination should produce samples free of artifactual turbidity.

6.3.2 *Materials*—The primary filter pack should consist of an inert granular material (generally ranging from gravel to very fine sand, depending on formation grain size distribution) of selected grain size and gradation that is installed in the annulus between the well screen and the borehole wall. Washed and screened silica sands and gravels, with less than 5 % non-siliceous materials, should be specified.

6.3.3 *Design*—The design theory of filter pack gradation is based on mechanical retention of formation materials.

6.3.3.1 1 For formation materials that are relatively coarse-grained (i.e., fine, medium and coarse sands and gravels), the grain size distribution of the primary filter pack is determined by calculating the d-30 (30 % finer) size, the d-60 (60 % finer) size, and the d-10 (10 % finer) size of the filter pack. The first point on the filter pack grain-size distribution curve is the d-30 size. The primary filter pack is usually selected to have a d-30 grain size that is about 4 to 6 times greater than the d-30 grain size of the formation material being retained (see Fig. 1). A multiplication factor of 4 is used if the formation material is relatively fine-grained and well sorted or uniform (small range in grain sizes); a multiplication factor of 6 is used if the formation is relatively coarse grained and poorly sorted or non-uniform (large range in grain sizes). Thus, 70 % of the filter pack will have a grain size that is 4 to 6 times larger than the d-30 size of the formation materials. This ensures that the filter pack is coarser (with a higher hydraulic conductivity) than the formation material, and allows for unrestricted ground-water flow from the formation into the monitoring well.

The next 2 points on the filter pack grain-size distribution curve are the d-60 and d-10 grain sizes. These are chosen so that the ratio between the two grain sizes (the uniformity coefficient) is less than 2.5. This ensures that the filter pack has a small range in grain sizes and is uniform (see technical Note 5). The d-60 and d-10 grain sizes of the filter pack are calculated by a trial and error method using grain sizes that are close to the d-30 size of the filter pack. After the d-30, d-60 and d-10 sizes of the filter pack are determined, a smooth curve is drawn through these points. The final step in filter pack design is to specify the limits of the grain size envelope, which defines the permissible range in grain sizes for the filter pack. The permissible range on either side of the grain size curve is 8 %. The boundaries of the grain size envelope are drawn on either side of the filter pack grain-size distribution curve, and filter pack design is complete. A filter medium having a grain-size distribution as close as possible to this curve is then obtained from a local sand supplier.

6.3.3.2 In formation materials that are predominantly fine-grained (finer than fine to very fine sands), soil piping can occur when a hydraulic gradient exists between the formation and the well (as would be the case during well development and sampling). To prevent soil piping in these materials, the following criteria are used for designing granular filter packs:

$$\frac{\text{d-15 of filter}}{\text{d-85 of formation}} \; </= 4 \text{ to } 5 \quad \text{and} \quad \frac{\text{d-15 of filter}}{\text{d-15 of formation}} \; >/= 4 \text{ to } 5$$

The left half of this equation is the fundamental criterion for the prevention of soil piping through a granular filter, while the right half of the equation is the hydraulic conductivity criterion. This latter criterion serves the same purpose as multiplying the d-30 grain size of the formation by a factor of between 4 and 6 for coarser formation materials. Filter pack materials suitable for retaining formation materials in formations that are predominantly fine-grained are themselves, by necessity, relatively fine-grained (e.g., fine to very fine sands), presenting several problems for well designers and installers. First, well screen slot sizes suitable for retaining such fine-grained filter pack materials are not widely available (the smallest commercially available slotted well casing is 0.006 in. [6 slot]; the smallest commercially available continuous-slot wire-wound screen is 0.004 in. [4 slot]). Second, the finest filter pack material practical for conventional (tremie tube) installation is a 40 by 70 (0.008 by 0.018 in.) sand, which can be used with a well screen slot as small as 0.008-in. (8 slot). Finer grained filter pack materials cannot be placed practically by either tremie tubes or pouring down the annular space or down augers. Thus, the best method for ensuring proper installation of filter packs in predominantly fine-grained formation materials is to use pre-packed or sleeved screens, which are described in detail in Practice D 6725. A 50 by 100 (0.011 by 0.006 in.) filter-pack sand can be used with a 0.006-in. slot size pre-packed or sleeved screen, and a 60 by 120 (0.0097 by 0.0045 in.) filter-pack sand can be used with a 0.004-in. (4 slot) slot size pre-packed or sleeved screen. Filter packs that are finer than these (e.g., sands as fine as 100 by 120 [0.006 by 0.0045 in.], or silica flour as fine as 200 mesh [0.003 in.]) can only be installed within stainless steel mesh sleeves that can be placed over pipe-based screens. While these sleeves, or the space between internal and external screens in a pre-packed well screen may be as thin as 1/2-in. (1.27 cm), the basis for mechanical retention dictates that a filter-pack thickness of only two or three grain diameters is needed to contain and control formation materials. Laboratory tests have demonstrated that a properly sized filter pack material with a thickness of less than 1/2-in. (1.27 cm) successfully retains formation particles regardless of the velocity of water passing through the filter pack [3].

6.3.3.3 The limit of mechanical filtration for monitoring wells is defined by the finest filter pack material that can be practically installed via a pre-packed or sleeved screen—silica flour with a grain size of 0.003 in. (200 mesh), encased within a very fine mesh screen of stainless steel or other suitable material. This fine a filter pack material will retain formation material as fine as silt, but not clay. Formations with a small fraction of clay (up to about 20 %) can be successfully monitored, as long as the wells installed in these formations are properly developed (see Guide D 5521). For mechanical filtration to be effective in formations with more than 50 % fines, the filter pack design would have to include silt-sized particles in the filter pack in order to meet the design criteria, which is impractical, as placement would be impossible and screen mesh fine enough to retain the material is not commercially available. Therefore, formations with more than 50 % passing a #200 sieve, and having more than 20 % clay-sized material, should not be monitored using conventional well designs. Alternative monitoring technologies should be used in these formations..

NOTE 3—When installing a monitoring well in solution-channeled limestone or highly fractured bedrock, the borehole configuration of void spaces within the formation surrounding the borehole is often unknown. Therefore, the installation of a filter pack becomes difficult and may not be possible.

NOTE 4—This practice presents a design for monitoring wells that will be effective in the majority of formations. Applicable state guidance may differ from the designs contained in this practice.

NOTE 5—Because the well screen slots have uniform openings, the filter pack should be composed of particles that are as uniform in size as is practical. Ideally, the uniformity coefficient (the quotient of the 60 % passing, D-60 size divided by the 10 % passing D-10 size [effective size]) of the filter pack should be 1.0 (that is, the D-60 % and the D-10 % sizes should be identical). However, a more practical and consistently achievable uniformity coefficient for all ranges of filter pack sizes is 2.5. This value of 2.5 should represent a maximum value, not an ideal.

NOTE 6—Although not recommended as standard practice, often a project requires drilling and installing the well in one phase of work. Therefore, the filter pack materials must be ordered and delivered to the drill site before soil samples can be collected. In these cases, the suggested well screen slot size and filter pack material combinations are presented in Table 1.

NOTE 7—Silica flour can alter water chemistry, particularly for transuranics, and its use should be evaluated against the monitoring program analytes

6.4 *Well Screen*:

6.4.1 *General*—The purposes of the well screen are to provide designed openings for ground-water flow through the well, and to prevent migration of filter pack and formation

TABLE 1 Recommended (Achievable) Filter Pack Characteristics for Common Screen Slot Sizes

Size of Screen Opening, mm (in.)	Slot No.	Sand Pack Mesh Size Name(s)	1 % Passing Size (D-1), mm	Effective Size, (D-10), mm	30 % Passing Size (D-30), mm	Range of Uniformity Coefficient	Roundness (Powers Scale)
0.125 (0.005)	5[A]	100	0.09 to 0.12	0.14 to 0.17	0.17 to 0.21	1.3 to 2.0	2 to 5
0.25 (0.010)	10	20 to 40	0.25 to 0.35	0.4 to 0.5	0.5 to 0.6	1.1 to 1.6	3 to 5
0.50 (0.020)	20	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
0.75 (0.030)	30	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
1.0 (0.040)	40	8 to 12	1.2 to 1.4	1.6 to 1.8	1.7 to 2.0	1.1 to 1.6	4 to 6
1.5 (0.060)	60	6 to 9	1.5 to 1.8	2.3 to 2.8	2.5 to 3.0	1.1 to 1.7	4 to 6
2.0 (0.080)	80	4 to 8	2.0 to 2.4	2.4 to 3.0	2.6 to 3.1	1.1 to 1.7	4 to 6

[A] A 5-slot (0.152-mm) opening is not currently available in slotted PVC but is available in Vee wire PVC and Stainless; 6-slot opening may be substituted in these cases.

---

[3] (1) Driscoll, F.G., 1986, Groundwater and Wells, Johnson Division, St. Paul, MN, pg.443

material into the well. The well screen design is based on either the grain-size distribution of the formation (in the case of a well with a naturally developed filter pack), or the grain-size distribution of the primary filter pack material (in the case of a filter-packed well). The screen openings must be small enough to retain most if not all of the formation or filter-pack materials, yet large enough to maintain ground-water flow velocities, from the well screen/filter pack interface back to the natural formation materials, of less than 0.10 ft/s (0.03 m/s). If well screen entrance velocities exceed 0.10 ft/s (0.03 m/s), turbulent flow conditions can occur, resulting in mobilization of sediment from the formation and reductions in well efficiency.

6.4.2 *Materials*—TThe well screen should be new, machine-slotted casing or continuous wrapped wire-wound screen composed of materials compatible with the monitoring environment, as determined by the site characterization program. The screen should be plugged at the bottom (unless a sediment sump is used), and the plug should generally be of the same material as the well screen. This assembly must have the capability to withstand well installation and development stresses without becoming dislodged or damaged. The length of the well screen open area should reflect the thickness of the target monitoring zone. Immediately prior to installation, the well screen should be cleaned (see either Practice D 5088 or Practice D 5608) with water from a source of known chemistry, if it is not certified clean by the manufacturer, and delivered, and maintained in a clean environment at the site.

NOTE 8—Well screens are most commonly composed of PVC or stainless steel. Stainless steel may be specified based on knowledge of the occurrence of microbially influenced corrosion in formations (specifically reducing or acid-producing conditions).

6.4.3 *Diameter*—TThe minimum nominal internal diameter of the well screen should be chosen based on factors specific to the particular application (such as the outside diameter of the purging and sampling device(s) to be used in the well). Well screens as small as 1/2-in. (1.27 cm) nominal diameter are available for use in monitoring well applications.

6.4.4 *Design*—The design of the well screen should be determined based on the grain size analysis (per Test Method D 422) of the interval to be monitored and the gradation of the primary filter pack material. In granular, non-cohesive formation materials that will fall in easily around the screen, filter packs can be developed from the native formation materials—filter pack materials foreign to the formation are not necessary. In these cases of naturally developed filter packs, the slot size of the well screen is determined using the grain size of the materials in the surrounding formation. The well screen slot size selected for this type of well completion should retain at least 70 % of formation materials—the finest 30 % of formation materials will be brought into the well during development, and the objectives of filter packing (to increase hydraulic conductivity immediately surrounding the well screen, and to promote easy flow of ground water into and through the screen) will be met. In wells in which a filter pack material of a selected grain size distribution is introduced from the surface, the screen slot size selected should retain at least 90 %, and preferably 99 %, of the primary filter pack materials. The method for determining the primary filter pack design is described in 6.3.3.

6.4.5 *Prepacked or Sleeved Well Screens*—An alternative to designing and installing filter pack and well screens separately is to use a pre-packed or sleeved screen assembly. A pre-packed well screen consists of an internal well screen, an external screen or filter medium support structure, and the filter medium contained between the screens, which together comprise an integrated structure. The internal and external screens are constructed of materials compatible with the monitored environment, and are usually of a common slot size specified by the well designer to retain the filter pack material. The filter pack is normally an inert (e.g., siliceous) granular material that has a grain-size distribution chosen to retain formation materials. A sleeved screen consists of a slotted pipe base over which a sleeve of stainless steel mesh filled with selected filter media is installed. Pre-packed or sleeved screens may be used for any formation conditions, but they are most often used where heaving, running or blowing sands make accurate placement of conventional well screens and filter packs difficult, or where predominantly fine-grained formation materials are encountered. In the latter case, using pre-packed or sleeved screens is the only practical means of ensuring that filter pack materials of the selected grain-size distribution (generally fine to very fine sands) are installed to completely surround the screen.

NOTE 9—The practice of using a single well screen/filter pack combination (e.g., 0.010 in. [0.254 mm]) well screen slot size with a 20/40 sand) for all wells, regardless of formation grain-size distribution, will result in siltation of the well and significant turbidity in samples when applied to formations finer than the recommended design. It will also result in the loss of filter pack, possible collapse of the screen, and invasion of overlying well construction materials (e.g., secondary filter pack, annular seal materials, grout) when applied to formations coarser than the recommended design. For these reasons, the universal application of a single well screen/filter pack combination to all formations is not recommended, and should be avoided.

6.5 *Riser*:

6.5.1 *Materials*—TThe riser should be new pipe composed of materials that will not alter the quality of water samples for the constituents of concern and that will stand up to long-term exposure to the monitoring environment, including potential contaminants. The riser should have adequate wall thickness and coupling strength to withstand the stresses imposed on it during well installation and development. Each section of riser should be cleaned (see either Practice D 5088 or Practice D 5608) using water from a source of known chemistry immediately prior to installation.

NOTE 10—Risers are generally constructed of PVC, galvanized steel or stainless steel.

6.5.2 *Diameter*—The minimum nominal internal diameter of the riser should be chosen based on the particular application. Risers as small as ½-in. (1.25-cm) in diameter are available for applications in monitoring wells.

6.5.3 *Joints (Couplings)*—Threaded joints are recommended. Glued or solvent-welded joints of any type are not recommended because glues and solvents may alter the chemistry of water samples. Because square profile flush joint threads (Specification F 480) are designed to be accompanied by O-ring seals at the joints, they do not require PTFE taping. However, tapered threaded joints should be PTFE taped to prevent leakage of water into the riser.

6.6 *Casing*—Where conditions warrant, the use of permanent casing installed to prevent communication between water-bearing zones is encouraged. The following subsections address both temporary and permanent casings.

6.6.1 *Materials*—The material type and minimum wall thickness of the casing should be adequate to withstand the forces of installation. All casing that is to remain as a permanent part of the installation (that is, in multi-cased wells) should be new and cleaned to be free of interior and exterior protective coatings.

NOTE 11—The exterior casing (temporary or permanent multi-cased) is generally composed of steel, although other appropriate materials may be used.

6.6.2 *Diameter*—Several different casing sizes may be required depending on the geologic formations penetrated. The diameter of the borehole and the well casing for conventionally filter packed wells should be selected so that a minimum annular space of 2 in. (5 cm) is maintained between the inside diameter of the casing and outside diameter of the riser to provide working space for a tremie pipe. For naturally developed wells and pre-packed or sleeved screen completions, this annular space requirement need not be met. In addition, the diameter of the casings in multi-cased wells should be selected so that a minimum annular space of 2 in. (5 cm) is maintained between the casing and the borehole (that is, a 2-in. [5 cm] diameter screen will require first setting a 6-in. [15.2 cm] diameter casing in a 10-in. [25.4 cm] diameter boring).

NOTE 12—Under difficult drilling conditions (collapsing soils, rock, or cobbles), it may be necessary to advance temporary casing. Under these conditions, a smaller annular space may be maintained.

6.6.3 *Joints (Couplings)*—The ends of each casing section should be either flush-threaded or beveled for welding.

6.7 *Sediment Sump*—A sediment sump, a length of blank pipe, generally of the same diameter and made of the same material as the riser and well screen -- may be affixed to the bottom of the screen, and capped with a bottom plug, to collect fine-grained material brought into the well by the process of well development. A drainage hole may be drilled in the bottom of the sump to prevent the sump from retaining water in the event that the water level outside the well falls below the bottom of the well screen. Because the sediment that collects in the sump may harbor geochemistry-altering microflora and reactive metal oxides, this sediment must be removed periodically to minimize the potential for sample chemical alteration.

6.8 *Protective Casing*:

6.8.1 *Materials*—Protective casings may be made of aluminum, mild steel, galvanized steel, stainless steel, cast iron, or structural plastic pipe. The protective casing should have a lid capable of being locked shut by a locking device or mechanism.

6.8.2 *Diameter*—The inside dimensions of the protective casing should be a minimum of 2 in. (5 cm) and preferably 4 in. (10 cm) larger than the nominal diameter of the riser to facilitate the installation and operation of sampling equipment.

6.9 *Annular Sealants*—TThe materials used to seal the annulus may be prepared as a slurry or used un-mixed in a dry pellet, granular, or chip form. Sealants should be selected to be compatible with ambient geologic, hydrogeologic, geochemical and climatic conditions and any man-induced conditions (e.g., subsurface contamination) anticipated during the life of the well.

6.9.1 *Bentonite*—Bentonite should be powdered, granular, pelletized, or chipped sodium montmorillonite from a commercial source, free of impurities that may adversely impact the water quality in the well. Pellets consist of roughly spherical units of moistened, compressed bentonite powder. Chips are large, irregularly shaped, and coarse granular units of bentonite free of additives. The diameter of pellets or chips selected for monitoring well construction should be less than one fifth the width of the annular space into which they are placed to reduce the potential for bridging. Granules consist of coarse to fine particles of unaltered bentonite, typically smaller than 0.2 in. (5.0 mm). It is recommended that the water chemistry of the formation in which the bentonite is intended for installation be evaluated to ensure that it is suitable to hydrate the bentonite. Some water-quality conditions (e.g., high chloride content, high concentrations of certain organic solvents or petroleum hydrocarbons) may inhibit the hydration of bentonite and result in an ineffective seal.

6.9.2 *Cement*—Each type of cement has slightly different characteristics that may be appropriate under various physical and chemical conditions. Cement should be one of the five Portland cement types that are specified in Specification C 150. The use of quick-setting cements containing additives is not recommended for use in monitoring well installation. Additives may leach from the cement and influence the chemistry of water samples collected from the monitoring well.

6.9.3 *Grout*—The grout backfill that is placed above the bentonite annular seal and secondary filters (see Fig. 1) is ordinarily a thick liquid slurry consisting of either a bentonite (powder or granules, or both) base and water, or a Portland cement base and water. Often, bentonite-based grouts are used when it is desired that the grout remain workable for extended periods of time during well construction or flexible (that is, to accommodate freeze-thaw cycles) during the life of the well. Cement-based grouts are often used when filling cracks in the surrounding geologic material, adherence to rock units, or a rigid setting is desired.

6.9.3.1 *Mixing*—The mixing (and placing) of a grout backfill should be performed with precisely recorded weights and volumes of materials, and according to procedures stipulated by the manufacturer that often include the order of component mixing. The grout should be thoroughly mixed with a paddle-type mechanical mixer or by recirculating the mix through a pump until all lumps are disintegrated. Lumpy grout should not be used in the construction of a monitoring well to prevent bridging within the tremie pipe.

NOTE 13—Lumps do not include lost circulation materials that may be added to the grout if excessive grout losses occur.

6.9.3.2 *Typical Bentonite-Based Grout*—When a bentonite-based grout is used, bentonite, usually unaltered, should be placed in the water through a venturi device. A typical

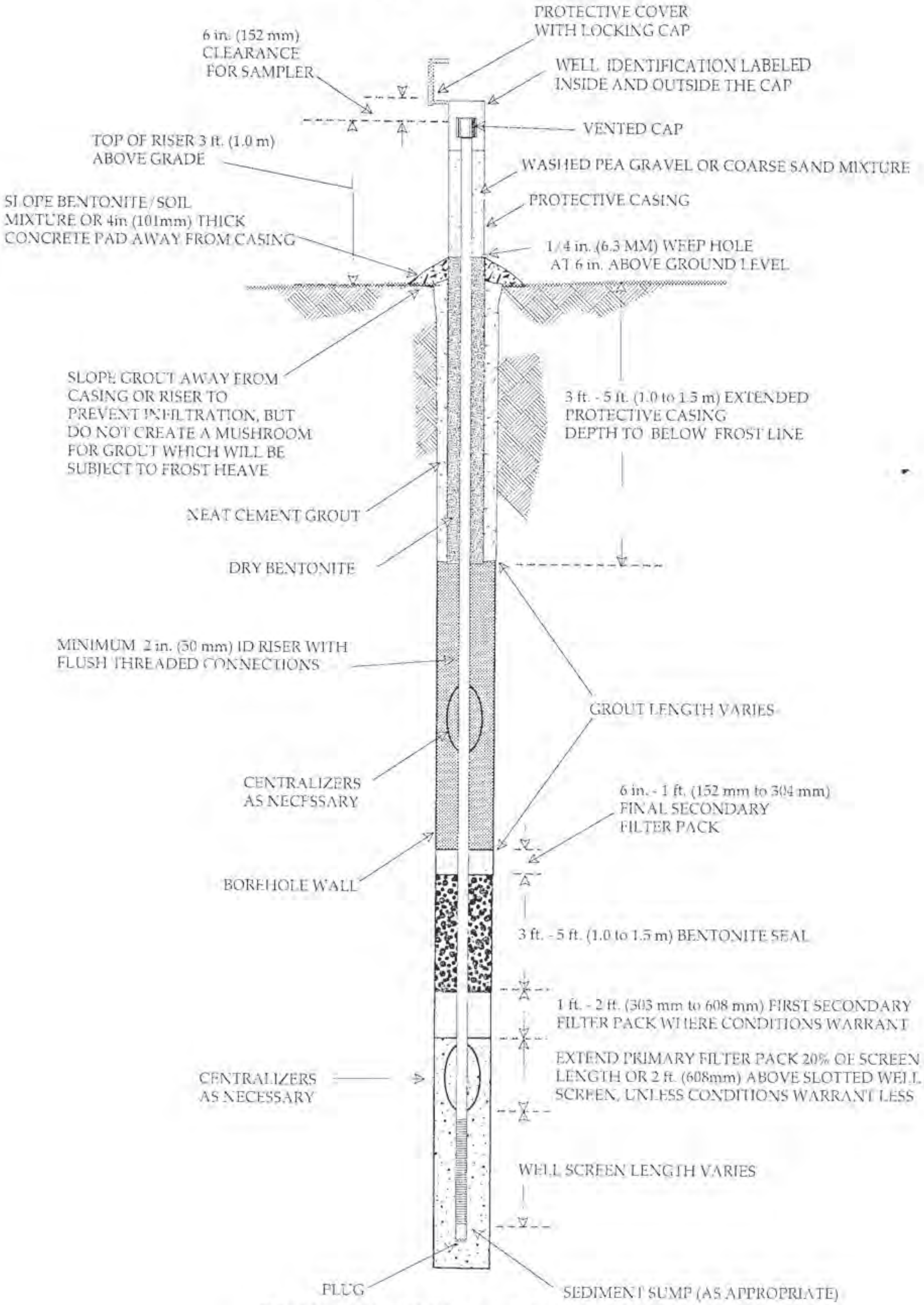


FIG. 1 Monitoring Well Design—Single–Cased Well

unbeneficiated bentonite-based grout consists of about 1 to 1.25 lb (0.57 kg) of unaltered bentonite to each 1 gal (3.8 L) of water. 100 % bentonite grouts should not be used for monitoring well annular sealants in the vadose zone of arid regions because of the possibility that they may desiccate. This could result in migration of water into the screened portion of the well from zones above the target monitoring zone.

NOTE 14—High solids bentonite grouts (minimum 20 % by weight with water) and other bentonite-based grouts may contain granular bentonite to increase the solids content and other components added under manufacturer's directions to either stiffen or retard stiffening of the mix. All additives to grouts should be evaluated for their effects on subsequent water samples.

6.9.3.3 *Typical Cement-Based Grout*—A typical cement-based grout consists of about 6 gal. (23 L) of water per 94-lb. (43-kg) bag of Type I Portland cement. Though not recommended because of the chemical incompatability of bentonite with cement (2, 3), from 3 to 8 % (by dry weight) of unaltered bentonite powder is often added after the initial mixing of cement and water to retard shrinkage and provide plasticity..

6.10 *Secondary Filter Packs*:

6.10.1 *Materials*—A secondary filter pack is a layer of material placed in the annulus between the primary filter pack and the bentonite seal, and/or between the bentonite seal and the grout backfill (see Fig. 1 and Fig. 2).

6.10.2 *Gradation*—The secondary filter pack should be uniformly graded fine sand with 100 % by weight passing the #30 U.S. Standard sieve, and less than 2 % by weight passing the #200 U.S. Standard sieve.

6.11 *Annular Seal and Filter Pack Installation Equipment*—The equipment used to install the annular seals and filter pack materials should be cleaned (if appropriate for the selected material) using water from a source of known quality prior to use. This procedure is performed to prevent the introduction of materials that may ultimately alter water quality samples.

7. Drilling Methods

7.1 The type of equipment required to create a stable, open, vertical borehole for installation of a monitoring well depends upon the site geology, hydrology, and the intended use of the data. Engineering and geological judgment and some knowledge of subsurface geological conditions at the site is required for the selection of the appropriate drilling method(s) utilized for drilling the exploratory soil borings and monitoring wells (see Guide D 6286). Appropriate drilling methods for investigating and installing monitoring wells at a site may include any one or a combination of several of the following methods: hollow-stem auger (Guide D 5784); direct (mud) rotary (Guide D 5783); direct air-rotary (Guide D 5782); direct rotary wireline casing advancement (Guide D 5876); dual-wall reverse-circulation rotary (Guide D 5781); cable-tool (Guide D 5875); or various casing advancement methods (Guide D 5872). Whenever feasible, it is advisable to utilize drilling procedures that do not require the introduction of water or drilling fluids into the borehole, and that optimize cuttings control at ground surface. Where the use of water or drilling fluid is unavoidable, the selected fluid should have as little impact as possible on the water samples for the constituents of interest. The chemistry of the fluid to be used should be evaluated to determine the potential for water quality sample alteration. In addition, care should be taken to remove as much drilling fluid as possible from the well and the surrounding formation during the well development process. It is recommended that if an air compressor is used, it should be equipped with an oil air filter or oil trap to minimize the potential for chemical alteration of ground-water samples collected after the well is installed. 8. Monitoring Well Installation

8. Monitoring Well Installation

8.1 *Stable Borehole*—A stable borehole must be constructed prior to attempting the installation of monitoring well screen and riser. Steps must be taken to stabilize the borehole before attempting installation if the borehole tends to cave or blow in, or both. Boreholes that are not straight or are partially obstructed should be corrected prior to attempting the installation procedures described herein.

8.2 *Assembly of Well Screen and Riser*:

8.2.1 *Handling*—TThe well screen, sediment sump, bottom plug and riser should be either certified clean from the manufacturer or steam-cleaned or high-pressure hot-water washed (whichever is appropriate for the selected material) using water from a source of known chemistry immediately prior to assembly. Personnel should take precautions to assure that grease, oil, or other contaminants that may ultimately alter the water sample do not contact any portion of the well screen and riser assembly. As one precaution, for example, personnel should wear a clean pair of cotton, nitrile or powder-free PVC (or equivalent) gloves while handling the assembly..

8.2.2 *Riser Joints (Couplings)*—Flush joint risers with square profile (Specification F 480) threads do not require PTFE taping to achieve a water tight seal; these joints should not be taped. O-rings made of a material of known chemistry, selected on the basis of compatibility with contaminants of concern and prevailing environmental conditions, should be used to assure a tight seal of flush-joint couplings. Couplings are often tightened by hand; however, if necessary, steam-cleaned or high-pressure water-cleaned wrenches may be utilized. Precautions should be taken to prevent damage to the threaded joints during installation, as such damage may promote leakage past the threads.

8.3 *Setting the Well Screen and Riser Assembly*—When the well screen and riser assembly is lowered to the predetermined level in the borehole and held in position, the assembly may require ballast to counteract the tendency to float in the borehole. Ballasting may be accomplished by filling the riser with water from a source of known and acceptable chemistry or, preferably, using water that was previously removed from the borehole. Alternatively, the riser may be slowly pushed into the fluid in the borehole with the aid of hydraulic rams on the drill rig and held in place as additional sections of riser are added to the column. Care must be taken to secure the riser assembly so that personnel safety is assured during the installation. The assembly must be installed straight and plumb, with centralizers installed at appropriate locations (typically every 20 to 30 ft [6 to 9 m]). Difficulty in maintaining a straight installation may be encountered where the weight of the well screen and riser assembly is significantly less than the buoyant force of the fluid in the borehole. The riser should extend above grade and be capped temporarily to deter entrance of foreign materials during final completion.

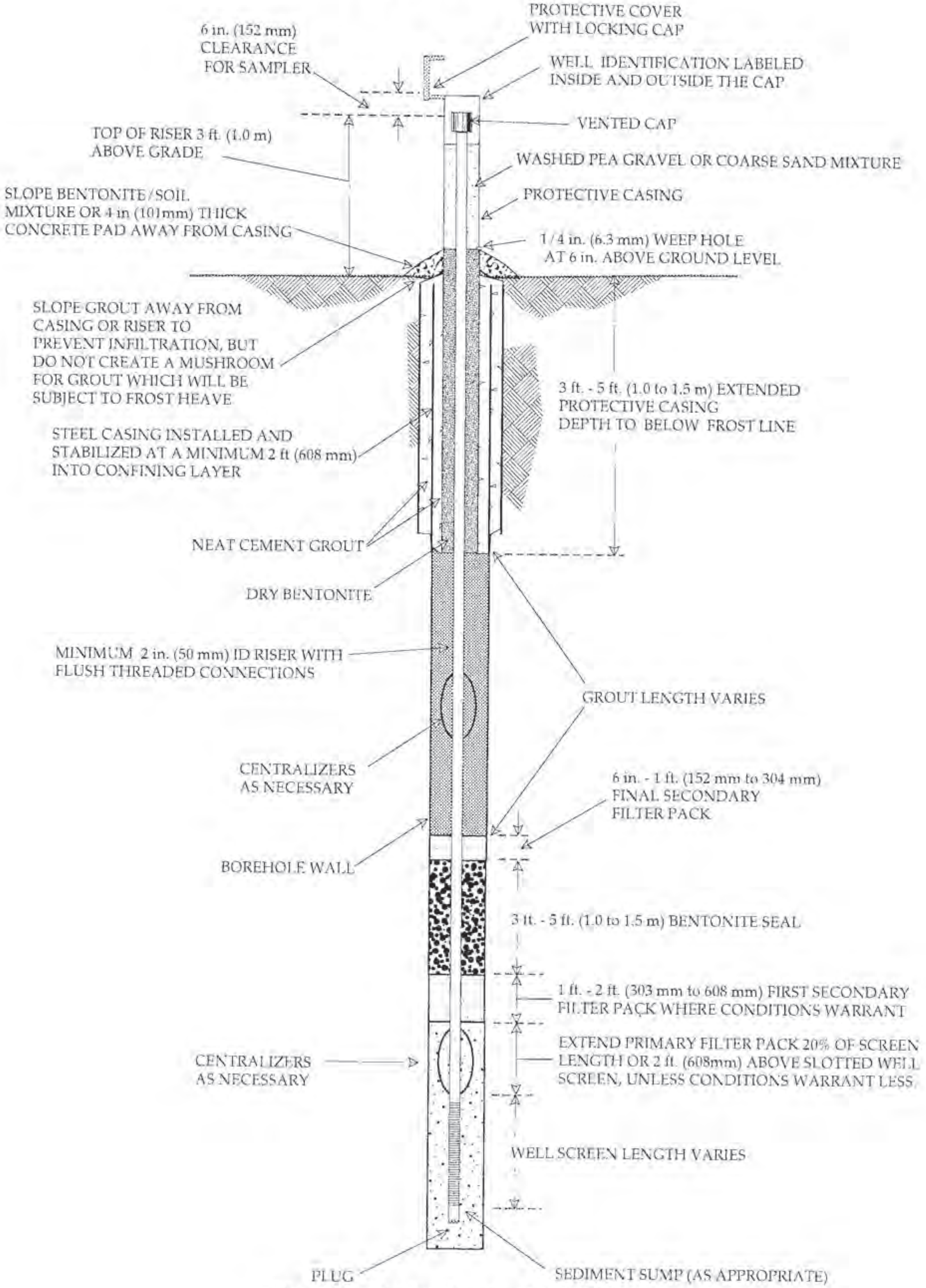


FIG. 2 Monitoring Well Design—Multi–Cased Well

8.4 *Installation of the Primary Filter Pack*:

8.4.1 *Volume of Filter Pack*—TThe volume of filter pack required to fill the annular space between the well screen and borehole should be calculated, measured, and recorded on the well completion diagram during installation. To be effective, the filter pack should extend above the screen for a distance of about 20 % of the length of the well screen but not less than 2 ft. (0.6 m) (see Figs. 1 and 2). Where there is hydraulic connection between the zone to be monitored and the overlying strata, this upward extension should be gauged to prevent seepage from overlying hydrologic units into the filter pack. Seepage from other units may alter hydraulic head measurements or the chemistry of water samples collected from the well.

8.4.2 *Placement of Primary Filter Pack*—Placement of the well screen is preceded by placing no less than 2 % and no more than 10 % of the primary filter pack into the bottom of the borehole using a decontaminated, flush threaded, 1-in. (25-mm) minimum internal diameter tremie pipe. Alternatively, the filter pack may be added directly between the riser pipe and the auger or drive/temporary casing and the top of the filter pack located using a tamper or a weighted line. The well screen and riser assembly is then centered in the borehole. This can be done using one or more centralizer(s) or alternative centering devices located not more than 10 ft (3 m) above the bottom of the well screen (see Figs. 1 and 2). Centralizers should not be located in the well screen. The remaining primary filter pack is then placed in increments as the tremie is gradually raised or as the auger or drive/temporary casing is removed from the borehole. As primary filter pack material is poured into the tremie pipe, water from a source of known and acceptable chemistry may be added to help deliver the filter pack to the intended interval in the borehole. The tremie pipe or a weighed line can be used to measure the top of the primary filter pack as work progresses. If bridging of the primary filter pack material occurs, the bridged material should be broken mechanically prior to proceeding with the addition of more filter pack material. The elevation (or depth below ground surface), volume, and gradation of primary filter pack should be recorded on the well completion diagram (see Fig. 2 for an example).

8.4.3 *Withdrawal of the Temporary Casing/Augers*—If used, the drive/temporary casing or hollow stem auger is withdrawn, usually in stipulated increments. Care should be taken to avoid lifting the riser with the withdrawal of the temporary casing/augers. To limit borehole collapse in stable formations, the temporary casing or hollow stem auger is usually withdrawn until the lower-most point on the temporary casing or hollow stem auger is at least 2 ft (0.6 m), but no more than 5 ft (1.5 m) above the filter pack for unconsolidated materials; or at least 5 ft (1.5 m), but no more than 10 ft (3.0 m), for consolidated materials. In highly unstable formations, withdrawal intervals may be much less. After each increment, it should be ascertained that the primary filter pack has not been displaced during the withdrawal operation (using a weighed measuring device).

8.5 *Placement of First Secondary Filter*—A secondary filter pack may be installed above the primary filter pack to prevent the intrusion of the bentonite grout seal into the primary filter pack (see Figs. 1 and 2). To be effective, a measured and recorded volume of secondary filter material should be added to extend 1 to 2 ft (0.3 to 0.6 m) above the primary filter pack. As with the primary filter, a secondary filter must not extend into an overlying hydrologic unit (see 8.4.1). The well designer should evaluate the need for this filter pack by considering the gradation of the primary filter pack, the hydraulic heads between adjacent units, and the potential for grout intrusion into the primary filter pack. The secondary filter material is poured into the annular space through a decontaminated, flush threaded, 1-in. (25-mm) minimum internal diameter tremie pipe lowered to within 3 ft (1.0 m) of the placement interval. Water from a source of known and acceptable chemistry may be added to help deliver the filter pack to its intended location. The tremie pipe or a weighed line can be used to measure the top of the secondary filter pack as work progresses. The elevation (or depth below ground surface), volume, and gradation of the secondary filter pack should be recorded on the well completion diagram.

8.6 *Installation of the Bentonite Seal*—A bentonite pellet or a slurry seal is placed in the annulus between the borehole and the riser pipe on top of the secondary or primary filter pack (see Figs. 1 and 2). This seal retards the movement of cement-based grout backfill into the primary or secondary filter packs. To be effective, the bentonite seal should extend above the filter packs approximately 3 to 5 ft (1.0 to 1.5 m), depending on local conditions. The bentonite slurry seal should be installed using a positive displacement pump and a side-discharge tremie pipe lowered to the top of the filter pack. The tremie pipe should be raised slowly as the bentonite slurry fills the annular space. Bentonite pellets or chips may be poured from the surface and allowed to free-fall into the borehole. As a bentonite pellet or chip seal is poured into the borehole, a tamper may be necessary to tamp pellets or chips into place or to break bridges formed as the pellets or chips stick to the riser or the walls of the water-filled portion of the borehole. If the bentonite seal is installed above the water level in the borehole, granular bentonite should be used as the seal material – *bentonite pellets or chips should not be used in the unsaturated zone.* Granular bentonite should be poured into the borehole and installed in lifts of 2 in., then hydrated with water from a source of known chemistry. The tremie pipe or a weighed line can be used to measure the top of the bentonite seal as the work progresses. Sufficient time should be allowed for the bentonite pellet seal to hydrate or the slurry annular seal to expand prior to grouting the remaining annulus. The volume and elevation (or depth below ground surface) of the bentonite seal material should be measured and recorded on the well completion diagram.

8.7 *Final Secondary Filter Pack*—A 6-in. to 1-ft (0.15 to 0.3-m) secondary filter may be placed above the bentonite seal in the same manner described in 8.5 (see Figs. 1 and 2). This secondary filter pack will provide a layer over the bentonite seal to limit the downward movement of cement-based grout backfill into the bentonite seal. The volume, elevation (or depth below ground surface), and gradation of this final secondary filter pack should be documented on the well completion diagram.

8.8 *Grouting the Annular Space*:

8.8.1 *General*—Grouting procedures vary with the type of well design. The following procedures will apply to both single- and multi-cased monitoring wells. Paragraphs 8.8.2 and 8.8.3 detail those procedures unique to single- and multi-cased installations, respectively.

8.8.1.1 *Volume of Grout*—An ample volume of grout should be mixed on site to compensate for unexpected losses to the formation. The use of alternate grout materials, including grout containing gravel, may be necessary to control zones of high grout loss. The volume and location of grout used to backfill the remaining annular space is recorded on the well completion diagram.

8.8.1.2 *Grout Installation Procedures*—The grout should be pumped down hole through a side-discharge tremie pipe using a positive displacement pump (e.g., a diaphragm pump, moyno pump, or similar pump) to reduce the chance of leaving voids in the grout, and to displace any liquids and drill cuttings that may remain in the annulus. In very shallow wells, grouting may be accomplished by gravity feeding grout through a tremie pipe. With either method, grout should be introduced in one continuous operation until full-strength grout flows out of the borehole at the ground surface without evidence of drill cuttings, drilling fluid, or water.

8.8.1.3 *Grout Setting and Curing*—The riser should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser. The amount of time required for the grout to set or cure will vary with the grout mix and ambient temperature and should be documented on the well completion diagram.

8.8.2 *Specific Procedures for Single-Cased Wells*—Grouting should begin at a level directly above the final secondary filter pack (see Fig. 1) if used, or above the bentonite pellet, chip or slurry seal. Grout should be pumped using a side-discharge tremie pipe to dissipate the fluid-pumping energy against the borehole wall and riser, reducing the potential for infiltration of grout into the primary filter pack. The tremie pipe should be kept full of grout from start to finish, with the discharge end of the pipe completely submerged as it is slowly and continuously lifted. Approximately 5 to 10 ft (1.5 to 3.0 m) of tremie pipe should remain submerged until grouting is complete. For deep installations or where the joints or couplings of the selected riser cannot withstand the collapse stress exerted by a full column of grout as it is installed, a staged grouting procedure may be used. If used, the drive/temporary casing or hollow-stem auger should be removed in increments immediately following each increment of grout installation and before the grout begins to set. If casing removal does not commence until grout pumping is completed, then, after the casing is removed, additional grout may be periodically pumped into the annular space to maintain a continuous column of grout up to the ground surface.

8.8.3 *Specific Procedures for Multi-Cased Wells*—If the outer casing of a multi-cased well cannot be driven to form a tight seal between the surrounding stratum (strata) and the casing, it should be installed in a pre-drilled borehole. After the borehole has penetrated not less than 2 ft. (0.6 m) of the first targeted confining stratum, the outer casing should be lowered to the bottom of the boring and the annular space pressure grouted. Pressure grouting requires the use of a grout shoe or packer installed at the end of the outer casing to prevent grout from moving up into the casing. The grout must be allowed to cure and form a seal between the casing and the borehole prior to advancing the hole to the next hydrologic unit. This procedure is repeated as necessary to advance the borehole to the desired depth. Upon reaching the final depth, the riser and screen should be set through the inner casing. After placement of the filter packs and bentonite seal, the remaining annular space is grouted as described in 8.8.2 (see Fig. 2).

NOTE 15—When using a packer, pressure may build up during grout injection and force grout up the sides of the packer and into the casing.

8.9 *Well Protection*—Well protection refers specifically to installations made at the ground surface to deter unauthorized entry to the monitoring well, to prevent damage to or destruction of the well, and to prevent surface water from entering the annulus. The methods described in Practice D 5787 should be used for well protection.

8.9.1 *Protective Casing*—Protective casing should be used for all monitoring well installations. In areas that experience frost heaving, the protective casing should extend from below the depth of frost penetration (3 to 5 ft [1.0 to 1.5 m] below grade, depending on local conditions), to slightly above the top of the well casing. The protective casing should be initially placed before final set of the grout. The protective casing should be sealed and immobilized in concrete placed around the outside of the protective casing above the set grout. The protective casing should be stabilized in a position concentric with the riser (see Figs. 3 and 1). Sufficient clearance, usually 6 in. (0.15 m) should be maintained between the lid of the protective casing and the top of the riser to accommodate sampling equipment. A ¼-in. (6.3-mm) ddiameter weep hole should be drilled in the protective casing approximately 6 in. (15 cm) above ground surface to permit water to drain out of the annular space between the protective casing and the riser. In cold climates, this hole will also prevent water freezing between the protective casing and the well casing. Dry bentonite pellets, granules, or chips should then be placed in the

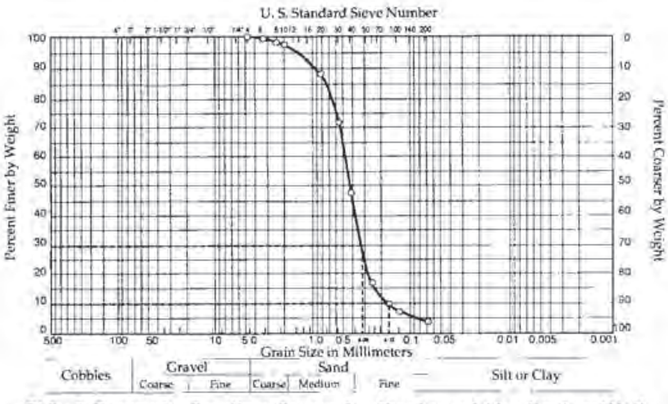


FIG. 3 Example Grading Curve for Design of Monitoring Well Screens

annular space below ground level within the protective casing. Coarse sand or pea gravel or both should be placed in the annular space above the dry bentonite pellets and to just above the weep hole to prevent entry of insects. All materials chosen should be documented on the well completion diagram. The monitoring well identification number should be clearly visible on the inside and outside of the protective casing.

8.9.2 *Completion of Surface Installation*—The well protection installation may be completed in one of three ways:

8.9.2.1 In areas subject to frost heave, place a soil or bentonite/sand layer adjacent to the protective casing sloped to direct water drainage away from the well.

8.9.2.2 In regions not subject to frost heave, a concrete pad, sloped slightly to provide water drainage away from the well, should be placed around the installation.

8.9.2.3 Where monitoring well protection must be installed flush with the ground, an internal cap should be fitted on top of the riser within the manhole or vault. This cap should be leak-proof so that if the vault or manhole should fill with water, the water will not enter the well casing. Ideally, the manhole cover cap should also be leak-proof..

8.9.3 *Additional Protection*—In areas where there is a high probability of damaging the well (high traffic, heavy equipment, poor visibility), it may be necessary to enhance the normal protection of the monitoring well through the use of posts, markers, signs, or other means, as described in Practice D 5787. The level of protection should meet the damage threat posed by the location of the well.

9. Well Development

9.1 *General*—Well development serves to remove fine-grained material from the well screen and filter pack that may otherwise interfere with water quality analyses, to restore the formation properties disturbed during the drilling process, and to improve the hydraulic characteristics of the filter pack and hydraulic communication between the well and the hydrologic unit adjacent to the well screen. Methods of well development vary with the physical characteristics of hydrologic units in which the monitoring well is screened and with the drilling method used.

9.2 *Development Methods and Procedures*—The methods and procedures for well development described in Guide D 5521 should be followed to ensure a proper well completion.

9.3 *Timing and Duration of Well Development*—Well development should begin either after the riser, well screen and filter pack are installed and before the bentonite seal and grout are installed (the preferred time), or after the monitoring well is completely installed and the grout has cured or set. In the former case, the installer may add filter pack material to the borehole before the bentonite seal is installed to compensate for settlement that typically occurs during the development process. This allows the installer to maintain the desired separation between the top of the screen and the bentonite seal. In the latter case, the possibility exists that settlement of the filter pack may result in the bentonite seal settling into the top of the screen. Development should be continued until representative water, free of the drilling fluids, cuttings, or other materials introduced or produced during well construction, is obtained. Representative water is assumed to have been obtained when turbidity readings stabilize and the water is visually clear of suspended solids. The minimum duration of well development will vary with the method used to develop the well. The timing and duration of well development and the turbidity measurements should be recorded on the well completion diagram.

9.4 *Well Recovery Test*—A well recovery test should be performed immediately after and in conjunction with well development. The well recovery test provides an indication of well performance and provides data for estimating the hydraulic conductivity of the screened hydrologic unit. Readings should be taken at intervals suggested in Table 2 until the well has recovered to 90 % of its static water level.

NOTE 16—If a monitoring well does not recover sufficiently for sampling within a 24-hr period and the well has been properly developed, the installation should not generally be used as a monitoring well for detecting or assessing low level organic constituents or trace metals. The installation may, however, be used for long-term water-level monitoring if measurements of short-frequency water-level changes are not required.

10. Installation Survey

10.1 *General*—The vertical and horizontal position of each monitoring well in the monitoring system should be surveyed and subsequently mapped by a licensed surveyor. The well location map should include the location of all monitoring wells in the system and their respective identification numbers, elevations of the top of riser position to be used as the reference point for water-level measurements, and the elevations of the ground surface protective installations. The locations and elevations of all permanent benchmark(s) and pertinent boundary marker(s) located on-site or used in the survey should also be noted on the map.

10.2 *Water-Level Measurement Reference*—The water-level measurement reference point should be permanently marked, for example, by cutting a V-notch into the top edge of the riser pipe. This reference point should be surveyed in reference to the nearest NAVD reference point.

10.3 *Location Coordinates*—The horizontal location of all monitoring wells (active or decommissioned) should be surveyed by reference to a standardized survey grid or by metes and bounds.

10.4 *Borehole Deviation Survey*—A borehole deviation survey, to determine the direction and distance of the bottom of the well relative to the top of the well and points in between, should be completed in wells deeper than 100 feet and in wells installed in dipping formations.

11. Monitoring Well Network Report

11.1 TTo demonstrate that the goals set forth in the Scope have been met, a monitoring well network report should be prepared. This report should:

TABLE 2 Suggested Recording Intervals for Well Recovery Tests

Time Since Starting Test	Time Interval
0 to 15 min	1 min
15 to 50 min	5 min
50 to 100 min	10 min
100 to 300 min (5 h)	30 min
300 to 1440 min (24 h)	60 min

11.1.1 Locate the area investigated in terms pertinent to the project. This should include sketch maps or aerial photos on which the exploratory borings, piezometers, sample areas, and monitoring wells are located, as well as topographic items relevant to the determination of the various soil and rock types, such as contours, streambeds, etc. Where feasible, include a geologic map and geologic cross sections of the area being investigated.

11.1.2 Include copies of all well boring test pits and exploratory borehole logs, initial and post-completion water levels, all laboratory test results, and all well completion diagrams.

11.1.3 Include the well installation survey.

11.1.4 Describe and relate the findings obtained in the initial reconnaissance and field investigation (Section 5) to the design and installation procedures selected (Sections 7-9) and the surveyed locations (Section 10).

11.1.5 This report should include a recommended decommissioning procedure that is consistent with those described in Guide D 5299 and/or with applicable regulatory requirements.

12. Keywords

12.1 aquifer; borehole drilling; geophysical exploration; ground water; monitoring well; site investigation

CATEGORY 7: MONITORING WELL INSTALLATION AND ABANDONMENT

Section 7.3

NAC Chapter 534 – Underground Water and Wells

[NAC-534 Revised Date: 6-16]

CHAPTER 534 - UNDERGROUND WATER AND WELLS

GENERAL PROVISIONS

WELL DRILLING LICENSES

DUTIES OF WELL DRILLERS

DRILLING, CONSTRUCTION AND PLUGGING OF WELLS AND BOREHOLES

WAIVERS

ENFORCEMENT

GENERAL PROVISIONS

NAC 534.010 Definitions. (NRS 534.020, 534.110) As used in this chapter, unless the context otherwise requires, the words and terms defined in NAC 534.015 to 534.245, inclusive, have the meanings ascribed to them in those sections.

(Supplied in codification; A by St. Engineer, 1-9-90; 12-30-97)

NAC 534.015 "Abandon" defined. (NRS 534.020, 534.110) "Abandon" means to discontinue the use of a well or borehole or to leave the well or borehole in such a state of disrepair that to use it would be impracticable, may result in contamination of groundwater or may otherwise pose a hazard to the health or safety of the general public.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.020 "Annular space" defined. (NRS 534.020, 534.110) "Annular space" means the space between two cylindrical objects, one of which surrounds the other, such as the space between the walls of the well bore and the casing.

[St. Engineer, Drilling Wells Reg. § 1.01, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97)

NAC 534.030 "Aquifer" defined. (NRS 534.020, 534.110) "Aquifer" has the meaning ascribed to it in NRS 534.0105.

[St. Engineer, Drilling Wells Reg. § 1.02, eff. 5-19-81] — (NAC A 1-9-90)

NAC 534.040 "Artesian well" defined. (NRS 534.020, 534.110) "Artesian well" has the meaning ascribed to it in NRS 534.012.

[St. Engineer, Drilling Wells Reg. § 1.03, eff. 5-19-81] — (NAC A 1-9-90)

NAC 534.041 "Bentonite chips" defined. (NRS 534.020, 534.110) "Bentonite chips" means a crushed or crushed and formed raw, native predominantly sodium montmorillonite clay which:

1. Has a size gradation between 3/4 inch and 8 mesh;

2. Is designed for dry installation that hydrates and swells upon contact with water as a sealant for hole plugging, casing seals or any vertical seal to prevent water movement up or down a borehole; and

3. May be coated to retard hydration for in-water applications.

➥ The term includes, without limitation, chip bentonite, bentonite pellets or bentonite tablets.

(Added to NAC by St. Engineer by R039-12, eff. 6-29-2012)

NAC 534.042 "Bentonite grout" defined. (NRS 534.020, 534.110) "Bentonite grout" means a commercially manufactured product consisting of the sodium montmorillonite that, when mixed with water pursuant to the specifications recommended by the manufacturer, is specifically designed by the manufacturer to seal and plug wells and boreholes and:

1. Consists of not more than 80 percent water and not less than 20 percent sodium bentonite by weight of water, except that additional additives may increase the solids ratio above and beyond the minimum 20 percent sodium bentonite;

2. Is easily hydrated when mixed with fresh water in the ratio of 24 gallons for every 50-pound bag of bentonite grout;

3. Has hydraulic conductivity or permeability values of 10^{-7} centimeters per second or less; and

4. Has a fluid weight of not less than 9.4 pounds per gallon.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.043 "Blast hole" defined. (NRS 534.020, 534.110) "Blast hole" means a borehole that is drilled and, as soon as practicable, is loaded with explosives for mining purposes.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.045 "Board" defined. (NRS 534.020, 534.110) "Board" means the statewide Well Drillers' Advisory Board.

(Added to NAC by St. Engineer, eff. 1-9-90)

NAC 534.047 "Borehole" defined. (NRS 534.020, 534.110) "Borehole" means a penetration in the ground that is deeper than the longest dimension of its opening at the surface and is made to obtain geologic, geophysical or geotechnical information relating to engineering or for any purpose other than for use as a well.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012)

NAC 534.048 "Bridge" defined. (NRS 534.020, 534.110) "Bridge" means an obstruction in the well bore or annular space of a borehole or well caused when the walls of the well bore collapse or when materials are jammed or wedged into the well bore or annular space.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.050 "Casing" defined. (NRS 534.020, 534.110) "Casing" means the conduit required to prevent waste and contamination of the groundwater and to hold the formation open during the construction or use of the well.

[St. Engineer, Drilling Wells Reg. § 1.04, eff. 5-19-81] — (NAC A 1-9-90)

NAC 534.060 "Cement grout" defined. (NRS 534.020, 534.110) "Cement grout" means a mixture consisting of equal parts by volume of portland cement and sand, consisting of a grain size of not more than 2 millimeters, with not more than 6 gallons of water for each 94-pound bag (1 cubic foot) of cement. For example, one cubic yard of cement grout contains 12 bags of cement, 72 gallons of water and not more than 13 cubic feet of sand.

[St. Engineer, Drilling Wells Reg. § 1.14, eff. 5-19-81] — (NAC A 1-9-90; R039-12, 6-29-2012)

NAC 534.065 "Cement-bentonite grout" defined. (NRS 534.020, 534.110) "Cement-bentonite grout" means a mixture of sodium bentonite and portland cement that, when mixed with water, is specifically designed to seal and plug instrumentation boreholes and:

1. Consists of a range of water to cement to bentonite ratios by weight of between 2.5 to 1 to 0.3 and 4 to 1 to 1. For example, the ratio by weight of 2.5 to 1 to 0.3 is obtained by mixing 30 gallons of water per 94-pound bag of portland cement with 25 pounds of bentonite and the ratio by weight of 4 to 1 to 1 is obtained by mixing 45 gallons of water per 94-pound bag of portland cement with 94 pounds of bentonite;
2. Has hydraulic conductivity or permeability values of 10^{-7} centimeters per second or less;
3. Has a fluid weight of not less than 10 pounds per gallon; and
4. Has a 28-day compressive strength of at least 100 pounds per square inch.

(Added to NAC by St. Engineer by R039-12, eff. 6-29-2012)

NAC 534.070 "Concrete grout" defined. (NRS 534.020, 534.110) "Concrete grout" means a mixture of portland cement, sand, 1/4-inch minus aggregate and water which contains at least five bags of cement per cubic yard of concrete and not more than 7 gallons of clean water per bag of cement (1 cubic foot or 94 pounds).

[St. Engineer, Drilling Wells Reg. § 1.13, eff. 5-19-81] — (NAC A 1-9-90)

NAC 534.080 "Conductor casing" defined. (NRS 534.020, 534.110) "Conductor casing" means the temporary or permanent casing used in the upper portion of the well bore to prevent collapse of the formation during the construction of the well or to conduct the gravel pack to the perforated or screened areas in the casing.

[St. Engineer, Drilling Wells Reg. § 1.05, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97)

NAC 534.094 "Contaminant" defined. (NRS 534.020, 534.110) "Contaminant" means any chemical, mineral, live organism, organic material, radioactive material or heated or cooled water that may adversely affect the quality of groundwater.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.095 "Contamination" defined. (NRS 534.020, 534.110) "Contamination" means the impairment of water quality by the introduction of contaminants into the groundwater.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.097 "Development of a well" defined. (NRS 534.020, 534.110) "Development of a well" means the process of cleaning out materials introduced during the drilling process before putting a well into service and increasing the discharge capacity of the well.

(Added to NAC by St. Engineer by R044-14, eff. 10-24-2014)

NAC 534.100 "Division" defined. (NRS 534.020, 534.110) "Division" means the Division of Water Resources of the State Department of Conservation and Natural Resources.

[St. Engineer, Drilling Wells Reg. § 1.07, eff. 5-19-81]

NAC 534.110 "Domestic use" defined. (NRS 534.020, 534.110) "Domestic use" has the meaning ascribed to it NRS 534.013.

[St. Engineer, Drilling Wells Reg. § 1.08, eff. 5-19-81] — (NAC A 1-9-90)

NAC 534.112 "Drill rig" defined. (NRS 534.020, 534.110) "Drill rig" means any power-driven percussion, rotary, boring, coring, digging, jetting or augering machine used in the construction of a well or borehole.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.113 "Drive point well" defined. (NRS 534.020, 534.110) "Drive point well" means a temporary monitoring well constructed by driving a drive point attached to the end of a section of pipe into the ground for the purpose of obtaining geotechnical or environmental information. The term is synonymous with a push point well.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.120 "Exploratory well" defined. (NRS 534.020, 534.110) "Exploratory well" means a borehole or well constructed to determine the availability, quantity or quality of water or whether an aquifer is capable of transmitting water to a well.

[St. Engineer, Drilling Wells Reg. § 1.09, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R044-14, 10-24-2014)

NAC 534.140 "Groundwater" defined. (NRS 534.020, 534.110) "Groundwater" means water below the surface of the land that is in a zone of saturation.

[St. Engineer, Drilling Wells Reg. § 1.11, eff. 5-19-81] — (NAC A 12-30-97)

NAC 534.144 "Instrumentation borehole" defined. (NRS 534.020, 534.110) "Instrumentation borehole" means a borehole constructed by intentionally placing or leaving any monitoring instrumentation in the hole as the hole is plugged and sealed at the time of construction.

(Added to NAC by St. Engineer by R039-12, eff. 6-29-2012)

NAC 534.148 "Monitoring well" defined. (NRS 534.020, 534.110) "Monitoring well" means any well that is constructed to evaluate, observe or determine the quality, quantity, temperature, pressure or other characteristic of groundwater or an aquifer. The term includes an observation well, piezometer, drive point well or vapor extraction well. The term does not include an instrumentation borehole that is plugged and sealed and is not open to the atmosphere upon completion.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012)

NAC 534.150 "Neat cement" defined. (NRS 534.020, 534.110) "Neat cement" means a mixture of:

1. Clean water and cement in a ratio of not more than 5.2 gallons of water per bag of portland cement (1 cubic foot or 94 pounds); or

2. Clean water, cement and sodium bentonite in a ratio of not more than 7.8 gallons of water per 3.76 pounds of sodium bentonite by dry weight and one bag of portland cement (1 cubic foot or 94 pounds).

[St. Engineer, Drilling Wells Reg. § 1.12, eff. 5-19-81] — (NAC A 12-30-97)

NAC 534.160 "Nominal size" defined. (NRS 534.020, 534.110) "Nominal size" means the manufactured commercial designation of the diameter of a casing. An example would be casing with an outside diameter of 12 3/4 inches which may be nominally 12-inch casing by manufactured commercial designation.

[St. Engineer, Drilling Wells Reg. § 1.15, eff. 5-19-81]

NAC 534.165 "Observation well" defined. (NRS 534.020, 534.110) "Observation well" means a borehole in which a temporary casing has been set and which is used to observe, test and measure the elevation of the water table, the pressure variations within an aquifer and the movement of contaminants inside or outside a zone of saturation.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.175 "Permit" defined. (NRS 534.020, 534.110) "Permit" means the written permission from the State Engineer to appropriate public waters for a beneficial use from a surface or underground source, at a specific point of diversion, under limited circumstances.

(Added to NAC by St. Engineer, eff. 1-9-90)

NAC 534.179 "Piezometer" defined. (NRS 534.020, 534.110) "Piezometer" means a well that is constructed to measure water pressure or soil moisture tensions at one or more discrete intervals.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.182 "Pitless adapter" defined. (NRS 534.020, 534.110) "Pitless adapter" means a commercially manufactured device designed for attachment to openings through the casing of a water well that permits water service pipes to pass through the wall or an extension of a casing and prevents the entry of contaminants into the well or water supply.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.183 "Plug" defined. (NRS 534.020, 534.110) "Plug" means the procedure in which a well or borehole is sealed after it is abandoned.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.185 "Public land survey" defined. (NRS 534.020, 534.110) "Public land survey" means the description of the location of land using the survey system of the United States Government and includes the 40-acre subdivision within a quarter-quarter section, quarter section, section, township and range.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006)

NAC 534.188 "Reconditioning" defined. (NRS 534.020, 534.110) "Reconditioning" means the deepening, reaming, casing, recasing, perforating, reperforating, installing of liner pipe, packers and seals or any other significant change in the design or construction of a water well.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.189 "Rehabilitation" defined. (NRS 534.020, 534.110) "Rehabilitation" means the process of revitalizing an existing well by various methods that do not cause a significant change in the design or construction of the well, including, without limitation, chemical treatment, brush cleaning, surging and high-pressure jetting.

(Added to NAC by St. Engineer by R044-14, eff. 10-24-2014)

NAC 534.190 "Seal" defined. (NRS 534.020, 534.110) "Seal" means the watertight seal established in a borehole or the annular space between the well casings or a well casing and the well bore to prevent the inflow or vertical movement of surface water or shallow groundwater, or to prevent the outflow or vertical movement of water under artesian pressures. The term includes a sanitary seal.

[St. Engineer, Drilling Wells Reg. § 1.19, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97)

NAC 534.192 "Seismic shot hole" defined. (NRS 534.020, 534.110) "Seismic shot hole" means a borehole in which an explosion is detonated to assist studies of the geology of the earth.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.194 "Sodium bentonite" defined. (NRS 534.020, 534.110) "Sodium bentonite" means a colloidal clay that:

1. Consists primarily of the weathered volcanic clay mineral montmorillonite where sodium is the predominant, exchangeable cation;
2. Has the ability to swell; and
3. Is easily hydrated when mixed with fresh water to form bentonite drilling fluids or bentonite grout.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012)

NAC 534.195 "Static water level" defined. (NRS 534.020, 534.110) "Static water level" means the stabilized level or elevation of the surface of the water in a well or borehole that is not being pumped and is not affected by the pumping of other wells or boreholes.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97)

NAC 534.205 "Vapor extraction well" defined. (NRS 534.020, 534.110) "Vapor extraction well" means any well constructed to remove vapors that may contaminate the groundwater.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.210 "Waste" defined. (NRS 534.020, 534.110) "Waste" has the meaning ascribed to it in NRS 534.0165.

[St. Engineer, Drilling Wells Reg. § 1.21, eff. 5-19-81] — (NAC A 1-9-90)

NAC 534.220 "Well" defined. (NRS 534.020, 534.110) "Well" means a penetration in the ground made for the purpose of measuring, testing, sampling or producing groundwater. The term includes a water well, monitoring well or exploratory well.

[St. Engineer, Drilling Wells Reg. § 1.22, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R039-12, 6-29-2012)

NAC 534.235 "Well bore" defined. (NRS 534.020, 534.110) "Well bore" means a cylindrical hole made in the construction or drilling of a well.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.240 "Well driller" defined. (NRS 534.020, 534.110) "Well driller" has the meaning ascribed to it in NRS 534.017.

[St. Engineer, Drilling Wells Reg. § 1.24, eff. 5-19-81] — (NAC A 1-9-90)

NAC 534.243 "Well Driller's Report" defined. (NRS 534.020, 534.110) "Well Driller's Report" means the log and record of work for a drilled or plugged well required to be submitted to the State Engineer pursuant to NRS 534.170 and NAC 534.340.

(Added to NAC by St. Engineer by R044-14, 10-24-2014)

NAC 534.245 "Well drilling" and "drilling a well" defined. (NRS 534.020, 534.110)

1. "Well drilling" and "drilling a well" have the meaning ascribed to them in NRS 534.0175.

2. As used in NRS 534.0175, the State Engineer interprets "well drilling" and "drilling a well" to include, without limitation, the reconditioning and rehabilitation of a well.

(Added to NAC by St. Engineer by R009-06, eff. 6-1-2006; A by R044-14, 10-24-2014)

WELL DRILLING LICENSES

NAC 534.280 Application for license. (NRS 534.020, 534.110, 534.140) An application for a well-drilling license must be submitted to the Division in person or by mail. The application:

1. Must be completed and signed by the applicant on a form provided by the Division;
2. Must be accompanied by the fee prescribed in NRS 534.140; and
3. Is valid for 1 year after the date of submission of the application.

[St. Engineer, Drilling Wells Reg. § 2.01, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.282 Qualifications of applicant; denial of application. (NRS 534.020, 534.110, 534.140)

1. An applicant for a well-drilling license must:

(a) Be at least 18 years of age;

(b) Be a citizen of the United States, or be lawfully entitled to remain and work in the United States;

(c) Submit an application and the fee pursuant to NAC 534.280;

(d) Demonstrate a good working knowledge of:

(1) Standard drilling practice;

(2) The regulations of the State Engineer and applicable laws relating to well drilling; and

(3) The method by which land is described by public land survey;

(e) Have at least 2 years of full-time experience under the supervision of a licensed well driller in good standing with the State Engineer as a water well driller that is determined to be appropriate by the State Engineer for the license for which the applicant applies;

(f) Have at least four professional references determined to be satisfactory and appropriate by the State Engineer for the license for which the applicant applies; and

(g) Pass an examination, consisting of the following sections:

(1) A written examination which includes:

(I) A written test consisting of questions on which the applicant must obtain a passing score of at least 80 percent; and

(II) A test of the applicant's ability to use a standard 7.5 minute topographic map from the United States Geological Survey to provide the public land survey description of the location of a well, which will be scored on a pass or fail basis; and

(2) An oral examination conducted by the Board.

2. The State Engineer will deny an applicant a license if the applicant:

(a) Fails to notify the Division at least 3 working days before the scheduled examination date that he or she cannot appear for the examination as instructed by a notice to appear before the State Engineer or the Board;

(b) Fails to pass all sections of the examination described in paragraph (g) of subsection 1 within the period for which the application is valid pursuant to NAC 534.280; or

(c) Fails to pass any section of the examination described in paragraph (g) of subsection 1 after two consecutive attempts.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.286 Oral examination of applicants. (NRS 534.020, 534.110) Except as otherwise provided in NAC 534.288, the Board shall conduct the oral examination section of the examination for each applicant for a well-drilling license. The oral examination section of the examination must be conducted to determine the sufficiency of the applicant's:

1. Knowledge of the provisions of this chapter and chapter 534 of NRS, including, without limitation, knowledge of the minimum standards established in this chapter for the construction, plugging, development or testing of wells;
2. Qualifications and experience;
3. Proficiency in the operating procedures and construction methods associated with the various types of drilling rigs used for well drilling; and
4. Ability to resolve problems that may arise during the construction, plugging, development or testing of a well.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R044-14, 10-24-2014)

NAC 534.288 Board not required to conduct oral examination of certain applicants. (NRS 534.020, 534.110) The Board is not required to conduct the oral examination section of the examination for an applicant for a well-drilling license who:

1. Receives a score of less than 80 percent on the written test portion of the written examination; or
2. Is unable to demonstrate his or her ability to locate a well by public land survey on a topographic map.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R044-14, 10-24-2014)

NAC 534.290 Revocation or denial of license. (NRS 534.020, 534.110, 534.150, 534.160)

1. The State Engineer may revoke or refuse to reissue a well-drilling license if the State Engineer determines, after an investigation and a disciplinary hearing, that the well driller has:

(a) Been found to be incompetent as a well driller by the State Engineer or the Board;

(b) Supplied false information to an owner of a well or a holder of a permit or his or her agent; or

(c) Failed to report information concerning improper construction or improper plugging of a well pursuant to NAC 534.355.

2. The State Engineer will avail himself or herself of the services of the Board pursuant to NRS 534.150 if the State Engineer determines that to do so is appropriate under the circumstances.

[St. Engineer, Drilling Wells Reg. §§ 8.01 & 8.02, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006)

NAC 534.292 Notice to renew license; notification by well driller of change in mailing address. (NRS 534.020, 534.110, 534.140)

1. The Division will send by mail to each licensed well driller a notice to renew his or her license approximately 30 days before the expiration of the license. Failure to receive the notice does not relieve a well driller of the well driller's obligation to file the appropriate forms and pay the fee for renewal in a timely manner.
2. A well driller shall notify the Division of any change in his or her mailing address within 30 days after the change.

(Added to NAC by St. Engineer, eff. 1-9-90; A by R039-12, 6-29-2012)

NAC 534.2923 Renewal of license: Application for renewal. (NRS 534.020, 534.110, 534.140) A well driller may renew his or her well-drilling license by submitting a renewal application to the Division in person or by mail so that the Division receives the application not later than

June 15. The renewal application must:

1. Be completed and signed by the well driller on a form provided by the Division;

2. Be accompanied by the renewal fee prescribed in NRS 534.140; and

3. Except as otherwise provided in subsection 4 of NAC 534.2927, include documentation satisfactory to the Division that the applicant has completed eight credit units of continuing education within the previous year beginning July 1 and ending June 30. At least once within two consecutive renewal periods, the units of continuing education completed by an applicant must include the successful completion of the following courses offered by the Division:

(a) "Nevada Well Drilling Regulations and Statutes"; and

(b) "Well Drilling Forms: How to Properly Complete a Well Driller's Report, Notice of Intent Card, Affidavit of Intent to Abandon and Waivers."

(Added to NAC by St. Engineer by R009-06, eff. 6-1-2006; A by R009-06, 6-1-2006, eff. 7-1-2008; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.2925 Renewal of license: Processing of and action on application. (NRS 534.020, 534.110, 534.140, 534.160)

1. The Division shall process each application submitted for renewal of a well-drilling license pursuant to NAC 534.2923 in the order in which the applications are received by the Division. If the State Engineer determines that an application is complete and the applicant is qualified, the Division shall renew the license for the period ending on June 30 of the year after approval of the renewal.

2. The Division shall not renew a license if the State Engineer determines, upon investigation and after a hearing held upon at least 15 days' notice sent by registered or certified mail to the licensed well driller, that the well driller:

(a) Has not submitted all required notices of intent to drill to the Division as required by NAC 534.320;

(b) Has not furnished a copy of the Well Driller's Report for every well drilled to the State Engineer pursuant to NRS 534.170 and NAC 534.340;

(c) Has not complied with all orders requiring the repair or plugging of improperly constructed wells;

(d) Is not otherwise in compliance with this chapter or chapter 534 of NRS; or

(e) Has accumulated 100 demerit points or more against his or her license.

3. If the State Engineer determines, after consultation with the Board, that a well driller has an unacceptable history of noncompliance with this chapter and chapter 534 of NRS, the Division may deny renewal, refuse renewal for a specified time, or renew the license of the well driller with conditions that the State Engineer considers appropriate. In making this determination, the State Engineer will consider:

(a) The actions of the well driller within the 5 years immediately preceding the date on which the renewal application is received by the Division with regard to his or her well-drilling license or other permits issued by the State Engineer pursuant to this chapter or chapter 534 of NRS.

(b) The failure to submit or the failure to submit in a timely manner by the well driller any corrections to a Well Driller's Report required pursuant to NAC 534.345.

(Added to NAC by St. Engineer by R009-06, eff. 6-1-2006; A by R044-14, 10-24-2014)

NAC 534.2927 Continuing education of well drillers. (NRS 534.020, 534.110, 534.140)

1. A credit unit of continuing education is earned for each hour the holder of a well-drilling license attends a workshop, seminar or course or participates in any other type of educational activity related to well drilling or related subjects approved by the Division. Such educational activities may include, without limitation, the completion of college courses or Internet courses, compiling and instructing courses approved by the Division, active participation on the board of a professional organization and authoring appropriate publications.

2. Documentation of completion of continuing education which is satisfactory to the Division includes, without limitation:

(a) A log, on a form provided by the Division, indicating the type of educational activity claimed, the sponsoring organization, the duration of the course or activity, the name of the instructor and the number of credit units; and

(b) Documents providing evidence of attendance at or participation in an educational activity, including, without limitation, a certificate of completion.

3. Except as otherwise provided in subsection 4, the Division shall deny the renewal of a license if, at the time of renewal, the well driller is unable to provide documentation of completion of the number of credit units of continuing education required by NAC 534.2923.

4. The Division may exempt a well driller from all or part of the number of credit units of continuing education required by NAC 534.2923 if the well driller:

(a) Served on active duty in the Armed Forces of the United States for 120 consecutive days or more during the licensing period immediately preceding the application for renewal;

(b) Was prevented from earning the number of credit units of continuing education required by NAC 534.2923 because of a physical disability, serious illness or other extenuating circumstances; or

(c) Is within the first renewal period after the well driller has applied or reapplied for his or her license.

5. A well driller who is not a resident of this State is subject to the same requirements of continuing education as a well driller who is a resident of this State.

6. The Division shall review each educational activity submitted to the Division to satisfy the continuing education requirements set forth in NAC 534.2923 to determine the number of credit units of continuing education, if any, to assign to the educational activity.

7. The Division is not obligated to provide credit units of continuing education for a course that was completed before the Division has approved the course.

(Added to NAC by St. Engineer by R009-06, eff. 6-1-2006; A by R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.293 Requirements to reinstate license if prior license has expired or been suspended or revoked. (NRS 534.020, 534.110, 534.140) To reinstate a license, a well driller whose license has been:

1. Expired for 1 year or less must:

(a) File a new application with the fee required by NRS 534.140;

(b) Pass the examination required by NAC 534.282 or petition the Division for and receive from the Division a waiver of the requirement to pass the examination; and

(c) Reduce the number of demerit points the well driller has accumulated against his or her license to zero.

2. Expired for more than 1 year or suspended or revoked must:

(a) File a new application with the fee required by NRS 534.140;

(b) Pass the examination required by NAC 534.282; and

(c) Reduce the number of demerit points the well driller has accumulated against his or her license to zero.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.294 Scope of authority under license; issuance of restricted licenses; request to modify scope of restricted license. (NRS 534.020, 534.110)

1. A well-drilling license authorizes the licensee to drill or plug the following types of wells:

(a) Water wells;

(b) Monitoring wells; and

(c) Geothermal wells.

2. The State Engineer may issue restricted well-drilling licenses that limit a well driller to a class of work or type of drilling rig, or both, for which the Board has determined the driller is qualified. The following restricted well-drilling licenses may be issued:

(a) A monitoring well-drilling license;

(b) A geothermal well-drilling license; and

(c) Any other class of well-drilling license determined to be appropriate by the Board and the State Engineer.

3. If a well driller wishes to modify the scope of his or her restricted well-drilling license, the well driller may submit a written request to the Division to appear before the Board for further examination.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R044-14, 10-24-2014)

DUTIES OF WELL DRILLERS

NAC 534.300 Designated basins; replacement wells; waivers. (NRS 534.020, 534.050, 534.110, 534.140)

1. Except as otherwise provided in subsection 6 and NAC 534.315, a well driller shall not drill a water well within a groundwater basin designated by the State Engineer until the well driller determines that a permit to appropriate the groundwater has been issued pursuant to NRS

534.050.

2. Except as otherwise provided in subsections 3, 5 and 6, a water well may be drilled to replace an existing well if a valid permit, waiver or certificate of water right exists for the well to be replaced.

3. If continued use will not be made of the existing well, the existing well must be plugged as required by NAC 534.420 at the time the replacement well is drilled. If continued use will be made of the existing well or the well owner does not want to plug the existing well, a permit must be issued for the replacement well before any drilling is commenced.

4. The replacement well must not be drilled more than 300 feet from the location of the existing point of diversion described in the permit, waiver or certificate and may not be moved outside of the 40-acre subdivision described in the permit, waiver or certificate. Drilling must not be suspended without completing the replacement well or plugging the original well unless approved by the Division.

5. If water service is available from an entity, including, without limitation, a public utility, a water district or a municipality presently engaged in furnishing water to the inhabitants of an area, a well for temporary use for which a revocable permit was granted pursuant to NRS 534.120 may not be drilled or replaced unless, pursuant to NAC 534.450, a waiver from the provisions of this section is first obtained from the Division.

6. In basins designated by the State Engineer, a waiver is required for any well:

(a) That does not comply with the requirements for construction prescribed in this chapter;

(b) The water appropriated from which will be used in constructing a highway or exploring for oil, gas, minerals or geothermal resources;

(c) That may be used as a monitoring well;

(d) That may be used as an exploratory well; or

(e) That is located in a shallow groundwater system for removing water for the purpose of alleviating potential hazards to persons and property resulting from the rise of groundwater caused by secondary recharge.

[St. Engineer, Drilling Wells Reg. §§ 10.01-10.03, 10.05 & 10.06, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.310 Nondesignated basins. (NRS 534.020, 534.050, 534.110, 534.140)

1. Except as otherwise provided in subsection 4 and NAC 534.315:

(a) In basins which have not been designated by the State Engineer, a person who drills a well before receiving a permit to appropriate water does so at the risk that a permit to appropriate water cannot be obtained; and

(b) A person shall not use water from a well until a permit or waiver has been obtained pursuant to NRS 534.050.

2. In basins which have not been designated by the State Engineer, the well driller may proceed to drill a well whether or not the owner of the property has a permit to appropriate water.

3. A replacement well must not be drilled more than 300 feet from the location of the existing point of diversion described in the permit, waiver or certificate and may not be moved outside of the 40-acre subdivision described in the permit, waiver or certificate. Drilling must not be suspended without completing the replacement well and plugging the original well unless approved by the Division.

4. In basins which have not been designated by the State Engineer, a waiver is required before any diversion of water may be made for any well:

(a) That does not comply with the requirements for construction prescribed in this chapter;

(b) The water appropriated from which will be used in constructing a highway or exploring for oil, gas, minerals or geothermal resources;

(c) That may be used as a monitoring well;

(d) That may be used as an exploratory well; or

(e) That is located in a shallow groundwater system for removing water for the purpose of alleviating potential hazards to persons and property resulting from the rise of groundwater caused by secondary recharge.

[St. Engineer, Drilling Wells Reg. Part 11, eff. 5-19-81] — (NAC A 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.315 Wells for domestic use. (NRS 534.020, 534.110, 534.140, 534.180)

1. Except as otherwise provided in subsection 8, permits to appropriate groundwater are not required for the drilling of wells for domestic use.

2. A well driller shall take into account the normal annual fluctuations in the demand for water of an area and, if the well is in a developed area, some annual drop in static water level.

3. Water may not be diverted from more than one well for domestic use in one single-family residence.

4. A well drilled for domestic use only must have a casing size not larger than 8.625 inches in diameter.

5. Except as otherwise provided in subsection 7, if a well drilled for domestic use cannot be reconditioned, a replacement well may be drilled if the original well is plugged as required by NAC 534.420 before the equipment used for well drilling is moved from the drilling site.

6. Except as otherwise provided in subsection 7, a well may be drilled for domestic use if not more than 2 acre-feet of water per year is diverted from the well for use by a single-family household, including a residence with a lawn, garden and domestic animals.

7. If water service is available from an entity, including, without limitation, a public utility, a water district or a municipality presently engaged in furnishing water to the inhabitants of the area, a well for domestic use may not be drilled, including, without limitation, deepened or reconditioned, or replaced unless a waiver from the provisions of this section is first obtained from the Division.

8. A permit must be obtained from the Division if:

(a) More than 2 acre-feet of water per year is diverted from a water well for domestic use;

(b) Water is used for purposes other than domestic use; or

(c) The single-family dwelling is furnished water by an entity that is authorized to furnish water to the inhabitants of the area where the dwelling is located.

[St. Engineer, Drilling Wells Reg. § 10.04 + Part 12, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R044-14, 10-24-2014)

NAC 534.320 Notice of intent to drill: Submission; approval by Division required; contents; fees; correction; forms. (NRS 534.020, 534.110, 534.140)

1. Except as otherwise provided in subsection 2, a well driller shall not set up a well rig or commence drilling or plugging a well until the well driller has submitted to the Division a notice of intent to drill and the Division has approved the notice of intent to drill.

2. The notice of intent to drill must be submitted for work on an exploratory, water or monitoring well. A well driller shall notify the Division before drilling or plugging a geothermal well by submitting a notice of intent to drill if a permit to appropriate water is required pursuant to NRS 534.050. Submission of a notice of intent to drill is not required for the rehabilitation of an existing well.

3. The notice of intent to drill submitted pursuant to subsection 1 must give the name of the person for whom the work is being performed, the location of the well by public land survey, the lot number, block number and county assessor's parcel number, the purpose of the well, the date on which the work is to be commenced, the type of work to be done and the diameter of casing to be installed. The notice must be accompanied by the filing fee required by NRS 533.435 and must include:

(a) The signature of the contractor or the well driller responsible for the work;

(b) The license number of the well driller responsible for the work; and

(c) If applicable, the governmental agency identification number mandating the installation of the well, such as the number of a water right permit, waiver, case file or facility identification.

4. The notice of intent to drill submitted pursuant to subsection 1 must be received by the Division at least 3 working days before the well rig is to be set up. If a permit or waiver is required for the drilling operation, the number of the permit or waiver issued by the Division must be indicated on the notice of intent to drill in addition to the information required by subsection 3.

5. In addition to the requirements of subsections 3 and 4, the notice of intent to drill must include global positioning system coordinates which:

(a) Are either identified by latitude and longitude using decimal degrees or are identified using coordinates of the Universal Transverse Mercator system; and

(b) Specify for each coordinate whether the North American Datum of 1927, North American Datum of 1983 or the World Geodetic System 1984 was used.

6. If a well driller omits any of the information required by this section from the notice of intent to drill submitted to the Division pursuant to subsection 1, the Division may return the notice of intent to drill to the well driller for correction. A well driller must not set up the well rig or commence drilling or plugging the well until the well driller receives approval of the corrected notice of intent to drill from the Division.

7. A well driller may submit the notice of intent to drill required pursuant to subsection 1 to the Division in an electronic format if the Division approves this manner of submission for the well driller before the well driller submits the notice of intent to drill.

8. The forms evidencing notice of intent to drill will be furnished by the Division to the well driller on request and will be stamped and self-addressed.

9. If a well is to be drilled or plugged in a township that is located north of the Mount Diablo baseline, the notice of intent to drill must be submitted to the office of the Division located in Carson City. If a well is to be drilled or plugged in a township which is located south of the Mount Diablo baseline, the notice of intent to drill must be submitted to the office of the Division located in Las Vegas.

[St. Engineer, Drilling Wells Reg. Part 4, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.325 Notice of intent to drill: Lapse; new notice. (NRS 534.020, 534.110, 534.140)

1. If the drilling or plugging of a well described on a notice of intent to drill is not commenced within 60 days after the Division approves the notice of intent to drill, the notice of intent to drill lapses and a new notice of intent to drill must be submitted and approved by the Division before such activity may proceed. The new notice of intent to drill must include the number of the lapsed notice of intent to drill.

2. The well driller may set up the drill rig and commence drilling or plugging a well immediately after the Division receives and approves the new notice of intent to drill.

3. The well driller shall indicate on the Well Driller's Report for the well the number of the notice of intent to drill that the well driller last submitted for that well.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R044-14, 10-24-2014)

NAC 534.330 Responsibilities of licensed well driller at drilling site. (NRS 534.020, 534.110, 534.140) A well driller licensed by the State Engineer:

1. Must be present at the well-drilling site when the drill rig is in operation and when any activity involving the construction, reconditioning or plugging of the well is conducted. If the licensed well driller leaves the drilling site, the drilling operation must be shut down until that licensed well driller or another well driller licensed pursuant to this chapter returns to the site. If the Division determines that drilling operations occurred during any period in which a licensed well driller was not present at the well-drilling site, the Division may order the drilling operation to cease and conduct an investigation. The drilling operation may not recommence until the Division approves the drilling operation.

2. Shall ensure that the drilling of the well complies with:

(a) The provisions of this chapter;

(b) The terms and conditions of any permit, waiver or order issued by the State Engineer; and

(c) The requirements of all other federal, state and local agencies which have jurisdiction over the land on which the well is to be drilled.

3. Shall carry the well driller's license card when he or she is present at the drilling site and produce the card when requested to do so by a representative of the Division.

4. Shall have in his or her possession at the well-drilling site the documentation of the approval by the Division of the notice of intent to drill submitted by the well driller for the well and shall produce that documentation upon request by a representative of the Division.

[St. Engineer, Drilling Wells Reg. § 2.02, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R044-14, 10-24-2014)

NAC 534.335 Responsibility to obtain written authorization from owner of land to access project if certain waiver granted. (NRS 534.020, 534.110) A waiver granted by the State Engineer pursuant to NAC 534.440 to 534.444, inclusive, and 534.448 does not extend to the well driller the right of ingress or egress across and upon public, private or corporate lands. To obtain such a right, the person who requested the waiver must obtain written authorization from the owner of the land to access the project area.

(Added to NAC by St. Engineer by R044-14, eff. 10-24-2014)

NAC 534.340 Well Driller's Report: Form; contents. (NRS 534.020, 534.110, 534.140, 534.170)

1. A Well Driller's Report must be submitted to the State Engineer within 30 days after the completion of the drilling or plugging of a well by the well driller pursuant to NRS 534.170 and must be typewritten or legibly handwritten in black ink on a form provided by the Division. Submission of a Well Driller's Report is not required for the rehabilitation of an existing well.

2. In addition to the information required pursuant to NRS 534.170, the following information must be contained in the Well Driller's Report:

(a) The complete name and address of the person for whom the work is being performed.

(b) The location of the well, including:

(1) A description of its location by public land survey and county assessor's parcel number.

(2) Global positioning system coordinates which:

(I) Are either identified by latitude and longitude using decimal degrees or are identified using coordinates of the Universal Transverse Mercator system; and

(II) Specify for each coordinate whether the North American Datum of 1927, North American Datum of 1983 or the World Geodetic System 1984 was used.

(3) In a Well Driller's Report for a well drilled for domestic use, the address of the house to be served by the well, the county assessor's parcel number and, if available, the lot and block description and the name of the subdivision.

(c) Any pumping test or development data.

(d) An accurate identification of the water-bearing formations.

(e) The static water level, measured from the land surface.

(f) Any applicable water rights permit or waiver number.

(g) The temperature of the water in the well measured in degrees Fahrenheit.

3. An accurate description of the perforations in the casing must be set forth in the section of the Well Driller's Report that contains a record of the well casing.

4. If the well is tested by:

(a) Pumping pursuant to subsection 3 of NRS 534.170, the information must be reported on the Well Driller's Report in gallons per minute of flow.

(b) Flow, the length of time it takes to fill a container of known capacity, if the flow is not too large to be accurately measured in that manner, must be reported on the Well Driller's Report.

➥ The duration of such testing must not exceed 72 hours, unless otherwise approved by the Division.

[St. Engineer, Drilling Wells Reg. Part 7, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.345 Well Driller's Report: Completion; execution; submission; correction. (NRS 534.020, 534.110, 534.140, 534.170)

1. All work performed by the well driller during the drilling operation must be accurately described in the Well Driller's Report submitted by the well driller pursuant to NRS 534.170 and NAC 534.340.

2. The completed Well Driller's Report must be signed by:

(a) The licensed well driller who is present at the well-drilling site as required pursuant to NAC 534.330; or

(b) The drilling contractor responsible for the work.

3. A well driller may submit the Well Driller's Report in an electronic format if the Division approves this manner of submission for the well driller before the well driller submits the Well Driller's Report.

4. If any of the information required to be included by this chapter or chapter 534 of NRS is omitted from a Well Driller's Report, the Division shall return the Well Driller's Report to the well driller for correction. Any corrections to the Well Driller's Report must be made and submitted to the State Engineer within 30 days after the date on which the well driller receives the returned Well Driller's Report from the Division. If corrections are made to the returned Well Driller's Report and submitted to the State Engineer 31 days or more after the date on which the Division returned the Well Driller's Report to the well driller for correction, the Well Driller's Report will be accepted by the State Engineer but the late submittal of the Well Driller's Report shall be deemed to be a failure to file the Well Driller's Report and the Division shall assess demerit points against the license of the well driller pursuant to NAC 534.500.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R044-14, 10-24-2014)

NAC 534.350 Identification of well rig. (NRS 534.020, 534.110, 534.140) The name and address of the contractor drilling the well must be conspicuously displayed in legible letters at least 3 inches high on the drill rig operated or owned by that contractor.

[St. Engineer, Drilling Wells Reg. Part 9, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R044-14, 10-24-2014)

NAC 534.355 Reporting of improper construction or plugging of well. (NRS 534.020, 534.110, 534.140) A licensed well driller who becomes aware of specific information relating to improper construction or improper plugging of a well shall report that information to the Division as soon as practicable.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006)

DRILLING, CONSTRUCTION AND PLUGGING OF WELLS AND BOREHOLES

NAC 534.358 Construction of well: Compliance with chapter 445A of NAC in certain circumstances. (NRS 534.020, 534.110) If a well is regulated by the Bureau of Safe Drinking Water of the Division of Environmental Protection of the State Department of Conservation and Natural Resources, the well must be constructed in accordance with chapter 445A of NAC.

(Added to NAC by St. Engineer by R039-12, eff. 6-29-2012)

NAC 534.360 Construction of well: Casing. (NRS 534.020, 534.060, 534.110, 534.140)

1. Except as otherwise provided in subsection 2, all wells must be cased to the bottom of the well bore and constructed to prevent contamination or waste of the groundwater.

2. If no additional water is developed in the bottom portion of a well bore, neat cement, cement grout or concrete grout must be placed by tremie pipe in an upward direction from the bottom of the well bore to the bottom of the casing.

3. The casing must:

(a) Except as otherwise provided in this paragraph and NAC 534.362, be of new steel or clean and sanitary used steel. Materials other than steel may be used if the design of the well or the subsurface conditions prevent the use of steel casing and a professional engineer who holds a license issued pursuant to chapter 625 of NRS has approved the casing materials.

(b) Be free of pits and breaks.

4. The thickness of the wall of the casing must:

(a) For depths of 300 feet or less, conform to the following minimum specifications, allowing for mill tolerance:

(1) If the conductor casing is 50 feet or less in depth, the thickness of the wall must be:

(I) At least 0.141 or 9/64 of an inch if the wall is made of a material other than galvanized steel pipe that has been corrugated; or

(II) At least 0.109 or 7/64 of an inch if the wall is made of galvanized steel pipe that has been corrugated.

(2) If the depth of the conductor casing exceeds 50 feet, and for all production or intermediate casing, the wall must be sufficiently thick to conform to the casing sizes listed in sub-subparagraphs (I) to (IV), inclusive:

(I) If the casing is smaller than 10 inches nominal size, the wall must be at least 0.188 or 3/16 of an inch thick.

(II) For 10-, 12-, 14- and 16-inch nominal size casing, the wall must be at least 0.250 or 1/4 of an inch thick.

(III) For 18- and 20-inch nominal size casing, the wall must be at least 0.312 or 5/16 of an inch thick.

(IV) For casing larger than 20 inches nominal size, the wall must be at least 0.375 or 3/8 of an inch thick.

(b) For depths of more than 300 feet, be increased in accordance with the American Water Works Association Standard A100-06, which is hereby adopted by reference. A copy of the standard may be obtained by mail from the American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado 80235-3098, by telephone at (800) 926-7337 or at the Internet address http://www.awwa.org, at a cost of $88.

5. The top of the casing on all wells must be at least 18 inches above the surface of the ground or the finished grade.

6. All production casing joints must be threaded and coupled or welded and be watertight. If the casing joints are welded, each joint must be welded completely. Spot welds of casing joints are prohibited.

7. The well driller shall ensure that the integrity of any casing to be used in the construction of the well has not been impaired by storage, shipping, handling, perforating or exposure to ultraviolet light.

[St. Engineer, Drilling Wells Reg. § 3.01, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.362 Construction of well: Thermoplastic casing. (NRS 534.020, 534.060, 534.110, 534.140)

1. New thermoplastic water well casing made of polyvinyl chloride may be used as casing in a well if the casing:

(a) Is clearly marked as well casing; and

(b) Complies with the standards adopted by ASTM International designated as ASTM F480-12, or the current F480 designation at the time of installation, which are hereby incorporated by reference. A copy of the standards may be obtained by mail from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, Pennsylvania 19428-2959, by telephone at (610) 832-9585 or at the Internet address http://www.astm.org, at a cost of $57.

2. If polyvinyl chloride well casing is used:

(a) The differential pressures that may occur during the installation of casing, the development of the well and the operation of the well must be considered by the well driller and the person responsible for designing the well.

(b) The wall thickness must:

(1) For nominal diameters that are 6 inches or less, conform to a rating of schedule 40 or heavier. For example, a nominal pipe that is 6 inches in diameter and has a rating of schedule 40 must have a wall thickness of at least 0.280 inch. The ASTM standard dimension ratio that would exceed this standard is an ASTM standard dimension ratio of 21 or heavier. An ASTM standard dimension ratio of 26 would not satisfy the requirements of this subparagraph for nominal diameters that are 6 inches or less.

(2) For nominal diameters that are more than 6 inches, conform to the ASTM standard dimension ratio of 21 or heavier. The standard dimension ratio is equal to the outside diameter divided by the wall thickness. For example, a nominal pipe that is 8 inches in diameter and has an ASTM standard dimension ratio of 21 must have a wall thickness of at least 0.410 inch. A rating of schedule 40 would not satisfy the requirements of this subparagraph for a nominal pipe that is 8 inches in diameter and has a wall thickness of 0.322 inch.

(c) The joint connections must be:

(1) Flush-threaded;

(2) Threaded and coupled; or

(3) Joined with nonmetallic couplings that are sealed with elastomeric sealing gaskets and which consist of flexible thermoplastic splines that are inserted into precisely machined grooves in the casing.

➥ The joint connections must not be glued or joined by restraining devices that clamp into or otherwise damage the surface of the casing. If the joint connections are flush-threaded or threaded and coupled, the well driller shall ensure that the connections are not overtightened.

3. If polyvinyl chloride well casing is used in a water well or monitoring well, the well driller shall set a protective steel casing which complies with the provisions of NAC 534.360 and extends not less than 5 feet inside the sanitary seal and not less than 18 inches above the finished grade. The top of the protective casing must be fitted with a locking cap or a standard sanitary well cap.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006; R039-12, 6-29-2012)

NAC 534.370 Construction of well: Prevention of contamination; use of additives; securing against unauthorized entry; suspension of drilling. (NRS 534.020, 534.110, 534.140)

1. The well driller shall take the precautions necessary to:

(a) Seal off any known zones of poor quality water which may affect the zones of good quality water in the well.

(b) Prevent contamination or waste of groundwater.

2. Any additive used in drilling a well, including, without limitation, lost circulation materials, must be capable of being broken down and removed from the borehole and must not contaminate or induce contamination of the groundwater or be an organic substance unless certified as appropriate for use in a potable aquifer under Drinking Water Treatment Chemicals - Health Effects, NSF/ANSI Standard 60-2014, which is hereby adopted by reference. A copy of the standard may be obtained by mail from NSF International/Techstreet, 3916 Ranchero Drive, Ann Arbor, Michigan 48108, by telephone at (800) 699-9277 or at the Internet address http://www.techstreet.com/nsf/products, at a cost of $325. As used in this subsection:

(a) “Lost circulation materials” means substances added to drilling fluids when drilling fluids are being lost to the formations downhole.

(b) “Organic substance” includes, without limitation, paper products, wood products, brans, hulls, grains, starches, hays, straws and proteins.

3. If it becomes necessary for the driller to discontinue the drilling operation before completion of the well, the well must be covered securely to prevent a contaminant from entering the casing or borehole and rendered secure against entry by children, domestic animals and wildlife.

4. After drilling is completed, all openings must be closed off to prevent contamination of the well. A sanitary well cap or welded plate must be welded to the well.

5. If drilling is suspended for any reason, the Division must be notified within 24 hours after drilling is suspended or before the drilling equipment is moved from the drilling site, whichever occurs first. The suspension of drilling without completing or plugging the well must be approved by the Division.

[St. Engineer, Drilling Wells Reg. §§ 3.14 & 3.15, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R044-14, 10-24-2014)

NAC 534.375 Measures required before constructing new water well and if contaminant or contaminated water is encountered during construction of water well. (NRS 534.020, 534.110, 534.140)

1. Before commencing construction of a new water well, a licensed well driller shall investigate the drilling conditions, the geology of potential aquifers and overlying materials in the area in which the new water well is located by examining Well Driller's Reports in the database maintained on the Division's website for wells located in the area in which the new water well will be located.

2. If a contaminant or contaminated water is encountered during the construction of a water well, the strata which contain the contaminant or contaminated water must be cased or sealed in such a manner that the contaminant or contaminated water does not commingle with or impair other strata or the water contained in other strata. The well driller shall, by grouting or by using special seals or packers, prevent the movement of the contaminant or contaminated water in the well bore.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R044-14, 10-24-2014)

NAC 534.378 Construction of well: Measures required if artesian condition is encountered. (NRS 534.020, 534.060, 534.110, 534.140)

1. If an artesian condition is encountered in a well, the well driller shall, in addition to complying with the provisions of subsections 2 and 3 of NRS 534.060, ensure that unperforated casing extends through the confining strata above the artesian zone. The annular space between the casing and the walls of the well bore must be sealed by placing neat cement, cement grout or bentonite chips by tremie pipe in an upward direction from the top of the artesian zone to the level necessary to prevent the leakage of artesian water above or below the surface.

2. Any flow of artesian water must be stopped completely in the manner set forth in subsection 3 of NRS 534.060 before the drill rig is removed from the drill site.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006; R039-12, 6-29-2012)

NAC 534.380 Construction of well: Seals. (NRS 534.020, 534.060, 534.110, 534.140)

1. Except as otherwise provided in subsection 2, before the drill rig is removed from the drill site of a well, the annular space between the well bore and the casing must be sealed to a minimum depth of 50 feet below ground level by:

(a) Placing neat cement, cement grout, concrete grout or bentonite chips from the sealing depth to 20 feet from the surface; and

(b) Placing neat cement, cement grout or concrete grout from 20 feet below the surface to the surface.

➥ If sodium bentonite chips are placed in the annular space, the chips must be placed in such a manner that a bridge does not occur. If bentonite chips are poured in standing water, the bentonite chips must be screened to eliminate the fines.

2. Before the drill rig is removed from the drill site of a well, the annular space between the well bore and the casing must be sealed to a depth of greater than 50 feet below ground level if sealing to such a depth is required by subsection 1 of NAC 534.370, NAC 534.375, subsection 1 of NAC 534.378 or paragraph (b) of subsection 1 of NAC 534.390. If the well is regulated by the Bureau of Safe Drinking Water of the Division of Environmental Protection of the State Department of Conservation and Natural Resources, the annular space must be sealed in accordance with NAC 445A.66905.

3. The casing must be centered as nearly as practicable in the well bore to allow the sanitary seal to surround the casing.

4. If a temporary conductor casing is used, it must be withdrawn during the placement of the grout.

5. If a pitless adapter is used:

(a) The sanitary seal must begin not more than 5 feet below ground level;

(b) The sanitary seal must extend at least 50 feet below the bottom elevation of the pitless adapter; and

(c) The portion of the casing above the sanitary seal must be backfilled to ground level with uncontaminated soil which is compacted.

6. A pipe used to feed gravel through the cement seal or to provide access to the interior of the well must be fitted with a watertight cap.

7. A licensed well driller must place the seal or directly supervise the placement of the seal.

8. The seal must be placed:

(a) In the annular space within 3 days after the casing is set and before the drill rig is removed from the drill site.

(b) In one continuous mass from the minimum depth of 50 feet below ground level to the surface.

(c) By tremie pipe in an upward direction to displace the fluid to the surface of the ground, if any fluid is standing in the well bore above the sealing depth.

9. The diameter of the well bore must be at least 4 inches larger than the largest diameter of the outside of the outermost casing to be used, including any joints or collars. If a fill pipe for gravel is installed, the diameter of the well bore must be 4 inches larger than the largest diameter of the casing plus the largest diameter of the fill pipe for gravel. A fill pipe for gravel or any other pipe to provide access to the interior of the well must be completely surrounded by the seal. A conductor casing may be used to convey the gravel pack. If a conductor casing is used:

(a) The diameter of the well bore must be at least 4 inches larger than the largest diameter of the conductor casing; and

(b) The annular space between the conductor casing and the well bore must be sealed.

10. A watertight seal must be installed at the surface level between the conductor casing and the production casing to prevent any contaminants from entering the gravel pack conductor area. A welded plate or a seal consisting of neat cement, cement grout or concrete grout from a minimum depth of 10 feet below ground level to the surface must be used. If a welded plate is used, the entire length of the plate must be welded to the conductor casing and production casing.

[St. Engineer, Drilling Wells Reg. §§ 3.02-3.13 & 3.16, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.390 Construction of well: Location near river, lake, perennial stream, unlined reservoir or unlined canal**;** compliance with permit or waiver. (NRS 534.020, 534.060, 534.110, 534.140)

1. If a well, other than a monitoring well, is drilled within 1/4 mile of a river, lake, perennial stream, unlined reservoir or unlined canal:

(a) Perforations in the production casing are prohibited from ground level to a depth of 100 feet.

(b) The well must be sealed to a depth of 100 feet.

(c) A permanent conductor casing may be used to convey the gravel pack to the 100-foot level.

2. If a well is being drilled pursuant to a permit or waiver, the well driller is responsible for satisfying the terms and conditions of the permit or waiver concerning the construction of the well.

[St. Engineer, Drilling Wells Reg. Part 5, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97)

NAC 534.420 Plugging of well: General requirements. (NRS 534.020, 534.110)

1. Except as otherwise provided in NAC 534.422, wells other than monitoring wells must be plugged in the manner prescribed in this section by a well driller licensed by the State Engineer.

2. A well driller shall:

(a) Ensure that in accordance with NAC 534.320 a notice of intent to drill is received by the Division not less than 3 working days before the drill rig is moved to the location where the well will be plugged; and

(b) Notify the Division not less than 24 hours before beginning to plug the well.

3. Before the well driller begins to plug the well, he or she shall:

(a) If possible, obtain the Well Driller's Report for that well from the Division or the owner of the well.

(b) Visually inspect the area around the well and examine Well Driller's Reports in the database maintained on the Division's website to identify any well in the area in which the well to be plugged is located that may be impacted by the plugging activities. If such a well is identified, the well driller shall request an alternative plan for plugging the well pursuant to NAC 534.422.

4. A well must be plugged pursuant to this section by:

(a) Removing the pump or debris from the well bore with appropriate equipment; and

(b) If an annular cement seal was not installed, attempting to break the casing free with appropriate equipment so that the casing may be pulled from the well.

5. If the casing in the well:

(a) Breaks free, the well driller shall plug the borehole in the manner prescribed in NAC 534.4371 as the casing is pulled from the well. The well must be plugged from the total depth of the well to the surface of the well, in stages if necessary, to displace in an upward direction any fluid or debris in the well.

(b) Except as otherwise provided in paragraph (c), does not break free, the well driller shall perforate that portion of the casing which extends from the bottom of the well to not less than 50 feet above the top of the uppermost saturated groundwater stratum or to the surface of the well, or to the level of the annular seal if the annular seal remains intact. That portion of the casing must be perforated with not less than four equidistant cuts per each 2 linear feet to allow the plugging fluid to penetrate the annular space and the geologic formation. The perforations made in each 2 linear feet of the casing must be made along a horizontal plane of the well bore. A well with a diameter of more than 8 inches in nominal size must be perforated a sufficient number of additional times per linear foot to ensure that the plugging fluid penetrates into the annular space and formation. The well driller shall then plug the well from the total depth of the well to 50 feet above the uppermost saturated groundwater stratum or to within 20 feet of the surface of the well with neat cement, cement grout or bentonite grout or, if authorized under an alternative plan pursuant to NAC 534.422, with bentonite chips. The well driller may use uncontaminated fill from the top of the plug installed 50 feet above the uppermost saturated groundwater stratum to within 20 feet of the surface of the well. The well driller shall place a surface plug in the well consisting of neat cement, cement grout or concrete grout from a depth of at least 20 feet to the surface of the well.

(c) Does not break free and there is no evidence of a sanitary seal around the well casing, the well driller shall perforate the casing from the bottom of the well to not less than 50 feet above the uppermost saturated groundwater stratum and from a depth of at least 50 feet to the surface of the well. The casing must be perforated with not less than four equidistant cuts per each 2 linear feet to allow the plugging fluid to penetrate the annular space and the geologic formation. The perforations made in each 2 linear feet of the casing must be made along a horizontal plane of the well bore. A well with a diameter of more than 8 inches in nominal size must be perforated a sufficient number of additional times per linear foot to ensure that the plugging fluid penetrates into the annular space and the geologic formation. The well driller shall then plug the well from the total depth of the well to 50 feet above the uppermost saturated groundwater stratum or within 50 feet of the surface of the well with neat cement, cement grout or bentonite grout or, if authorized under an alternative plan pursuant to NAC 534.422, with bentonite chips. The well driller may use uncontaminated fill from the top of the plug installed 50 feet above the uppermost saturated groundwater stratum to within 50 feet of the surface of the well. The well driller shall place a surface plug in the well consisting of neat cement or cement grout from a depth of at least 50 feet to the surface of the well.

6. A well driller shall submit a Well Driller's Report to the State Engineer within 30 days after a water well has been plugged. The Well Driller's Report must contain the location of the well by public land survey and county assessor's parcel number, the name of the owner of the well, the condition of the well, the static water level before plugging and a detailed description of the method of plugging, including, but not limited to:

(a) The depth of the well;
(b) The depth to which the materials used to plug the well were placed;
(c) The type, size and location of the perforations which were made in the casing;
(d) The debris encountered in, milled out of or retrieved from the well; and
(e) The materials used to plug the well.

7. If there is any standing liquid in the interval of the well bore that is being plugged, all grout materials used pursuant to this section must be placed by tremie pipe in an upward direction.

[St. Engineer, Drilling Wells Reg. Part 14, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.422 Plugging of well: Use of exceptional method. (NRS 534.020, 534.110)

1. A well driller who wishes to plug a well in a manner that does not comply with the provisions set forth in NAC 534.420 must request a waiver pursuant to NAC 534.450.

2. If the Division authorizes the well driller to plug the well in a manner other than the manner set forth in NAC 534.420, the well driller shall comply with the instructions he or she receives from the Division, if any, relating to the manner in which the well must be plugged.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.424 Plugging of well: Responsibility for cost. (NRS 534.020, 534.110)

1. If a well is located on private land, the owner of the land at the time the well is plugged is responsible for the cost of plugging the well.

2. If a well is located on public land, the person who last drilled or used the well is responsible for the cost of plugging the well. If the person who last drilled or used the well does not plug the well after receiving notice from the Division by certified mail, return receipt requested, that the

well must be plugged, the Division shall notify the person who owns the land on which the well is located that it is his or her responsibility to plug the well.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006)

NAC 534.426 Plugging of well: Artesian conditions. (NRS 534.020, 534.110) If an artesian condition is encountered in any well such that water is flowing at the surface, the artesian water strata must be contained pursuant to NRS 534.060 and NAC 534.378 and the well must be sealed by placing concrete grout, cement grout or neat cement by tremie pipe in an upward direction from the bottom of the well to the surface. The owner and the lessor of the land on which the well is located, the operator of the exploration project and the drilling contractor for the project shall take the necessary steps to prevent the loss of water above or below the surface and to prevent the vertical movement of water in the well bore.

(Added to NAC by St. Engineer by R039-12, eff. 6-29-2012)

NAC 534.427 Mandatory plugging of certain wells. (NRS 534.020, 534.110)

1. If any type of permit, certificate, waiver or application to appropriate water from a water well is cancelled, abrogated, forfeited, withdrawn, expired or denied, the well must be plugged in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422.

2. A well, other than a water well drilled for a domestic purpose, must be plugged in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422 if:

(a) The Division has not issued a permit or waiver for the well; or

(b) The well is not located in a designated basin and there is no reasonable expectation of obtaining a valid permit, waiver or certificate of water right from the Division.

3. A well, including a water well drilled for a domestic purpose, must also be plugged in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422 if the State Engineer sends a notice to the owner of the well by certified mail, return receipt requested, indicating that the well must be plugged and either:

(a) The State Engineer has determined that the well is in any manner defective; or

(b) The Division makes a finding that:

(1) The well tends to impair existing rights or the safety and welfare of the residents of this State;

(2) The mechanical integrity of the construction of the well has failed or is unknown;

(3) The well was not drilled in compliance with the provisions of this chapter;

(4) The well was not drilled in compliance with the provisions of chapter 534 of NRS;

(5) The well tends to cause contamination of the groundwater aquifer;

(6) There is no evidence of impending use of the well for any legal purpose or that no legal use of the well is allowed; or

(7) The well tends to cause water to be wasted above or below the surface of the well.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R044-14, 10-24-2014)

NAC 534.430 Means to measure level of water in well required. (NRS 534.020, 534.110, 534.140)

1. Except as otherwise provided in subsection 3, each well that is drilled must have:

(a) An access port near the top of the casing that is not less than 2 inches in diameter;

(b) A commercially manufactured sanitary well cap that may be easily removed to determine the level of water in the well; or

(c) A reliable electronic means to measure the level of water in the well.

2. An access port must have a watertight, screw-type cap seal to prevent contamination and must be kept closed.

3. On wells that are 8 5/8 inches in diameter or smaller, the access may be a 1-inch hole at the top of the casing or in the casing cover with a removable plug or bolt.

4. As used in this section, “access port” means an opening in the top of a well casing in the form of a tapped hole and plug or a capped pipe welded on the casing to permit entry of a device to measure the water level of the well.

[St. Engineer, Drilling Wells Reg. Part 6, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.432 Mandatory plugging of well as result of noncompliance with requirements for well drilling. (NRS 534.020, 534.110, 534.140, 534.160) If a well was:

1. Constructed by a person who, at the time the well was constructed, was not the holder of a well-drilling license issued pursuant to NRS 534.140; or

2. Not constructed or completed in compliance with the provisions of this chapter as determined by the State Engineer,

➥ the well must be plugged in the manner prescribed in NAC 534.420 at the expense of the person who constructed the well.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006; R039-12, 6-29-2012)

NAC 534.4351 Monitoring wells: Restrictions on construction. (NRS 534.020, 534.110, 534.140, 534.170) A monitoring well must be:

1. Drilled only by a well driller who is licensed by the State Engineer; and

2. Constructed in accordance with the provisions of this chapter, except for any provision that is waived by the State Engineer.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006; R044-14, 10-24-2014)

NAC 534.4353 Monitoring wells: Responsibilities of owner; permits; affidavit of responsibility for plugging. (NRS 534.020, 534.060, 534.110, 534.140)

1. The owner of a monitoring well shall ensure that the well:

(a) Is constructed in accordance with the provisions of this chapter or a waiver and does not allow contamination of groundwater during its use; and

(b) Is plugged upon abandonment in accordance with NAC 534.4365 when the well is no longer monitored or when otherwise required.

2. A permit to appropriate water or a waiver from the State Engineer is required to drill and collect data from a monitoring well.

3. The well driller shall, when submitting the notice of intent to drill pursuant to NAC 534.320, submit to the Division a notarized affidavit, on a form prescribed by the Division, from the person who will be responsible for plugging the well upon abandonment acknowledging that responsibility.

4. The owner of a monitoring well shall maintain a record of the current status of the monitoring well and shall notify the Division in writing as soon as practicable after determining that the well will no longer be used.

5. If a monitoring well or any other well is to be used to remove a contaminant from groundwater, an environmental permit must be obtained from the State Engineer pursuant to the provisions of NRS 533.437 to 533.4377, inclusive.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.4355 Monitoring wells: Casing; prevention of contamination. (NRS 534.020, 534.060, 534.110, 534.140)

1. A well driller shall install casing in a monitoring well. If polyvinyl chloride casing is used, it must comply with the standards adopted by reference pursuant to subsection 1 of NAC 534.362.

2. The well driller shall take the precautions necessary to prevent contamination of groundwater. The equipment used to construct a monitoring well must be decontaminated before the construction of the well is commenced.

3. The diameter of the casing must not exceed 4 inches in nominal size.

4. The connections of the casing must comply with the provisions of NAC 534.360 or 534.362. The connections must be made watertight by:

(a) Wrapping them with teflon tape;

(b) Placing a ring or gasket between them; or

(c) By any other method which will not introduce contaminants into the well except gluing.

5. Both ends of the casing must be capped.

6. The perforations must be of a width and length which will allow the strata to be observed while not permitting the infiltration of the gravel pack through the casing or allowing the contaminants or water from separate strata to commingle.

7. To ensure adequate space for the gravel pack and seals, the well bore of a monitoring well must, for the entire length of the casing placed in the well, be not less than 4 inches larger than the diameter of the casing.

8. Not more than one perforated or screened section of casing may be placed in the well bore of a monitoring well unless the vertical intervals of the well bore in between the screened sections are sealed with neat cement, cement grout or cement-bentonite grout.

9. Not more than one casing may be placed in the well bore of a monitoring well unless the vertical intervals of the well bore in between the screened sections of the casings are sealed with neat cement, cement grout or cement-bentonite grout.

10. Monitoring wells must be drilled an adequate distance from each other to ensure that there is no commingling of the contaminants or groundwater encountered in the wells.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.4357 Monitoring wells: Placement of gravel and seals in annular space. (NRS 534.020, 534.110, 534.140)

1. If the water or vapors which are being monitored in a monitoring well are not encountered within 5 feet below the surface of the ground, the well driller shall place in the annular space of the well:

(a) From the bottom of the well to a maximum of 2 feet above the uppermost perforation in the casing, a gravel pack which consists of quartz sand, silica or other materials which will not contaminate the groundwater or the geologic formation;

(b) From the gravel pack placed pursuant to paragraph (a) to a minimum of 2 feet above that gravel pack or to within 20 feet below the surface of the ground, a seal consisting of bentonite chips; and

(c) From the seal placed pursuant to paragraph (b) to the surface, a seal, with a minimum thickness of 20 feet below the surface, consisting of cement grout, neat cement or concrete grout.

2. If the water or vapors which are being monitored in a monitoring well are encountered within 5 feet below the surface of the ground, the well driller shall comply with the requirements of subsection 1, except that:

(a) The gravel pack required pursuant to paragraph (a) of subsection 1 must extend only 6 inches above the uppermost perforation in the casing; and

(b) The surface seal required pursuant to paragraph (c) of subsection 1 must be placed from 1 foot below the surface to the surface.

3. The well driller shall ensure that a bridge does not occur in the annular space during the placement of the gravel pack and seals required pursuant to this section.

4. If more than 20 continuous feet of grout are placed in the annular space of the well or if there is standing liquid in the well bore above the sealing depth, the grout must be placed by tremie pipe in an upward direction.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.4359 Monitoring wells: Measures required if contaminant or contaminated water is encountered. (NRS 534.020, 534.110, 534.140) If a contaminant or contaminated water is encountered during the construction of a monitoring well, the strata which contain the contaminant or contaminated water must be cased and sealed in such a manner that the contaminant or contaminated water does not commingle with or impair other strata or the water contained in other strata. The well driller shall seal the strata by grouting or by using special seals or packers, if necessary, to prevent the movement of the contaminants or contaminated water in the well bore.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4361 Monitoring wells: Surface pad; prevention of unauthorized use; additional protective measures. (NRS 534.020, 534.110, 534.140)

1. Unless the area surrounding a monitoring well is paved with concrete or asphalt, a surface pad must be installed around the casing at the surface.

2. A threaded or flanged cap or compression seal must be installed to prevent unauthorized use of the well. If the top of the well is flush with the surface and the well protector required pursuant to subsection 3 is of a type which may not be locked, the cap or seal must be of a type which may be locked.

3. The well must also be protected and secured by:

(a) If it is not necessary for the well to be flush with the surface:

(1) Setting a steel surface casing which complies with the requirements set forth in NAC 534.360 and extends not less than 5 feet below the surface pad and not less than 1 foot above the surface pad;

(2) Fitting the top of the steel casing with a locking cap; and

(3) Clearly marking the well as a monitoring well; or

(b) If it is necessary for the well to be flush with the surface:

(1) Placing a well protector capable of supporting vehicular travel which extends one-half inch above the surface pad or concrete or asphalt paving; and

(2) Clearly marking the well as a monitoring well.

4. As used in this section, "surface pad" means a formation of concrete or cement grout with a radius from the center of the well of not less than 12 inches and a thickness of not less than 3 1/2 inches which is set around a monitoring well at a slope to ensure that water flows away from the well.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.4363 Monitoring wells: Artesian conditions. (NRS 534.020, 534.060, 534.110, 534.140) If an artesian condition is encountered in a monitoring well, the well driller shall ensure that the well is sealed in the manner prescribed in NAC 534.378.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4365 Monitoring wells: Plugging. (NRS 534.020, 534.110)

1. Except as otherwise provided in this section, a monitoring well must be plugged by a licensed well driller within 30 days after monitoring is no longer required.

2. Except as otherwise provided in subsection 4, if the casing in the monitoring well cannot be removed from the well bore, the monitoring well must be plugged by placing neat cement by tremie pipe in an upward direction from the bottom of the well to the surface of the well.

3. Except as otherwise provided in subsection 4, if the casing in the monitoring well can be removed from the well bore, the bottom end of the casing in the monitoring well must be removed or perforated and neat cement must be placed by tremie pipe in an upward direction from the bottom of the well to the surface of the well as the casing is removed from the well bore. If the casing in the monitoring well does not exceed 4 inches in diameter, the casing may be used as the tremie pipe.

4. If a request for a waiver of the requirements in subsection 3 of NAC 534.4355 or NRS 534.4357 has been granted by the State Engineer pursuant to NAC 534.441, the well must be plugged in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.4367 Drive point wells. (NRS 534.020, 534.110, 534.140)

1. A well driller may construct a drive point well without placing in the annular space of the well the gravel pack and seals required pursuant to NAC 534.4357.

2. The diameter of the casing used in a drive point well which is not constructed pursuant to the provisions of NAC 534.4357 must not be larger than 2 inches in nominal size.

3. A drive point well which is not constructed pursuant to the provisions of NAC 534.4357 must be plugged within 60 days after the well is constructed. Upon abandonment, the casing must be removed from the well bore and the well bore must be plugged in the manner provided in NAC 534.4371.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012)

NAC 534.4369 Boreholes: Generally. (NRS 534.020, 534.110)

1. A borehole may be drilled or plugged by a person who is not a licensed well driller.

2. A person who constructs or plugs a borehole is not required to file with the Division a notice of intent to drill or plug the borehole.

3. A borehole may be drilled without obtaining from the Division a permit to appropriate water or a waiver of the requirement to obtain such a permit.

4. A person who drills or plugs a borehole, the operator of the exploration project or the owner of the land where the borehole is located must maintain a record of the drilling operation which includes:

(a) The dates on which the borehole is constructed and plugged;

(b) The location of the borehole as shown by public land survey;

(c) The depth and diameter of the borehole;

(d) The depth at which groundwater is encountered in the borehole; and

(e) The methods and materials used to plug the borehole.

5. The State Engineer may, at any time, require the person drilling or plugging the borehole, the operator of the exploration project or the owner of the land on which the borehole is located to submit to the State Engineer a copy of the record required pursuant to subsection 4 and any other information relating to the construction, operation or plugging of the borehole that the State Engineer determines is necessary.

6. The owner and the lessor of the land on which a borehole is located, the operator of the exploration project and the drilling or plugging contractor for the project shall ensure that the groundwater is uncontaminated during the drilling, operation or plugging of the borehole.

7. A borehole must not be used to divert water for any purpose.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006)

NAC 534.4371 Boreholes: Plugging requirements. (NRS 534.020, 534.110)

1. A borehole must be plugged within 60 days after it is drilled.

2. Except as otherwise provided in subsections 4, 7 and 8 and NAC 534.438, a borehole must be plugged:

(a) In the manner prescribed for plugging a well in NAC 534.420 or authorized pursuant to NAC 534.422; or

(b) If the uppermost saturated groundwater stratum is above the bottom of the borehole:

(1) By placing concrete grout, cement grout, neat cement or bentonite grout by tremie pipe in an upward direction from the bottom of the borehole to within 20 feet of the surface and by placing concrete grout, cement grout or neat cement from 20 feet below the surface to the surface;

(2) By placing bentonite chips specifically designed to be used to plug boreholes from the bottom of the borehole to within 20 feet of the surface and by placing concrete grout, cement grout or neat cement from 20 feet below the surface to the surface; or

(3) By placing any of the plugging materials described in this subsection from the total depth of the borehole to 50 feet above the uppermost saturated groundwater stratum and by placing concrete grout, cement grout, or neat cement from 20 feet below the surface to the surface.

3. If the concrete grout, cement grout, neat cement, bentonite grout or bentonite chips are not brought to within 20 feet of the surface pursuant to paragraph (b) of subsection 2, the person responsible for plugging the borehole shall:

(a) Measure the depth of the top of the lower plug with the appropriate equipment after he or she has allowed sufficient time for the lower plug to set up;

(b) Continue to install concrete grout, cement grout, neat cement, bentonite grout or bentonite chips until the top of the lower plug remains at least 50 feet above the top of the uppermost saturated groundwater stratum;

(c) Install uncontaminated fill material or one of the plugging materials described in this subsection from the top of the lower plug to within 20 feet of the surface; and

(d) Place concrete grout, cement grout or neat cement from 20 feet below the surface to the surface.

4. If the elevation of the bottom of the borehole is higher than the preexisting natural elevation of the uppermost saturated groundwater stratum, the borehole must be plugged by:

(a) Backfilling the borehole from the bottom of the borehole to within 20 feet of the surface with uncontaminated soil; and

(b) Placing concrete grout, cement grout or neat cement from 20 feet below the surface to the surface.

5. If bentonite chips or uncontaminated soil is placed in the borehole, they must be placed in such a manner that a bridge does not occur. If poured in standing water, bentonite chips must be screened to eliminate the fines. Bentonite chips may be placed by tremie pipe.

6. If casing is set in a borehole, the borehole must be completed as a well pursuant to the provisions of this chapter. The borehole must be plugged pursuant to NAC 534.420 or as authorized pursuant to NAC 534.422 or the casing must be removed from the borehole when it is plugged. The upper portion of the borehole may be permanently cased if the annular space between the casing and the walls of the borehole is completely sealed from the bottom of the casing to the surface pursuant to NAC 534.380.

7. If there is evidence that water-draining formations (lost circulation), or water-bearing formations of different water quality or hydraulic head were encountered during the original borehole construction and if bentonite chips or bentonite grout is used as the plugging material, the well driller must, in addition to the requirements of this section, place neat cement across the water-confining formations so that the plugging fluid penetrates the geologic formation to prevent the vertical movement of water. Any drilling casing or pipe that does not break free, and occludes the placement of neat cement across a confining formation, must be perforated so that the plugging fluid penetrates the annular space and the geologic formation in that interval.

8. If the water-bearing formations are unknown and any drilling casing or pipe does not break free, the well driller must plug the borehole in accordance with paragraph (b) of subsection 5 of NAC 534.420 so that the plugging fluid penetrates the annular space and the geologic formation in the perforated intervals.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.4373 Boreholes: Responsibility for plugging. (NRS 534.020, 534.110) The owner and lessor of the land on which a borehole is located, the operator of the exploration project and the plugging contractor for the project are jointly and severally responsible for plugging the borehole pursuant to this chapter.

(Added to NAC by St. Engineer, eff. 12-30-97)

NAC 534.4375 Boreholes, blast holes and seismic shot holes: Artesian conditions. (NRS 534.020, 534.060, 534.110) If an artesian condition is encountered in any borehole, blast hole or seismic shot hole, the artesian water strata must be contained pursuant to NRS 534.060 and NAC 534.378, and the borehole, blast hole or seismic shot hole must be sealed by placing concrete grout, cement grout, bentonite chips or neat cement by tremie pipe in an upward direction from the bottom of the borehole to the surface. The owner and lessor of the land on which a borehole is located, the operator of the exploration project and the drilling contractor for the project shall take the necessary steps to prevent the loss of water above or below the surface and to prevent the vertical movement of water in the well bore.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012)

NAC 534.4376 Instrumentation boreholes. (NRS 534.020, 534.110)

1. An instrumentation borehole may be drilled by an unlicensed well driller.
2. The installation of monitoring instruments and simultaneous plugging must be:
(a) Completed by a well driller who is licensed in this State; or
(b) Supervised and documented by the responsible project geologist, hydrologist or engineer.
3. An instrumentation borehole must be permanently plugged at the time of completion pursuant to NAC 534.4371.
4. Documentation of each instrumentation borehole must be completed and maintained pursuant to NAC 534.4369.

(Added to NAC by St. Engineer by R039-12, eff. 6-29-2012)

NAC 534.43763 Electrical cathodic protection conductor deemed specific type of instrumentation borehole. (NRS 534.020, 534.110) For the purposes of this chapter, an electrical cathodic protection conductor is a part of a system to prevent corrosion or to provide electrical grounding and is deemed to be a specific type of instrumentation borehole.

(Added to NAC by St. Engineer by R039-12, eff. 6-29-2012)

NAC 534.43767 Core hole deemed specific type of borehole. (NRS 534.020, 534.110) For the purposes of this chapter, a core hole is deemed to be a specific type of borehole.

(Added to NAC by St. Engineer by R039-12, eff. 6-29-2012)

NAC 534.4377 Treatment of certain holes as boreholes. (NRS 534.020, 534.110)

1. If the construction of a seismic shot hole or a hole used for the installation of electrical conductors as part of a system to prevent corrosion or provide electrical grounding may cause waste or contamination of the groundwater, the hole shall be deemed a borehole for the purposes of NAC 534.4369 and 534.4371.

2. Any borehole which is drilled for oil, gas or geothermal resource observation, temperature gradient survey, production or injection purposes shall be deemed a borehole for the purposes of NAC 534.4369 and 534.4371, unless another governmental agency has requirements that are the same as or more strict than the requirements of this chapter.

3. Any borehole which is drilled for oil, gas or geothermal resource observation, temperature gradient survey, production or injection purposes, and which has casing or tubing installed for more than 60 days, shall be deemed a well or a monitoring well for the purposes of NAC 534.4351 to

534.4365, inclusive, and subsection 6 of NAC 534.4371, unless another governmental agency has requirements that are the same as or more strict than the requirements of this chapter.

4. Any borehole drilled for geothermal heat loop installation shall be deemed a borehole for the purposes of NAC 534.4369 and 534.4371, unless another governmental agency has requirements that are the same as or more strict than the requirements of this chapter.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R039-12, 6-29-2012)

NAC 534.438 Prerequisites to using bentonite grout to seal, grout or plug borehole. (NRS 534.020, 534.110) Before using bentonite grout to seal, grout or plug a borehole, the responsible project geologist, hydrologist or engineer using the bentonite grout must:

1. Consider the geology encountered in the borehole and any requirements set forth in this chapter or chapter 534 of NRS in his or her selection of the bentonite grout;

2. Mix the bentonite grout and place the bentonite grout in accordance with specifications recommended by the manufacturer; and

3. Place additional cement plugs as necessary, across low permeability geologic formations encountered in the borehole, to ensure that no water can move vertically in the borehole.

(Added to NAC by St. Engineer by R009-06, eff. 6-1-2006; A by R039-12, 6-29-2012)

WAIVERS

NAC 534.440 Waiver to drill exploratory well to determine quality or quantity of water in designated basin. (NRS 534.020, 534.050, 534.110)

1. A request for a waiver to drill an exploratory well to determine the quality or quantity of water pursuant to NRS 534.050 in a designated basin must be submitted to the State Engineer in writing and contain the following information:

(a) The location by public land survey, county assessor's parcel number, map of the vicinity and plat map of the exploratory well anticipated to be drilled;

(b) The name, address and telephone number of the person who:

(1) Is collecting data from the exploratory well; and

(2) Will be available to answer questions concerning the well;

(c) The reason for requesting a waiver;

(d) The proposed diameter and depth of the exploratory well;

(e) The estimated starting and completion dates of the exploratory well, not to exceed 90 days after authority is given to drill;

(f) The name, address and telephone number of the person who will be responsible for plugging the well, and the name, address and telephone number of the owner of the land where the well will be located if the owner is not the person responsible for plugging the well; and

(g) A notarized affidavit, on a form prescribed by the Division, from the person who will be responsible for plugging the well upon abandonment acknowledging that responsibility.

2. Each waiver for an exploratory well will bear a unique number preceded by the letter "W." The notice of intent to drill submitted to the Division pursuant to NAC 534.320 and the Well Driller's Report submitted to the Division pursuant to NRS 534.170 must bear this number.

3. The duration of the development and testing of the flow of the exploratory well must not exceed 72 hours, unless otherwise approved in the waiver.

4. A copy of the waiver must be in the possession of the well driller at the drill site.

5. The exploratory well must be:

(a) Plugged by the well driller in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422 within 3 days after the completion of the aquifer tests for which the well was drilled; or

(b) Except as otherwise provided in this paragraph, completed as a well pursuant to the provisions of this chapter before the drill rig is removed from the drill site. The wellhead must be secured at the surface and water may not be used from the well until a permit to appropriate underground water is approved. If a permit to appropriate underground water is not approved at the location of the well within 1 year after the date of completion of the well, the well must be plugged in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422.

6. The water from the exploratory well may not be used for any purpose other than the purposes set forth in the waiver without the written approval of the State Engineer.

7. A waiver to drill an exploratory well will not be granted pursuant to this section for a well in an area in which the Division determines there is sufficient information existing concerning the aquifer for the area.

[St. Engineer, Drilling Wells Reg. Part 16, eff. 5-19-81] — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.441 Waiver to drill monitoring well. (NRS 534.020, 534.050, 534.110)

1. A request for a waiver to drill a monitoring well must be submitted to the State Engineer in writing and contain:

(a) The location of the proposed monitoring well by public land survey, county assessor's parcel number, map of the vicinity and plat map;

(b) The name, address and telephone number of the owner of the land on which the monitoring well will be located;

(c) A statement of the reason for requesting the waiver;

(d) A proposed construction sketch of the monitoring well;

(e) The name of the monitoring well or, if a waiver is requested for multiple monitoring wells, a list of all monitoring wells for which a waiver is requested on the "Additional Well Locations" form;

(f) If requested or previously required, a current, updated copy of the list setting forth the numbers of the monitoring wells for which waivers have been issued previously and the disposition of those wells;

(g) The name, address and telephone number of the person who:

(1) Will collect data from the monitoring well; and

(2) Will be available to answer questions concerning the monitoring well; and

(h) A notarized affidavit, on a form prescribed by the Division, from the person who will be responsible for plugging the well upon abandonment acknowledging that responsibility.

2. A waiver to drill a monitoring well will bear a unique number preceded by the letters "MO." The notice of intent to drill submitted to the Division pursuant to NAC 534.320 and the Well Driller's Report submitted to the Division pursuant to NRS 534.170 must bear this number.

3. A copy of the waiver must be in the possession of the well driller at the drill site.

4. The monitoring well must be completed as a well pursuant to the provisions of this chapter or the waiver before the drill rig is removed from the drill site.

5. Water from the monitoring well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the State Engineer.

(Added to NAC by St. Engineer by R039-12, eff. 6-29-2012; A by R044-14, 10-24-2014)

NAC 534.442 Waiver to use water to explore for minerals. (NRS 534.020, 534.050, 534.110)

1. A request for a waiver to allow a temporary use of water from an existing well to explore for minerals or to drill a well and to use the water from the well to explore for minerals must be submitted to the State Engineer in writing and contain:

(a) The amount of water that will be used from the well each day, which must not exceed 5 acre-feet per project;

(b) A brief description of the manner in which the water will be put to a beneficial use;

(c) The location of the water well by public land survey, county assessor's parcel number, map of the vicinity and plat map;

(d) The name, address and telephone number of the person who will be responsible for plugging the well, and the name, address and telephone number of the owner of the land where the well will be located if the owner is not the person responsible for plugging the well;

(e) A notarized affidavit, on a form prescribed by the Division, from the person who will be responsible for plugging the well upon abandonment acknowledging that responsibility;

(f) The name, address and telephone number of a person who will be available to answer questions concerning the well; and

(g) The date the project is scheduled to be completed.

2. A waiver granted for the temporary use of water from a well for the exploration of minerals will bear a unique number preceded by the letters "MM." The notice of intent to drill submitted to the Division pursuant to NAC 534.320 and the Well Driller's Report submitted to the Division pursuant to NRS 534.170 must bear this number.

3. A copy of the waiver must be in the possession of the well driller at the drill site.

4. The well must be plugged in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422 within 3 days after the completion of the project.

5. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the State Engineer.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.444 Waiver to use water to explore for oil, gas or geothermal resources. (NRS 534.020, 534.050, 534.110)

1. A request for a waiver to allow the temporary use of water from an existing well to explore for oil, gas or geothermal resources, or to drill a well and use the water from the well to explore for oil, gas or geothermal resources, must be submitted to the State Engineer in writing and contain:

(a) The location of the proposed water well and the oil, gas or geothermal well by public land survey, county assessor's parcel number, map of the vicinity and plat map;

(b) The oil, gas or geothermal state or federal permit and lease number, name of the well and American Petroleum Institute number, if assigned;

(c) The amount of water that will be used from the well each day, which must not exceed 5 acre-feet per each well;

(d) The date the project is scheduled to be completed;

(e) The name, address and telephone number of the person responsible for plugging the well, and the name, address and telephone number of the owner of the land if the owner is not the person who is responsible for plugging the well;

(f) A notarized affidavit, on a form prescribed by the Division, from the person who will be responsible for plugging the well upon abandonment acknowledging that responsibility; and

(g) The name, address and telephone number of a person who will be available to answer questions concerning the well.

2. A waiver that allows the temporary use of water from a water well to explore for oil, gas or geothermal resources will bear a unique number preceded by the letters "OG." The notice of intent to drill submitted to the Division pursuant to NAC 534.320 and the Well Driller's Report submitted to the Division pursuant to NRS 534.170 must bear this number.

3. A copy of the waiver must be in the possession of the well driller at the drill site.

4. The well must be plugged in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422 within 3 days after the completion of the project or upon expiration of the waiver, whichever occurs first.

5. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the State Engineer.

6. A waiver will not be granted pursuant to this section if the State Engineer determines that the quantity of water requested will adversely affect or impair existing water rights or domestic wells.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.446 Waiver to use water for construction of highway. (NRS 534.020, 534.050, 534.110)

1. A request for a waiver to allow the temporary use of water from an existing well for the construction of a highway, or to drill a well and use the water from the well for the construction of a highway, must be submitted to the State Engineer in writing and contain:

(a) The location of the proposed water well by public land survey, county assessor's parcel number, map of the vicinity and plat map;

(b) The project and contract number, if applicable;

(c) The total amount of water that will be used from the well each day;

(d) The name, address and telephone number of the contractor responsible for plugging the well, and the name, address and telephone number of the owner of the land where the well will be located if the owner is not the person responsible for plugging the well in accordance with NAC 534.420;

(e) A notarized affidavit, on a form prescribed by the Division, from the person who will be responsible for plugging the well upon abandonment acknowledging that responsibility;

(f) The name, address and telephone number of a person who will be available to answer questions concerning the project; and

(g) The date the project is scheduled to be completed.

2. A waiver that allows the temporary use of water from a well for the construction of a highway will bear a unique number preceded by the letter "C." The notice of intent to drill submitted to the Division pursuant to NAC 534.320 and the Well Driller's Report submitted to the Division

pursuant to NRS 534.170 must bear this number.

3. A copy of the waiver must be in the possession of the well driller at the drill site.

4. The well must be plugged in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422 within 3 days after the completion of the project or upon expiration of the waiver, whichever occurs first.

5. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the State Engineer.

(Added to NAC by St. Engineer, eff. 1-9-90; A 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.448 Waiver to drill well in shallow groundwater system to alleviate certain potential hazards. (NRS 534.020, 534.050, 534.110)

1. A request for a waiver to drill a well in a shallow groundwater system for removing water for the purpose of alleviating potential hazards to persons and property resulting from the rise of groundwater caused by secondary recharge must be submitted to the State Engineer in writing and contain:

(a) The location of the proposed well by public land survey, county assessor's parcel number, map of the vicinity and plat map;

(b) The project and contract number, if applicable;

(c) The total amount of water that will be used from the well each day;

(d) The name, address and telephone number of the person responsible for plugging the well, and the name, address and telephone number of the owner of the land where the well will be located if the owner is not the person responsible for plugging the well;

(e) A notarized affidavit, on a form prescribed by the Division, from the person who will be responsible for plugging the well upon abandonment acknowledging that responsibility;

(f) The name, address and telephone number of a person who will be available to answer questions concerning the project; and

(g) The date the project is scheduled to be completed.

2. A waiver to drill a well in a shallow groundwater system for removing water for the purpose of alleviating potential hazards to persons and property resulting from the rise of groundwater caused by secondary recharge will bear a unique number preceded by the letters "DW." The notice of intent to drill submitted to the Division pursuant to NAC 534.320 and the Well Driller's Report submitted to the Division pursuant to NRS 534.170 must bear this number.

3. A copy of the waiver must be in the possession of the well driller at the drill site.

4. The well must be plugged in the manner prescribed in NAC 534.420 or authorized pursuant to NAC 534.422 within 3 days after the completion of the project or upon expiration of the waiver, whichever occurs first.

5. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the State Engineer.

6. Written authorization from the appropriate agency for the discharge of dewatering water must be submitted with the waiver request.

7. A waiver will not be granted pursuant to this section if the State Engineer determines that the quantity of water requested will adversely affect or impair existing water rights or domestic wells.

(Added to NAC by St. Engineer, eff. 12-30-97; A by R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.449 Waiver of requirement to plug well. (NRS 534.020, 534.060, 534.110)

1. The owner of a well, other than a well drilled for domestic use, who wishes to obtain a waiver pursuant to subsection 7 or 8 of NRS 534.060 from the requirement that a well be plugged must submit a written request for the waiver to the State Engineer. The State Engineer may, for good cause shown, grant such a waiver. The State Engineer will not grant such a waiver if the State Engineer determines that the well is dry or abandoned. The waiver is valid for 1 year after the date on which the waiver is approved. On or before the date on which the waiver is no longer valid, the owner of the well may submit a request to extend the waiver or to make the waiver permanent, if appropriate, as determined by the State Engineer.

2. A request for a waiver, the extension of a waiver or to make a waiver permanent made pursuant to subsection 1 must:

(a) Be made on a form provided by the State Engineer;

(b) Include sufficient information and evidence for the State Engineer to determine that the well is not in any manner defective, including, without limitation, that the conditions set forth in subsection 2 of NAC 534.427 do not apply to the well;

(c) Include a notarized affidavit, on a form prescribed by the Division, from the person who will be responsible for plugging the well upon abandonment acknowledging that responsibility; and

(d) Provide evidence that the well would be useful as a site for monitoring groundwater.

(Added to NAC by St. Engineer by R009-06, eff. 6-1-2006; A by R039-12, 6-29-2012; R044-14, 10-24-2014)

NAC 534.450 Waiver of requirement of this chapter. (NRS 534.020, 534.110)

1. Except as otherwise provided in subsection 2, the State Engineer may, for good cause shown, waive a requirement of the provisions of this chapter.

2. The State Engineer will not waive the requirements set forth in subsection 4 of NAC 534.360.

3. A request for a waiver of a requirement of this chapter must be made in writing to the State Engineer and include:

(a) A detailed statement of the reason for requesting the waiver and the section of this chapter to be waived;

(b) The location or proposed location of the well by public land survey;

(c) The name and address of the owner of the well;

(d) The street address of the location of the well or, if there is no street address, a description of the location of the proposed well, including, but not limited to, common landmarks and cross-streets near the location of the well;

(e) The county assessor's parcel number for the location of the proposed well;

(f) A description of the proposed design and a sectional drawing of the proposed well that includes the depths to the aquifers, the locations of the screens and seals and the materials that will be used;

(g) A notarized affidavit, on a form prescribed by the Division, from the person who will be responsible for plugging the well upon abandonment acknowledging that responsibility;

(h) Any available data to categorize the hydraulic heads, water quality and permeability characteristics of the aquifer; and

(i) Any other information required pursuant to the provisions of this chapter.

4. After reviewing the request, the State Engineer will issue a written notice of his or her decision to the responsible party.

5. Each waiver will bear a unique number preceded by the letter "R." The notice of intent to drill submitted to the Division pursuant to NAC 534.320 and the Well Driller's Report submitted to the Division pursuant to NRS 534.170 must bear this number.

6. The well driller shall ensure that the well complies with the provisions of the waiver and have a copy of the waiver in the well driller's possession when he or she drills the well.

7. The water from the well may not be used for any purpose other than the purpose set forth in the waiver without the written approval of the State Engineer.

[St. Engineer, Drilling Wells Reg. Part 15, eff. 5-19-81) — (NAC A 1-9-90; 12-30-97; R009-06, 6-1-2006; R039-12, 6-29-2012; R044-14, 10-24-2014)

ENFORCEMENT

NAC 534.500 Assessment of demerit points against license of well driller; suspension and reinstatement of license; removal of demerit points. (NRS 534.020, 534.110)

1. The Division shall assess demerit points against the license of a licensed well driller who is found by the State Engineer to have violated any provision of this chapter or chapter 534 of NRS pursuant to the following table:

Classification of Violations	Maximum Demerits
Notice of Intent/Approval	
Failing to submit a notice of intent to drill to the Division as required by NAC 534.320	25

Classification of Violations	Maximum Demerits
Failing to notify the Division or obtain approval from the Division as required by NAC 534.370 if drilling is suspended or drilling equipment is moved from the drilling site before a well is completed or plugged	75
Well Driller’s Report	
Failing to furnish a copy of a Well Driller’s Report to the State Engineer as required by NRS 534.170, intentionally making a material misstatement of fact in a Well Driller’s Report submitted to the State Engineer pursuant to NRS 534.170 or intentionally making a material misstatement of fact in an amendment to a Well Driller’s Report submitted to the State Engineer pursuant to NRS 534.170	75
Submitting a Well Driller’s Report to the State Engineer pursuant to NRS 534.170 more than 30 days after a well is completed	10
Submitting a Well Driller’s Report to the Division pursuant to NAC 534.420 more than 30 days after a water well has been plugged	10
Licenses	
Intentionally making a material misstatement of fact in an application for a well-drilling license	100
A well driller failing to have the well driller’s license card in his or her possession at a drilling site or failing to produce the license card when requested to do so by a representative of the Division as required by NAC 534.330	10
Failing to have a licensed well driller at a well-drilling site when a drill rig is in operation or when any activity involving the construction, reconditioning or plugging of the well is conducted as required by NAC 534.330. (Demerit points will be assessed against the license of the principal well driller for the well-drilling company and against the license of the well driller listed on the notice of intent to drill.)	50
Well construction and plugging	

Classification of Violations	Maximum Demerits
Failing to comply with any provision of this chapter which establishes standards for the construction, reconditioning or plugging of a well, including, without limitation, improperly placing the annular seal, constructing a well with substandard well casing, using improper products or procedures during the construction, reconditioning or plugging of a well and failing to protect against contamination...	75
Failing to make a well accessible to measurements of the water level of the well as required by NAC 534.430......................................	30
Failing to prevent, control or stop the flow of water from an artesian well as required by NRS 534.060 and NAC 534.378....................	30
Approvals	
Drilling a replacement well more than 300 feet from the location of the existing point of diversion described in the permit, waiver or certificate or moving the replacement well outside of the 40-acre subdivision described in the permit, waiver or certificate of water right in violation of NAC 534.300..	25
Failing to comply with any term or condition of a permit, waiver or order issued by the State Engineer concerning the drilling or plugging of a well as required by NAC 534.330, including, without limitation, the depth of the annular seal, the location of perforations and the minimum or maximum depth of the well........	50
Miscellaneous	
Any other violation of any of the provisions of this chapter or chapter 534 of NRS...	.... To be determined by the Division based on the severity of the violation, but not to exceed 100

2. The Division shall assess demerit points against the license of a well driller only:

(a) After the State Engineer makes a finding that the well driller has violated a provision of this chapter or chapter 534 of NRS as provided in subsection 1;

(b) After the Division gives written notice of an alleged violation to the well driller by registered or certified mail to the last known address of the well driller which specifies the provision of this chapter or chapter 534 of NRS that the well driller is alleged to have violated;

(c) If, within 30 days after the date on which the well driller receives a notice of an alleged violation sent pursuant to paragraph (b), the well driller has failed to respond to the notice of an alleged violation or provides a response to the notice of an alleged violation that is unsatisfactory, as determined by the Division; and

(d) After the conditions set forth in paragraphs (a), (b) and (c) are satisfied, regardless of when the violation occurred.

3. If a licensed well driller accumulates 100 or more demerit points, the State Engineer may, after giving notice and holding a hearing pursuant to NRS 534.160 to determine that the violations which resulted in the demerit points occurred, suspend the license of the well driller indefinitely. If the State Engineer suspends the license of a well driller, the Division shall notify the well driller that his or her license is suspended and the well driller is prohibited from engaging in any activity for which a well-drilling license issued pursuant to NRS 534.140 is required until the license of the well driller is reinstated.

4. A well driller whose license has been suspended pursuant to subsection 3 may have the license reinstated if the well driller:

(a) Satisfies the requirements set forth in subsection 2 of NAC 534.293;

(b) Appears before the State Engineer at a hearing and the State Engineer finds that the well driller is competent to engage in the practice of well drilling in the State of Nevada; and

(c) Resolves any outstanding complaints related to his or her license as a well driller to the satisfaction of the Division.

5. The Division shall reduce the number of demerit points accumulated against the license of a well driller whose license has been suspended pursuant to subsection 3 and reinstated pursuant to subsection 4 to zero.

6. Demerit points assessed against the license of a well driller may be removed by the Division as follows:

(a) Five demerit points may be removed for each credit unit of continuing education approved by the Division and successfully completed by the well driller, as determined by the Division up to a maximum of 50 points per year. The credit units of continuing education that must be completed for the purposes of the removal of demerit points pursuant to this paragraph are in addition to those required by NAC 534.2923.

(b) One-half of the demerit points assessed against the license of a well driller may be removed if the well driller is determined by the State Engineer to not have violated a provision of this chapter or chapter 534 of NRS for the entire year before his or her license is required to be renewed pursuant to NRS 534.140.

(c) Twenty demerit points may be removed if the well driller takes and passes the written examination for a license as a well driller. The Division may remove demerit points pursuant to this paragraph once every other year.

(Added to NAC by St. Engineer by R009-06, eff. 6-1-2006; A by R044-14, 10-24-2014)

CATEGORY 7: MONITORING WELL INSTALLATION AND ABANDONMENT

Section 7.4

Nevada Division of Environmental Protection (NDEP) – Guidance Document for Design of Groundwater Monitoring Wells

Nevada Division of Environmental Protection
GUIDANCE DOCUMENT FOR DESIGN OF GROUNDWATER MONITORING WELLS

WTS - 4
(Revised 1996)

Information from the items listed below shall be presented as a minimum in a submittal for monitoring well installation. The Bureau of Water Pollution Control reserves the right to require further information as needed.

All monitoring wells must be drilled by a water well driller licensed in the State of Nevada. Drilling must be conducted in accordance with the requirements listed in NAC 534. Monitoring wells constructed for Division of Environmental Protection projects or pursuant to an Administrative Order require NDEP approval prior to installation.

The attached pages taken from the draft regulations from the State Engineer's regulations for Well Drillers (NAC 534) are to be used in reference to this policy.

Regulatory authority for requirements listed below come from:

NRS 445A.660
NAC 534

Key Words:

NDEP - Nevada Division of Environmental Protection
NDWR - Nevada Division of Water Resources
NRS - Nevada Revised Statute
NAC - Nevada Administrative Code

1. <u>Monitoring Well Casing</u>

   A. Casing must have a minimum inside diameter of 1 inch.

   B. Casing material will be chosen based upon groundwater geochemistry and parameters to be monitored.

   C. All items presented in NAC 534 must be satisfied.

   D. The well must be capped at both ends.

2 Well Log

The well log of the drilling must accompany the as-built drawings for the well. It is recommended that this well log be done by a registered geologist with experience in the field.

3. Monitoring Well Screen

A. The screen in a ground water monitoring well must extend a minimum of one (1) foot above the maximum seasonal high water table.

B. All items of NAC 534 must be satisfied.

C. Well screen shall extend into the groundwater table to a determined depth that is based upon the hydrogeology at the site and parameters to be monitored.

4. Monitoring Well Filter Pack

A. All items of NAC 534 (draft) must be satisfied.

5. Well Seals (Filter Pack Seal, Annular Seal)

A. All items of NAC 534 must be satisfied after consultation with NDEP.

6) Surface Pad

A. The well head must be protected from damage and vandalism. Where subject to traffic there must be an appropriate box which is traffic rated. If subject to flooding, the top of the well should extend a minimum of twelve (12) inches above the ground surface with an appropriate cover. In all locations a locking device must be provided.

B. There shall be a seal surrounding the well casing to prevent the flow of surface water in and along the edge of the bore hole. A bentonite plug of no less than two foot thickness shall be placed directly above the gravel pack. The annulus must be sealed from the bentonite plug to the surface with cement and bentonite mixture. The well cap must be water-tight.

7. Well Siting

Upgradient groundwater monitoring wells shall be located at the most distant upgradient point of the facility property, but not more than 250 feet from the outer edge of the land disposal system.

Downgradient groundwater monitoring wells shall be located no further than 250 feet from the outer edge of the disposal system. These wells shall be placed in the direction of the groundwater flow at the site.

8. Monitoring Well Development

All monitoring wells must be developed prior to sampling.

The primary goal in monitoring well development is to reduce the amount of fines entering the well casing during sampling. Examples of acceptable well development shall include:

Overpumping and backwashing
Bailing and mechanical surging

Where applicable, all requirements for well development listed in NAC 534 shall be followed. Care must be taken to allow the seals to set before mechanically developing the well. Allowing 72 hours time elapse between well construction and development should be adequate.

9. All monitoring well closures must be done in accordance with the requirements from the State Engineer (NAC 534).

Recommended reference documents:

Subsurface Characterization and Monitoring Techniques
EPA/625/R-93\/003a 1993

Groundwater R. Allan Freeze/John A. Cherry 1979

CATEGORY 8: SOIL SAMPLING

Section 8.1

US EPA Environmental Response Team Standard Operating Procedures – Soil Sampling

U. S. EPA ENVIRONMENTAL RESPONSE TEAM

STANDARD OPERATING PROCEDURES

SOP: 2012
PAGE: 1 of 13
REV: 0.0
DATE: 02/18/00

SOIL SAMPLING

CONTENTS

SUPERCEDES: SOP #2012; Revision 0.0; 11/16/94; U.S. EPA Contract 68-C4-0022.

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to describe the procedures for the collection of representative soil samples. Sampling depths are assumed to be those that can be reached without the use of a drill rig, direct-push, or other mechanized equipment (except for a back-hoe). Analysis of soil samples may determine whether concentrations of specific pollutants exceed established action levels, or if the concentrations of pollutants present a risk to public health, welfare, or the environment.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the actual procedures used should be documented and described in an appropriate site report.

Mention of trade names or commercial products does not constitute U.S. Environmental Protection Agency (EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

Soil samples may be collected using a variety of methods and equipment depending on the depth of the desired sample, the type of sample required (disturbed vs. undisturbed), and the soil type. Near-surface soils may be easily sampled using a spade, trowel, and scoop. Sampling at greater depths may be performed using a hand auger, continuous flight auger, a trier, a split-spoon, or, if required, a backhoe.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Chemical preservation of solids is not generally recommended. Samples should, however, be cooled and protected from sunlight to minimize any potential reaction. The amount of sample to be collected and proper sample container type are discussed in ERT/REAC SOP #2003 Rev. 0.0 08/11/94, *Sample Storage, Preservation and Handling*.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

There are two primary potential problems associated with soil sampling - cross contamination of samples and improper sample collection. Cross contamination problems can be eliminated or minimized through the use of dedicated sampling equipment. If this is not possible or practical, then decontamination of sampling equipment is necessary. Improper sample collection can involve using contaminated equipment, disturbance of the matrix resulting in compaction of the sample, or inadequate homogenization of the samples where required, resulting in variable, non-representative results.

5.0 EQUIPMENT

Soil sampling equipment includes the following:

- Maps/plot plan
- Safety equipment, as specified in the site-specific Health and Safety Plan
- Survey equipment or global positioning system (GPS) to locate sampling points
- Tape measure
- Survey stakes or flags
- Camera and film
- Stainless steel, plastic, or other appropriate homogenization bucket, bowl or pan
- Appropriate size sample containers
- Ziplock plastic bags
- Logbook
- Labels
- Chain of Custody records and custody seals
- Field data sheets and sample labels
- Cooler(s)
- Ice
- Vermiculite
- Decontamination supplies/equipment
- Canvas or plastic sheet
- Spade or shovel
- Spatula
- Scoop
- Plastic or stainless steel spoons
- Trowel(s)
- Continuous flight (screw) auger
- Bucket auger
- Post hole auger
- Extension rods
- T-handle
- Sampling trier
- Thin wall tube sampler
- Split spoons
- Vehimeyer soil sampler outfit
    - Tubes
    - Points
    - Drive head
    - Drop hammer
    - Puller jack and grip
- Backhoe

6.0 REAGENTS

Reagents are not used for the preservation of soil samples. Decontamination solutions are specified in ERT/REAC SOP #2006 Rev. 0.0 08/11/94, *Sampling Equipment Decontamination*, and the site specific work plan.

7.0 PROCEDURES

7.1 Preparation

1. Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies required.
2. Obtain necessary sampling and monitoring equipment.
3. Decontaminate or pre-clean equipment, and ensure that it is in working order.
4. Prepare schedules and coordinate with staff, client, and regulatory agencies, if appropriate.
5. Perform a general site survey prior to site entry in accordance with the site specific Health and Safety Plan.
6. Use stakes, flagging, or buoys to identify and mark all sampling locations. Specific site factors, including extent and nature of contaminant, should be considered when selecting sample location. If required, the proposed locations may be adjusted based on site access, property boundaries, and surface obstructions. All staked locations should be utility-cleared by the property owner or the On-Scene-Coordinator (OSC) prior to soil sampling; and utility clearance should always be confirmed before beginning work.

7.2 Sample Collection

7.2.1 Surface Soil Samples

Collection of samples from near-surface soil can be accomplished with tools such as spades, shovels, trowels, and scoops. Surface material is removed to the required depth and a stainless steel or plastic scoop is then used to collect the sample.

This method can be used in most soil types but is limited to sampling at or near the ground surface. Accurate, representative samples can be collected with this procedure depending on the care and precision demonstrated by the sample team member. A flat, pointed mason trowel to cut a block of the desired soil is helpful when undisturbed profiles are required. Tools plated with chrome or other materials should not be used. Plating is particularly common with garden implements such as potting trowels.

The following procedure is used to collect surface soil samples:

1. Carefully remove the top layer of soil or debris to the desired sample depth with a pre-cleaned spade.

2. Using a pre-cleaned, stainless steel scoop, plastic spoon, or trowel, remove and discard a thin layer of soil from the area which came in contact with the spade.

3. If volatile organic analysis is to be performed, transfer the sample directly into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval or location into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.2 Sampling at Depth with Augers and Thin Wall Tube Samplers

This system consists of an auger, or a thin-wall tube sampler, a series of extensions, and a "T" handle (Figure 1, Appendix A). The auger is used to bore a hole to a desired sampling depth, and is then withdrawn. The sample may be collected directly from the auger. If a core sample is to be collected, the auger tip is then replaced with a thin wall tube sampler. The system is then lowered down the borehole, and driven into the soil to the completion depth. The system is withdrawn and the core is collected from the thin wall tube sampler.

Several types of augers are available; these include: bucket type, continuous flight (screw), and post-hole augers. Bucket type augers are better for direct sample recovery because they provide a large volume of sample in a short time. When continuous flight augers are used, the sample can be collected directly from the flights. The continuous flight augers are satisfactory when a composite of the complete soil column is desired. Post-hole augers have limited utility for sample collection as they are designed to cut through fibrous, rooted, swampy soil and cannot be used below a depth of approximately three feet.

The following procedure is used for collecting soil samples with the auger:

1. Attach the auger bit to a drill rod extension, and attach the "T" handle to the drill rod.

2. Clear the area to be sampled of any surface debris (e.g., twigs, rocks, litter). It may be advisable to remove the first three to six inches of surface soil for an area approximately six inches in radius around the drilling location.

3. Begin augering, periodically removing and depositing accumulated soils onto a plastic sheet spread near the hole. This prevents accidental brushing of loose material back down the borehole when removing the auger or adding drill rods. It also facilitates refilling the hole, and avoids possible contamination of the surrounding area.

4. After reaching the desired depth, slowly and carefully remove the auger from the hole. When sampling directly from the auger, collect the sample after the auger is removed from the hole and proceed to Step 10.

5. Remove auger tip from the extension rods and replace with a pre-cleaned thin wall tube sampler. Install the proper cutting tip.

6. Carefully lower the tube sampler down the borehole. Gradually force the tube sampler into the soil. Do not scrape the borehole sides. Avoid hammering the rods as the vibrations may cause the boring walls to collapse.

7. Remove the tube sampler, and unscrew the drill rods.

8. Remove the cutting tip and the core from the device.

9. Discard the top of the core (approximately 1 inch), as this possibly represents material collected before penetration of the layer of concern. Place the remaining core into the appropriate labeled sample container. Sample homogenization is not required.

10. If volatile organic analysis is to be performed, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly.

    When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

11. If another sample is to be collected in the same hole, but at a greater depth, reattach the auger bit to the drill and assembly, and follow steps 3 through 11, making sure to decontaminate the auger and tube sampler between samples.

12. Abandon the hole according to applicable state regulations. Generally, shallow holes can simply be backfilled with the removed soil material.

7.2.3 Sampling with a Trier

The system consists of a trier, and a "T" handle. The auger is driven into the soil to be sampled and used to extract a core sample from the appropriate depth.

The following procedure is used to collect soil samples with a sampling trier:

1. Insert the trier (Figure 2, Appendix A) into the material to be sampled at a 0° to 45° angle from horizontal. This orientation minimizes the spillage of sample.

2. Rotate the trier once or twice to cut a core of material.

3. Slowly withdraw the trier, making sure that the slot is facing upward.

4. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7.2.4 Sampling at Depth with a Split Spoon (Barrel) Sampler

Split spoon sampling is generally used to collect undisturbed soil cores of 18 or 24 inches in length. A series of consecutive cores may be extracted with a split spoon sampler to give a complete soil column profile, or an auger may be used to drill down to the desired depth for sampling. The split spoon is then driven to its sampling depth through the bottom of the augured hole and the core extracted.

When split spoon sampling is performed to gain geologic information, all work should be performed in accordance with ASTM D1586-98, "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils".

The following procedures are used for collecting soil samples with a split spoon:

1. Assemble the sampler by aligning both sides of barrel and then screwing the drive shoe on the bottom and the head piece on top.

2. Place the sampler in a perpendicular position on the sample material.

3. Using a well ring, drive the tube. Do not drive past the bottom of the head piece or compression of the sample will result.

4. Record in the site logbook or on field data sheets the length of the tube used to penetrate the material being sampled, and the number of blows required to obtain this depth.

5. Withdraw the sampler, and open by unscrewing the bit and head and splitting the barrel. The amount of recovery and soil type should be recorded on the boring log. If a split sample is desired, a cleaned, stainless steel knife should be used to divide the tube contents in half, longitudinally. This sampler is typically available in 2 and 3 1/2 inch diameters. A larger barrel may be necessary to obtain the required sample volume.

6. Without disturbing the core, transfer it to appropriate labeled sample container(s) and seal tightly.

7.2.5 Test Pit/Trench Excavation

A backhoe can be used to remove sections of soil, when detailed examination of soil characteristics are required. This is probably the most expensive sampling method because of the relatively high cost of backhoe operation.

The following procedures are used for collecting soil samples from test pits or trenches:

1. Prior to any excavation with a backhoe, it is important to ensure that all sampling locations are clear of overhead and buried utilities.

2. Review the site specific Health & Safety plan and ensure that all safety precautions including appropriate monitoring equipment are installed as required.

3. Using the backhoe, excavate a trench approximately three feet wide and approximately one foot deep below the cleared sampling location. Place excavated soils on plastic sheets. Trenches greater than five feet deep must be sloped or protected by a shoring system, as required by OSHA regulations.

4. A shovel is used to remove a one to two inch layer of soil from the vertical face of the pit where sampling is to be done.

5. Samples are taken using a trowel, scoop, or coring device at the desired intervals. Be sure to scrape the vertical face at the point of sampling to remove any soil that may have fallen from above, and to expose fresh soil for sampling. In many instances, samples can be collected directly from the backhoe bucket.

6. If volatile organic analyses are required, transfer the sample into an appropriate, labeled sample container with a stainless steel lab spoon, or equivalent and secure the cap tightly. Place the remainder of the sample into a stainless steel, plastic, or other appropriate homogenization container, and mix thoroughly to obtain a homogenous sample representative of the entire sampling interval. Then, either place the sample into appropriate, labeled containers and secure the caps tightly; or, if composite samples are to be collected, place a sample from another sampling interval into the homogenization container and mix thoroughly. When compositing is complete, place the sample into appropriate, labeled containers and secure the caps tightly.

7. Abandon the pit or excavation according to applicable state regulations. Generally, shallow excavations can simply be backfilled with the removed soil material.

8.0 CALCULATIONS

This section is not applicable to this SOP.

9.0 QUALITY ASSURANCE/QUALITY CONTROL

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration

activities must occur prior to sampling/operation, and they must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OHSA and corporate health and safety procedures, in addition to the procedures specified in the site specific Health & Safety Plan..

12.0 REFERENCES

Mason, B.J. 1983. Preparation of Soil Sampling Protocol: Technique and Strategies. EPA-600/4-83-020.

Barth, D.S. and B.J. Mason. 1984. Soil Sampling Quality Assurance User's Guide. EPA-600/4-84-043.

U.S. Environmental Protection Agency. 1984 Characterization of Hazardous Waste Sites - A Methods Manual: Volume II. Available Sampling Methods, Second Edition. EPA-600/4-84-076.

de Vera, E.R., B.P. Simmons, R.D. Stephen, and D.L. Storm. 1980. Samplers and Sampling Procedures for Hazardous Waste Streams. EPA-600/2-80-018.

ASTM D 1586-98, ASTM Committee on Standards, Philadelphia, PA.

APPENDIX A
Figures
SOP #2012
February 2000

FIGURE 1. Sampling Augers

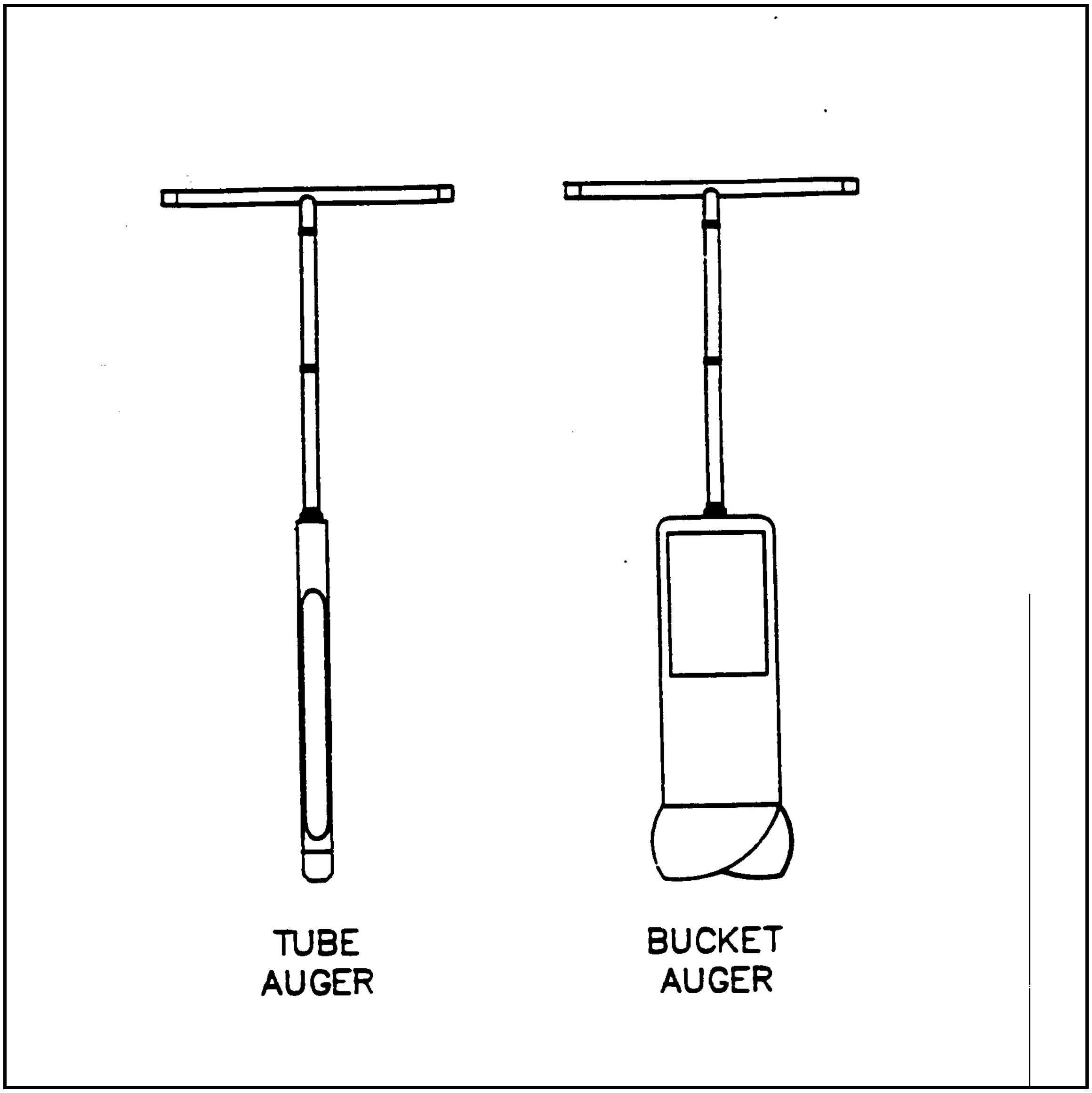
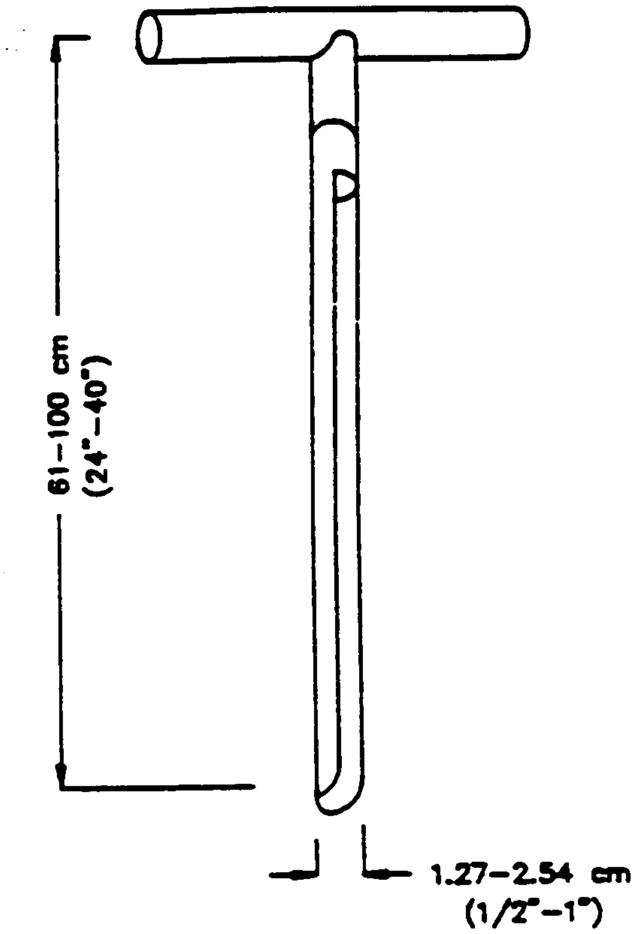


FIGURE 2. Sampling Trier



CATEGORY 8: SOIL SAMPLING

Section 8.2

Standard Guide for Direct Push Soil Sampling for Environmental Site Characterization

Designation: D6282/D6282M – 14

Standard Guide for Direct Push Soil Sampling for Environmental Site Characterizations[1]

This standard is issued under the fixed designation D6282/D6282M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide addresses direct push soil samplers, which may also be driven into the ground from the surface or through prebored holes. The samplers can be continuous or discrete interval units. Samplers are advanced by static push, or impacts from hammers, or vibratory methods, or a combination thereof, to the depth of interest. Both single tube and dual (double) tube systems may be advanced for soil sampling with direct push methods. Direct push methods are most often used to collect geo-environmental soil samples. These soil samples are used for soil classification (Practice D2488) and lithologic/hydrostratigraphic logging as well as being sub-sampled for contaminant and chemical analyses.

1.2 Other drilling and sampling methods may apply for samples needed for engineering and construction applications. This guide does not address single sampling events in the immediate base of the drill hole using rotary drilling equipment that employ cuttings removal as the sampler is advanced. Other sampling standards, such as Test Method D1586, Practices D1587 and D3550, and summarized in Guide D6169 apply to rotary drilling activities (Guide D6286). The guide does not cover open chambered samplers operated by hand such as augers, agricultural samplers operated at shallow depths, or side wall samplers.

1.2.1 While Sonic Drilling is considered a direct push method this standard may not apply to larger equipment addressed in Practice D6914.

1.3 Guidance on collection and handling of samples, are given in Practices D4220 and D6640. Samples for chemical analysis often must be subsampled and preserved for chemical analysis using special techniques such as Practice D4547, D6418, and D6640. Additional information on environmental sample preservation and transportation is available in other references **(1, 2, 3, 4, 5, 6)**[2]. Samples for soil classification may be preserved using procedures given in Practice D4220 similar to Class A. In most cases, a direct push sample is considered as Class B in Practice D4220 but is protected, representative, and suitable for chemical analysis. The samples taken with this practice do not usually produce Class C and D (with exception of thin wall samples of standard size) samples for laboratory testing for engineering properties, such as shear strength and compressibility. If sampling is for chemical evaluation in the Vadose Zone, consult Guide D4700 for any special considerations.

1.4 Insertion methods described include static push, impact, percussion, other vibratory/sonic driving, and combinations of these methods using direct push equipment adapted to drilling rigs, cone penetrometer units, and specially designed percussion/direct push combination machines. Hammers providing the force for insertion include drop style, hydraulically activated, air activated and mechanical lift devices.

1.5 Direct push soil sampling is limited to soils and unconsolidated materials that can be penetrated with the available equipment. The ability to penetrate strata is based on hammer energy, carrying vehicle weight, compactness of soil, and consistency of soil. Penetration may be limited or damage to samplers and conveying devices can occur in certain subsurface conditions, some of which are discussed in 5.6. Successful sample recovery also may be limited by the ability to retrieve tools from the borehole. Sufficient retract force must be available when attempting difficult or deep investigations.

1.6 This guide does not address the installation of any temporary or permanent soil, groundwater, vapor monitoring, or remediation devices.

1.7 The practicing of direct push techniques may be controlled by local regulations governing subsurface penetration. Certification, or licensing requirements, or both, may need to be considered in establishing criteria for field activities.

1.8 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

---

[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

Current edition approved May 1, 2014. Published July 2014. Originally approved in 1998. Last previous edition approved in 2005 as D6282–98(2005), which was withdrawn in January 2014 and reinstated in May 2014. DOI: 10.1520/D6282-14.

[2] The boldface numbers in parentheses refer to a list of references at the end of this standard.

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.10 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a projects's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
D3694 Practices for Preparation of Sample Containers and for Preservation of Organic Constituents
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4220 Practices for Preserving and Transporting Soil Samples
D4547 Guide for Sampling Waste and Soils for Volatile Organic Compounds
D4700 Guide for Soil Sampling from the Vadose Zone
D5088 Practice for Decontamination of Field Equipment Used at Waste Sites
D5092 Practice for Design and Installation of Groundwater Monitoring Wells
D5299 Guide for Decommissioning of Groundwater Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities
D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D6001 Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization
D6067 Practice for Using the Electronic Piezocone Penetrometer Tests for Environmental Site Characterization
D6169 Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations
D6286 Guide for Selection of Drilling Methods for Environmental Site Characterization
D6418 Practice for Using the Disposable En Core Sampler for Sampling and Storing Soil for Volatile Organic Analysis
D6640 Practice for Collection and Handling of Soils Obtained in Core Barrel Samplers for Environmental Investigations
D6724 Guide for Installation of Direct Push Groundwater Monitoring Wells
D6725 Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers
D6914 Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface Monitoring Devices
D7242 Practice for Field Pneumatic Slug (Instantaneous Change in Head) Tests to Determine Hydraulic Properties of Aquifers with Direct Push Groundwater Samplers
D7648 Practice for Active Soil Gas Sampling for Direct Push or Manual-Driven Hand-Sampling Equipment

3. Terminology

3.1 *Definitions*—For definitions of common terminology terms used within this guide refer to Terminology D653. Definitions for additional terms related to direct push water sampling for geoenvironmental investigations are in accordance with Guide D6001.

3.1.1 *assembly length, n*—length of sampler body and riser pipes.

3.1.2 *direct push sampler, n*—sampling devices that are advanced into the soil to be sampled without drilling or borehole excavation.

3.1.3 *extension rod, n*—hollow steel rod, threaded, in various lengths, used to advance and remove samplers and other devices during direct pushing boring. Also known as drive rod. In some applications, small diameter solid extension rods are used through hollow drive rods to activate closed samples at depth.

3.1.4 *incremental drilling and sampling, n*—insertion method where rotary drilling and sampling events are alternated for incremental sampling. Incremental drilling often is needed to penetrate harder or deeper formations.

3.1.5 *push depth, n*—the depth below a ground surface datum to which the lower end, or tip, of the direct-push sampling device is inserted.

3.1.6 *sample interval, n*—defined zone within a subsurface strata from which a sample is gathered.

3.1.7 *sample recovery, n*—the length of material recovered divided by the length of sampler advancement and stated as a percentage.

3.1.8 *soil core, n*—cylindrical shaped specimen recovered from a soil sampler of soil, sediments, or other unconsolidated accumulations of solid particles produced by deposition or the physical and chemical disintegration of rocks and which may or may not contain organic matter.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *closed barrel sampler, n*—a sampling device with a piston or other secured device that is held to block the movement of material into the barrel until the blocking device is removed or released. Liners are required in closed barrel samplers. Also may be referred to as a protected type sampler.

3.2.2 *impact heads/drive heads, n*—pieces or assemblies that fit to top of the above ground portion of the direct push tool assembly to receive the impact of the hammering device and transfer the impact energy to sampler extensions or drive rods.

3.2.3 *open barrel sampler, n*—sampling barrel with open end allowing material to enter at any time or depth. Also may be referred to as an unprotected type sampler.

3.2.4 *piston lock, n*—device to lock the sampler piston in place to prevent any entry of a foreign substance into the sampler chamber prior to sampling.

3.2.5 *single tube system, n*—a system whereby single extension/drive rods with sampler attached are advanced into the subsurface strata to collect a soil sample.

3.2.6 *solid barrel sampler, n*—a soil sampling device consisting of a continuous or segmented tube with a wall thickness sufficient to withstand the forces necessary to penetrate the strata desired and gather a sample. A cutting shoe and a connecting head are attached to the barrel.

3.2.7 *split barrel sampler, n*—a soil sampling device consisting of the two half circle tubes manufactured to matching alignment, held together on one end by a shoe and on the other by a connecting head.

3.2.8 *dual tube systems, n*—a system whereby inner and outer tubes are advanced simultaneously into the subsurface strata to collect a soil sample. The outer tube is used for borehole stabilization. The inner tube for is used sampler recovery and insertion.

4. Summary of Guide

4.1 Direct push soil sampling consists of advancing a sampling device into subsurface soils by applying static pressure, by applying impacts, or by applying vibration, or any combination thereof, to the above ground portion of the sampler extensions until the sampler has been advanced to the desired sampling depth. The sampler is recovered from the borehole and the sample removed from the sampler. The sampler is cleaned and the procedure repeated for the next desired sampling interval. Sampling can be continuous for full depth borehole logging or incremental for specific interval sampling. Samplers used can be protected type for controlled specimen gathering or unprotected for general soil specimen collection.

5. Significance and Use

5.1 Direct Push Soil Sampling is used extensively in environmental site characterization of soils below ground surface and can also be used for subsurface geotechnical site characterization (**3**, **7**, **8**, **9-12**, **13**). Limited early studies have been done using Direct Push Soil Sampling for environmental investigations (**14**, **15**, **16**). These methods are preferred for environmental site characterization over rotary drilling sampling methods (D6169, D6286) because they are minimally intrusive (less disruptive to the soil column) and they do not generate soil cuttings which could be contaminated and require characterization and safe disposal. Direct Push soil samplers are grouped into two categories; Single Tube and Dual (Double) Tube systems.

5.1.1 *Dual Tube Systems*—Dual tube soil sampling systems are preferred for use because the bore hole is protected and sealed by the outer casing during operations. However, in some conditions when sampling below the groundwater, a sealed single tube sampler (5.1.2) must to be used to avoid sample cross contamination. Figure 1 shows how a Double Tube system is used. The outer tube stays in place to protect and seal the borehole and prevents potential cross contamination of the boring and the soil sample. Dual tube systems allow for rapid continuous sampling both above and below the water table. When sampling is not required, a sealed inner drive point can be locked in for driving through zones not targeted for sampling or through obstructions or difficult to sample formations.

5.1.1.1 Dual tube systems facilitate deployment of other testing and sampling systems (Test Method D1586 and Practice D1587) and sensors, groundwater sampling (D6001), water testing (D7242), and even monitoring well installations (D6724, D6725). Well installations may require use of specially designed expendable tips that facilitate well construction.

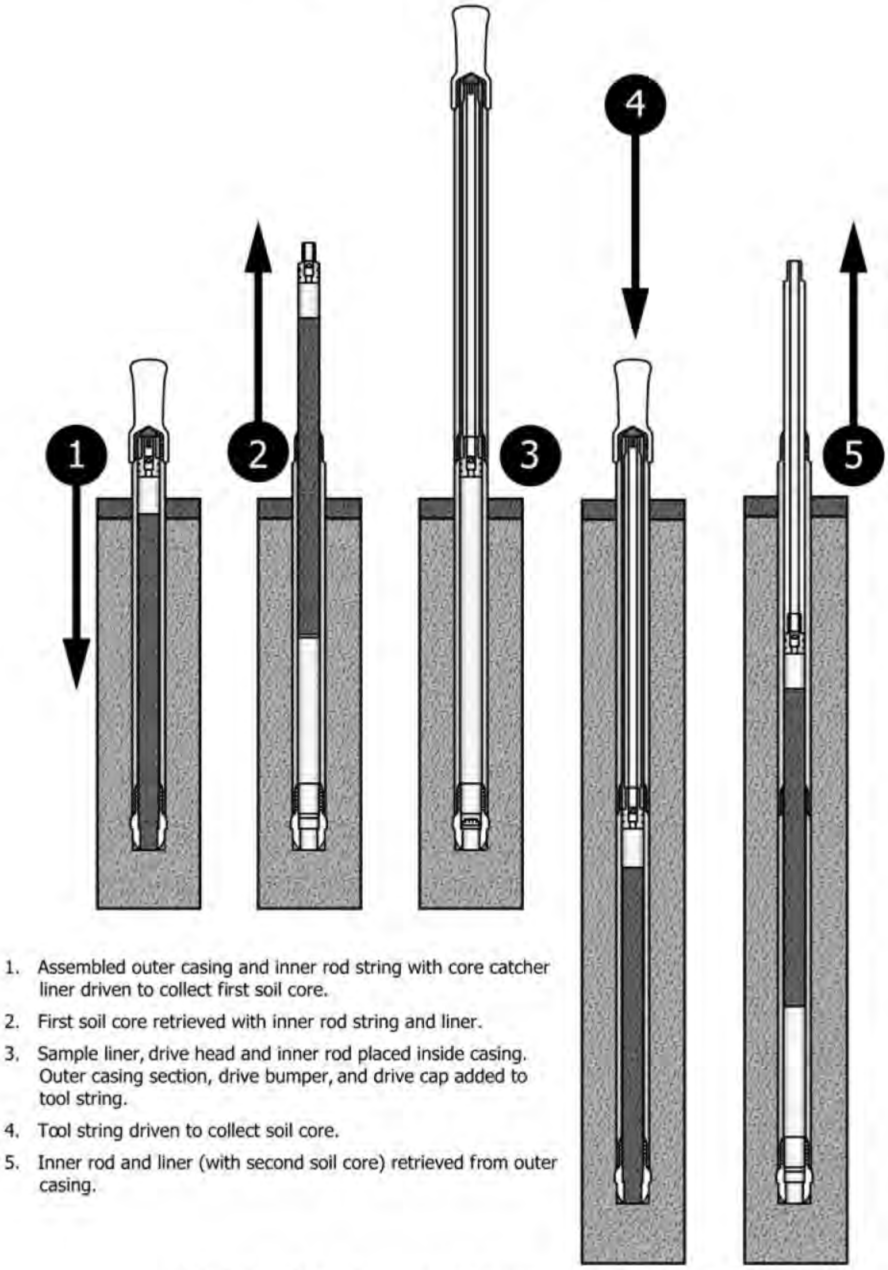
5.1.1.2 In larger Dual Tube systems with inside diameters of at least 75 mm the Standard Penetration Test (D1586) is often conducted in the bottom of the boring. Reliable SPT N values can be obtained in most soil formations that are not disturbed by the driving of the casing. Cohesionless sands and very soft clays may be disturbed during advancement of the Dual System to the test depth and should be evaluated or flagged if suspect. Reliable N values may not be obtained if there is evidence of heave or borehole instability from the base of the borehole to the inside the casing.

5.1.1.3 Dual tube systems are easily grouted and sealed for completion because the outer casing keeps an open sealed borehole for insertion of grout tubes.

5.1.1.4 As shown on Fig. 1, continuous sampling is done with an opening left at the bottom of the outer casing during the sampling process. This is fine as long as the formation is stable between sampling events. If there are heaving conditions into the outer casing the outer casing may be retracted to set the sampler barrel in position. The instability can be improved by maintaining a water level balance in the outer casing and using slower retraction of the sampler string during withdraw. If the material stability ids a problem then one must deploy a sealed single tube piston sampler (5.1.2) into the boring to retrieve samples.

5.1.1.5 A constant outer tube diameter of the Dual Tube system generally has more friction than some Single Tube rod driven samplers so may require larger equipment capable of higher more percussion and push forces. Dual Tube systems approaching 100 to 150 mm outside diameter have been developed and require larger direct push equipment.

5.1.2 *Single Tube Systems*—Sealed single tube samples assure that the soil sample is not cross contaminated by other soils or fluids inside the bore hole so they are preferred sampling method to use below groundwater. Single tube soil



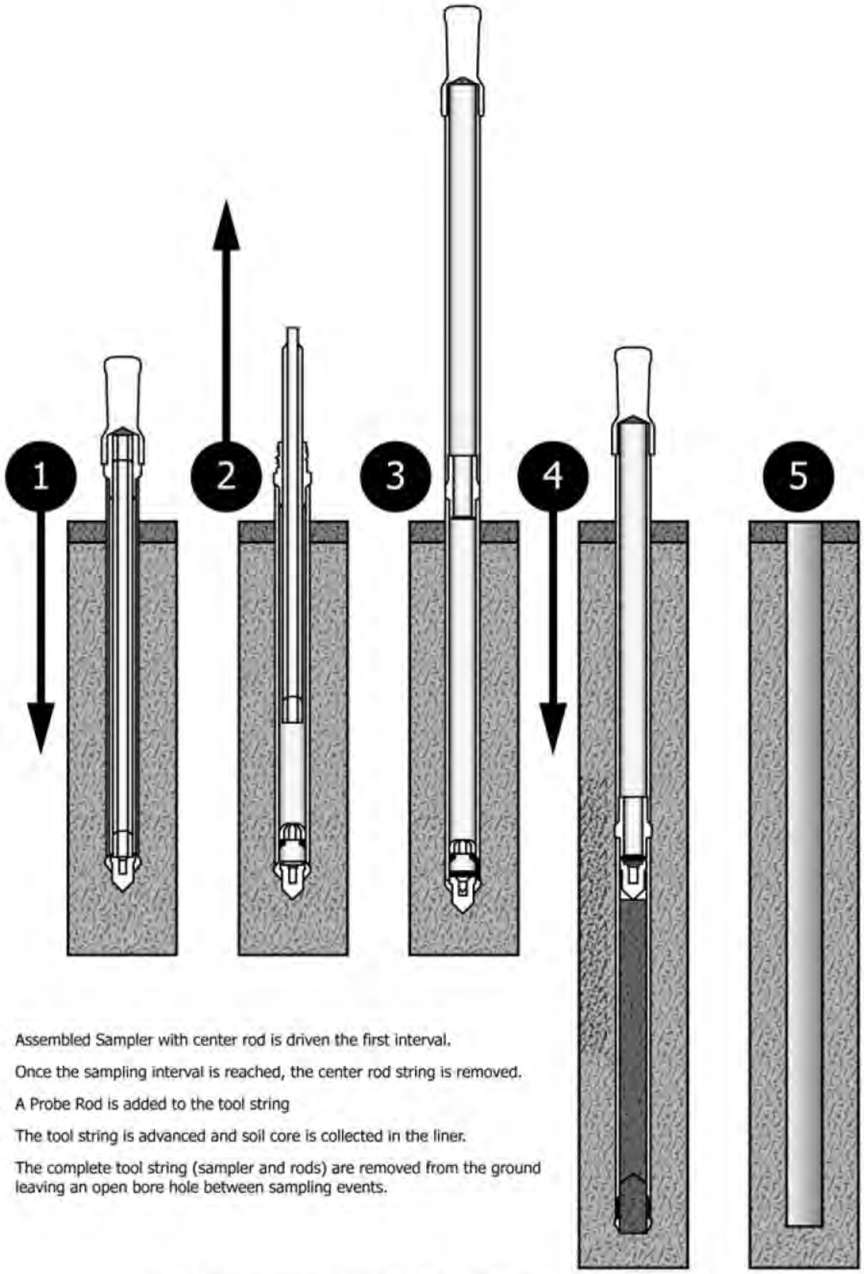
1. Assembled outer casing and inner rod string with core catcher liner driven to collect first soil core.
2. First soil core retrieved with inner rod string and liner.
3. Sample liner, drive head and inner rod placed inside casing. Outer casing section, drive bumper, and drive cap added to tool string.
4. Tool string driven to collect soil core.
5. Inner rod and liner (with second soil core) retrieved from outer casing.

FIG. 1 Dual Tube Direct Push Soil Sampler Operation

sampling systems are most often used for single incremental discrete soil sampling events but can also be used in continuous sampling modes with limitations listed below. Sealed piston type samples assure the best preservation of sample and assure no cross contamination of the soil. Figure 2 shows the basic operation of a single tube sampler. The sampler includes a sealed piston point to prevent soil intrusion during advancement to the target sample depth. The piston is then unlocked using various mechanisms and the sample is pushed to the design length. The complete sampler tube and drive rods are removed from the ground to retrieve the sample leaving an open hole after sampling.

5.1.2.1 The disadvantage to single tube sampling is that the hole left in the ground may not stay open and it would be difficult to grout if required. If positive proof of grouting is required it may be necessary to push a re-entry grout tube to the sample depth to grout the hole (D6001). Another disadvantage is possible travel of contaminants down the open hole. If cross contamination is a concern than a dual tube sampler system should be used.

5.1.2.2 Many single tube systems use drive rods of smaller diameter than the sampler body. The use of smaller diameter drive rods raises two concerns when sampling. First the soil above the sampler body may cave on the sampler and cause



1. Assembled Sampler with center rod is driven the first interval.
2. Once the sampling interval is reached, the center rod string is removed.
3. A Probe Rod is added to the tool string
4. The tool string is advanced and soil core is collected in the liner.
5. The complete tool string (sampler and rods) are removed from the ground leaving an open bore hole between sampling events.

FIG. 2 Single Tube Direct Push Soil Sampler Operation

retraction problems. Second, if chemical analysis is required and the sampler will penetrate and cross contaminated zones there is concern that fluids from layers up above may run down the open annulus above the sampler causing cross contamination.

5.1.2.3 Single tube piston samplers are sometimes used in conjunction with Cone Penetrometer Testing (CPT) (D6067) and can be used in other geotechnical drilling (D6169) in the base of a drill hole.

5.1.2.4 Continuous Sampling operations may be conducted in the same hole with limitations. Using the sealed piston sampler, consecutive samples can be obtained in the same hole by re-driving the sealed piston sampler to a deeper target depths.

5.1.2.5 Open tube samplers without a piston (Fig. 3) should not be used except in rare cases. Use of an unsealed open barrel sampler without a sealed piston multiple times in the same sampling hole will result in cross contamination of samples from the hole wall, cave, and heaving. Continuous soil sampling using an open barrel is sometimes performed above the water table where boreholes are very stable. This sampling mode should never be used below the water table. A sealed sample is required to assure no cross contamination.

5.2 Direct push methods of soil sampling are used for geologic investigations, subsurface soil matrix contamination studies, and water quality investigations. Examples of a few types of investigations in which direct push sampling may be

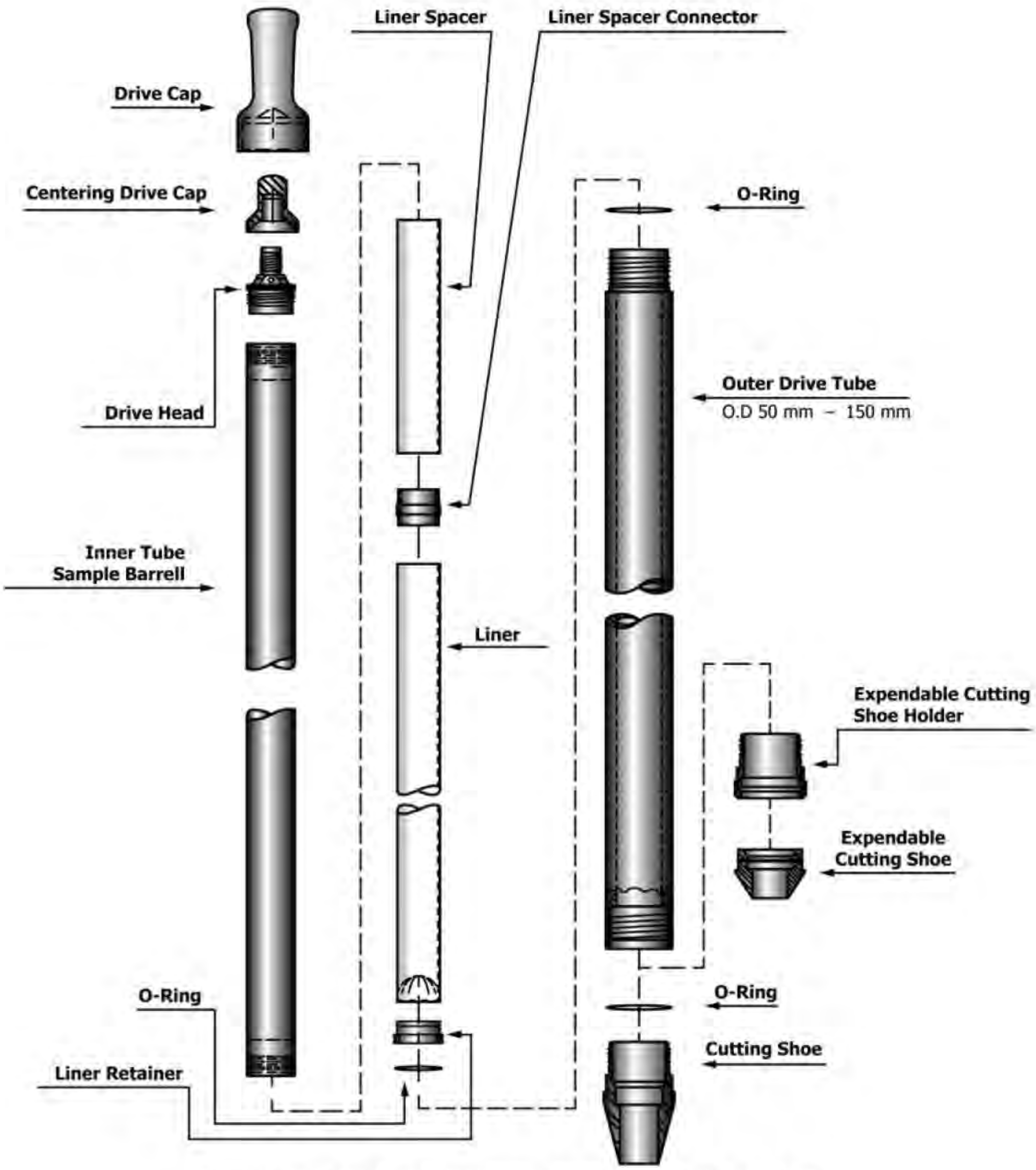


FIG. 3 Dual Tube Soil Sampler with Solid Inner Barrel and Liner

used include site assessments, underground storage tank investigations, and hazardous waste site investigations (17-19). Continuous sampling is used to provide a lithological detail of the subsurface strata and to gather samples for classification and index tests or for chemical testing. These investigations frequently are required in the characterization of hazardous waste sites. Samples, gathered by direct push methods, provide specimens necessary to determine the types and concentration of contaminants in soils and sediments, and in most circumstances, the contained pore fluids (7, 8, 9, 10, 11, 12, 13). Procedures for soil core handling for chemical testing are given standard D6640. Sampling for Volatile Organic Compounds (VOC) is addressed in Guide D4547 and often the core may be rapidly subsampled on site using other methods such as D6418 or other similar small hand core samplers. Samples for other chemical characterization generally require subsampling into glass or plastic jars or vials and preserved with refrigeration (See EPA test methods in SW-846 (4)). Verify containers and preservation requirements meet the data quality objectives as specified by the lead regulatory agency, in the project work plan, and with the selected analytical laboratory.

5.3 Direct push methods can provide accurate information on the characteristics of the soils encountered and of the chemical composition if provisions are made to ensure that discrete samples are collected, that sample recovery is maximized, and that clean decontaminated tools are used in the sample gathering procedure. For purposes of this guide, "soil" shall be defined in accordance with Terminology D653. Using sealed or protected sampling tools, cased boreholes, and proper advancement techniques can assure good representative samples. Direct push boreholes may be considered as a supplementary part of the overall site investigation or may be used for the full site investigation if site conditions permit. As such, they should be directed by the same procedural review and quality assurance standards that apply to other types of subsurface borings. A general knowledge of subsurface conditions at the site is beneficial.

5.4 Soil strata profiling to shallow depths may be accomplished over large areas in less time than with conventional drilling methods because of the rapid sample gathering potential of the direct push method. More site time is available for actual productive investigation as the time required for ancillary activities, such as decontamination, rig setup, tool handling, borehole backfill, and site clean-up is reduced over conventional drilling techniques. Direct push soil sampling has benefits of smaller size tooling, smaller diameter boreholes, and minimal investigative derived waste.

5.5 The direct push soil sampling method may be used as a site characterization tool for subsurface investigation and for remedial investigation and corrective action. The initial direct push investigation program can provide good soil and sediment stratigraphic information depending on the soil density and particle size, determine groundwater depth, and provide samples for field screening and for formal laboratory analysis to determine the types and concentrations of chemical contaminants in the soil or sediments and contained pore fluids. The method does not provide samples for laboratory test if engineering properties (Class C and D D4220).

5.6 This guide may not be the correct method for investigations in all cases. As with all drilling methods, subsurface conditions affect the performance of the sample gathering equipment and methods used. Direct push methods are not effective for solid rock and are marginally effective in partially weathered rock or very dense soils. These methods can be utilized to determine the rock surface depth. The presence or absence of groundwater can affect the performance of the sampling tools. Compact gravelly tills containing boulders and cobbles, stiff clay, compacted gravel, and cemented soil may cause refusal to penetration. Certain cohesive soils, depending on their water content, can create friction on the sampling tools which can exceed the static delivery force, or the impact energy applied, or both, resulting in penetration refusal. Some or all of these conditions may complicate removal of the sampling tools from the borehole as well. Sufficient retract force should be available to ensure tool recovery. As with all borehole advancement methods, precautions must be taken to prevent cross contamination of aquifers through migration of contaminants up or down the borehole. Regardless of the tool size, the moving of drilling and sampling tools through contaminated strata carries risks. Minimization of this risk should be a controlling factor in selecting sampling methods and drilling procedures. The user should take into account the possible chemical reaction between the sample and the sampling tool itself, sample liners, or other items that may come into contact with the sample (**3, 4**).

5.7 In some cases this guide may combine water sampling, or vapor sampling, or both, with soil sampling in the same investigation. Guides D6001 and D4700, D7648 can provide additional information on procedures to be used in such combined efforts. D3740 provides evaluation factors for the activities in this standard.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Criteria for Selection

6.1 Important criteria to consider when selecting sampling tools include the following:

6.1.1 Size of sample.

6.1.2 Sample quality (Class A,B,C,D) for physical testing. Refer to Practice D4220.

6.1.3 Sample handling requirements, such as containers, preservation requirements. Refer to Practice D6640.

6.1.4 Soil conditions anticipated.

6.1.5 Groundwater depth anticipated and perched water tables.

6.1.6 Boring depth required.

6.1.7 Types and concentrations of contaminants in the soil or sediments and contained pore fluids.

6.1.8 Probability of cross contamination.

6.1.9 Available funds.

6.1.10 Estimated cost.

6.1.11 Time constraints.

6.1.12 History of tool performance under anticipated conditions (consult experienced users and manufacturers).

6.2 Important criteria to consider when selecting direct push equipment include the following:

6.2.1 Site accessibility.

6.2.2 Site visibility.

6.2.3 Soil conditions anticipated.

6.2.4 Boring depth required.

6.2.5 Borehole sealing requirements.

6.2.6 Equipment performance history.

6.2.7 Personnel requirements.

6.2.8 Decontamination requirements.

6.2.9 Equipment grouting capability.

6.2.10 Local regulatory requirements.

7. Apparatus

7.1 *General*—A direct push soil sampling system consists of a sample collection tool, hollow extension rods for advancement, retrieval, and transmission of energy to the sampler, and an energy source to force sampler penetration. Auxiliary tools are required to handle, assemble and disassemble, clean, and repair the sample collection tools and impact surfaces. Necessary expendable supplies are sample containers, sample container caps, sample liners, sample retainers, appropriate lubricants, and personal safety gear. The following text and subsequent figures tell and show the overall intent of this standard; however, if the exact configuration and dimensions vary in a particular tooling configuration, yet the intent is still met, that particular tooling configuration is acceptable to be used as a part of complying with this standard.

7.2 *Direct Push Tool Soil Sampling Systems*—Direct push soil samplers are described in two groups; Dual Tube and Single Tube Systems.

7.2.1 *Dual Tube System*—Figures 3 and 4 are examples of typical Dual Tube direct push soil samplers. The Outer Drive Tube which is generally the same diameter. Diameters range from 50 to 150 mm [2 to 6 inches]. The outer drive tube is sometimes referred to as Probe rod in the drawings. Outer drive tube friction can be reduced by using oversized cutting shoes or other friction reducers. The Outer drive tube stays in the ground and seals and protects borehole collapse as the sampling progresses to depth.

7.2.1.1 *Sampler*—Figure 3 shows a sampler with a solid inner barrel with a liner inside the barrel. Figure 4 shows just an inner liner without the solid barrel. The solid barrel may be required in situations where liner damage may occur. The length of sample ranges from 2 to 6 ft [0.5 to 1.5 m] and diameters range from 50 to 125 mm [2-5 inches]. The sampler is normally held in place with a series of inner rods that fit inside the outer tube and connect to the drive cap so both the outer rods and inner rods are advanced together. The inner rods are used to place and remove the sampler barrels during sampling events. There are other means of locking the sample barrel in place besides inner rods such as wire line latching systems.

7.2.1.2 The outer drive tube is equipped with a Cutting Shoe on the end the is designed specifically for the sampler system such that the liners, o-rings, and core catchers all fit in place correctly and the shoe cuts the core to slides into the sampler liner with minimal disturbance. There are different cutting

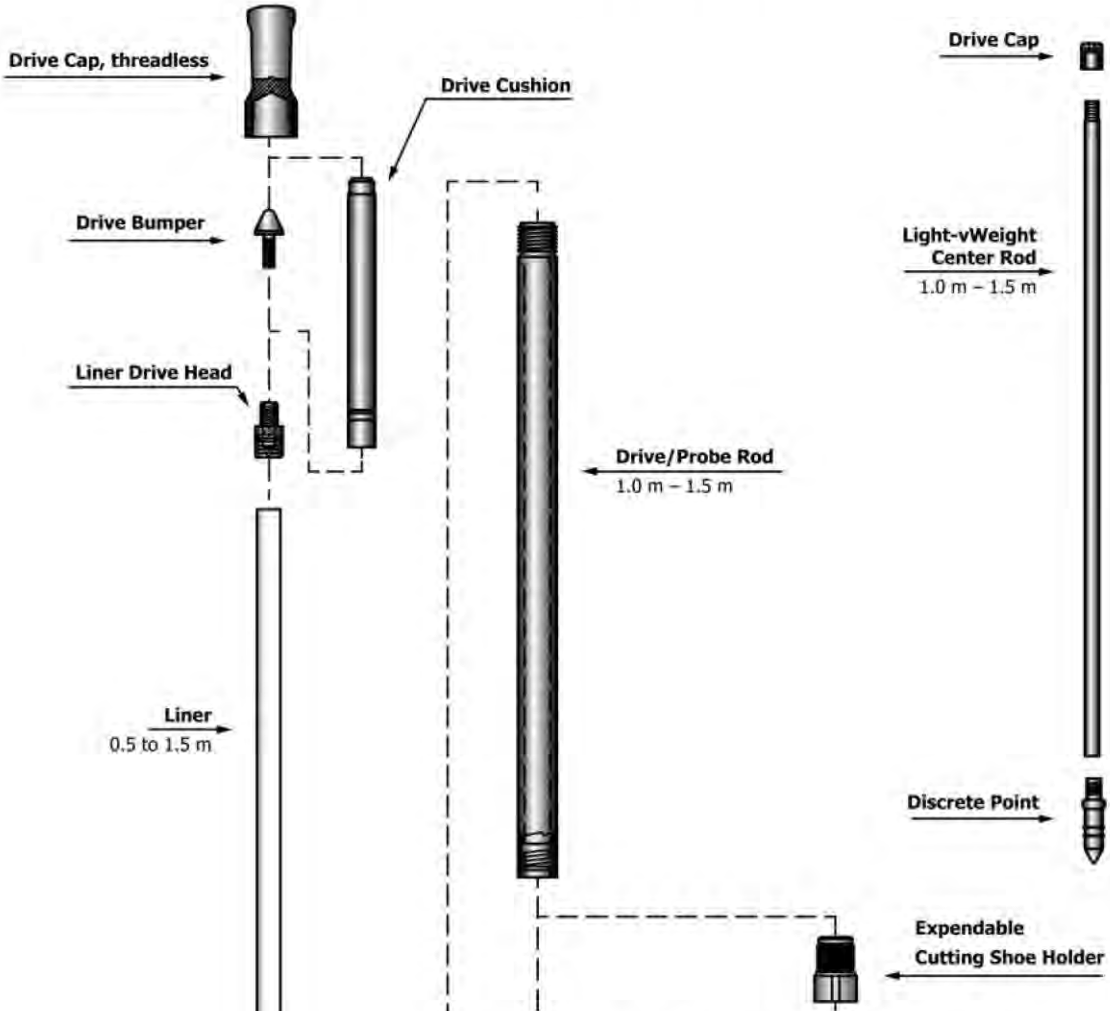
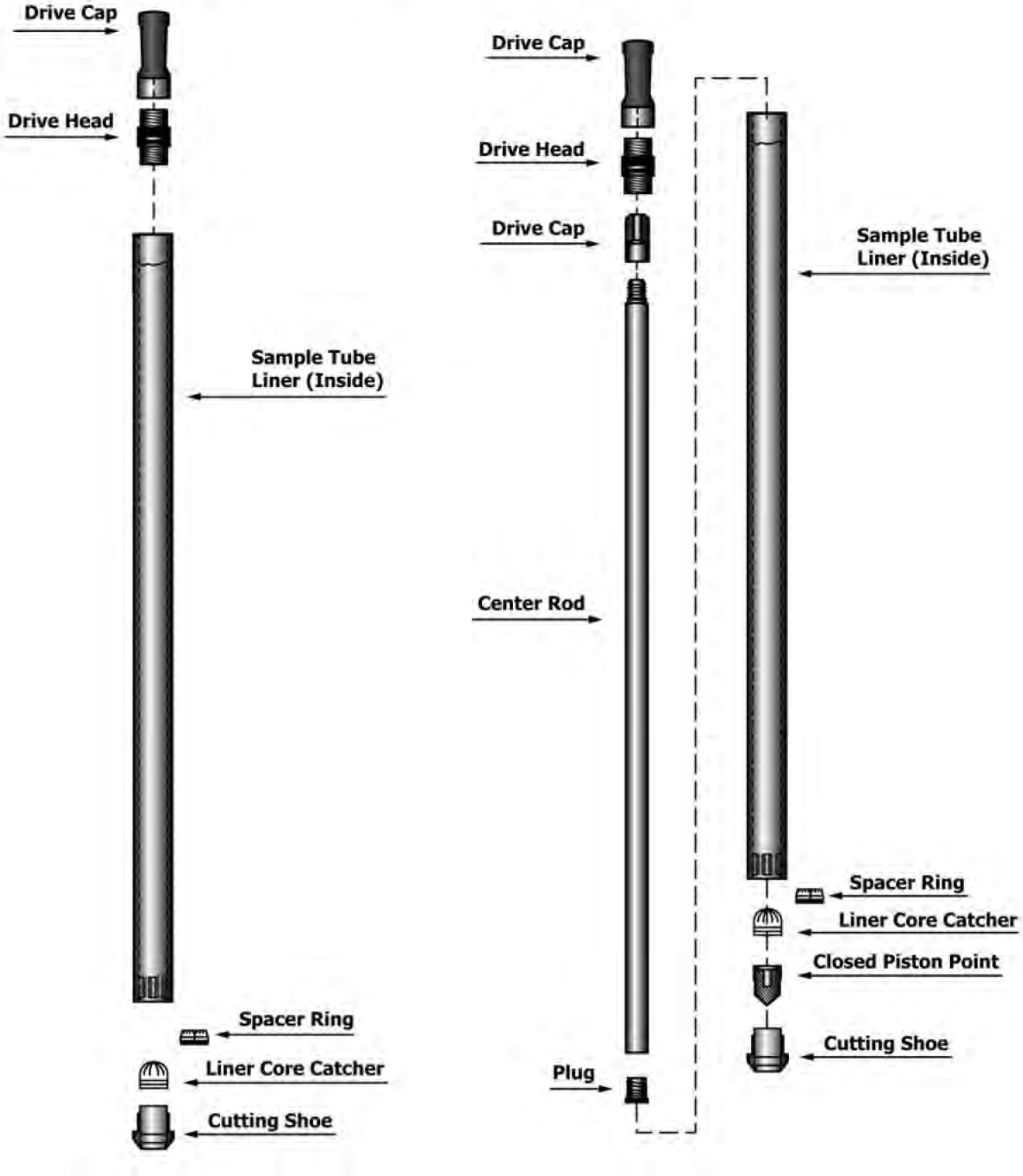


FIG. 4 Dual Tube Sampler with Inner Liner and Inner Rods



Open-Tubed System **Closed-Point System**

FIG. 5 Typical Single Tube Sampling System Used in Either Open Tube or Sealed (Closed) Piston Point

shoes for differing soil conditions (see Appendix X1) so the correct design must be used in the soils to be sampled. The Cutting Shoe is the most important feature that effects soil core recovery or quality. General purpose cutting shoes are successful in a wide range of soil deposits but if the recover is poor one should change the cutting shoe design for the soils to be sampled. Special expendable cutting shoes (Figs. 4 and 5) can be used when the planned investigation requires post sampling installations such as monitoring wells (D6724, D6725).

7.2.1.3 Core catchers can be used to help the soil recovery by preventing loss of core. Figure 3 shows a core catcher built into the sample liner. Core catchers should be used in most all soil conditions. The catcher does not disturb the soil except in very soft soils. The use of a catcher assures that if clean sands are encountered they can be recovered without running/falling out of the liner.

7.2.1.4 Figure 4 shows a discrete point with inner rods that can be inserted into the dual tube system in place of the sampler barrel to advance the system without sampling. It can be used to drive through difficult formations and intervals where sampling is not required.

7.2.2 *Single Tube Samplers*—Figures 5 and 6 show some single tube sampler systems. Figure 5 shows a Single Tube system used in either an open or sealed mode. Sample lengths

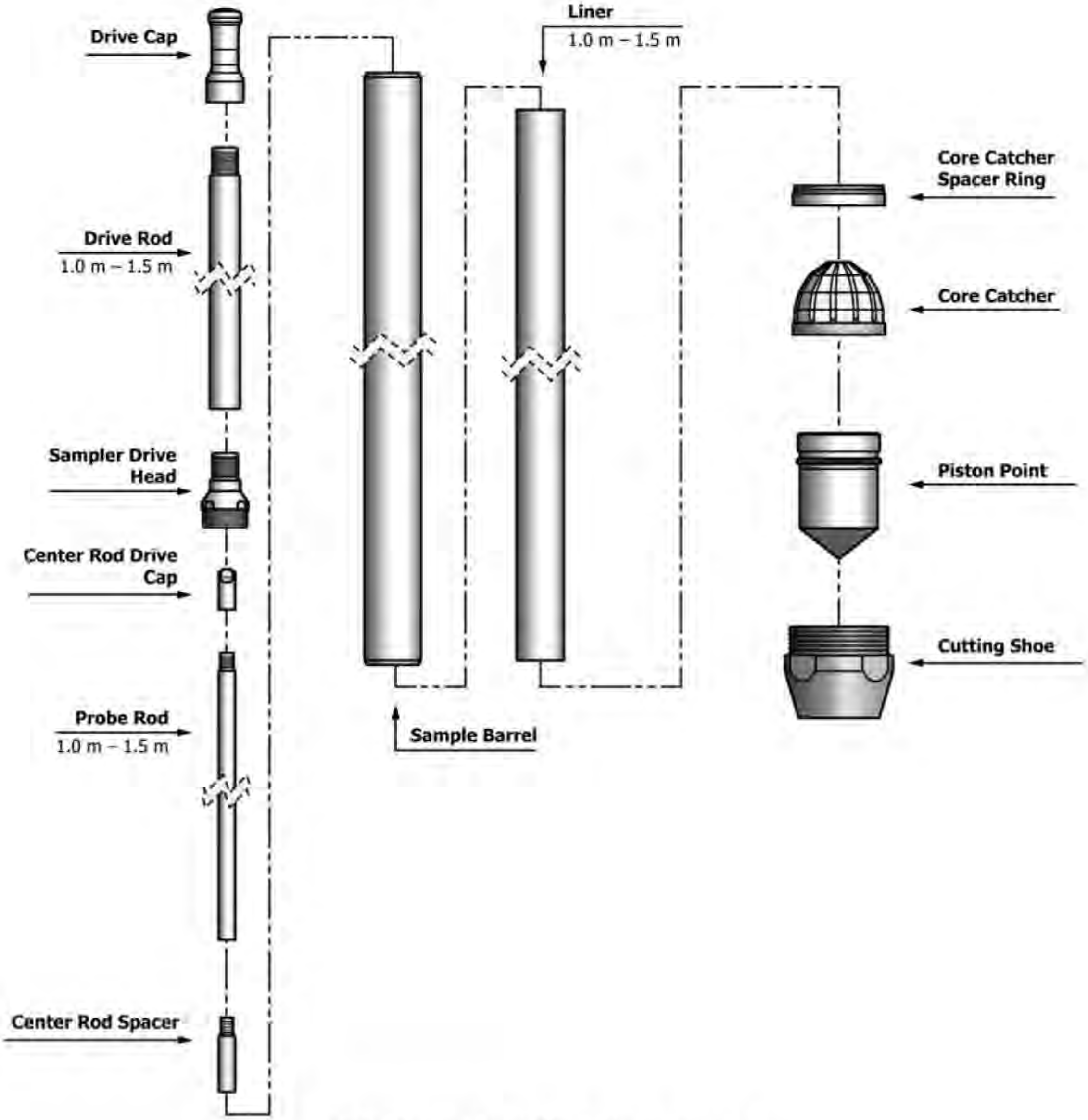


FIG. 6 Sealed Single Tube Piston Sampler

range from 0.5 to 1.5 m [2 to 5 ft]. Typical sample diameters range from 30 to 100 mm [1 to 4 inches]. Figure 6 shows the Sealed single tube sampler with solid barrel, inner liner, piston point, and cutting shoe. The sealed system includes the piston and inner rod are locked inside the liner and the sampler is advanced to the sampling depth. The piston is unlocked using rods or other methods prior to the sampling push. The sample barrel is equipped with a cutting shoe which is specifically designed to cut the core for optimal recovery.

7.2.2.1 Figure 7 shows a typical piston sampler deployed on CPT rigs (D6067) (**20**). It uses a simple ball system to unlock the piston when the sampling depth is reached.

7.2.2.2 A Core Catcher is sometimes used to add in recovery of sands and low plasticity silts. This catcher is reusable and is not built into the liner. In many cases the catcher is not required as the piston system creates a vacuum to hold the sample in the liner.

7.2.2.3 Figure 5 shows the single tube sampler use without the piston in an open sampling mode. As discussed in section 5.1.2.5, the use of an open sampler for consecutive sampling events is extremely limited.

7.3 *Sampler Extension/Drive Rods*—Sampler extension/drive rods are lengths of rod or tube generally constructed of steel to withstand the pushing or percussion forces applied. Inner rods used with Dual Tube systems can be made with thinner walls to provide lightweight tooling to minimize manual effort in sampling. Extension drive rods lengths range from 1.0 to 1.5 m [3 to 5 ft] but are available in various lengths. Rod lengths should be mated with casing and sampling equipment used. Thread types and classes vary between equipment manufacturers. Rod joints can be sealed to prevent fluid intrusion with "O" rings. TFE-fluorocarbon washers or TFE-fluorocarbon tape. Because of the percussive effort, joint

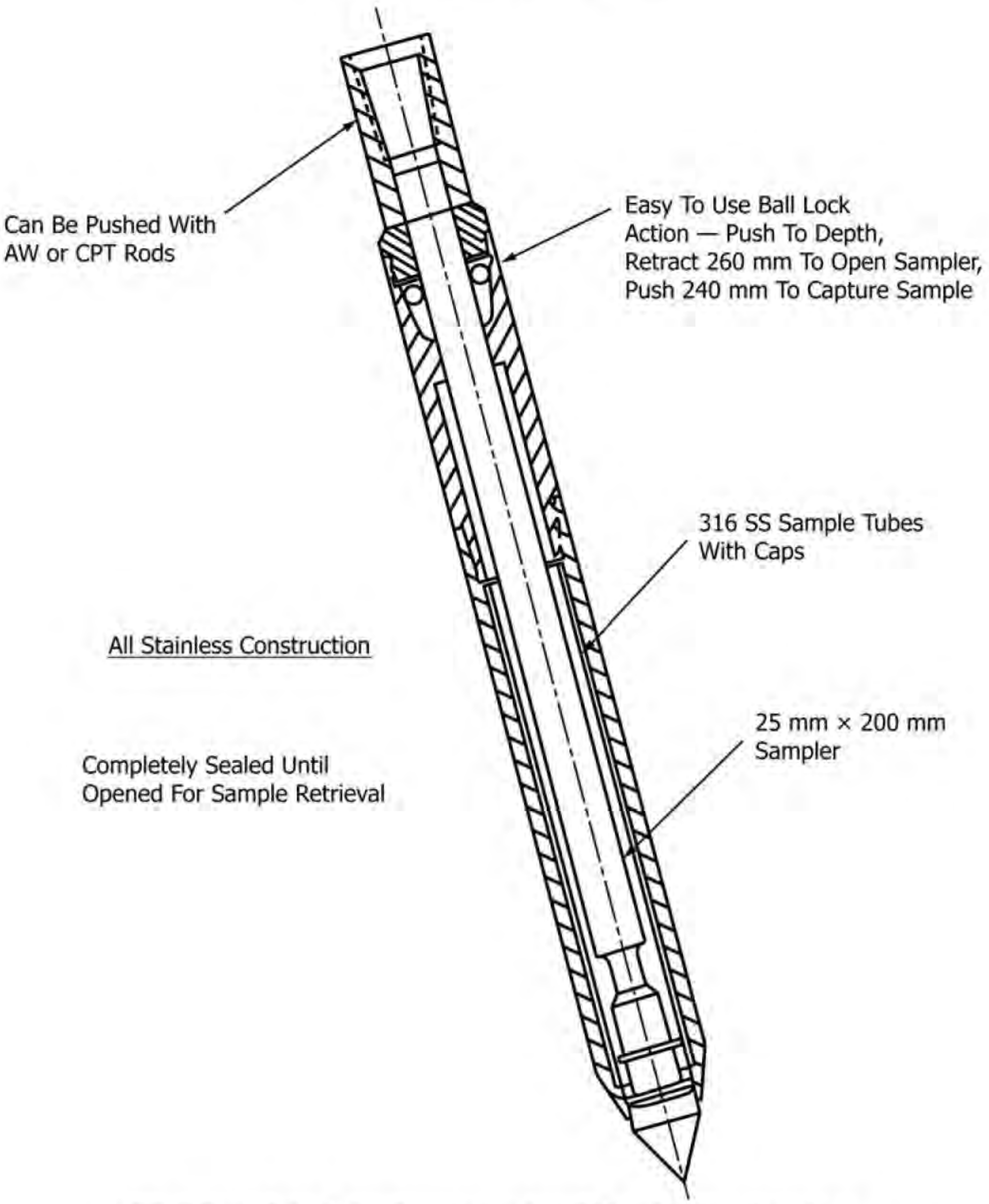


FIG. 7 Single Tube Piston Sampler Used on CPT and Drilling Operations

seals should be checked for each sampling effort. Dual Tube outer rods should have sufficient inside diameter to accommodate the equipment necessary to perform the desired action. For Direct Push monitoring well installation (D6724, D6725) research has shown **(21)** that the minimum nominal 100-mm [4-inches] inside diameter requirement normally specified for rotary drilled monitoring wells (D5092) is not required for the installation of smaller diameter direct push wells.

7.4 *Sampler Liners*—Sampler liners are used to collect and store samples for shipment to laboratories, for field index testing of samples and for removing samples from solid barrel type samplers. Most chemical testing of the soil core, if performed, requires rapid or immediate sub-sampling, containerization, and preservation of samples (see 5.2) for testing and therefore the material of the liner and interaction of the liner with chemicals is not a major concern. Liners are only used to retain soils for long term for classification and geotechnical index properties testing. Liners are available in lengths from 150 mm [6 in.] to 1.5 m [5.0 ft]. Liners should be sealed in accordance with Practice D4220 or sealed subsamples taken when samples are collected for moisture content physical testing. Liners generally are split in the field for subsampling. Individually split liners are available in some sizes for field use. The liner should have a slightly larger inside diameter than the soil specimen to reduce soil friction and enhance recovery (see 7.5). When a slightly oversized liner is used, the potential for air space exists around the sample. Certain chemical samples may be affected by the enclosed air. Liners having less tolerance may be required and a shortened sampled interval used to reduce friction in the liner. Metal liners can be reused after proper cleaning and decontamination. Plastic liners should be disposed of properly after use.