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Nevada
Environmental
Restoration
Project

Corrective Action Investigation Plan for Project Shoal Area CAU No. 416

Controlled Copy No.:

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Environmental Restoration
Division

U.S. Department of Energy
Nevada Operations Office

DOE/NV--454

CORRECTIVE ACTION INVESTIGATION PLAN FOR PROJECT SHOAL AREA CAU NO. 416

DOE Nevada Operations Office
Las Vegas, Nevada

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CORRECTIVE ACTION INVESTIGATION PLAN
FOR PROJECT SHOAL AREA
CAU NO. 416

Approved by: Janet Appenzeller-Wing (signature) Date: 8/21/96

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Nevada Environmental Restoration Project

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List of Acronyms and Abbreviations

AEC	U.S. Atomic Energy Commission
BGS	Below ground surface
CAIP	Corrective Action Investigation Plan
CAS	Corrective Action Site(s)
CAU	Corrective Action Unit
CFR	Code of Federal Regulations
DoD	U.S. Department of Defense
DOE/NV	U.S. Department of Energy, Nevada Operations Office
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DQO	Data Quality Objective(s)
DRI	Desert Research Institute
EPA	U.S. Environmental Protection Agency
ERP	Environmental Restoration Program
FFACO	Federal Facility Agreement and Consent Order
ft	Foot (feet)
HASP	Health and Safety Plan
IDW	Investigation-derived waste
IT	IT Corporation
ITLV	IT Corporation, Las Vegas Office
LDR	Land Disposal Restrictions
LLW	Low-level waste
LTHMP	Long-term Hydrologic Monitoring Program
m	Meter(s)
MCLs	Maximum Contaminant Level(s)
mg/kg	Milligram(s) per kilogram
mg/L	Milligram(s) per liter
mL	Milliliter(s)
NAC	Nevada Administrative Code
NDEP	Nevada Division of Environmental Protection
pCi/g	PicoCurie(s) per gram
pCi/L	PicoCurie(s) per liter

List of Acronyms and Abbreviations *(Continued)*

PPE	Personal protective equipment
PSA	Project Shoal Area
QA/QC	Quality Assurance and Quality Control
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RPD	Relative percent difference
SDWA	Safe Drinking Water Act
SGZ	Surface Ground Zero
SQP	Standard Quality Practice
SQUIRT	Samplers Qualified Under ITLV Required Training
TC	Toxicity Characteristic
TCLP	Toxicity Characteristic Leaching Procedure
TPH	Total petroleum hydrocarbon(s)
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
%R	Percent recovery

1.0 Introduction

This Corrective Action Investigation Plan (CAIP) is part of an ongoing U.S. Department of Energy (DOE)-funded project for the investigation of Corrective Action Unit (CAU) No. 416, Project Shoal Area (PSA). Project Shoal was conducted to determine whether seismic waves produced by underground nuclear testing could be differentiated from naturally occurring earthquakes. The PSA site is located approximately 30 miles southeast of Fallon, Nevada, in the northern portion of Sand Springs Mountains in Churchill County (Figure 1-1). This CAIP will be implemented in accordance with the Federal Facility Agreement and Consent Order (FFACO), the Industrial Sites Quality Assurance Project Plan (DOE, 1994), and all applicable Nevada Division of Environmental Protection (NDEP) policies and regulations (NDEP, 1992).

1.1 Purpose

The PSA CAIP consists of a surface and subsurface PSA investigation. The purpose of the surface investigation is to determine if the materials within a PSA impoundment (mudpit) are contaminated, and if so, to determine the extent of the contamination and the appropriate corrective action. The purpose of the subsurface investigation, as described in the FFACO Appendix VI, is to collect aquifer and groundwater quality data to model the groundwater flow and contaminant transport. This model will then be used to establish a CAU boundary and buffer zone that encompasses the extent of the contamination.

1.2 Scope

The scope of this investigation will include sampling the material in the PSA impoundment, installation of bedrock groundwater monitoring wells, collection of site-specific aquifer data, hydrogeologic modeling, and review of possible remedial actions.

1.3 Federal Facility Agreement and Consent Order Requirements

The FFACO requires that CAIPs include or reference management, technical, quality assurance, health and safety, public involvement, field sampling, and waste management information needed to conduct the investigation. The management aspects of this project are discussed in the U.S. Department of Energy, Nevada Operations Office (DOE/NV) Environmental Restoration Program (ERP) Project Management Plan. The technical aspects of this corrective action investigation are discussed in this document. Field and laboratory Quality Assurance and Quality Control (QA/QC) issues are detailed in the Industrial Sites Quality Assurance Project

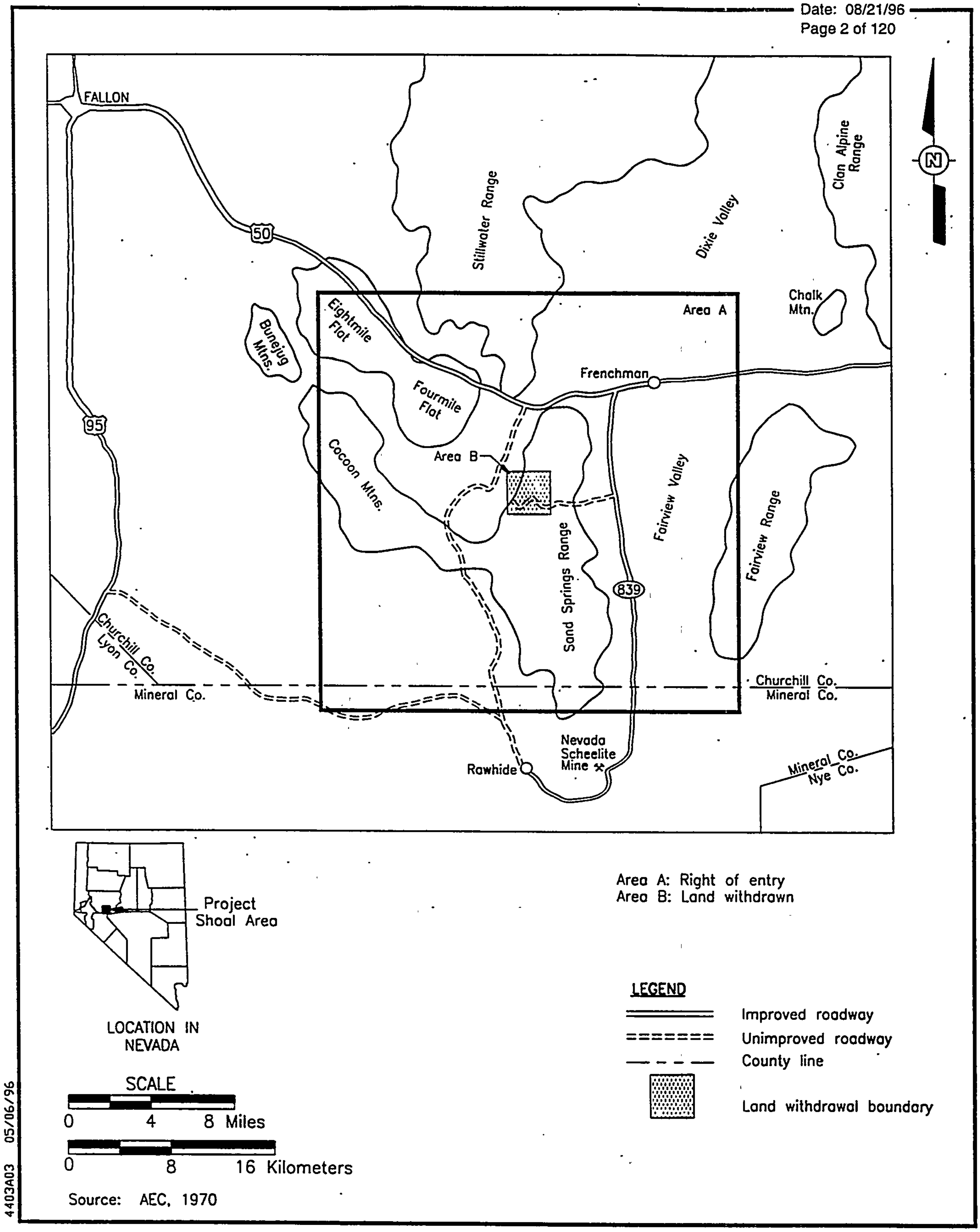


Figure 1-1
Location of the Project Shoal Area

Plan (QAPP) and in approved contractor Standard Quality Procedures. Health and safety are documented in the DOE/NV ERP Health and Safety Plan (HASP) and a site-specific HASP will be written just prior to commencement of field work. Public involvement will follow the requirements stipulated in the Public Involvement Plan in Appendix V of the FFACO. Field sampling activities are discussed in Section 4.0 of this CAIP and waste management is described in Section 5.0 of this CAIP.

2.0 Project Shoal Area Site History

2.1 Overview

Detailed information on the site history can be found in the draft *Project Shoal Preliminary Site Characterization Report* (DOE, 1996), which was used as the source of information for this section. Project Shoal was part of the Vela Uniform Program, a joint effort of the U.S. Department of Defense (DoD) and the U.S. Atomic Energy Commission (AEC) to study the effects of different geological media on seismic waves produced by underground nuclear detonations and to determine if seismic waves produced from underground nuclear testing could be differentiated from natural earthquakes (Desert Research Institute [DRI], 1988). The PSA in Churchill County, Nevada (Figure 2-1), was selected as the tentative PSA site in 1961 and after a yearlong geologic exploration of the area, it was confirmed as the chosen site and preparations for the test began in late 1962.

The Shoal event consisted of detonating a nuclear device with a 12-kiloton yield on October 26, 1963. The device was placed in granitic rock at 367 meters (m) (1,204 feet [ft]) below ground surface via a 3.7- by 1.8-m (12- by 6-ft) shaft, 402 m (1,320 ft) deep; a 2.4- by 2.4-m (8- by 8-ft) drift, 320 m (1,050 ft) to the east; and a 9-m (30-ft) vertical "buttonhook raise" (AEC, 1970, p. 9). In addition the drift was extended 97 m (320 ft) west from the base of the shaft.

Data collected from the post-shot drill-back indicated that the shot cavity collapsed, producing a rubble-filled chimney 52 m (171 ft) in diameter and 109 m (356 ft) high with an 11-m (36-ft) void at the top (Korver et al., 1965, p. 4-5). The actual source term for the event is not available, however, using the estimates from Borg et al. (1976) the combined inventory from the fission products and neutron activation has decayed to less than 1 percent of the original inventory. Residual radionuclides are most likely contained in the insoluble melt rubble at the bottom of the shot cavity.

There was no venting of particulate debris during or after the explosion although some radionuclides, mostly gases, may have been injected into fractures as far as 135 m (443 ft) from the shot point. Gaseous short-lived radionuclides (iodine-131, xenon-131m, and xenon-133) were liberated into the air during drill-back or were brought to the surface on drill equipment or in circulating drilling mud. These radionuclides were trapped by filters and were subsequently

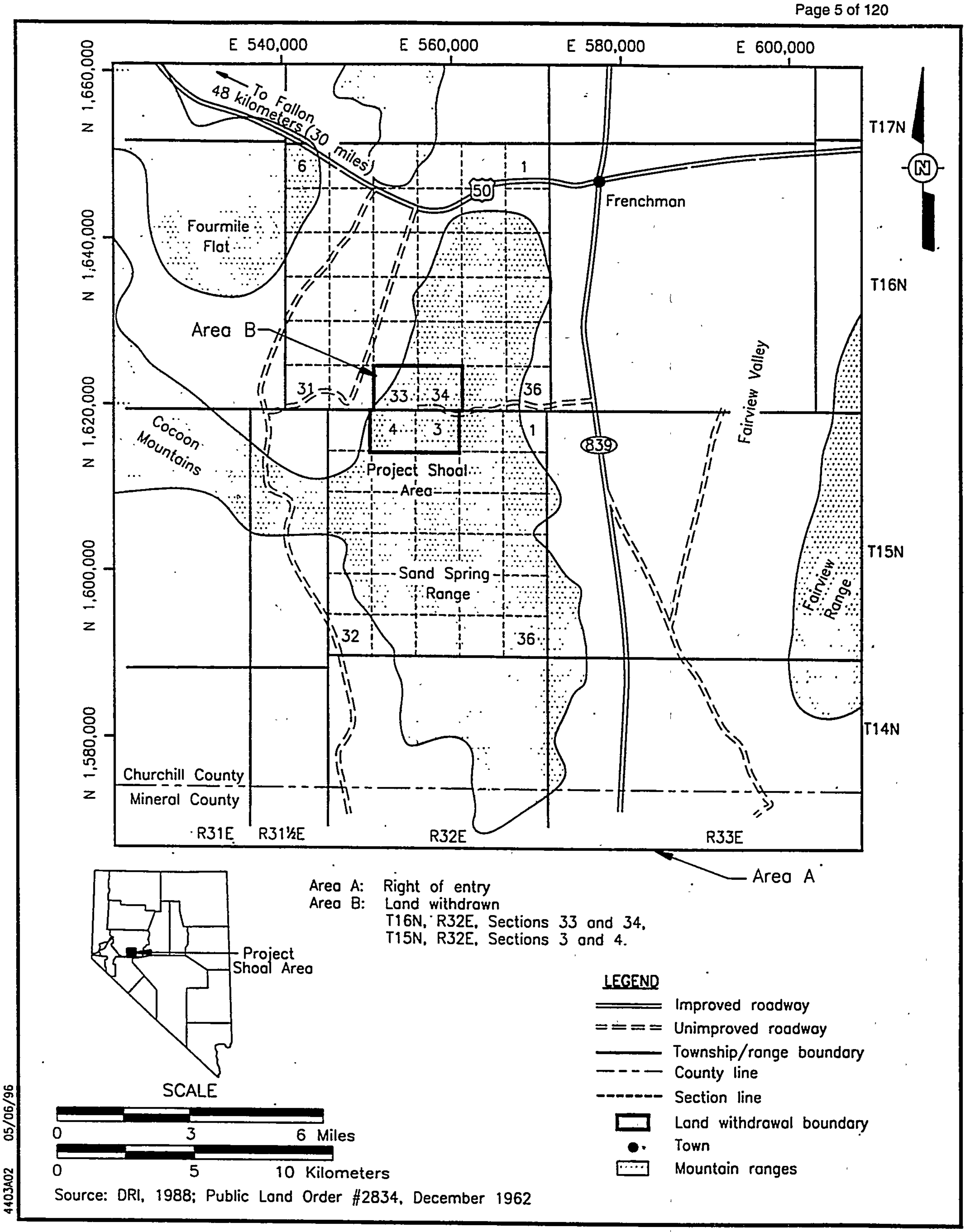


Figure 2-1
Project Shoal Area

mixed with clean soil and buried in the impoundment area (mudpit) beneath uncontaminated soil (Gardner and Nork, 1970, p. 39).

2.2 Potential Site Contamination

Review of pre-event site characterizations, operations, closure reports, and aerial photos has identified two areas within the PSA that may have been impacted by the underground test and support activities conducted at the site: the post-shot mudpit and the shot cavity. Surface contamination is associated with the impoundment (mudpit) used during the post-shot drilling activities. Localized groundwater contamination around the shot cavity is probable, although no site-specific groundwater data have been collected with respect to radionuclide contamination. Water quality data from wells and springs to the east and west of the PSA Surface Ground Zero (SGZ) area are collected annually as part of the off-sites Long-term Hydrologic Monitoring Program (LTHMP), but data cannot currently be collected from the immediate SGZ area because the PSA test borings and wells have all been abandoned.

In the FFACO, the following five corrective action sites (CASs) are identified at the PSA area:

- Muck Pile (emplacement shaft cuttings), CAS 57-06-02
- Mudpit (impoundment), CAS 57-09-01
- Emplacement Shaft, CAS 57-49-01
- Event Cavity, CAS 57-57-001
- Waste Pile/Oil Cans, CAS 57-98-01

Only the mudpit (impoundment) will be sampled during the PSA corrective action investigation. The waste pile/oil cans will be addressed under the ERP "Housekeeping" sites sampling program, and it is assumed that the emplacement shaft will be backfilled with the material in the muck pile. Analytical samples from the event cavity cannot be collected, so it will not be addressed as a part of the CAIP.

2.2.1 PSA Impoundment

Review of the above mentioned reports and photos and a site visit have identified only one drilling mud impoundment (mudpit) at the PSA. During a site visit on August 23, 1994, by DOE and IT Corporation (IT) representatives, an impoundment 12 to 15 m (40 to 50 ft) in diameter that appeared to contain drilling mud was located (Deshler, 1996). The location of this impoundment corresponds well with the post-shot impoundment location indicated in Fauver's (1986) *Hazardous Waste Installation Assessment Report,* (Figure 2-2). A site visit by DOE and

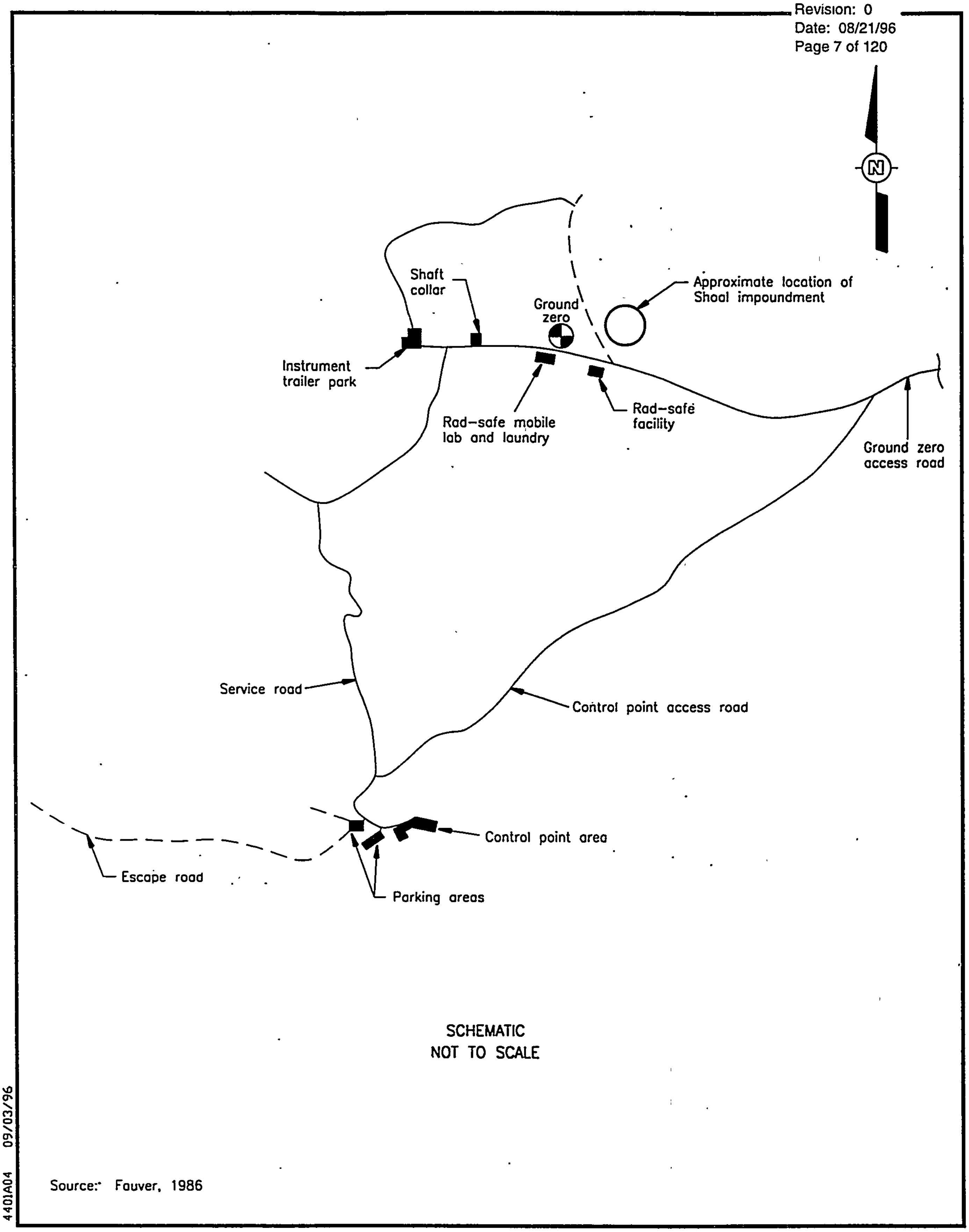


Figure 2-2
Approximate Location of Project Shoal Area Impoundment

IT representatives on March 12, 1996, documented the location and the dimensions of this impoundment (Figure 2-3). Historical documents suggest a second pit may exist; however, a thorough site reconnaissance failed to locate it.

All contaminated soil and cuttings resulting from the post-shot drilling activities were reportedly combined with clean soil and buried in the impoundment area. The three identified contaminants of concern in this soil were short-lived radioisotopes: of iodine (iodine-131) and xenon (xenon 131m and xenon-133). Iodine-131 and xenon-131m decay to a stable isotope of xenon (xenon-131) in 8 and 11.8 days, respectively, and xenon-133 decays to a stable isotope of cesium (cesium-133) in 5.2 days. Because of the short half-lives of these radionuclides, it is likely that they have decayed to below detectable levels in the soils buried in the impoundment. There were no documents detailing the release of nonradioactive hazardous materials found during the literature/records review completed as part of the preliminary site characterization process. One soil sample was collected from the surface of the impoundment and analyzed for toxicity characteristic (TC) metals (as discussed in the *Hazardous Waste Installation Report,* [Fauver, 1986]). The results of the Toxicity Characteristic Leaching Procedure (TCLP) analysis showed 8.2 milligrams per liter (mg/L) of barium. The detected barium concentration is 8 percent of the 100 mg/L concentration considered hazardous in Title 40 Code of Federal Regulations (CFR), Section 261.24 (Fauver, 1986, p. 19). No other metals were identified in the sample.

2.2.2 Groundwater

Groundwater contamination at PSA is associated with the installation and yield of the Shoal test device and neutron activation of the Sand Springs granite adjacent to the shot cavity. No LTHMP points or monitoring wells exist within the 2,560-acre withdrawn area because the PSA test borings and wells were abandoned (Figure 2-4). A regional groundwater monitoring well and spring sampling network is currently maintained by the U.S. Environmental Protection Agency (EPA) in its PSA LTHMP (Figure 2-5). Bedrock monitoring wells will be installed at the SGZ area to investigate potential radionuclide transport and water quality near the shot cavity. The new wells will be added to the LTHMP after the initial round of groundwater samples are collected. Well installation details and objectives are provided in Appendix A.

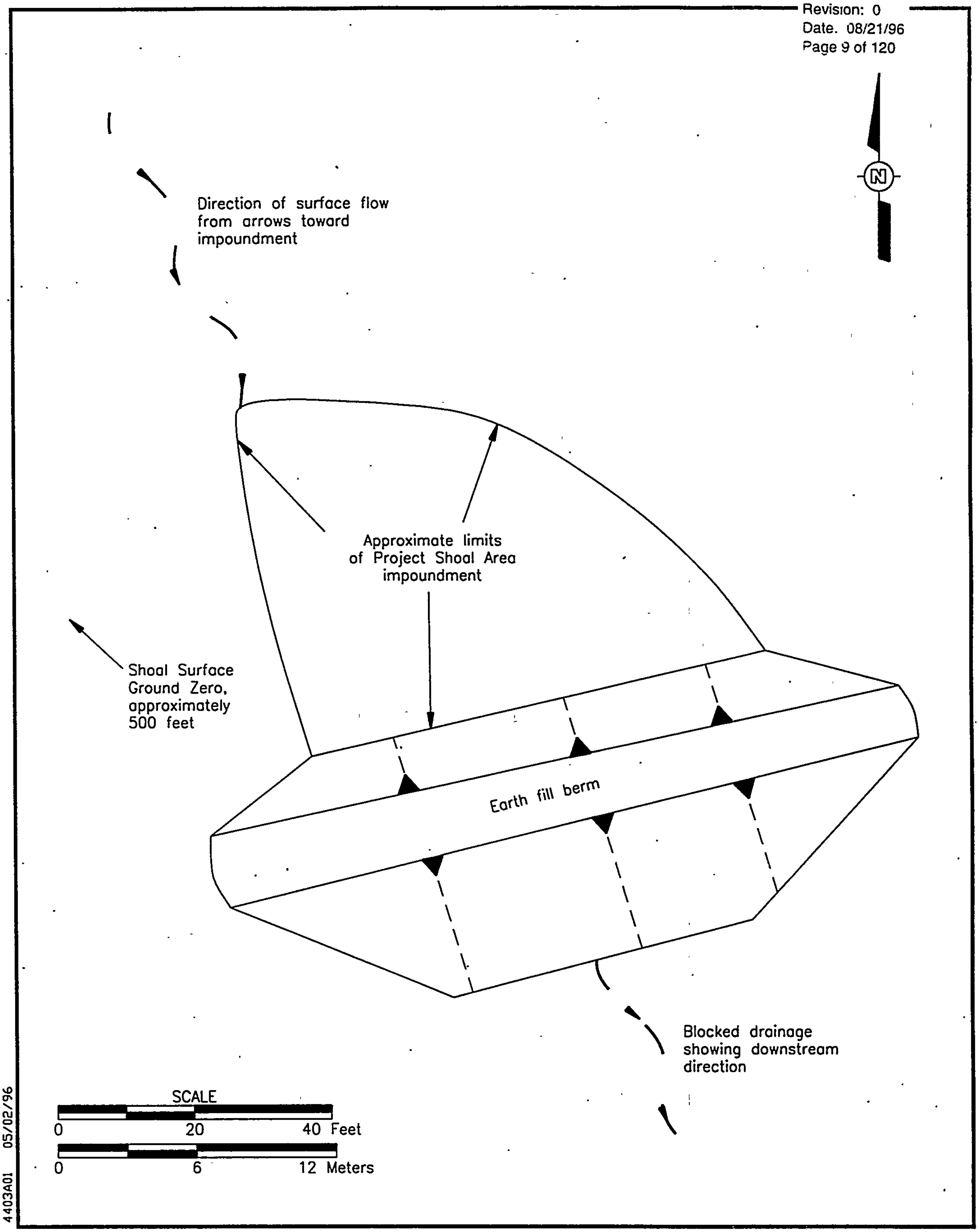


Figure 2-3
Approximate Configuration of Berm and Impoundment Project Shoal Area

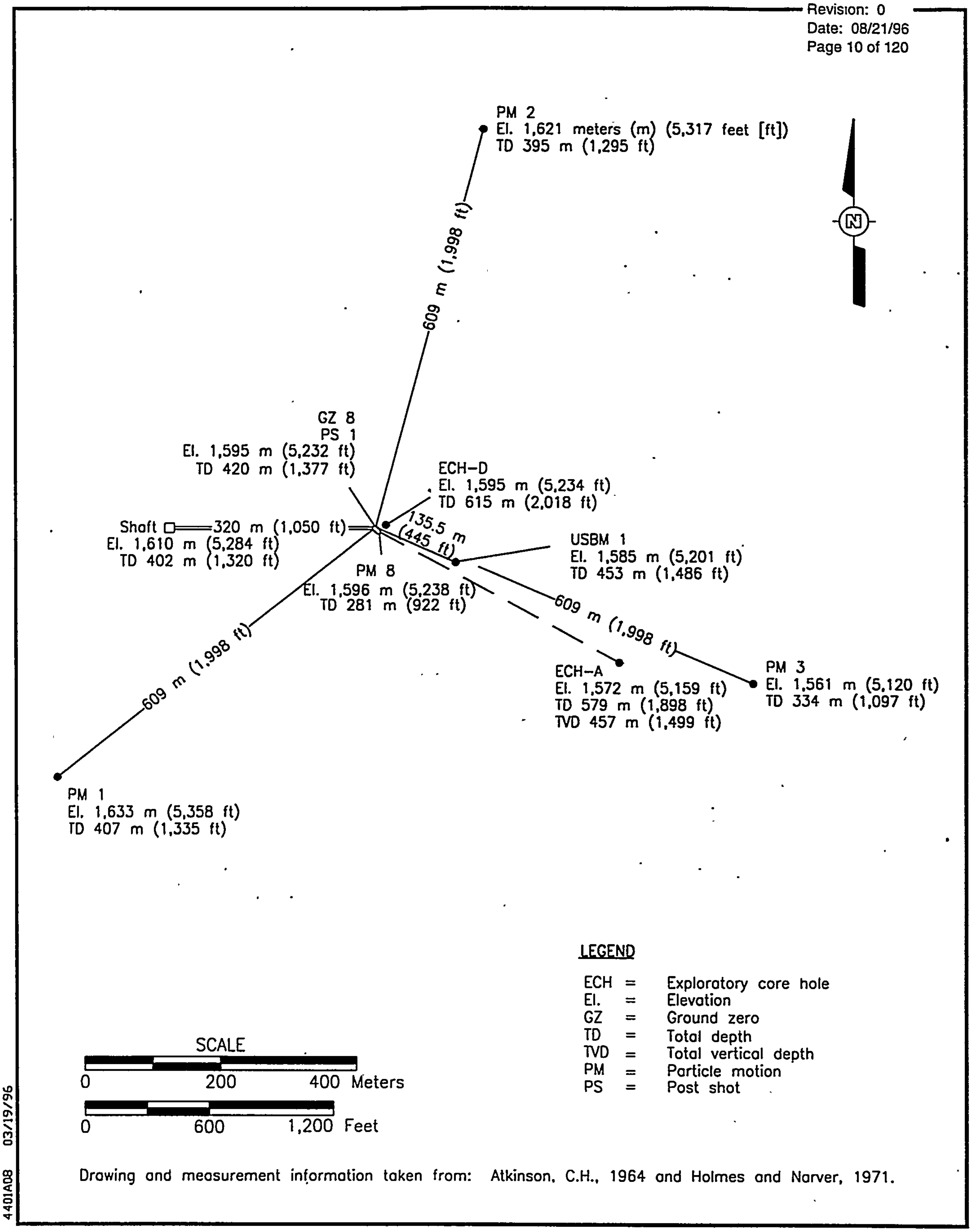


Figure 2-4
Location of Deep Borings

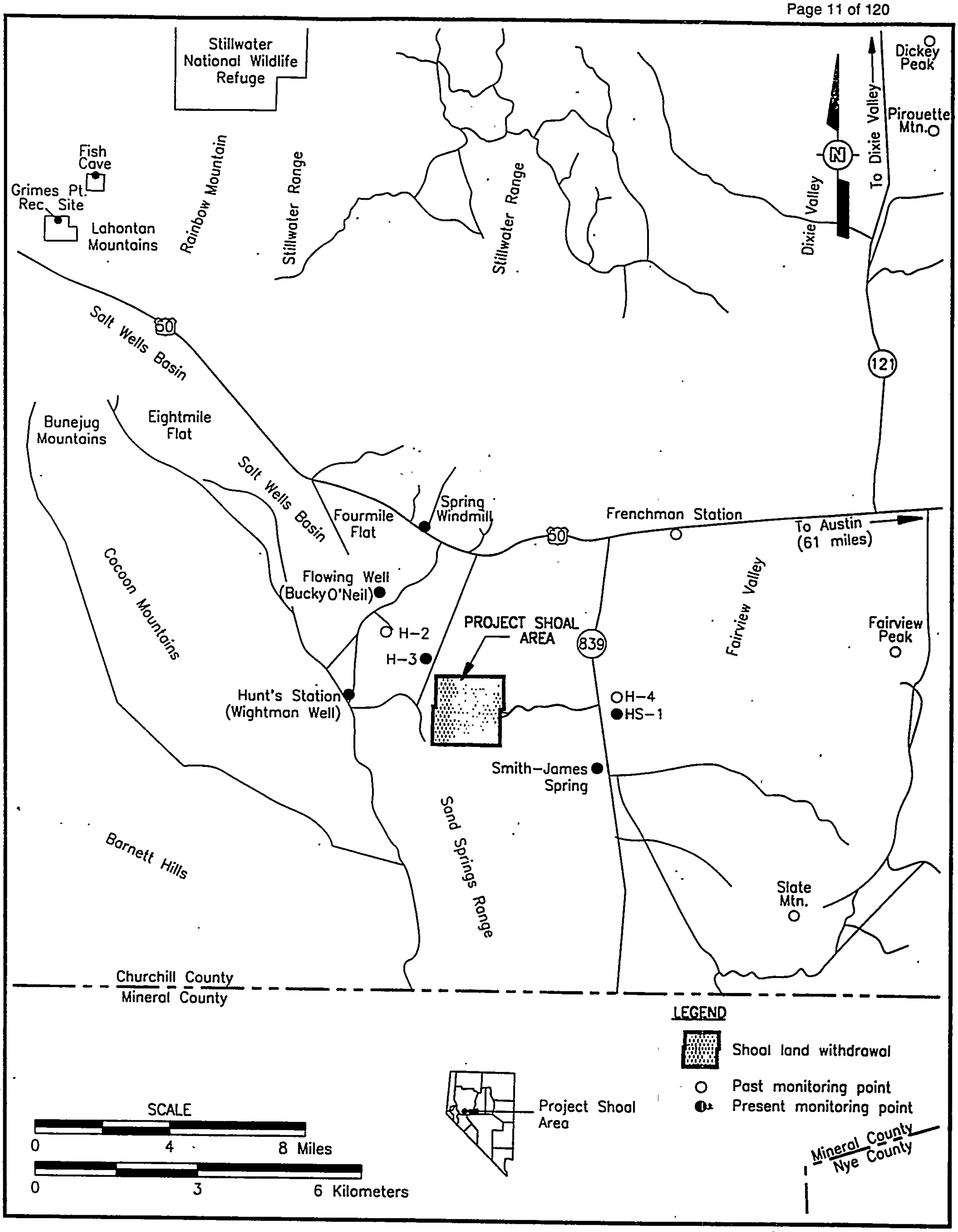


Figure 2-5
Long-term Hydrological Monitoring Program Sampling Locations for the Project Shoal Area

3.0 Objectives

The objectives for the corrective action investigation of the PSA site were established by using the Data Quality Objectives (DQO) process developed by the EPA (1993 and 1994). The DQOs are qualitative and quantitative statements that specify the type, amount, and quality of the environmental data required to support corrective action decisions for the site.. The DQO process was employed to clearly define the purposes for which environmental data will be collected and used, and to design a data collection program that will satisfy these purposes.

3.1 Surface Conceptual Model (Soil)

A preliminary site conceptual model has been developed to identify potential contaminant migration routes and exposure pathways from the impoundment (Figure 3-1). The conceptual model is based on the following assumptions:

- The impoundment is situated in an arroyo.
- The bottom of the impoundment is within a short vertical distance of, if not directly on, granitic bedrock (Figure 3-1).
- Groundwater is approximately 305 m (1,000 ft) below the ground surface (BGS).
- The material present in the impoundment is a relatively homogeneous mixture of native soils, drill cuttings, and drilling mud and is covered by at least 2 feet of clean native soil.

The preliminary conceptual model postulates that there is one contaminant migration route from the impoundment: mobilization and transport downstream along the soil/bedrock interface. The potential exposure route is by ingestion and/or inhalation of contaminated soil resulting from intrusion into the impoundment or arroyo sediments.

3.2 Subsurface Conceptual Model (Groundwater)

Regional groundwater conditions at the PSA have been generally outlined in previous studies of the Sand Springs range and vicinity by DOE, Desert Research Institute (DRI), U.S. Geological Survey (USGS), and others (Appendix A). Hydrogeologic data collected to document pre-shot conditions indicate the Sand Springs Range is a groundwater recharge area (University of Nevada, 1965). Intermittent runoff from seasonal precipitation infiltrates the thin soil veneer at PSA and penetrates the water-bearing joints, fractures, and faults of the Sand Springs granite as

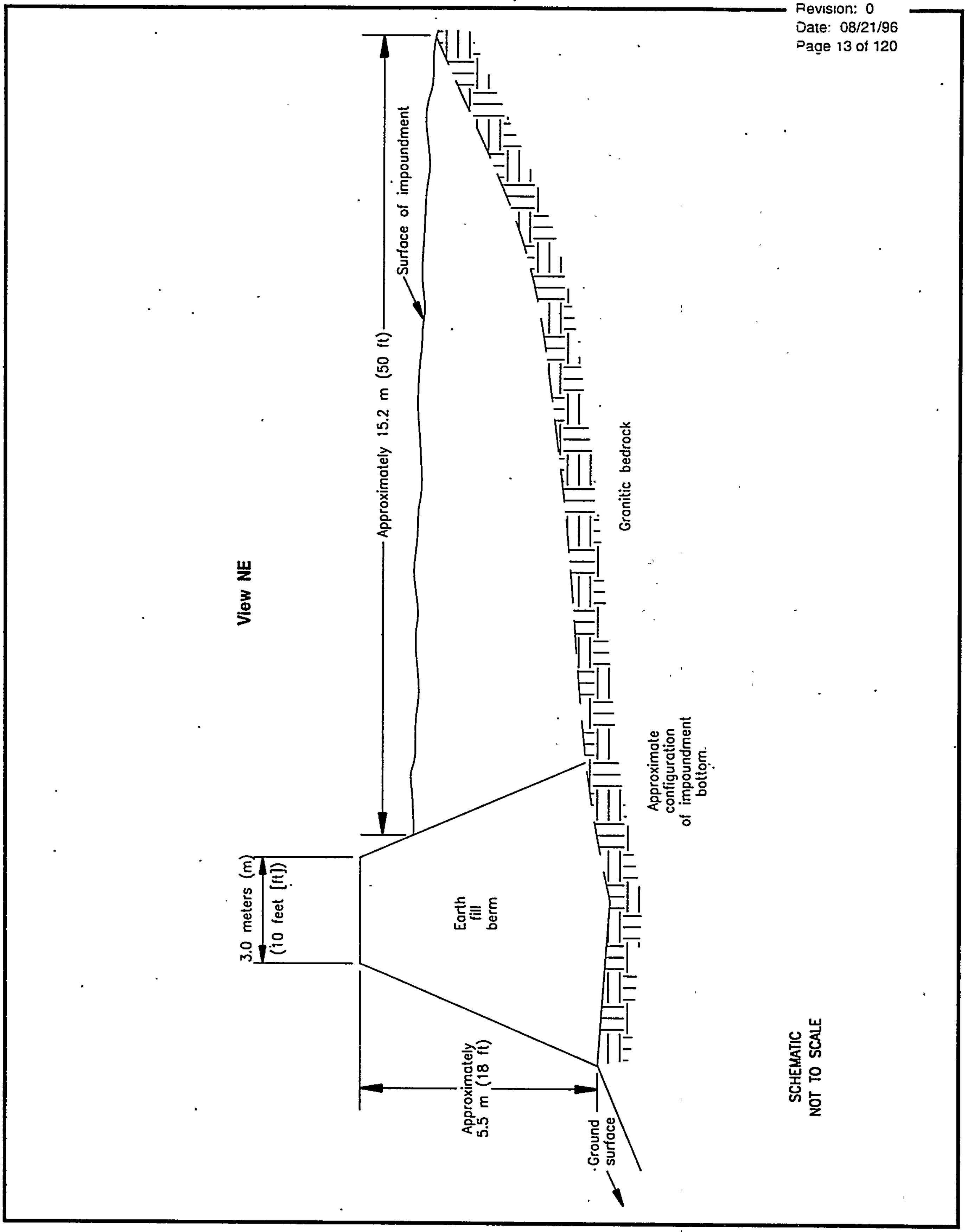


Figure 3-1
Diagramatic Cross Section
Shoal Impoundment

unsaturated flow to the water table about 305 m (1,000 ft) BGS. Groundwater velocity is poorly defined, but limited hydrologic data suggest a groundwater flow divide exists to the west of SGZ that splits the regional flow direction into easterly and westerly components (Cohen and Everett, 1963) (Figure 3-2). Both hydraulic conductivity and the local and regional hydraulic gradients are also poorly defined in the area.

As discussed in Gardner and Nork (1970), the PSA detonation essentially dewatered the area immediately adjacent to the shot cavity, lowering the groundwater level in the vicinity of the working point. The groundwater system has likely returned to pre-shot conditions over the 33 years since the test and the shot cavity is probably now filled with groundwater. Over the time since the test, radionuclides with short half-lives have decayed to below the Recommended Concentration Guide. Because radionuclides with relatively long half-lives, except tritium, tend to sorb to mineral surfaces, these contaminants are not expected to readily transport from the immediate shot cavity and chimney area. In addition, some radionuclides will remain encased within the melt glass of the shot cavity. Because tritium does not sorb, its transport from the shot cavity area likely commenced once the shot cavity was filled with groundwater.

Groundwater flow and contaminant transport at PSA is governed by the physical makeup of the fractures in the Sand Springs granite (e.g., fracture extent, interconnection, size, shape, orientation). Groundwater modeling will be completed to predict flow and the fate and transport of radionuclide contaminants at PSA. Historical groundwater data and specific objectives and details of the proposed groundwater model for PSA are presented in Appendix A.

3.3 Contaminants of Potential Concern

3.3.1 Surface (Soil)

As discussed in Section 2.2.1, the PSA impoundment was used to store drilling effluent generated during drilling of the post-shot borehole PS-1. The drilling fluids used were bentonite drilling mud, air, and air-mist. Because the post-shot borehole penetrated the shot cavity, fission products resulting from the test are the primary contaminants of potential concern. A daily log for the post-shot borehole drilling operation is provided in the *Project Manager's Report Project Shoal* (AEC, 1964). The daily log indicates that drilling mud was used to:

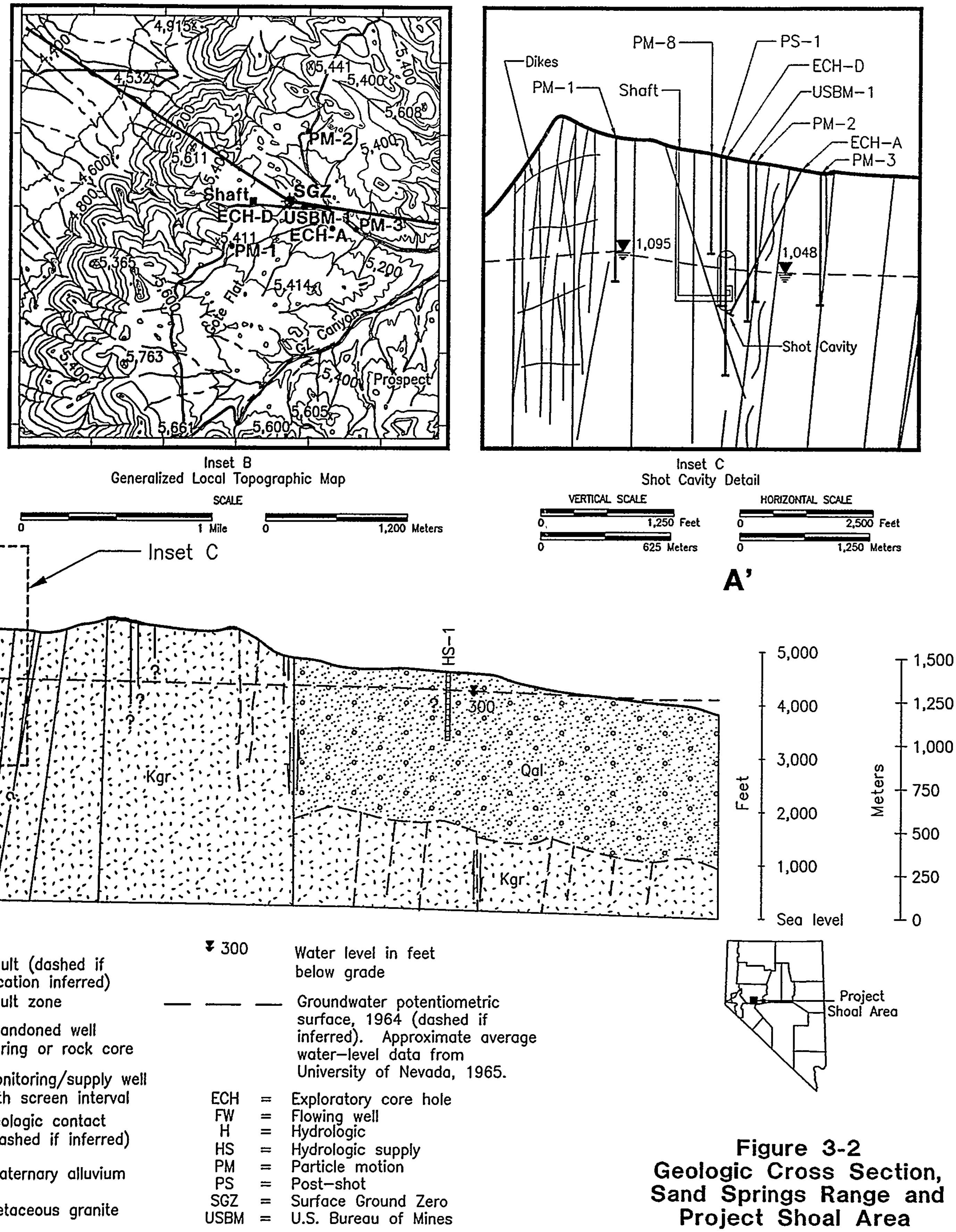
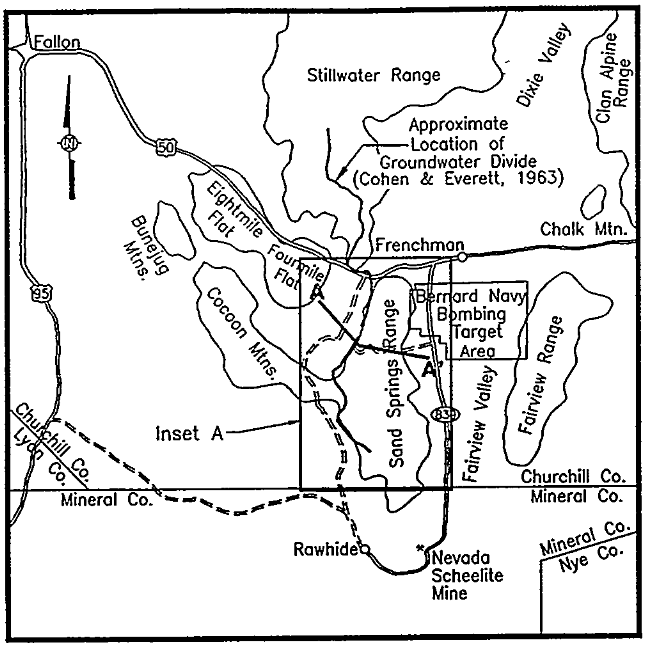


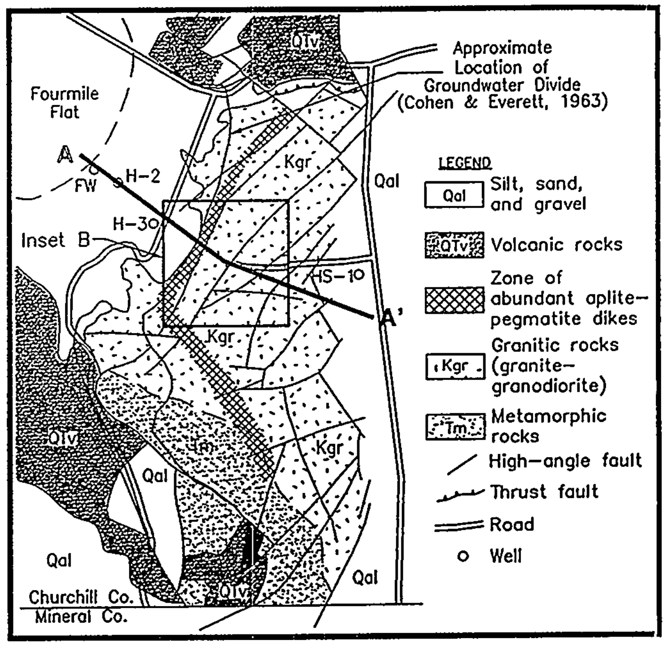
Figure 3-2
Geologic Cross Section, Sand Springs Range and Project Shoal Area



Sand Springs Range
Site Location Map and Lines of Cross Section

SCALE

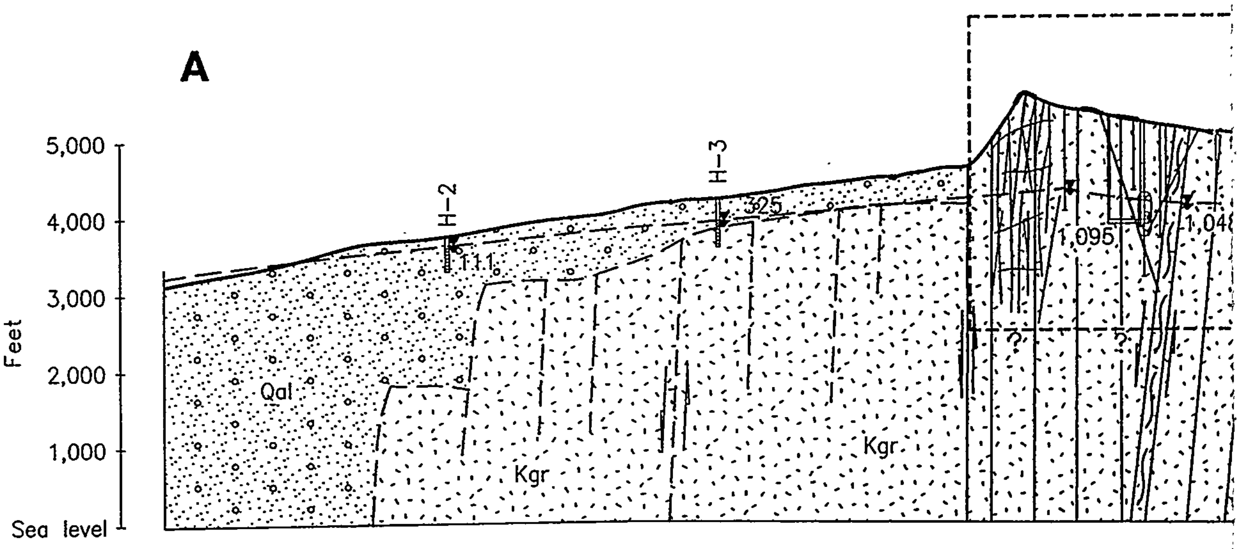
0 12 Miles 0 20 Kilometers



Inset A
Generalized Regional Geologic Map

SCALE

0 6 Miles 0 9,000 Meters



APPROXIMATE VERTICAL SCALE

0 2,500 5,000 Feet

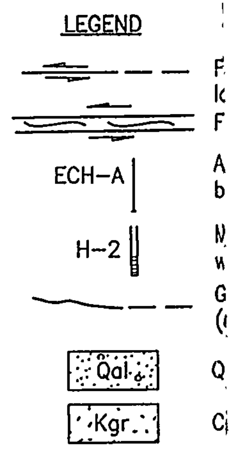
0 1,250 2,500 Meters

APPROXIMATE HORIZONTAL SCALE

0 5,000 10,000 Feet

0 1,500 3,000 Meters

VERTICAL EXAGGERATION = 2X



Sources: Compiled and modified from:
Atkinson, 1964
Cohen and Everett, 1963
Hazelton–Nuclear Science Corp., 1965
Holmes and Narver, 1971
University of Nevada, 1965
U.S. Atomic Energy Commission, 1970
U.S.G.S. Fourmile Canyon Topographic Quadrangle, 1979

Notes: For detailed shaft, drift, and shot cavity geology, see University of Nevada, 1965.

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- Drill through the uppermost 100 feet of rock
- Combat a loss of circulation in the uppermost 183 m (600 ft) of the hole: both drilling mud and cement grout were used for this purpose
- Drill through cement grout from grade to 183 m (600 ft) BGS; the grout was introduced to the hole to fix the loss of circulation
- Attempt to drill through boulders from approximately 920 to 970 feet BGS.

The daily log also suggests that no diesel and/or other drilling mud additives were used in the post-shot borehole drilling mud except for loss-of-circulation materials. Additives used to combat the circulation problems included cotton seed husks and cane fibers. Because diesel was typically used for its lubricating properties for drilling in fine-grained material (like shale), it may not have been needed for drilling in granite or cement grout, nor was it likely to be needed for controlling the loss of circulation. Based on the information provided in the daily log, contamination of the drilling mud by total petroleum hydrocarbons (TPH) or other substances such as barium (from barite) or chromium (from chrome lignosulfonate) is not expected. Barite and chrome lignosulfonate additives have been used in drilling mud at other sites, such as the Central Nevada Test Area.

Air was used to drill through rock (before the circulation loss problem was encountered) from 30.5 to 183 m (100 to 600 ft) BGS, and air-mist (a mixture of air, water, and detergent) was used to drill from 183 m (600 ft) BGS to the bottom of the hole at approximately 424 m (1,391 ft) BGS. No contaminants other than fission products are expected in the effluent from the air and air-mist drilling operations.

3.3.2 Subsurface (Groundwater)

The primary contaminants of concern for groundwater are man-made radionuclides resulting from underground testing at the PSA including:

- Original nuclear material that has not undergone fission or thermonuclear reaction
- Direct products of nuclear reaction, such as the fission products cesium-137 and strontium-90
- Neutron activation products in the immediate vicinity of the explosion, such as tritium

These contaminants can migrate by leaching into the groundwater, by direct injection, or by fracture injection. To date, there have been no site-specific sampling efforts to detect radionuclides in the groundwater at the PSA.

3.4 DQO Process

The DQO process is a systematic planning tool for establishing criteria for data type, quantity, and quality and for developing data collection programs that satisfy the needs of the project. It is an iterative seven-step process as follows:

- State the problem
- Identify the decision
- Identify the inputs to the decision
- Define the study boundaries
- Develop a decision rule
- Specify limits on the decision errors
- Optimize the design for obtaining data

These seven steps have been applied to the PSA site to identify a course of action.

3.4.1 Statement of the Problem

3.4.1.1 Surface (Soil)

The soil present in the PSA impoundment may contain contaminants that pose a threat to human health and the environment. In addition, surface water flowing into the impoundment could mobilize contaminants and transport them through the containment dike, underneath the dike, or along the soil/bedrock interface into the arroyo sediments downstream from the dike.

3.4.1.2 Subsurface (Groundwater)

The PSA underground nuclear test was detonated below the water table. Although the transmissive properties of the Sand Springs granite are believed to be poor (Nevada Bureau of Mines et al., 1964), the test was conducted in a groundwater recharge area and flow of groundwater through the cavity and the surrounding area is expected. There are no groundwater monitoring wells in the immediate SGZ area to determine if there is a threat to groundwater and assess groundwater flow direction.

3.4.2 Identification of the Decision

3.4.2.1 Surface (Soil)

The decisions to be made for the surface are whether the material in the impoundment is contaminated, whether the contaminant is migrating, and if so, what actions need to be taken. This CAIP has been designed to generate sufficient environmental data to determine the presence or absence of contamination in the impoundment and, if contamination is present, to support selection of the appropriate remedial action to address the contamination.

3.4.2.2 Subsurface (Groundwater)

The primary decision to be made for the subsurface is the location of the acceptable contaminant boundary within which water use restrictions will be implemented to prevent exposure to potentially contaminated groundwater. Remediation of the groundwater is not practical because the primary contaminant of concern (tritium) is not treatable/removable using any known treatment technologies.

3.4.3 Identification of Inputs to the Decision

3.4.3.1 Surface (Soil)

The primary inputs to the decision will be chemical analytical data from soil samples collected from the impoundment and from the arroyo sediments downstream from the impoundment.

3.4.3.2 Subsurface (Groundwater)

The primary inputs to support decisions for the subsurface will be the extent of groundwater contamination, which will be estimated through numerical groundwater flow and contaminant transport modeling. The data needed for modeling are the type and amount of contaminants generated by the test that could be available to migrate and the physical flow characteristics of the aquifer.

- Literature reviews, including information on the estimated yield of the PSA test, will be used to identify the type and amount of contaminants that could be available to migrate.
- Data on physical flow characteristics will be gathered from existing literature for the site and for similar aquifers (if available) and from test data from the newly installed monitoring wells.

3.4.4 Definition of the Study Boundaries

3.4.4.1 Surface (Soil)

The horizontal boundaries of the study area are 3 m (10 ft) around the impoundment and above the containment dike and 15 m (50 ft) down the arroyo from the downgradient toe of the containment dike. The vertical boundaries are the top of the material in the impoundment and 0.6 m (2 ft) below the bottom of the impoundment material or until refusal (Figure 3-1).

3.4.4.2 Subsurface (Groundwater)

The spatial extent of the subsurface study area is from well H-3 in the basin on the west to well HS-1 in the basin on the east, and the current institutional boundaries on the north and south (Figure 2-5).

3.4.5 Development of the Decision Rules

3.4.5.1 Surface (Soil)

The analytical results for the samples collected from the impoundment and adjacent soils will be used to determine if the impoundment requires remediation. If concentrations for all targeted analytes are below action levels (see Section 3.5.1 for a discussion of action levels), no further action will be required. If concentrations for targeted analytes are equal to or greater than action levels, remedial alternatives will be evaluated, such as no action, removal and off-site disposal, and *in situ* containment and capping, and an appropriate alternative will be selected based on the type(s), concentration(s), and mobility of contaminants encountered.

3.4.5.2 Subsurface (Groundwater)

If the predicted contaminant boundary is outside of the current institutional boundary, the boundary will be expanded to the predicted contaminant boundary.

3.4.6 Specification of Limits on Decision Errors

3.4.6.1 Surface (Soil)

The primary decision errors in implementing the surface investigation portion of this CAIP are deciding that no further action is required when concentrations of contaminants of potential concern in the impoundment actually exceed action levels (a false positive error) or deciding that active remedial action is required when concentrations of all contaminants of potential concern are actually below action levels (a false negative error).

The primary consequence of a false positive error is that contamination would remain in place without controls and potential threats to human health and the environment would continue. The primary consequence of a false negative error would be spending funds on active remediation when no remedial action was required.

Control of potential errors depends foremost on an accurate representation of the site in the conceptual model (Section 3.1) because the conceptual model is used to design the sampling and analysis program. If the conceptual model is accurate, the sampling and analysis program generally will provide adequate data for supporting decisions. The decision error rate goal for the surface investigation portion of this project has been set at no more than a 10 percent chance of making a decision error.

3.4.6.2 Subsurface (Groundwater)

The primary decision errors in implementing the subsurface investigation portion of this CAIP are deciding that the existing institutional boundary is sufficient to prevent contact with contaminated groundwater when the contaminant boundary actually should be expanded (a false positive error) or that the contaminant boundary needs to be expanded to protect human health and the environment when the existing boundary is adequate for that need (a false negative error).

The primary consequence of a false positive error is that there would be no controls on water use in portions of the groundwater system that could be impacted by contaminants and potential threats to human health and the environment would continue. The primary consequence of a false negative error would be restricting or eliminating water use in areas that the plume will not impact. It should be noted, however, that the long-term hydrologic monitoring program will continue regardless of where the contaminant boundary is established, which will provide added protection to human health and the environment through point-of-use monitoring.

3.4.7 Optimization of the Design for Obtaining Data

The sampling and analysis program for the PSA site is described in Section 4.0. This program is designed to provide sufficient environmental data to support the remedial decisions to be made for the impoundment and PSA groundwater, and to minimize the potential for making decision errors.

The sampling program for the impoundment has been designed to provide sufficient data to allow statistical determination of whether targeted analytes are presented in the impoundment soils at hazardous levels. This determination will be made using the procedures described in Chapter 9 of the EPA publication SW-846, *Tests Methods for Evaluating Solid Waste, Physical/Chemical Methods.* The mean concentration (or activity) and standard deviation of each targeted analyte in the impoundment soils will be used to calculate the number of samples necessary to make that determination at the 90 percent confidence level (equivalent to the decision error rate goal discussion in Section 3.4.6.1). Based on the existing information about the likely concentrations of the contaminants of concern in the impoundment soils, it was decided by the DQO process participants that nine composite samples of the soils in the impoundment would be sufficient for the statistical determination. The samples will be collected in a systematic fashion using a grid to ensure adequate coverage of the impoundment.

As discussed in Section 3.4.3.2, the decision for the groundwater contaminant boundary will be based primarily on modeling results. Contaminant boundaries will be identified at several confidence levels, including the 90 percent confidence level, as discussed in Appendix VI, Section 3.2 of the FFACO.

3.5 Measurement Objectives

3.5.1 Surface (Soil)

As discussed in Section 3.3.1, the primary contaminants of concern for the PSA impoundment are fission products, and all soil and sediment samples collected from the study area will be analyzed for these contaminants. To verify that diesel fuel or other common drilling mud additives were not used in the post-shot borehole drilling mud, the samples collected from within the impoundment will be analyzed for TPH, total barium, and total chromium.

The decision rules for the impoundment are based on whether targeted analyses exceed action levels. The action levels identified for this CAIP are not necessarily the cleanup goals for the impoundment, but are only intended to ensure that the analytical methods selected for the project are capable of measuring the contaminants of potential concern at or below levels of concern. For the purpose of this CAIP, the action levels in soil for the targeted analytes are:

- Fission products (man-made radionuclides) - analytical laboratory reporting limits
- TPH - 100 milligrams per kilogram (mg/kg), which is the NDEP regulatory action level for TPH (Nevada Administrative Code [NAC] 459.9973)
- Barium (total) - 4,000 mg/kg, which is the draft 40 CFR 264 Subpart S-recommended action level for barium
- Chromium (total) - 400 mg/kg for chromium, which is the draft 40 CFR 264 Subpart S-recommended action level for hexavalent chromium. Although hexavalent chromium is not expected in the impoundment, there is no Subpart S-recommended action level for trivalent chromium when direct contact is the pathway of concern; in the hexavalent chromium value is being used to establish measurement objectives.

The draft 40 CFR 264 Subpart S-recommended action levels were selected in accordance with the NDEP Contaminated Soil and Ground Water Remediation Policy (NDEP, 1992) for sites where ingestion or dermal exposure to contaminants is the primary exposure pathway.

The analytical measurement objectives for the soil and sediment samples have been established at 50 percent of the action level value to ensure that the analytical methods selected for the project are capable of meeting quantitation limit needs for the project. Table 3-1 provides a list of the analytical methods to be used, the measurement objectives for the targeted analytes, and the quantitation limits for the targeted analytes. The quantitation limits are typically reported by the analytical laboratory to be used for the project for the specified analytical methods. As indicated in the table the analytical methods specified for the project are capable of measuring the targeted analytes at levels significantly below the measurement objectives.

Table 3-1 also lists the analytical accuracy and precision typically achieved by the analytical laboratory for the methods specified.

3.5.2 Subsurface (Groundwater)

As discussed in Section 3.4.3.2 and Appendix A, the primary inputs to the groundwater compliance boundary decision will be the modeling results. Groundwater analytical data collected from the new monitoring wells will be used to augment and enhance data from the literature for the modeling effort.

Table 3-1
PSA Impoundment Investigation Measurement Objectives

Analyte	Method	Measurement Goal	Analytical Reporting Limit	Precision (RPD)	Accuracy (%R)
Gross Alpha	SM 7110[a]	1 pCi/g	1 pCi/g	±25	75-125
Gross Beta	SM 7110	3 pCi/g	3 pCi/g	±25	75-125
Gamma-spec	HASL 300, 4.5.2.3[b]	1 pCi/g	1 pCi/g	±25	75-125
Tritium	EERF H-01[c]	1 pCi/g	1 pCi/g	±25	75-125
TPH (diesel)	8015[d] Modified	50 mg/kg	25 mg/kg	±40	61-144
Barium	6010[e]	2,000 mg/kg	20 mg/kg	±35	75-125
Chromium	6010[e]	200 mg/kg	1 mg/kg	±35	75-125

[a]American Public Health Association, *Standard Methods for the Examination of Water and Wastewater*
[b]U.S. Department of Energy *Environmental Measurements Laboratory Procedure Manual,* HASL-300
[c]U.S. Environmental Protection Agency (EPA) Eastern Environmental Radiation Facility
[d]EPA SW-846, *Test Methods for Evaluating Solid Waste,* 3rd Edition, modified according to the California State Water Resources Control Board, *Leaking Underground Fuel Tank Field Manual, Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure*, Appendix B.
[e]EPA, SW-846, *Test Methods for Evaluating Solid Waste,* 3rd Edition

pCi/g - PicoCuries per gram
mg/kg - Milligrams per kilogram
RPD - Relative percent difference
%R - Percent recovery

Groundwater samples collected from the monitoring wells will be analyzed for radionuclides, general water quality parameters, and hydrogen, oxygen, and carbon isotopes (^{13}C and ^{14}C). Of the targeted analytes, the following have regulatory limits that can be used to establish measurement objectives for the project:

- Tritium - 20,000 picoCuries per liter (pCi/L), which is the tritium activity assumed by EPA to produce a dose of 4 millirems/year, which is the Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) for beta particle and photon radioactivity from man-made radionuclides (40 CFR 141.16)

- Gross alpha - 15 pCi/L, which is the SDWA MCL for gross alpha particle activity (40 CFR 141.15)

- Chloride - 250 mg/L, which is the SDWA secondary MCL for chloride (40 CFR 143.3)

- Nitrate - 10 mg/L, which is the SDWA MCL for nitrate (40 CFR 141.62)
- Sulfate - 250 mg/L, which is the SDWA MCL for sulfate (40 CFR 143.3)

Like the soil measurement objectives, the measurement objectives for the groundwater analyses have been established at 50 percent of the regulatory limits for the above analytes, and at the analytical reporting limits for the remaining analytes to ensure that the analytical methods selected are capable of meeting the project quantitation limit needs. Table 3-2 provides the analytical methods selected for the groundwater samples, and the quantitation limits typically reported by the analytical laboratory to be used for the project. As indicated in the table, the methods specified for the project are capable of meeting the measurement objectives.

3.6 Schedule

Field work will begin after the approval of this CAIP by the NDEP. Upon approval of this plan, NDEP will be notified of the scheduled start date for the field activities at least 10 working days prior to the start of field work. The expected completion schedule, in working days (assuming a 5 day work week), is:

- Day 0: Mobilize drill crew and Geoprobe® to the site.
- Day 5: Finish impoundment (mudpit) characterization.
- Day 20: Complete drilling, borehole geophysical logging, and well development.
- Day 21: Start groundwater sampling and installation of pressure transducers to monitor water levels.
- Day 25: Complete groundwater sampling.
- Day 26: Demobilize the drill crew from the site.
- Day 35: Receive analytical results for the impoundment sampling.
- Day 55: Receive analytical results from the groundwater sampling.
- Three months after completion of drilling or when the water levels stabilize as defined in section 4.2 aquifer testing will begin.
- Complete aquifer testing 2 weeks after start of testing.

Factors beyond DOE/NV's control, such as weather or delays in receipt of laboratory results may delay field activities. If such delays occur, NDEP will be notified verbally.

Within eight months of receipt of validated analytical results from the final field activities, a Corrective Action Decision document will be submitted to NDEP.

Table 3-2
PSA Groundwater Investigation Measurement Objectives

Analyte	Method	Measurement Goal	Analytical Reporting Limit	Precision (RPD)	Accuracy (%R)
Gross Alpha	EPA 900.0[a]	7 pCi/L	1 pCi/L	±25	75-125
Gross Beta	EPA 900.0[a]	4 pCi/L	4 pCi/L	±25	75-125
Gamma Spectroscopy	EPA 901.1[a]	20 pCi/L	20 pCi/L	±25	75-125
Tritium	EPA[b]	10,000 pCi/L	50 pCi/L	±25	75-125
Enriched Tritium	EPA[b]	5 pCi/L	5 pCi/L	20	80-120
Specific Conductivity	SM 2510 B[c]	10 µmho/cm	10 µmho/cm	±25	75-125
Silica	SM 4500-Si F[c]	1.0 mg/L	1.0 mg/L	±25	75-125
pH	SM 4500-H B[c]	0.02 pH unit	0.02 pH unit	±25	75-125
Alkalinity	GS I-1030-85[d]	5 mg/L	5 mg/L	±25	75-125
Chloride	SM 4500-Cl E[c]	125 mg/L	0.5 mg/L	±25	75-125
Sulfate	SM 4110 B[c]	125 mg/L	0.5 mg/L	±25	75-125
Nitrate	SM 4500-NO_3 F[c]	5 mg/L	0.01 mg/L	±25	75-125
Sodium	SM 3111 B[c]	0.1 mg/L	0.1 mg/L	±25	75-125
Potassium	SM 3111 B[c]	0.1 mg/L	0.1 mg/L	±25	75-125
Calcium	SM 3111 B[c]	0.2 mg/L	0.2 mg/L	±25	75-125
Magnesium	SM 3111 B[c]	0.1 mg/L	0.1 mg/L	±25	75-125
Hydrogen	DRI[e]	NA	NA	±0.2	100
Oxygen	DRI[e]	NA	NA	±0.04	100
^{14}C	DRI[e]	0.5 PMC	0.5 PMC	±0.3	98-100
^{13}C	DRI[e]	NA	NA	±0.04	75-100

[a]Prescribed Procedures for Measurement of Radioactivity in Drinking Water, U.S. Environmental Protection Agency, 1980
[b]Handbook of Radiochemical Methods, EPA
[c]Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 1992
[d]Methods for Determination of Inorganic Substances in Water and Fluvial Sediments, U.S. Geological Survey, 1985
[e]Desert Research Institute Environmental Isotopes Laboratory Procedures Manual, Version 3.0
[f]Desert Research Institute Environmental Isotopes Laboratory Procedures Manual, Version 2.0

mg/L - Milligrams per liter
NA - Not applicable
pCi/L - PicoCuries per liter
PMC - Percent modern carbon
RPD - Relative percent difference
µmho/cm - Micromhos per centimeter or 0.1 millisiemens per meter
%R - Percent recovery

4.0 Corrective Action Investigation

This section of the CAIP describes the methodology for the investigation of the PSA and the installation of groundwater monitoring wells. The DQO process has been implemented in order to design a data collection program that will support the site's data needs and to supply sufficient information to make a decision on a course of action. All sampling activities will be conducted in compliance with the Industrial Sites QAPP (DOE, 1994), the IT Corporation, Las Vegas Office (ITLV) Program Procedures Manual (IT, 1993), and all applicable approved contractor procedures. Requirements for field and laboratory environmental sampling QA/QC are contained in the Industrial Sites QAPP (DOE, 1994).

4.1 PSA Impoundment Investigation

A subsurface investigation will be conducted within and down stream of the PSA impoundment to answer the following questions:

- What are the physical and chemical characteristics of the material within the impoundment?
- What is the thickness and areal extent of the materials within the impoundment?
- Has there been any vertical and/or horizontal migration of materials from the impoundment?
- What are the levels of radionuclides and metals outside of the impoundment vicinity?

Soil samples will be collected from selected locations within, adjacent to, and downstream from the impoundment. A total of 14 locations will be sampled by means of a truck-mounted Geoprobe® system capable of collecting continuous core samples (Figure 4-1). Nine sample locations will be within the impoundment, and the remaining five sample locations will be located adjacent to and downstream from the impoundment.

A reference grab soil sample will be collected from 0 to 0.6 m (0 to 2 ft) BGS at an undisturbed location upgradient from the impoundment. The exact location of the reference sample will be determined in the field. Based on a review of the topography at the PSA, it is anticipated that the reference sample will be collected about 152 m (500 ft) upgradient from the impoundment. The reference sample will be analyzed for gross alpha/beta, gamma spec, chromium, and barium.

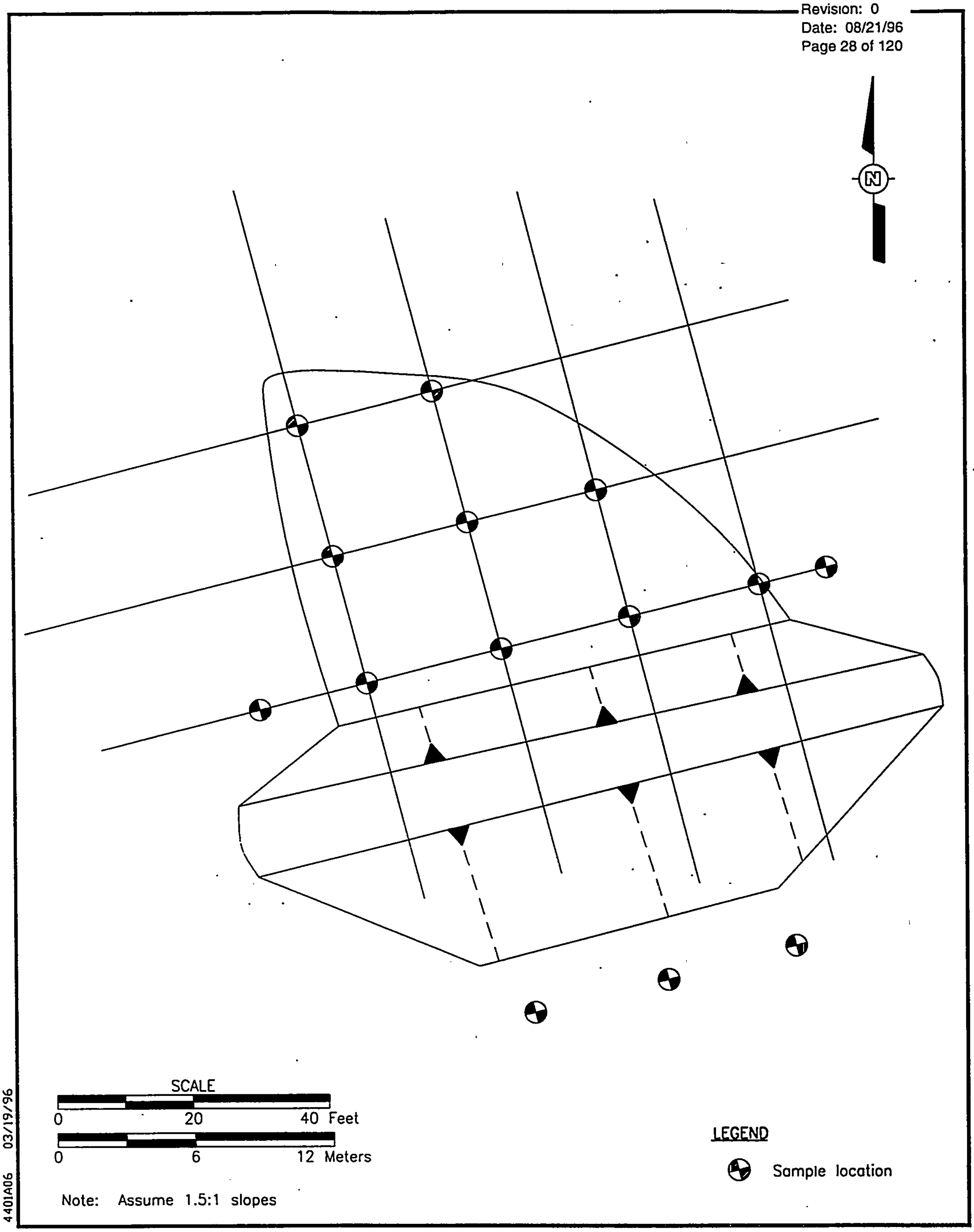

Figure 4-1
Sample Locations
Project Shoal Area Impoundment

Beginning at the ground surface, the core barrel will be advanced at 2-ft intervals and extracted. Core samples will be collected, logged, and described. Core samples of the impoundment materials will continue to be collected until the natural soils underlying the impoundment are reached. If possible, samples will be collected from five borings advanced below the interface between natural soil and impoundment materials to investigate the potential vertical migration of impoundment materials. The five borings advanced through the interface will be randomly selected from the nine borings advanced within the impoundment. If the interface can be observed in the cores, soil samples will be collected at 0.5 m (1.5 ft) below the interface. If the interface between natural soil and impoundment material cannot be detected in the field, (deep) samples to target potential vertical migration will be collected from just above the bedrock surface. If the bedrock surface is below 6 m (20 ft) BGS, the deep soil samples will be collected from 6 m (20 ft) BGS.

The volume of the Geoprobe® core barrel is approximately 320 milliliters (mL). If several borings are necessary to collect an adequate volume of soils, additional borings will be advanced in a circular pattern around the first boring location at a distance interval of not greater than 0.3 m (1 ft).

The impoundment materials collected at the nine sample locations will be composited into nine uniform samples and split out for the analyses noted in Table 4-1. Composite soil sampling will be completed in accordance with Standard Quality Practice (SQP) ITLV-0605 from the ITLV Program Procedures Manual (IT, 1993).

A grab sample of the natural substrate materials at five borings outside the impoundment will be analyzed according to Table 4-1. The samples outside the impoundment will be collected to target potential horizontal and downgradient migration of impoundment materials. The exact location of the natural soil borings will be determined in the field.

Materials collected from the core barrel will be described by a field geologist. A description of the retrieved materials will include as a minimum:

- Color
- Grain size
- Relative moisture (dry to wet)
- Relative density (loose to hard)
- Unified Soil Classification System (USCS) symbol

- Type of materials - fill or natural
- Depth interval of sample collected
- Contact between impounded materials and native materials
- Nature of material - stratified or massive.

Samples will be handled, packaged, and shipped in accordance with approved procedures and analyzed at a DOE-approved laboratory. Investigation-derived waste (IDW) will be managed according to the procedures detailed in Section 5.0.

After sampling, the cutting shoe, barrel, stop pin, and drive rods will be decontaminated by using a three-stage bath of Alconox and water. Decontamination fluids will be containerized for later disposal in accordance with all applicable regulations. Upon completion of sampling, the Geoprobe® soundings will be backfilled with bentonite pellets.

All samples collected will be analyzed for gross alpha/beta, gamma spectroscopy, and tritium. In addition, the samples taken from within the impoundment will be analyzed for TPH, total barium, and total chromium. One field duplicate sample and one matrix spike/matrix spike duplicate pair will be collected from the impoundment. The field duplicate will be analyzed for all targeted analytes. The matrix spike/matrix spike duplicate will be analyzed for TPH, barium, and chromium. A summary of the collected samples and the analytical methods is presented in Table 4-1.

4.2 Groundwater Investigation

Data gaps that need to be addressed are groundwater gradient, flow direction, and flow velocity. Existing data are such that the limits of the impacted groundwater at the site can only be stated with a high level of uncertainty. To establish a refined compliance boundary for the tritium contamination assumed to exist at the site, site-specific groundwater conditions will be evaluated by:

- Installation of three or four groundwater monitoring wells (Appendix A)

- Calculation of a gradient and flow direction from the water-level information collected from the new wells

- Collection of groundwater samples from each well for hydrochemical, isotopic, and radiological analysis (Table 4-2)

- Collection and radiological analysis of drill cuttings from each new well borehole
- Collection of downhole geologic and geophysical data
- Groundwater modeling.

Table 4-1
PSA Impoundment Sampling Requirements

Sample Location	Number of Samples	Sample Type	Constituent of Concern	Analytical Method	Container Type and Volume Required	Preservative
Impoundment Materials	10	Soil Composite	Gross Alpha/beta Gamma spec Tritium	QTES - 7110[a] HASL300 4.5.2.3[b] EPA EERF H-01[c]	4-oz glass or poly 8-oz glass or poly 8-oz glass or poly	none none none
Impoundment Materials	11	Soil Composite	TPH	8015M, Diesel[d]	8-oz glass with poly-lined cap	Cool to 4°C
Impoundment Materials	11	Soil Composite	Barium and Chromium	6010	8-oz glass	Cool to 4°C
Native Soils	5	Soil Grab	Gross Alpha/beta Gamma spec Tritium	QTES - 7110 HASL300 4.5.2.3 EPA EERF H-01	4-oz glass or poly 8-oz glass or poly 8-oz glass or poly	none none none
Reference Sample	1	Soil Grab	Gross Alpha/beta Gamma spec Barium, Chromium	QTES-7110 HASL 300 4.5.2.3 6010	4-oz glass or poly 8-oz glass or poly 8-oz glass	none none none Cool to 4°C
Cutting Samples	3	Soil Grab	Gamma spec	HASL 300 4.5.2.3	8-oz glass	none

[a]American Public Health Association. *Standard Methods for the Examination of Water and Wastewater*
[b]U.S. Department of Energy *Environmental Measurements Laboratory Procedure Manual*, HASL-300
[c]U.S. Environmental Protection Agency (EPA) Eastern Environmental Radiation Facility
[d]EPA SW-846, *Test Methods for Evaluating Solid Waste*, 3rd Edition, modified according to the California State Water Resources Control Board, *Leaking Underground Fuel Tank Field Manual. Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure*, Appendix B
[e]EPA, SW-846, *Test Methods for Evaluating Solid Waste*, 3rd Edition

Samples of the cuttings from the new well borings will be field-screened for gamma radiation and sent to the laboratory for gamma spectroscopic analysis. The cuttings samples will be collected from about 6 m (20 ft) below the level at which groundwater is first encountered while drilling the new wells. One sample from each new borehole will be collected for the gamma analysis.

Groundwater sampling will commence after the groundwater level has recovered and stabilized from drilling and development operations. Given the low storativity and hydraulic conductivity of the Sand Springs granite reported in earlier studies, groundwater in the new wells may not recover to static levels until several weeks have elapsed. Water-level recovery will be monitored by dedicated downhole transducers connected to data loggers. To minimize the time required to allow the water levels to stabilize, sampling will commence after one or all of the following criteria are met:

- Water levels recovered to 95 percent of the level first encountered during drilling
- The difference between the water level over 10 sequential days of measurement does not exceed 0.15 m (0.05 ft)
- Three months have elapsed since well development was completed.

The hydrogeologic investigation is fully detailed in Appendix A. IDW will be managed according to the procedures detailed in Section 5.0.

Table 4-2
Groundwater Sampling Requirements

Sample Location	Number of Samples	Parameter	Container Type and Volume Required	Preservative
New Groundwater Monitoring Wells	3	Gross Alpha	500-mL glass or poly	HNO_3 to pH<2
		Gross Beta	500-mL glass or poly	HNO_3 to pH<2
		Gamma spec	1-L glass or poly	HNO_3 to pH<2
		Tritium	200-mL glass	None
		Spec. Cond.	25-mL glass or poly	None
		Silica	25-mL glass or poly	None
		pH	25-mL glass or poly	None
		Alkalinity	200-mL glass or poly	None
		Chloride	25-mL glass or poly	None
		Sulfate	25-mL glass or poly	None
		Nitrate	25-mL glass or poly	None
		Sodium	25-mL glass or poly	HNO_3 to pH<2
		Potassium	25-mL glass or poly	HNO_3 to pH<2
		Calcium	25-mL glass or poly	HNO_3 to pH<2
		Magnesium	25-mL glass or poly	HNO_3 to pH<2
		Hydrogen	10-mL glass with poly-lined cap	None
		Oxygen	10-mL glass with poly-lined cap	None
		14 C	10-gal plastic	None
		13 C	500-mL glass or poly 1-L glass or poly 250-mL glass or poly	HNO_3 to pH<2 HNO_3 to pH<2 None

5.0 Waste Management Plan

Management of the wastes derived from the assessment field work will be determined based on regulatory requirements, field observations, and the results of DOE-approved, off-site laboratory analysis of site characterization samples. Administrative controls (e.g., decontamination procedures and characterization strategies) will minimize hazardous waste generated during site investigation activities. Hazardous and/or mixed waste, if it is generated, will be managed and disposed of in accordance with DOE Orders, U.S. Department of Transportation (DOT) requirements, NDEP regulations, Resource Conservation and Recovery Act (RCRA) regulations, and site-specific requirements. Decontamination activities will be performed according to approved procedures specified in the field sampling instructions and will be written considering the contaminants of concern present at the site.

5.1 Waste Minimization

Characterization activities have been planned to minimize the amount of IDW generated. The planned field technique will generate minimal soil waste in the form of cuttings. Fluids will be managed under a fluid management plan in accordance with the Nevada Water Pollution Control Act and its associated regulatory requirements. Soil waste generated that is not RCRA-regulated will be left at the site and used in site recountouring operations and/or construction of berms as required.

5.2 Potential Waste Streams

Based on preliminary sampling results of similar type sites and process knowledge, no mixed or transuranic waste streams are expected. It is also unlikely that hazardous wastes will be generated. It is possible that low-level, hydrocarbon and sanitary wastes will result from field activities. Potential waste constituents include tritium, fission products, and petroleum hydrocarbons.

Wastes generated during the characterization activities may include, but are not limited to:

- Decontamination rinsate
- Disposable sampling equipment (plastic, paper, sample containers, aluminum foil)
- Personal protective equipment (PPE)
- Development and sample purge water
- Drill cuttings/sand from the newly installed wells

5.3 Fluid Management

Fluids will be contained in tanks or lined sumps pending characterization and will be managed in accordance with a fluid management plan negotiated with the State of Nevada. Fluids found to meet fluid management criteria (i.e., less than or equal to five times the SDWA MCLs may be released to the ground surface. Fluids that do not meet fluid management criteria will be managed in accordance with applicable regulatory requirements and DOE Orders. Fluids that contain in excess of 100,000 pCi/L tritium will be contained in tanks or lined sumps and allowed to evaporate. If fluids are encountered that contain radionuclides above established health and safety or air quality limits (such as those listed in the National Emissions Standards for Hazardous Air Pollutants), drilling will be stopped until a management strategy is developed.

5.4 Sanitary Waste Management

Sanitary waste will be containerized in a manner that prevents spread of debris (i.e., in plastic bags, dumpsters, or drums) and will be transported to a sanitary waste landfill. Soils that are not RCRA-regulated or are below low-level waste (LLW) limits for radioactivity will be left on site.

5.5 Low-level Waste Management

LLW will be managed in accordance with DOE Orders and the requirements of the *Nevada Test Site Defense Waste Acceptance Criteria, Certification, and Transfer Requirements,* NVO-325, Rev. 1 (DOE, 1992). Liquid LLW will be evaporated on site. Solid IDW, such as sampling equipment and PPE, will be placed in plastic bags with an attached waste tracking tag in accordance with Standard Quality Practices. The bags will be placed in DOT-compliant drums, which will be properly labeled and locked or fitted with tamper-indicating devices. The drums will be staged at a designated Radioactive Materials Area pending disposal under NVO-325 criteria.

5.6 Hazardous Waste Management

Suspected hazardous wastes will be placed in DOT-compliant drums, which will be properly labeled and locked or fitted with tamper-indicating devices. Hazardous wastes will be staged at the site of generation pending characterization and transport to the Nevada Test Site Area 5 permitted Hazardous Waste Storage Site or to an off-site commercial permitted treatment, storage, and disposal facility.

5.7 Hydrocarbon Waste Management

Hydrocarbon waste (containing more than 100 parts per million TPH) will be properly containerized in bags or drums and will be transported to an appropriately permitted hydrocarbon waste management facility after the waste is fully characterized.

6.0 Reporting

Upon completion of field activities and receipt of the sample analytical and data validation results (as applicable), a report of findings will be produced. The report will, at a minimum, include the following:

- Drawings of the site, including appropriate site boundaries, sampling locations, estimated boundaries of contamination (if applicable), and other relevant features
- Discussions of the characterization methods used, including soil sampling methods, materials, and logs
- Information regarding the presence and concentrations of constituents of concern
- Tables summarizing laboratory and field-screening data
- Discussion regarding the adequacy of the characterization of the site
- Discussion regarding the quality control data obtained for the characterization
- Recommendations for further assessment, remediation, or closure of the site
- Photo documentation

In addition to the aforementioned scheduled deliverables, the DOE will notify the State of Nevada Division of Environmental Protection, as soon as it is practicable, of any findings that will require the alteration of this plan, or that will have a major impact on potential remedial action for the site and/or human health and the environment.

7.0 References

AEC, see U.S. Atomic Energy Commission.

American Public Health Association. 1992. *Standard Methods for the Examination of Water and Wastewater.* 18th Edition. Washington, DC.

Atkinson, C.H. 1964. *Subsurface Fracturing from a Nuclear Detonation in Granite,* PNE-3001, Bureau of Mines.

Borg, I.Y., R. Stone, H.B. Levy and L.D. Ramspott. 1976. "Information Pertinent to the Migration of Radionuclides in Ground Water at the Nevada Test Site, Part 1: Review and Analysis of Existing Information." Lawrence Livermore National Laboratory Report UCRL-52078 Pt. 1, 216 p.

Cohen P. and D.E. Everett. 1963. *A Brief Appraisal of the Ground-Water Hydrology of the Dixie-Fairview Area, Nevada,* Ground-Water Resources-Reconnaissance Series Report 23. State of Nevada: Department of Conservation and Natural Resources.

DRI, see Desert Research Institute.

Desert Research Institute. 1988. *CERCLA Preliminary Assessment of DOE's Nevada Operations Office Nuclear Weapons Testing Areas.* Las Vegas, NV.

Desert Research Institute. 1994. *Environmental Isotopes Laboratory Procedures Manual,* Version 2.0. Reno, NV.

Desert Research Institute. 1995. *Environmental Isotopes Laboratory Procedures Manual,* Version 3.0. Reno, NV.

Deshler, Richard M. IT Corporation. 1996. Telecon containing field notes and interview information, written by D. Krogbin, 24 January. Las Vegas, NV: ITLV.

DOE, see U.S. Department of Energy.

Fauver, D.N. 1986. *Hazardous Waste Installation Assessment Report.* Las Vegas, NV: Reynolds Electrical & Engineering Co., Inc.

Gardner, M.C., and W.E. Nork. 1970. *Evaluation of the Project Shoal Site, Fallon, Nevada, for Disposition, Including Identification of Restrictions, Part I,* NVO-1229-105. Report prepared for AEC/NVO. Las Vegas, NV.

Hazleton-Nuclear Science Corporation. 1963. *Project Shoal Post-Shot Hydrologic Safety,* AEC Report, VUF-1014.

Holmes and Narver, Inc. 1971. "Fallon Nevada Project Shoal Composite As-Built Plans, Elevations and Details," Drawing No. F-094-C19. For the U.S. Atomic Energy Commission.

IT, See IT Corporation.

IT Corporation. 1993. ITLV Program Procedures Manual, Standard Quality Practices. Las Vegas, NV: ITLV.

Korver, John, A., Charles R. Boardman, and Donald E. Rawson. 1965. *The Shoal Postshot Environment,* SDK 65-5. Lawrence Radiation Laboratory.

NDEP, see Nevada Division of Environmental Protection.

Nevada Division of Environmental Protection. 1992. *Contaminated Soil and Groundwater Remediation Policy.*

University of Nevada. 1965. Hydrological Investigations of the Sand Springs Range, Fairview Valley, and Fourmile Flat, Churchill County, Reno, NV.

U.S. Atomic Energy Commission, Nevada Operations Office. 1964. Project Managers Report, *Project Shoal,* NVO-11. Las Vegas, NV.

U.S. Atomic Energy Commission, Nevada Operations Office. 1970. *Site Disposal Report, Fallon Nuclear Test Site, (Shoal), Churchill County, Nevada,* NVO-73. Las Vegas, NV.

U.S. Department of Energy, 1992. *Environmental Measurements Laboratory Procedures Manual,* HASL-300. 27th Edition, Volume 1. New York, NY.

U.S. Department of Energy, Nevada Operations Office. 1992. *Nevada Test Site Defense Waste Acceptance Criteria, Certification, and Transfer Requirements,* NVO-325, Rev. 1, Las Vegas, NV, June.

U.S. Department of Energy, Nevada Operations Office. 1994. *Resource Conservation and Recovery Act Industrial Sites Quality Assurance Project Plan, Nevada Test Site, Nevada.* Las Vegas, NV: IT Corporation.

U.S. Department of Energy, Nevada Operations Office. 1996. *Draft Project Shoal Preliminary Site Characterization Report, Shoal Site, Nevada.* Las Vegas, NV: IT Corporation.

U.S. Environmental Protection Agency. 1975. *Handbook of Radiochemical Analytical Methods.* EPA/680/475/001. Las Vegas, NV.

U.S. Environmental Protection Agency. 1984. *Eastern Environmental Radiation Facility Radiochemistry Procedures Manual.* EPA/520/5-84/006. Washington, DC.

U.S. Environmental Protection Agency. 1986. *Test Methods for Evaluation, Solid Waste, Physical/Chemical Methods,* SW-846, Third Edition. Washington, DC.

U.S. Environmental Protection Agency. 1980. *Prescribed Procedures for Measurement of Radioactivity in Drinking Water.* EPA/600/4-80/032. Washington, DC.

U.S. Environmental Protection Agency. 1993. *Data Quality Objectives Process for Superfund,* EPA-540-R-93-071.

U.S. Environmental Protection Agency. 1994. *Guidance for the Data Quality Objectives Process,* QA/G-4.

USGS, see U.S. Geological Survey.

U.S. Geological Survey Map. 1979. "Fourmile Canyon Quadrangle, Nevada - Churchill Co., 7.5 Minute Series (Topographic)."

U.S. Geological Survey. 1985. "Methods for Determination of Inorganic Substances in Water and Fluvial Sediments." In Fishman, J.J., and L.C. Friedman, eds. 1985. *Techniques of Water Resources Investigations*, Book 5. USGS Open File Report 85-495. Denver, CO.

Appendix A
Project Shoal Area
Hydrogeologic Investigation Plan

PROJECT SHOAL AREA
HYDROGEOLOGIC INVESTIGATION PLAN

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THE NATURE OF THE SUBSURFACE PROBLEM

Source Term

The Shoal nuclear test produced significant quantities of radionuclides as a result of fission reactions and neutron activation. The precise quantities produced remain classified, but two sources of unclassified data exist: a Post-Shot Hydrologic Safety report by Hazleton-Nuclear Science Corp. (HNS) (1965), and a Nevada Offsites Integrated Risk Assessment by the Nevada Risk Assessment Management Program (NRAMP) group (Draft, 1996). HNS estimated the quantities and identity of radionuclides produced by Shoal considering the total yield, external neutron fluxes, and the type of chemical elements exposed to the fluxes (Table 1). NRAMP calculated radionuclide production using the ORIGEN2 code designed for nuclear reactors (Table 2).

The amount of the radionuclide source term available for transport in groundwater is called the "hydrologic source term" and is smaller than the radiologic source because many of the radionuclides cannot be transported by groundwater due to incorporation in the relatively insoluble melt glass or rapid decay (Smith et al., 1995). Those nuclides that do leach slowly out of melt debris often have strong sorbing properties that also limit migration. The few radionuclides produced in forms mobile in water are of greatest concern for radionuclide transport: tritium, ^{85}Kr, ^{36}Cl, ^{129}I, ^{99}Tc, and ^{125}Sb, and of these, tritium is present in the largest concentration for 100 to 200 years after a test (Smith et al., 1995).

TABLE 1 RADIONUCLIDE PRODUCTION FROM AN ASSUMED 12-KT SHOAL DEVICE, AS REPORTED BY HAZLETON-NUCLEAR SCIENCE (1965).

Nuclide	Half-Life in Years	Source*	Shot-Time Activity in curies
Ce^{144}	0.78	f	6.7×10^4
H^3	12.3	a	3.0×10^4
Pm^{147}	2.7	f	9.7×10^3
Ru^{106}	1.0	f	6.4×10^3
Cs^{137}	30.0	f	2.2×10^3
Fe^{55}	2.6	f	2.0×10^3
Sr^{90}	28.0	f	1.9×10^3
Sb^{125}	2.7	f	8.0×10^2
Eu^{155}	1.7	f & a	4.7×10^2
Sm^{151}	90.0	a & f	4.2×10^2
Cd^{113m}	14.0	f	3.0×10^1
Gd^{153}	0.6	a	1.5×10^1

*f = fission product
a = activation product
NOTE: Table 1 includes device and neutron-activation produced non-gaseous radionuclides in quantity greater than 10 curies and with half-lives greater than one-half year. The amount of fission produced tritium is small relative to the total neutron activation production of tritium and does not alter the above figure significantly.

TABLE 2. RADIONUCLIDES CONSIDERED FOR THE HYDROLOGICAL SOURCE TERM FOR PROJECT SHOAL IN CHURCHILL COUNTY, NEVADA (IN CURIES), AS REPORTED BY NRAMP (IN DRAFT).

	Isotope	Half-Life (years)	1996	in 10 years	in 100 years	in 1,000 years	in 10,000 years
1	H-3	12.3	59000	34000	220	0	0
2	C-14	5730	14000	14000	14000	12000	4100
3	Sm-151	90	1500	1400	720	0.7	0
4	Cl-36	301000	1500	1500	1500	1500	1400
5	Eu-155	4.71	1200	300	0.001	0	0
6	Fe-55	2.73	670	47	1.8E-09	0	0
7	Cs-137	30.2	620	490	62	5.7E-08	0
8	Si-32	100	560	560	510	190	0.013
9	Ca-41	103000	460	460	460	450	420
10	Sr-90	29.1	370	290	35	1.7E-08	0
11	Co-60	5.27	260	70	0.00051	0	0
12	Pu-241	14.4	160	99	1.3	4.7E-09	1.3E-19
13	Be-10	1.6E06	76	76	76	76	76
14	Pu-240	6560	54	54	53	48	19
15	Am-241*	433	20	22	22	5.1	2.8E-06
16	Pm-147	2.62	2.8	0.2	9.5E-12	0	0
17	Pm-145	17.7	1.6	1.1	0.033	1.6E-17	0
18	Cd-113m	14.1	0.72	0.45	0.0062	1.7E-21	0
19	K-40	1.28E09	0.56	0.56	0.56	0.56	0.56
20	Sb-125	2.76	0.27	0.022	3.7E-12	0	0
21	Ag-108m	130	0.19	0.18	0.11	0.00081	3.8E-25
22	Sn-126	100000	0.044	0.044	0.044	0.044	0.041
23	Np-237*	2.14E06	0.00014	0.00020	0.00087	0.0042	0.0053
24	U-236*	2.34E07	5.3E-05	6.8E-05	0.00021	0.0016	0.0098

*Long-lived daughter product

Near-Source Hydrology

The Shoal detonation occurred at a depth of 365 m in the Sand Springs granite, with groundwater generally occurring about 290 m below ground surface in the immediate test area. Thus, the Shoal hydrologic source term is in contact with groundwater. Nuclear detonations typically cause a temporary unsaturated zone in the immediate vicinity of the blast, as a result of high temperatures and pressures and increased porosity in the cavity and chimney. This region of depressed water levels recovers after the test as water from adjacent saturated rock infills the cavity, chimney, and drift workings. Migration of groundwater, and thus contaminants, away from the test cannot occur until water level recovery is complete, estimated as taking approximately 10 years at Shoal (HNS, 1965).

Once the rubble chimney is filled with groundwater, migration of contaminants from Shoal will be governed by the transport characteristics of the contaminants and the transport characteristics of the groundwater system. Data are available on the geochemistry of the granite, and scant data are published on distribution coefficients for strontium and cesium in Sand Springs granite (Nork, 1969), but following the logic of Smith et al. (1995), the following discussion will focus on tritium transport, which depends solely on the flow field.

Groundwater Flow in the Immediate Test Area

Groundwater transport in the Sand Springs granite occurs through a cross-cutting fracture network. Most fractures in the granite are steeply dipping to vertical and oriented NE-SW and NW-SE. Based on hydraulic tests and water level monitoring in six holes near ground zero (ECH-D, USBM-1, PM-1, PM-2, PM-3, and PM-8; Figure 1), it was concluded that the rate of groundwater movement in the vicinity of the test is low (University of Nevada, 1965, p.301). This is also supported by the rapid de-watering of most structural openings encountered in the underground workings mined for the shot (HNS, 1965). The hydrologic tests indicated a range of hydraulic conditions, but that in general, the transmissivity was lower than that measured at H-3 (which was less than 200 gpd/ft, or 0.3 cm^2/s; H-3 is completed in granite beneath a veneer of alluvium on the western fan below the range; Figure 2). A range of transmissivity near the site of 0.02 to 0.2 cm^2/s was based on recovery curves for the near-shot wells (HNS, 1965). The average hydraulic conductivity is on the order of 10^{-5} cm/s, but characterization of fracture flow is difficult and dependent on wells intercepting widely spaced hydrologic features. It is worth noting that zones were encountered in the underground workings that produced large quantities of water. These water-bearing zones could have conductivities of 10^{-1} to 1 cm/s (HNS, 1965).

Hydraulic gradients in the immediate Shoal area are questionable due to the effect of drilling and testing activities on water levels (Figure 3). Based on these questionable data, a groundwater divide is suspected northwest of the test, with a gradient of 0.15 to the southeast from PM-2 to PM-3, and a gradient of 0.013 from PM-3 to Fairview Valley. Though the head measurements suggest flow to Fairview Valley from the Shoal site, hydrochemical data suggest westward flow to Fourmile Flat (University of Nevada, 1965; Chapman et al., 1994), and neither pathway can be ruled out.

No data are available regarding the effective porosity of the fractured granite aquifer. Given that, as well as concerns regarding data quality for hydraulic conductivity and gradient, some earlier workers concluded that though the rate of groundwater movement in the granite is extremely low, "...it is not possible to compute accurately the rate..." (University of Nevada, 1965, p.275). Other workers have calculated velocity using the same University of Nevada dataset despite quality concerns, and reported velocities ranging from $1.6x10^{-6}$ cm/s to $1.6x10^{-5}$ cm/s (0.5 to 5 m/yr) (HNS, 1965; note that these values are not consistent with the data used for the calculations. An error may have resulted from using effective porosity as a percent without converting to the correct decimal value. Recalculating using the data in the report gives a range of $1.6x10^{-5}$ to $1.6x10^{-4}$ cm/s, or 5-50 m/yr). An estimate of westward velocity of 5 m/yr and eastward of 2.7 m/yr were reported by Chapman et al. (1995).

Groundwater Flow in the Region

The Sand Springs Range is located in a probable groundwater recharge area, based on the water table beneath the range being higher than that in the adjacent valleys, and the observation of decreasing head with depth in well ECH-D (University of Nevada, 1965). Local recharge infiltrates

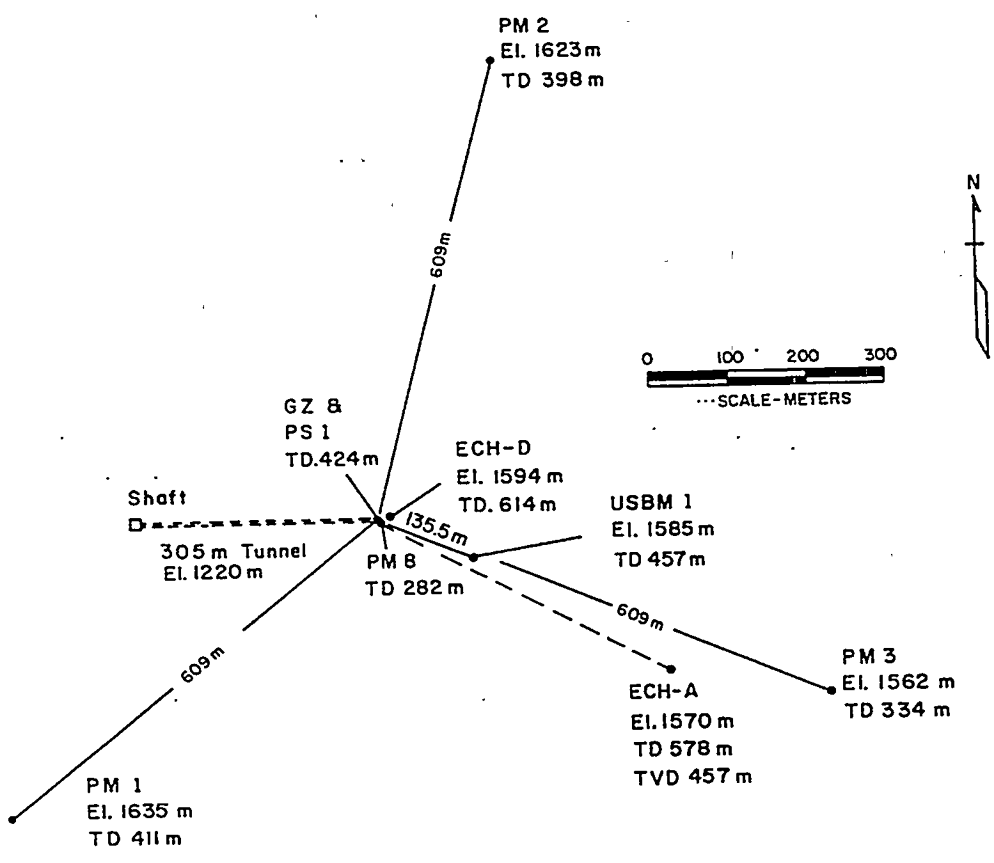


Figure 1. Drill hole locations, Shoal test site. From Hazleton-Nuclear Science (1965).

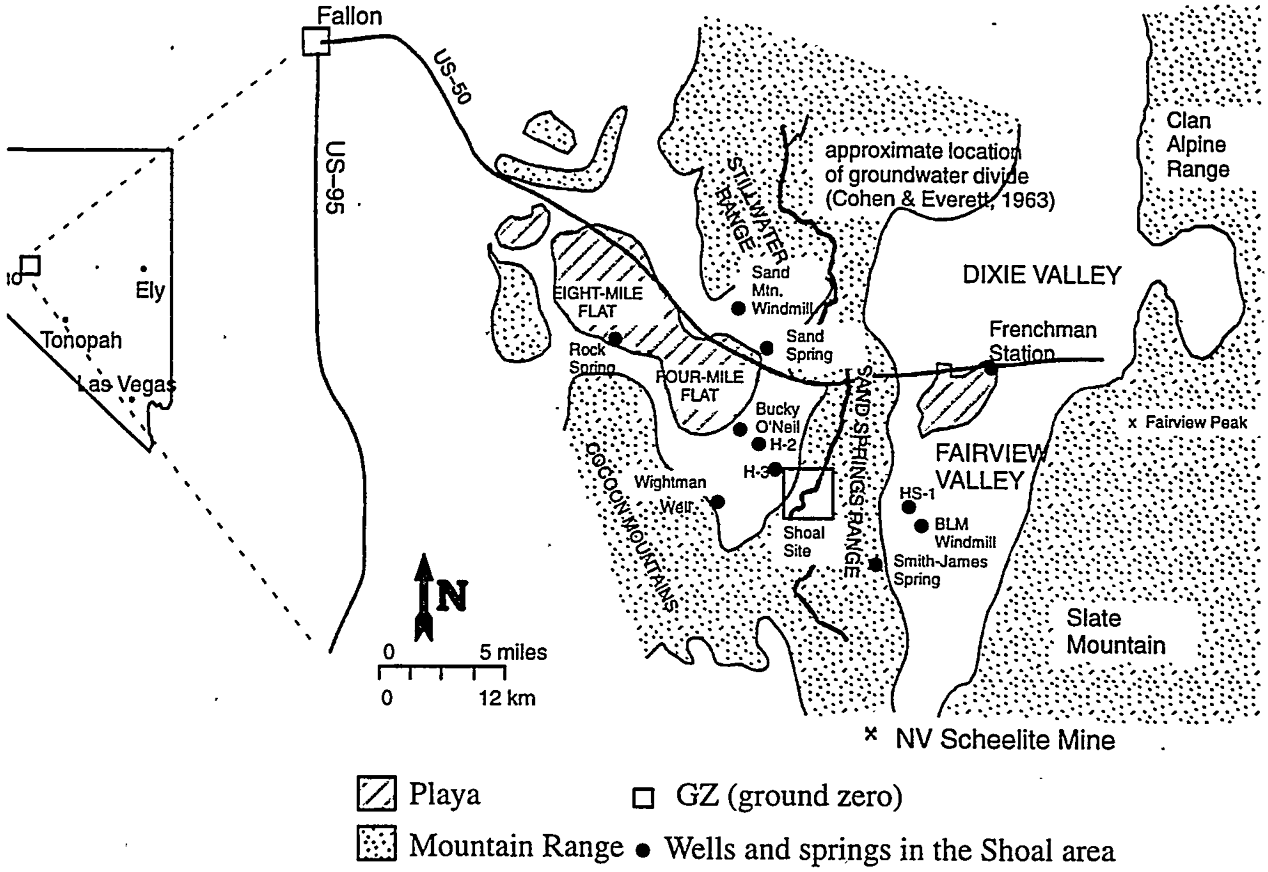


Figure 2. Map of the Sand Springs Range and vicinity showing the location of wells and springs near the Shoal Site (from Chapman et al., 1994).

through the thin soil cover and enters the groundwater system within the fractured granite. Though minor high-altitude seeps and springs are encountered elsewhere in the range, none are located in the Shoal area. Instead, groundwater is believed to move downgradient then laterally out to the adjacent valleys (Figure 4). The overall recharge rate and contribution of water to the valleys is believed to be low based on rainfall amounts, groundwater chemistry (University of Nevada, 1965), and groundwater age dates in the valleys (Chapman et al., 1994).

In the valleys, groundwater occurs in alluvial material eroded from the highland areas. Though hydraulic testing in wells installed for Shoal studies (HS-1 and H-4 in Fairview Valley and H-3 and H-2 in Fourmile Flat) indicated much higher transmissivities in the valley fill, hydraulic gradients on the valley floors are low and effective porosity greater than in the granite (University of Nevada, 1965), leading to moderate estimates of groundwater velocity in Fairview Valley of 2 x 10^{-5} cm/s

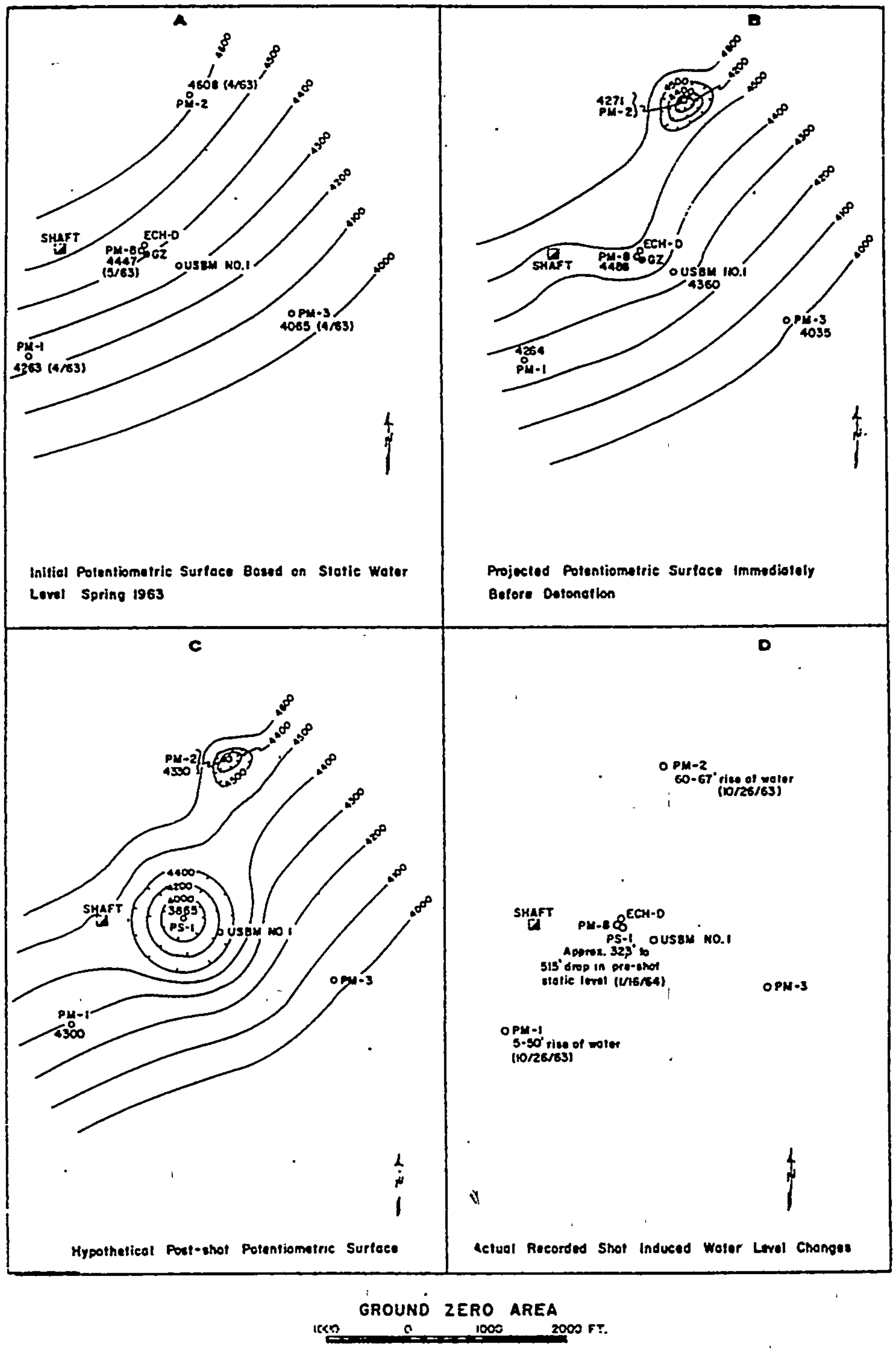


Figure 3. History of water levels in holes near Shoal ground zero with interpreted potentiometric surface (University of Nevada, 1965).

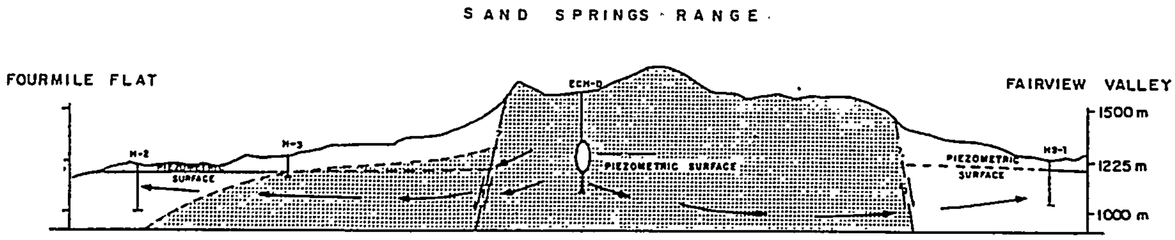


Figure 4. Vertical cross section with idealized groundwater flow arrows (Hazleton-Nuclear Science, 1965).

(6 to 7 m/yr) and in Fourmile Flat of 1.6 x 10^{-5}cm/s (4 to 5 m/yr) (University of Nevada, 1965; HNS, 1965). Using larger gradients calculated from the Shoal site to valley wells yields velocities on the order of 100 m/yr to HS-1 in Fairview Valley and 140 m/yr to Bucky O'Neil flowing well in Fourmile Flat (Chapman et al., 1995).

Baseline Risk Assessments

Three assessments of contaminant transport have been published: one by HNS (1965) where tritium, ^{137}Cs, and ^{90}Sr transport were all found to present a negligible hazard to regional water supplies; an exposure assessment of tritium transport by Chapman et al. (1995), which was performed for the Environmental Impact Statement for DOE activities in Nevada; and, a risk assessment of a large suite of contaminants transported to existing wells in the area by NRAMP (in draft). The tritium transport presented in Chapman et al. (1995) evaluated transport to hypothetical wells on both the eastern and western boundary, and transport to the first well on both the east and west pathway (Figure 5), and considered a range of hydraulic conditions for each flowpath. The range in excess cancer mortality risk is within the EPA goal for risk due to environmental contaminants (10^{-6}) at the closest existing well east of the site, HS-1, for all scenarios, but exceeds the EPA goal for cases of high spatial variability in hydraulic properties and/or high uncertainty in

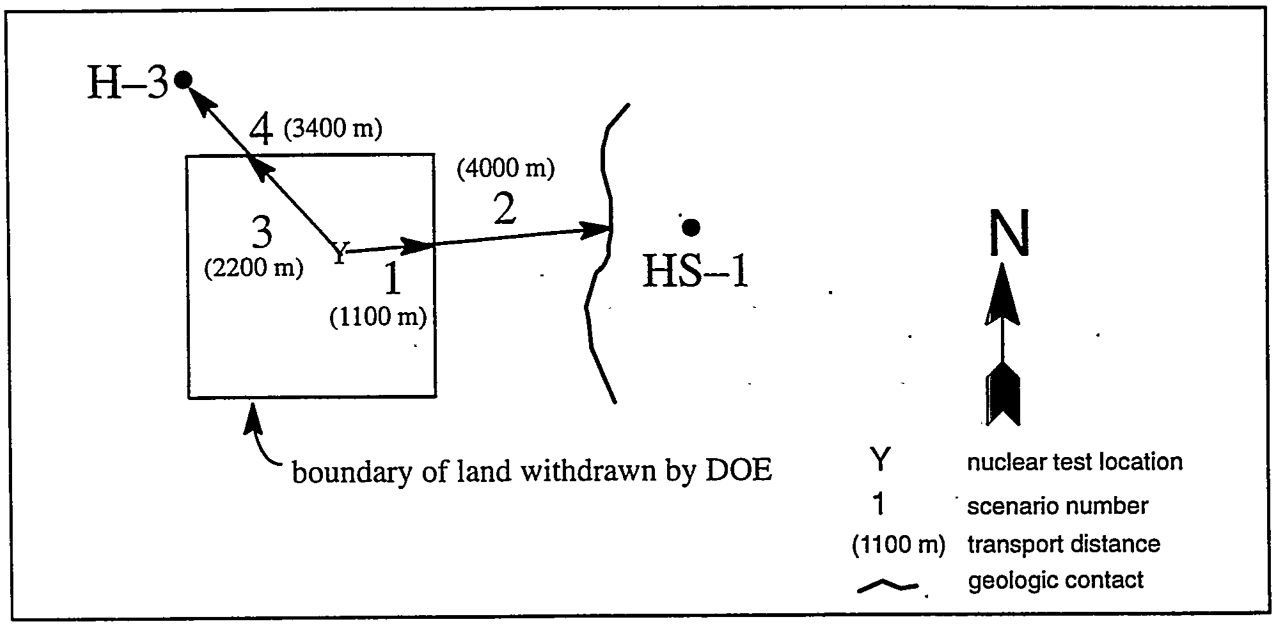


Figure 5. Diagram of the four transport scenarios considered, showing the scenario number and transport distance used in the calculations. The distance to HS-1 reflects the length of the flowpath through the granite rather than the full distance to the well. The diagram is not drawn to scale. (From Chapman *et al.*, 1995).

TABLE 3. HEALTH RISK RESULTS FOR THE GROUNDWATER TRANSPORT SCENARIOS CONSIDERED AT THE SHOAL SITE. The risk numbers bound the excess-cancer-mortality risk between the five and 95 percent levels on the cumulative risk function. Scenarios are identified on Figure 5. (From Chapman *et al.*, 1995).

Scenario	$\overline{U}$, m/yr			λ	90% Risk Confidence Interval		
1a	2.7	0	0.3	1/10 L	2×10^{-10}	to	8×10^{-7}
1b	2.7	20%	0.3	1/10 L	2×10^{-9}	to	7×10^{-6}
1c	2.7	40%	0.3	1/10 L	6×10^{-8}	to	2×10^{-4}
1d	2.7	0	0.6	1/10 L	3×10^{-9}	to	1×10^{-5}
1e	2.7	0	1.2	1/10 L	6×10^{-8}	to	2×10^{-4}
1f	2.7	40%	1.2	1/10 L	7×10^{-7}	to	2×10^{-3}
2a	2.7	0	0.3	1/10 L	4×10^{-24}	to	4×10^{-18}
2b	2.7	20%	0.3	1/10 L	3×10^{-20}	to	2×10^{-14}
2c	2.7	40%	0.3	1/10 L	5×10^{-15}	to	7×10^{-10}
2d	2.7	0	0.6	1/10 L	3×10^{-19}	to	1×10^{-13}
2e	2.7	0	1.2	1/10 L	5×10^{-15}	to	8×10^{-10}
2f	2.7	40%	1.2	1/10 L	4×10^{-12}	to	2×10^{-7}
3a	5	0	0.3	1/10 L	2×10^{-11}	to	1×10^{-7}
3b	5	20%	0.3	1/10 L	2×10^{-10}	to	1×10^{-6}
3c	5	40%	0.3	1/10 L	9×10^{-9}	to	6×10^{-5}
3d	5	0	0.6	1/10 L	3×10^{-10}	to	3×10^{-6}
3e	5	0	1.2	1/10 L	9×10^{-9}	to	6×10^{-5}
3f	5	40%	1.2	1/10 L	1×10^{-7}	to	6×10^{-4}
4a	5	0	0.3	1/10 L	4×10^{-15}	to	1×10^{-10}
4b	5	20%	0.3	1/10 L	2×10^{-13}	to	6×10^{-9}
4c	5	40%	0.3	1/10 L	7×10^{-11}	to	2×10^{-6}
4d	5	0	0.6	1/10 L	5×10^{-13}	to	2×10^{-8}
4e	5	0	1.2	1/10 L	8×10^{-11}	to	2×10^{-6}
4f	5	40%	1.2	1/10 L	3×10^{-9}	to	4×10^{-5}

mean velocity for the remaining three flowpaths (Table 3). Calculations considering less spatial variability and/or less uncertainty result in agreement with the EPA goal for all scenarios. In the NRAMP calculations, only tritium was found to be significant of all the nuclides considered. NRAMP found a maximum risk of 2 x 10^{-3} (mean plus one standard deviation) at well H-3, and 2 x 10^{-5} at HS-1. They consider these estimates conservative and note that they are higher than those in Chapman et al. (1995) because NRAMP assumed a larger source term, calculated their risk as an arithmetic rather than geometric mean, and used a 2 liter/day intake assumption rather than an age-dependent intake.

Data Problems

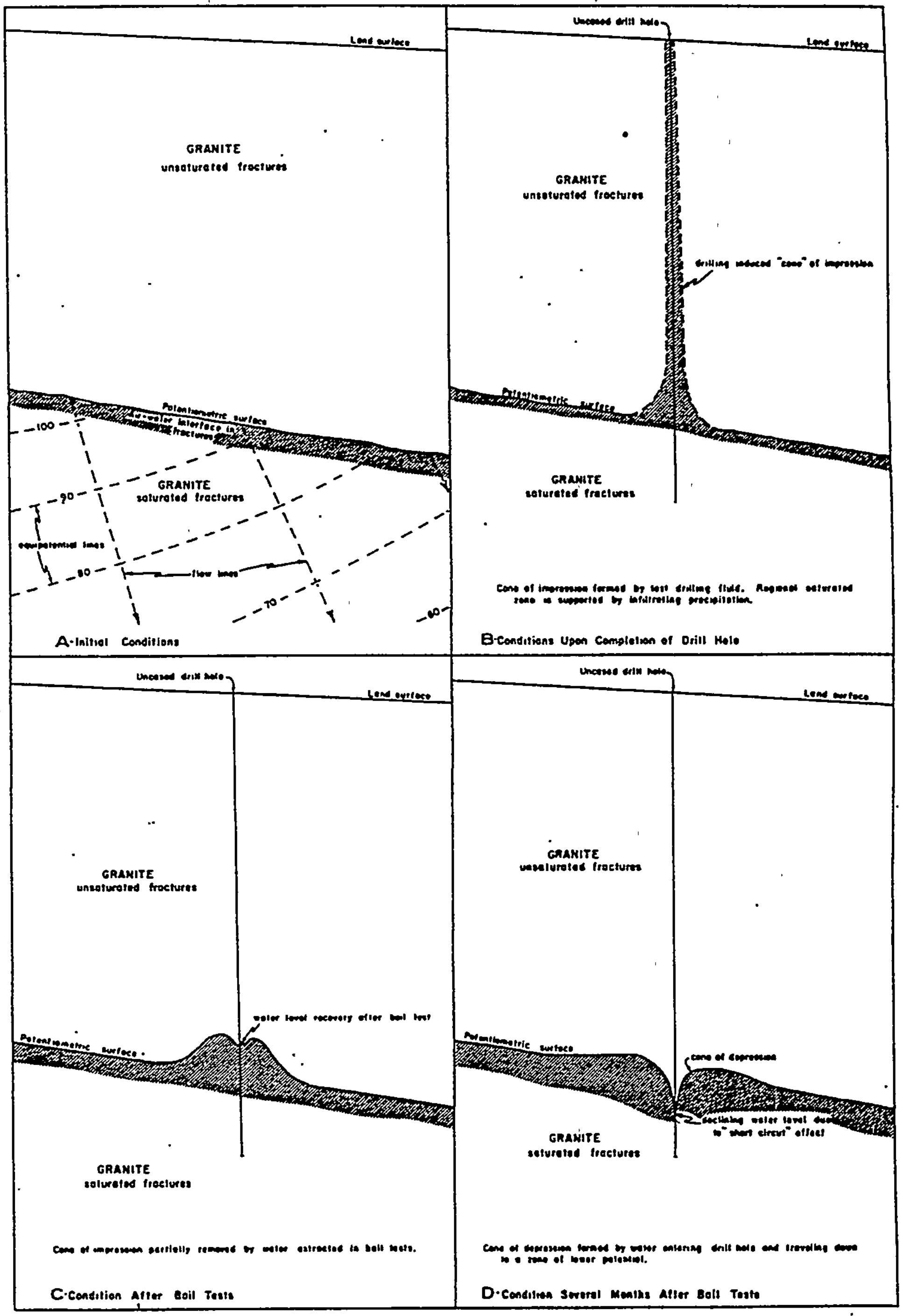
Substantial efforts were made to define Shoal Site hydrology at the time of the test and these efforts are well documented by University of Nevada (1965). Despite these efforts, problems remain in supporting predictions of contaminant migration. Most important among these are:

1. Uncertainty in the potentiometric surface in the test area, leading to uncertainty in the direction of flow (i.e., location of groundwater divide relative to the test) and magnitude of flow as related to the hydraulic gradient. The problem is best summed up by the original workers: "The validity of data on the potentiometric surface in the vicinity of Ground-Zero is questionable due to the effect of drilling and testing activities." This continues with "The 350-foot plus rise of ECH-D during the spring of 1963 while the PM holes were under construction suggests that much of the ground-water mound and associated gradients may be the result of introduced drilling water." (University of Nevada, 1965). In addition to the introduction of water during drilling, there were de-watering activities in the drift that may have been the cause of observed declines in water level with time. The possible impacts of these activities are diagrammed in Figure 6.

2. Unknown effective porosity. This is a common problem in fracture-dominated aquifers.

3. Unknown variability and correlation of hydraulic conductivity. As evidenced by the range of risk values presented in Chapman et al. (1995) (Table 3), transport of radionuclides is particularly sensitive to spatial variability in the flow field. Groundwater velocity, and thus contaminant transport, can be described by a mean value and spreading about that mean caused by a range of faster and slower flowpaths created by geologic heterogeneity. Because of the remediating action of decay, the leading edge of early arrivals in a plume is particularly important for describing peak radionuclide concentrations (Andricevic et al., 1994).

4. Scant data on sorption properties for the Sand Springs granite.



DIAGRAMMATIC HYDROLOGIC HISTORY OF BEDROCK TEST HOLES
GROUND ZERO AREA

Figure 6. Diagram of hydrologic history of holes in the Shoal ground zero area (University of Nevada, 1965).

The proposed field program will address the data gaps described in items 1, 2, and 3. The evaluation of proxy data from the site and use of parameter ranges determined at similar sites will be used to address item 4 and augment item 3 during the modeling phase.

SHOAL SUBSURFACE WORK PLAN

The characterization work for subsurface contamination at Shoal will have three primary parts:

1. Field work involving drilling and testing characterization wells at the site.

2. Modeling efforts to predict contaminant transport.

3. Housekeeping efforts to document existing conditions for all wells installed in the Shoal area by DOE (or its predecessor, the Atomic Energy Commission).

Each of these three efforts is described below.

Field Characterization Efforts

All wells drilled on the Sand Springs Range for the Shoal test have been plugged and there is currently no access to the groundwater beneath the Sand Springs Range in the Shoal vicinity. Given the questions regarding the true potentiometric surface in the Shoal test area, as well as related questions regarding the groundwater velocity, the characterization work at Shoal will include three, and possibly four, wells within the land area withdrawn by the Department of Energy around ground zero. The broad objective for the well program can be stated as providing additional data to support calculations of contaminant transport from the Shoal test. This includes data to support calculations of groundwater velocity and direction, and data to constrain boundary conditions regarding recharge from infiltrating precipitation. The following are the specific data objectives for the well drilling program:

- Determine the groundwater gradient in the test area under undisturbed conditions.

- Obtain information on the nature of permeability and porosity in the Sand Springs granite.

- Obtain information on recharge conditions.

- Obtain information on migration of contaminants from the nuclear test.

Well Location and Rationale

The objectives listed above will be reached by drilling three or four new wells (Figure 7). Exact well locations will not be determined until site visits evaluate drilling rig access and cultural resource impacts, but approximate locations have been identified. Well HC–1 (Hydrologic

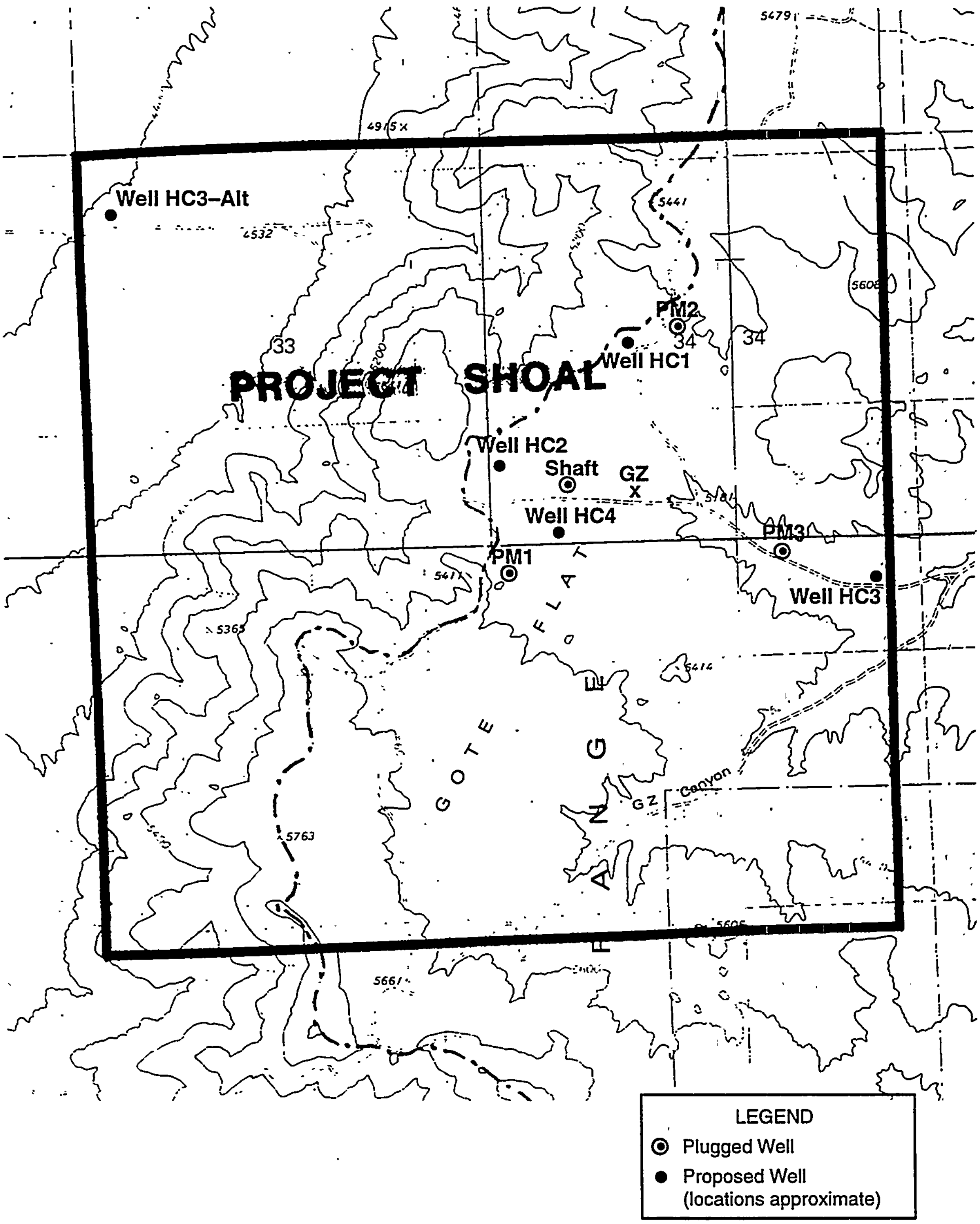


Figure 7. Proposed well drilling locations at Project Shoal. Heavy line represents area withdrawn by the Department of Energy; GZ indicates ground zero. For scale, the withdrawn area represents four square miles (the square is two miles on a side).

Characterization–1) will be drilled first and will be located west of abandoned well PM-2. Well HC–1 will resolve the great uncertainty in the static water level north of the test area, created by the more than 100 m variation in water levels measured at PM-2. Well HC–2, northwest of the shaft, will be drilled next and, if a water level is successfully obtained from the shaft, will help address the question of the location of the groundwater divide relative to the nuclear test. If the water levels at the shaft, well HC–1, and well HC–2 indicate flow to the east, well HC–3 will be drilled east of the abandoned well PM-3, down GZ Canyon. In addition to refining the potentiometric gradient eastward off the Sand Springs Range, well HC–3 will provide data on correlation of hydraulic properties across greater distances, necessary for predicting contaminant transport on the scale of several kilometers (current data coverage emphasizes spatial scales of hundreds of meters). If water levels indicate flow to the west, well HC–3 will be drilled on the western flank of the Sand Springs Range (Well HC–3–alt, on figure 7), completed in granite beneath the veneer of alluvium. This location would refine the western potentiometric gradient and provide data coverage at a greater distance, as with the other possible location of HC–3. Another alternate plan involves the possible drilling of well HC–4, which may be installed southwest of ground zero if water level data cannot be obtained from the shaft or if the gradient cannot be determined from the shaft and wells HC–1 and HC–2.

Well Drilling and Fluid Control

The drilling method will be selected to minimize disturbance to in situ hydraulic conditions and minimize the introduction of fluids to the subsurface. It is expected that a method such as a down-hole hammer will be used, with air to return the cuttings to the surface. The well locations are not expected to encounter event-related contaminants, with the possible exception of tritium. Water returns are expected to be small given that most of the drilling is in the unsaturated zone and the low hydraulic conductivity ($<3 \times 10^{-7}$ m/s) of the saturated granite. Based on a drilling rate of 7 minutes per foot (obtained during the drilling of the PM wells in 1963), the conductivity given above, and a saturated extent of 300 ft, maximum water production would be on the order of 15,000 gallons, and is expected to be much less due to anticipated faster penetration rates and conductivities less than 3×10^{-7}. In addition, given the spatial distribution of the wells, a contaminant plume is not likely to be encountered in more than one well. Fluid management will be conducted in accordance with the procedures outlined in Section 5.0 of this document.

Well Completion and Rationale

The wells will obtain valuable data simply by encountering the water table, but the target completion depths will be 250 to 300 ft below the water table. This depth will coincide with the depth below water where the nuclear shot was detonated. If significant contamination is detected during drilling (meaning the detection of gamma emitting nuclides), drilling will be halted and the well completed at that depth. The wells will be left as open holes below required surface casing. Prior drilling at the site apparently encountered no problems with hole stability, and the open holes will enhance hydrologic investigations. The holes will probably be drilled to a 9-7/8 inch diameter, allowing ample room for logging tools and leaving the possibility of installing well screen and casing with room to tremie in a gravel pack should permanent monitoring ability be chosen in the future.

Data Collection

1. Static water level will be estimated during drilling. Given the low storativity and low permeability reported for the Sand Springs granite, it may be months after drilling before the static water level has recovered for measurement and sampling. Therefore, the drilling program will be designed to obtain as much immediate data as possible. Drilling progress will be slowed as previously measured water levels are approached to improve resolution on identifying the top of the saturated zone via cuttings. Saturated cuttings will be collected at the surface for possible water extraction and analysis.

2. Geophysical logs (e.g., caliper, acoustic velocity, formation density) will be run to provide additional data for the sequential indicator simulation modeling of the spatial characteristics of aquifer properties (more information on the modeling is provided in the following section).

3. Perform a video log in each well to identify fracture zones that are contributing flow as the well recovers. The video will be evaluated to estimate effective porosity.

4. A transducer will be installed in each well to monitor water level recovery. The data will be used to determine when the static water level is reached, and for estimating transmissivity.

5. Once the wells have recovered, a temperature/electrical conductivity log will be run to identify potential inflow zones and the presence of vertical flow.

6. Thermal flowmeter measurements will be performed to determine direction and velocity of vertical flow in the well. Measurement locations will be picked based on zones of interest identified with the temperature/electrical conductivity log.

7. Water samples will be collected at locations identified based on the temp/EC log and thermal flowmeter measurements. Samples will be analyzed for tritium to identify migration from the Shoal test, and major ions, stable isotopes, and carbon isotopes (-13 and -14) to identify current recharge conditions at the the Sand Springs Range and

correlate with the differing water chemistries found in Fairview Valley and Fourmile Flat.

8. Point dilution tests will be performed to determine lateral flow velocities, once the test protocols are established from Nevada Test Site applications.

9. Slug tests will be performed to estimate aquifer properties.

10. Water levels will be monitored in the wells for a one-year period to identify and seasonal impacts on potentiometric levels. The monitoring will be performed using pressure transducers reporting to data loggers.

Predicting Contaminant Transport in the Subsurface

The Shoal underground nuclear test was detonated below the water table. Though the transmissive properties of the Sand Springs granite are believed to be poor (Nevada Bureau of Mines, et al., 1964), the test was conducted in a groundwater recharge area and flow of groundwater through the cavity and surrounding area is expected. This flow has the potential of transporting shot-related contaminants away from Shoal ground zero. Plans for remediating the site will rely upon predictions of contaminant transport. This prediction-based approach is followed for two reasons:

- There is no reasonable remediation process (e.g., pump-and-treat) for at least one of the primary contaminants of concern (tritium). It is expected that the appropriate remediation will be preventing exposure by restricting groundwater use in contaminated aquifers. Thus, the present location of contaminants is of less concern than predicting the future extent of migration.

- The hydrogeologic environment at Shoal is a fractured granite. The highly variable and unpredictable nature of fracture occurrence and interconnection render efforts to define plume geometry in the field infeasible.

Thus, the final product of the groundwater characterization phase at the Shoal site will be predictions of contaminant transport within desired confidence intervals. This will be achieved through three primary work elements:

1. Collection of data from the new characterization wells (described above).

2. Analysis of historic and newly acquired data from wells in the Shoal area to map aquifer properties and provide a framework for flow simulations that will determine the mean flow velocity, mean flow direction, and spatial characteristics of the flow field.

3. Predictions of solute migration to determine the boundary of specified contaminant concentrations in the aquifer.

The field efforts involved in the first phase are described in detail elsewhere, as are the existing data. The following discussion will emphasize the importance of collecting hydrologic data for the transport calculations, particularly data on flow velocities. All of the data gathered from the new wells will be useful for the modeling effort. Hydraulic head data will be used to constrain the flow model and calculate appropriate gradients. Hydrologic logging and borehole testing can provide data on hydraulic properties and flow velocities. Data from water sampling will be used to determine recharge boundary conditions, and perhaps constrain transport calculations if tritium is detected.

When environmental concerns focus on groundwater transport, a careful description of the subsurface, and hydrogeologic heterogeneity in particular, becomes necessary. To develop support for the transport calculations, there must be an adequate understanding of the geologic and hydrologic environment at Shoal. In virtually all regulated settings in the subsurface, the volume of aquifer modeled is many of orders of magnitude greater than the volume of geologic material actually observed or sampled (Journel and Alabert, 1989); this is especially true given the sparse data density at Shoal. In addition, the fractured granite nature of the Shoal Site make obtaining a description of geologic heterogeneity far more difficult than in cases of porous media flow. Tremendous extrapolation is necessary and introduces significant uncertainty into our geologic understanding. As a result, the modeling effort contains uncertainties that are a direct result of our incomplete knowledge.

Limited field characterization at Shoal severely restricts our knowledge of hydraulic properties at the site, particularly since extreme heterogeneity in hydraulic properties is characteristic of fractured granite terranes. Our approach will assemble and synthesize historic and newly acquired well data at Shoal, and augment that data as far as possible. Predictive models will then be carried out using the observed data, recognizing that the true range in hydrologic parameters may be much greater than observed. Parameter ranges at better-characterized granitic sites will be used to evaluate the potential transport impact of unobserved high permeability fractures at Shoal.

The scarcity of data points requires maximizing the hydrologic interpretations. The use of all available types of data (geological, geophysical, and hydrological) is needed to describe the geologic heterogeneity at Shoal in three dimensions and to quantify the uncertainty. The second work element will effectively multiply the data from the seven former wells in the ground zero area (PM-1, PM-2, PM-3, ECH-A, ECH-D, PM-8, USBM-1), and the three new wells and shaft, by using geophysical logs to supplement hydrologic data. Specifically, caliper, resistivity, gamma, and neutron logs (run prior to the Shoal test) will be used to infer fracture density and permeable zones and these high resolution data will be correlated between wells using sequential indicator simulation (SIS) methods. This volume-data generation technique has been successfully applied in a variety of environments. For example, DRI used SIS methods and geophysical data from boreholes in central

Yucca Flat (Pohlmann and Andricevic, 1994) and is currently applying the technique in Frenchman Flat, of the NTS. The analysis in Yucca Flat used geophysical log data and SIS methods to infer the three-dimensional distribution of fractured tuffs. This information will be important for delineating flow and transport features that would not have been revealed by analysis of the scarce traditional hydrologic data (e.g., aquifer tests).

Application of the technique to the Shoal Site will involve identifying logs that are likely to distinguish properties important to groundwater flow (particularly fractured zones), correlating between the geophysical logs and available hard data on hydraulic properties (hydraulic conductivity), then generating three-dimensional maps of hydraulic conductivity that characterize spatial anisotropy and connectivity patterns to be used as input for a numerical model of groundwater flow.

Difficulties applying the technique to the Shoal site center on the issue of data density. Well control close (within 600 m) to ground zero is relatively good, but from that point, it is 3400 m to the closest well. Some of these issues will be addressed during the field program via the location of the new wells (particularly well HC–3). These problems will persist in the flow modeling, though the flow calculations will have the advantage of the three dimensional permeability structure based on geophysical data. It is hoped that the data collected from the new wells will resolve issues of the position of ground zero relative to the groundwater divide beneath the Sand Springs Range. Given that substantial uncertainties in the flow field will remain even after the field investigations, the uncertainty will be included in the calculations by considering a reasonable range of boundary conditions, recording the resulting mean velocities, mean flow directions, and flow-field structures for input to the transport model.

The contaminant migration process is described in Dagan et al. (1992), Andricevic and Cvetkovic (1996), and Andricevic et al. (1994) through the Lagrangian concept of motion following a particle on the Darcy scale. The solute flux method evaluates movement of a solute from the source to a plane perpendicular to the direction of flow. Aquifer heterogeneity is included and represented by the variance of log-hydraulic conductivity, $\sigma^2_{\ln K}$ and the hydraulic conductivity integral scale, λ. The variance represents the variability of K in space and may range from near zero for homogeneous deposits to three, or higher, for extremely variable porous media (Hoeksema and Kitanidis, 1985). Because it is distributed in space, K usually has some degree of spatial correlation. The correlation length of K, λ, represents the distance beyond which there is no correlation between data points. The higher the value of λ, the greater the spatial continuity of K. When the log-normal distribution and the negative exponential covariance function are assumed, the heterogeneous, isotropic hydraulic conductivity field can be statistically characterized by three parameters: $\mu_{\ln K}$, $\sigma^2_{\ln K}$, and λ. The combination of the spatial variability of aquifer properties and the uncertainty in

Well Number Diameter in Depth to Water Discharge in GPM Pump Type Remarks the estimates of these properties causes the solute flux to be a random function described by a probability density function (pdf). The mean and variance of the solute flux are converted to the flux-averaged concentration by dividing by the groundwater flux, Q. Importantly, the variance of the solute flux allows calculation of the standard deviation so that the transport results can be presented within desired confidence intervals.

The previous application of the solute flux method to the Shoal site (Chapman et al., 1995) only calculated the transport of the plume in one dimension, laterally along the flowpath, resulting in a breakthrough curve and associated uncertainty at any desired distance downgradient. This approach is suitable for calculating the distance to a desired concentration- or risk-based limit, but provides no information on transverse plume spreading. The method which will be employed during the characterization phase will calculate not only the longitudinal spreading of the contaminant plume, but also the transverse spreading, creating a map of the plume. At specified distances downgradient, the breakthrough curves will be generated (concentration vs. time). Concentration as a function of transverse distance from the mean flow direction will also be calculated. Thus for any given distance down the mean flowpath, there will be a map of contaminant concentration in time and space. Numerous flowpath distances will be analyzed, mapping plume migration and allowing identification of the plane which meets the desired criteria of a mean tritium concentration of less than 20,000 pCi/l.

To summarize, the Shoal underground nuclear test was conducted in the saturated zone of a fractured granite aquifer. Site data are quite limited but will be enhanced by the planned hydrologic field activity of drilling three new wells. Fractured aquifers are very difficult to characterize and experience great variability in hydrologic properties. State-of-the-art data analysis approaches and proxy data will be applied to minimize the inevitable imperfect understanding of the hydrologic system and produce transport predictions.

Documentation of Status of Existing DOE Wells

As part of site characterization and data collection from the test, DOE (AEC) drilled a number of holes in the Shoal area (Tables 4 and 5). Four of these are in the adjacent valleys: HS-1 and H-4

Appendix B

Addendum 1: Corrective Action Investigation Plan for Project Shoal Area, CAU No. 416 Data Quality Objectives

The following is an addendum to Section 3 (DQOs) of the Corrective Action Investigation Plan (CAIP) for Project Shoal Area CAU No. 416. The addendum is based on guidance provided by NDEP for revisions to the Roller Coaster Lagoons DQOs on June 28, 1996.

3.4.1 - Statement of the Problem

3.4.1.1 - Surface (Soil)

This section is unchanged. Sections 2.2.1 and 3.3.1 of the CAIP provide more detailed information regarding potential contamination in the impoundment. Excerpts from the historical documentation that form the bases for these sections are included as Attachment A to this addendum.

3.4.1.2 - Subsurface (Groundwater)

This section is unchanged. Sections 2.2.2 and 3.3.2 and Appendix A of the CAIP provide more detailed information regarding potential contamination of the groundwater.

3.4.2 - Identification of the Decision

3.4.2.1 - Surface (Soil)

Replace the existing section with the following:

Implementation of the surface investigation portion of this CAIP is intended to support the following decisions:

- Determine whether the soils present in the impoundment are contaminated above preliminary action levels. Contaminants of potential concern and preliminary action levels are described in Section 3.5.1 of the CAIP.

- Determine whether contaminants present in the impoundment soils have migrated to the soils surrounding the impoundment and to the arroyo sediments downstream from the impoundment.

3.4.2.2 - Subsurface (Groundwater)

Replace the existing section with the following:

Implementation of the subsurface investigation portion of this CAIP is intended to determine the location of the contaminant boundary within which water use restrictions will be implemented to prevent exposure to potentially contaminated groundwater. The subsurface investigation is described in detail in Appendix A of the CAIP.

3.4.3 - Identification of Inputs to the Decision

3.4.3.1 - Surface (Soil)

Replace the existing section with the following:

The potential contamination of the impoundment soils will be evaluated by collecting systematic environmental samples within the impoundment. Potential contaminant migration from the impoundment will be evaluated by collecting samples from soils adjacent to the impoundment upstream from the containment dike, and collecting arroyo sediment samples below the downstream toe of the containment dike.

As discussed in Section 3.3.1 of the CAIP, the primary contaminants of concern for the impoundment soils, surrounding soils, and arroyo sediments are fission products. All soil and sediment samples collected from the study area will be analyzed for these contaminants of concern. To verify that diesel fuel or other common drilling mud additives were not used in the postshot borehole drilling mud, the samples collected from within the impoundment will be analyzed for TPH, total barium, and total chromium.

Although historical information is available for the site, it is not sufficient to confirm that any wastes disposed of in the impoundment would be considered RCRA listed wastes. Because of this, it is assumed that if the impoundment soils are removed as a part of site remediation, they would be characteristic wastes. The sampling and analysis program for the impoundment soils includes collection of three samples from within the impoundment for TCLP volatile and semivolatile organic compounds and TCLP metals analyses to determine whether any contaminants present in the impoundment soils exceed RCRA toxicity characteristic criteria to allow evaluation of remedial alternatives and to support waste management decisions.

3.4.3.2 - Subsurface (Groundwater)

Replace the existing section with the following:

The potential extent of groundwater contamination will be evaluated through modeling. The input parameters for modeling will be based on the following:

- Literature reviews, including information on the estimated yield of the Shoal test, will be used to identify the type and amount of contaminants that could be available to migrate.
- Data on physical flow characteristics will be gathered from existing literature for the site and for similar aquifers (if available).

The information obtained from literature will be augmented by geophysical and geochemical data collected from four new monitoring wells to be installed as a part of the CAIP implementation.

3.4.4- Definition of the Study Boundaries

3.4.4.1 - Surface (Soil)

Replace the existing section with the following:

The physical boundaries of the surface study area are:

- Three meters (10 feet) outside of the impoundment upstream from the containment dike
- Fifteen meters (50 feet) down the arroyo from the downstream toe of the containment dike
- Six meters (20 feet) below the impoundment or to bedrock, whichever is shallower

These boundaries are based on the preliminary site conceptual model discussed in Section 3.1 of the CAIP. The physical boundaries of the surface study area may change depending on the results of the analytical data generated during sampling. There are no temporal constraints or boundaries for collection and use of data for the surface study area.

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SITE DISPOSAL REPORT

FALLON NUCLEAR TEST SITE

(SHOAL)

CHURCHILL COUNTY, NEVADA

MAY 1970

UNITED STATES ATOMIC ENERGY COMMISSION

NEVADA OPERATIONS OFFICE

4.3 SECURITY ANALYSIS

As already discussed in Paragraph 3.3 b, SHOAL samples and analyses are classified and create a security problem. Therefore, for this reason, as well as health safety (discussed in Paragraphs 4.5 and 4.7 in which ground water movement calculations are given), an excavation and drilling exclusion area is required. The exclusion area lies between a level of plus 5,050 feet above mean sea level and plus 3,530 feet (i.e., between 180 feet and 1,700 feet below SGZ) and out to a horizontal distance of 3,300 feet from SGZ. Also included is any re-entry into drill holes or the shaft within the horizontal restrictions. This restricted area is shown on Figures 4 and 5 and becomes a part of the recommendations given in Paragraph 5.3.

4.4 STRUCTURAL SAFETY ANALYSIS

As stated in Paragraph 4.2 b, the SHOAL cavity collapsed immediately after detonation, with collapse moving upward until the bulking of the broken granite blocks provided a configuration of the void at the top that did not permit further in-fall. The area has a recent history of seismic activity; however, the present stability is not likely to be altered by earth tremors or ground water activity. Even if there shoul be some rearrangement of blocks in the chimney with some attendant subsidence, there are over 800 feet of granite in its natural state betwee the top of the chimney-cavity and the surface; thus, there should be no structural safety hazard.

Negligible consolidation of the chimney rubble might occur from large, nearby seismic activity, with consequent resumption of upward stoping. However, even a 20 percent compaction of the existing rubble would permit only another 20 to 30 feet maximum of ceiling in-fall. The present chimney should present no problem for physical stability and safety.

4.5 RADIOLOGICAL SAFETY ANALYSIS

Most of the nongaseous radioactive residue of the nuclear explosion was trapped in the melt portion at the bottom of the cavity or dispersed through the rubble chimney volume. The unfractured granite over the chimney has maintained its integrity as a radioactive shield; therefore, access to the radioactive melt can be achieved only by use of drilling equipment. Entry through the original shaft and drift has been effecti blocked by collapse of the shaft below 1,060 feet and by intervening sa plugs as well as the reinforced concrete cover slab sealing the shaft at the surface.

No radioactive materials were vented at shot time; however, minor radioactivity reached the surface during the postshot drill back. This release was mostly a gas under well-controlled conditions and was safely channeled into filters and traps. Soil and cuttings contaminated with short-lived radioisotopes of iodine and xenon resulting from postshot drilling operations were mixed with clean soil and buried beneath uncontaminated soil. A final radiological safety survey was made of the surface work and burial areas. Soil samples were collected and analyzed from all surface areas known to have been contaminated. The analysis of these samples together with the radiological survey indicate no radiation levels above natural background.

When the USBM#1 hole was reentered, small amounts of radioactivity were found in air when a plug at 411 to 511 feet was drilled out. Cracks or fractures, very likely opened by the detonation, permitted migration of radioactivity out to a distance of 445 feet.

There are no channels to provide communication of radioisotopes with the surface, except man-made openings (shafts, drifts, and bore holes); thus, if these structures are permanently sealed, subsurface contamination could not become a radiological health safety hazard. Because of the contamination within the SHOAL drift, cavity, and chimney, reentry into these areas by any means must be prohibited. Therefore, the necessity of an Excavation and Drilling Exclusion Area discussed in Paragraph 4.3 applies as a health safety precaution as well as a security restriction. (See Figure 4.)

4.6 CLIMATE AND METEOROLOGICAL EFFECTS ANALYSIS

The Sand Springs Mountain Range has a semiarid to subhumid climate. Temperatures range from below 0°F to over 100°F during the year. Rainfall and snowfall combined provide about 8 inches annual precipitation. No disposal safety problems are inferred from meteorological conditions. No known radioactive objects which are water soluble or flood transportable have been left on or near the surface with the exception of the buried soil and drill cuttings which were contaminated with short-lived radioisotopes. These radioisotopes have now decayed to below detectable levels. (Reference Paragraph 4.5.)

4.7 HYDROLOGIC SAFETY ANALYSIS

A local dewatered zone was created in the Sand Springs Range granite by (1) removal of water which seeped into the SHOAL underground workings during construction, (2) temporary displacement of ground water surrounding the detonation point caused by high pressures created by the blast, and (3) creation of new, unsaturated pore space in the explosion chimney-cavity and surrounding area. This dewatered region was not in equilibrium with the surrounding hydrologic potential field; therefore, water will move toward the hydrologic sink of the dewatered zone.

Radionuclides in solution may migrate beyond the rubble chimney through molecular diffusion during adjustment of the zone. However, large-scale transport of contaminated ground water will not occur until water in the underground workings and rubble chimney is in or near equilibrium with

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PROJECT MANAGER'S REPORT

PROJECT SHOAL

UNITED STATES ATOMIC ENERGY COMMISSION
NEVADA OPERATIONS OFFICE
May 1964

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Entry of all personnel into RADEX areas was controlled by the Project Manager through Federal Services, Inc., and the REECo Radiological Safety Organization. All personnel entering RADEX areas were equipped with appropriate anticontamination clothing, respiratory devices, and listed on the Area Dosage Registers. Personnel exiting RADEX areas were monitored for contamination and decontaminated as necessary at the check station.

d. Personnel Radiation Dosimetry and Analysis

All personnel at the Shoal Site were provided with film badges. Results for all film badges processed indicate no gamma exposure to any project participant.

Pretest urine specimens were obtained from project participants for use as a base line for internal exposure. Subsequent urine specimens were taken from these personnel during and following completion of the drilling program and analyzed. Analysis results of urine samples submitted indicated no internal exposure.

e. Decontamination

Large area decontamination was not necessary during or following this project. Some surface decontamination was required around the surface ground zero drill hole and in the catch basin for contaminated drilling debris. Although contamination levels were low, in order to leave the site unattended, it was necessary to scrape the surface and bury all contaminated soil. Before burial the contaminated soil was mixed with clean soil during the blading operation to reduce the concentrations. It was then placed in the basin and covered with several feet of clean top soil.

Minor decontamination was required on drilling equipment. The drill rig was decontaminated prior to removal from the surface ground zero position. Decontamination of drill pipe, drilling bits and associated equipment was successful on the majority of items.

f. Remote Monitoring Systems

1) Jordan Radector System

The Jordan Radector system utilized remote Neher-White ionization chambers. This system, having satisfactory shock resistant and distance characteristics and affording direct readout, was used to provide information during the test and following post-shot operation on any radioactivity which might have been released. The system consisted of 18 remotely positioned detectors on D-Day. Two of these were underground in the main drift and the remainder were located on the surface in an arc of 270° at distances ranging from 500 to 10,000 feet from surface ground zero. The readout panel was located in the Radiation Safety trailer at the CP and connected with the detector by field wire.

For the post-shot drilling operation a number of the far-out detectors were repositioned on the effluent exhaust system and direct readout meters located in the Radiological Safety Base Station. These units were located on each component of the exhaust system.

2) Remote Gamma Recorder System

The second system was a remote gamma recorder system. This system also utilized Jordan Radector components and was used to record gamma radiation dose rates on the drill rig and effluent exhaust system. Esterline-Angus recorders were modified to house the electronics of the Radector and connected to the meter circuit in place of the instrument meter. The recorder was then connected with the detector by field wire.

PROJECT MANAGER'S REPORT

PROJECT SHOAL

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2. Post-Shot Activities

As soon as it was determined that there was no release of radioactive gases or debris, recovery parties were allowed to enter the area to recover data. Projects utilizing film or light sensitive paper for recording were given priority for re-entry. These recoveries were mostly completed within three hours of the event. It was expected that the cavity collapse would occur at approximately H + 6 hours and for this reason the ground zero area and the area downwind from ground zero was kept clear during that time. Geophones installed in drift, shaft, and near the surface at the shaft were monitored continuously for any indication of cavity collapse; however, it was later determined that the cables from the geophones in the shaft and drift had been lost, but the surface geophones were operable and should have detected any collapse activity.

The drill rig for post-shot drilling was moved on-site on D + 2 and set up. Because of the belief that the cavity was intact, drilling plans were modified completely. It was decided to attempt a line-of-sight hole to enter the cavity at the top center. This procedure in itself would slow down drilling considerably, but plans were also made not to enter the cavity until about four weeks had elapsed for cooling and decay of the radioactivity. Drilling proceeded under these conditions while an exhaust system was set up to handle any radioactive gases encountered during drilling.

A line-of-site hole was maintained to 250 feet with only a small deviation obtained down to total depth. At 600 feet the hole was cemented to prevent leakage in the upper layers of the formation. Several voids and open fractures were entered at depths below 800 feet and the drilling became difficult because cuttings did not return to the surface and piled up in the hole. The hole was reamed and casing set to a depth of 937 feet and the hole continued through that to a depth of 1391 feet. The hole was logged for temperature and radiation. A side-wall sample was taken from near TD and other radioactive debris was obtained from cuttings on December 19. Samples were forwarded to LASL for analysis.

Drilling did not find a cavity where expected; it apparently collapsed immediately after formation at shot time. Only small amounts of radioactive gases and cuttings were encountered and the exhaust and scrubbing system worked satisfactorily to control release to the atmosphere.

The post-shot hole was closed off after lowering a drill stem to the bottom with a valve and pressure gage mounted on top. The top of the hole was cemented between the casing and drill stem and was completed on December 20, 1963.

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PROJECT MANAGER'S REPORT

PROJECT SHOAL

UNITED STATES ATOMIC ENERGY COMMISSION
NEVADA OPERATIONS OFFICE
May 1964

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APPENDIX C

WELL HISTORY - PROJECT SHOAL - POST SHOT NO. 1

10-29-63 Moved in and rigged up Brinkerhoff Drilling Co., National T-20 with 2 - 900 cfm compressors and 1 - 600 cfm compressor. Drilled rat hole.

10-30-63 Spudded in at 1:45 a.m. and drill an 11" hole (HTS-OWV bit) to 66' using mud as the circulating media. 9.2#/gallon, 39 viscosity. Drilling with 2000# on bit, 60 RPM and 200 psi on pump. Sperry Sun Surveys are:

46' - 0°15' S 10° W
62' - 0°05' N 60° W

10-31-63 Drilled an 11" hole from 66' to 88'.

66' to 79' 60 RPM, 10,000# 100 psi.
79' to 88' 45 RPM, 15,000# 150 psi.

11-1-63 Drilled 11" hole to 100', ran Sperry Sun Survey at 98' - 0°30' N 58° W. Pulled out and made up 17-1/2" Reed hole opener and 7-3/4" drill collars. Began opening hole at 1500 hours. Opened hole to 41'.

11-2-63 Opened hole to 17-1/2" from 41' to 98'. Rigged up and ran 102.38' (4 jts) of 13-3/8" - 54.50# casing including a Baker float shoe at 83.38' ground level and cemented with 201 cu. ft. of 50-50- Posmix cement plus 2% CaCl2 using B. J. Cementers. Mixed 0200 hours - 0210 hours. Displacement was calculated to have 10' plug inside casing, no bleed back when cement was in place.

Baker shoe	1.75'
13-3/8" casing: (1)	33.06
(2)	29.12
(3)	19.45
Baker Shoe	83.38
at Landing Joint	19.00
	102.83'

11-3-63 Backed off landing joint and installed blow out preventor. Nippled up after 4 hours of WOC Closed blind rams in BOP and pressured up with water to 1200 psi inside casing. Held pressure for 15 minutes. Pressure held o.k.

Picked up 5-1/2" drill pipe and one drill collar. Ran in and closed drill pipe rams. Pressure up with mud to 1,000 psi. Pressure held o.k. for 15 minutes.

Ran in to top of cement and blew water out of 13-3/8" casing.

11-4-63 Finished nippling well head. Ran in with 9-7/8" YC 26 button bit and 9-7/8" button reamer. Drilled out 13-3/8" casing shoe and drilled ahead to 124' with air. Installed cover for drilling head and made up sampling and bleed off manifold.

11-5-63 Drilled to 160' with 9-7/8" bit. Surveys:

132' - 0°07' N 74" E.
160' - 0°20 N 15° W.

11-6-63 Drilled to 183'. Picked up off bottom, closed drill pipe rams, pressured up to 100 psi, pressure dropped back to 62 psi in 15 minutes. Changed bits and drilled ahead to 206'. Surveys - 190' 0°25' N 67° W.

160' - 183' 72 RPM, 6-8000#
183' - 190' 72 RPM, 6-8000#
190' - 197' 72 RPM, 4-6000#
197' - 206' 55 RPM, 2-4000#

11-7-63 Drilled to 223', pulled out and changed bits, ran in with 9-7/8" Reed buttom bit and buttom reamer and drilled ahead to 231'. Survey, 221'-0°30' N 2° E.

11-8-63 Drilled to 231', closed rams and tested formation. Pumped in air at the rate of 1735 cfm at 50 psi stand pipe pressure, pressure under rams recorded as follows:

in 5 minutes - 32 psi
in 15 minutes - 32 psi
in 30 minutes - 32 psi
in 40 minutes - 32 psi.

Dripped input pressure on compressors to 32 psi and annulus pressure dropped to 9 psi in 5 minutes. Annular pressure remained at 9 psi for 15 minutes during period air was injected at 32 psi, stand pipe pressure.

Opened compressors wide open and after 3 minutes of injection, pressure on stand pipe was 63 psi, pressure on annulus built up to 32 psi. Closed system to shut in pressure, annulus pressure bled back to 3 psi in 2 minutes, 3 psi to 2 psi in 45 seconds and 2 psi to 1 psi in 10 minutes. Test completed at 1250 hours. Witnessed by Bob Burton, Sandia Corporation.

Drilled ahead to 279' with 9-7/8" bit and reamer and dry air. Survey:

251' - 0° 40' N 30°W.
278' - 0° 25' N 22°W.

11-9-63 Drilled ahead to 404' with dry air.

Surveys:

307' 0° 25' N 26° W
336' 0° 23' N. 72° W
367' 0° 25+.N 75° W
396' 0° 25' N 75° W

11-10-63 Drilled ahead to 503'.

Surveys:

427' 0°37' S 49° W.
458' 0°35' S 52° W.
489' 0°44' S 46° W.

11-11-63 Drilled ahead to 589'.

Surveys:

520' 0°43' S 54° W
551' 0°40' S 68° W
582' 0°40' S 80° W

11-12-63 Drilled ahead to 600', survey at 600', 0° 33', s 82° W. Pulled out of hole and replaced drill collars with 5 1/2" drill pipe. Ran in hole open ended and hooked up Halliburton truck. Mixed 42 viscosity mud and lost circulation material composed of 19 sacks of gel, 10 sacks of cotton seed hulls, 6 sacks of fibertex and 2 sacks of mica. Measured lost circulation material and mud thru Halliburton truck.

Began filling hole at 1125 hours with open ended drill pipe hung at 590'. Pumped in 500 cu. ft. of material, no returns. Mixed 300 cu. ft. mud and lost circulation material, pumped in hole. Tested fluid level inside drill pipe with wire line and probe, found fluid at 400' - 405'.

Mixed 445 cu. ft. of lost circulation material and 55 viscosity mud, added 4 sacks of cement to mud and pumped into hole, no returns. After 12 minutes waiting for fluid to equalize, ran inside of drill pipe and found fluid level at 375'.

Pumped a total of 1245 cu. ft. of mud and lost circulation material, equivalent to 222 bbls. fluid level remained at 375'. Total capacity of hole to 600' is 58.51 bbls. Total lost circulation material used:

60 sacks of gel
15 sacks of cotton seed hulls

15 sacks of Fisher Tex
11 sacks of Celo Seal
4 sacks of Mica

Ran in with 5 1/2" drill pipe hung open ended at 586'. Pumped in 545 cu. ft. of cement, composed of 15# gilsonite per sack of Type C cement, mixed 93-95# per cu. ft. slurry. Began mixing cement at 1755 hours, cement in place at 1815 hours, pulled out drill pipe.

11-13-63 Waited on cement until 0600 hours. Ran in with drill pipe and found top of cement at 415'. Pulled out of hole, rigged up lines for Stage #2.

Ran in with drill pipe hung at 399'. Began pumping in 93# cu. ft. cement slurry at 0827 hours. Pumped in 272 cu. ft. of cement slurry. Cement in place at 0837 hours. Ran in with wire line and weighted can, brought out sample of soft cement at 132'. Waited on cement from 0900 hours to 1500 hours.

Hooked up Halliburton truck and ran in with 2 stands of 5 1/2" drill pipe hung at 120'. Pumped in 117 cu. ft. of 93# cu. ft. of cement slurry. Filled to bottom of blow out preventer. Pulled pipe and hooked up lines to squeeze cement. Cement in place at 1541 hours.

Closed rams at 1555 hours. Cementers pumped in an additional 14 sacks of cement after rams were closed, pressure built up to 400 psi.

Squeeze - at 1638 hours, pumped in 2 cu. ft. of water under closed rams and pressure built up to maximum allowable to 200 psi. Pressure bled back to 100 psi in 2 1/2 minutes. Built up pressure to 220 psi, dropped off to 100 psi in 4 minutes. Increased to 200 psi, dropped to 30 psi in 20 minutes. Continued to build up pressure to 200 psi until 2120 hours at which time the volume of displacement fluid was so small that no cement was being squeezed away at the 200 psi allowable. Shut well in at 2120 hours after having displaced 5.76' of cement inside of 13 3/8" casing using approximately 5 cu. ft. of water. Standing cemented.

11-14-63 At 0600 hours, ran in with 9 7/8" bit to drill out cement with mud. Found top of cement inside 13 3/8" casing at 20'. (7' below BOP). Mixed mud to 40 viscosity using 30 sacks of gel and drilled out cement to 580' KB. Circulated 30 minutes at 580' with no loss of fluid. Pulled up to 138' and began blowing out mud with air. Continued to blow hole dry in 1 stand stages. Hole required 100 psi of pressure to unload on each stand.

After hole was blown dry, closed rams and built pressure up to psi. Pressure dropped back to 60 psi in 5 minutes. Checked line for leaks, pressured up to 100 psi again and pressure fell back to 40 psi in 5 minutes.

11-16-63 Mixed 40 vicosity mud in tank using 43 sacks of gel. Filled hole to bottom of blow out preventor. After 30 minutes, fluid had dropped 3' inside 13-3/8" casing.

Added 18 sacks of gel and built up viscosity to 90 vis mud. Filled hole by circulating and displacing hole. Fluid level was 7' below KB and after 30 minutes it had dropped an additional 1'.

Closed rams, pumped in 37.20 cu. ft. of mud under 0 pressure. Filled hole again, closed rams and pumped away 42 cu. ft. of mud under 0 pressure. Shut off pump and checked fluid level. Filled with 26 cu. ft. Waited 30 minutes, refilled with 57 cu. ft. Waited 30 minutes, filled with 53.4 cu. ft. Waited 30 minutes and filled with 135.8 cu. ft. Added 2 sacks of mica in last 10 cu. ft. Waited 30 minutes and filled with 112.8 cu. ft., waited 30 minutes filled with 115.8 cu. ft.

11-17-63 Ran in with drill pipe blowing hole dry to bottom for cement. With 5-1/2" drill pipe hung at 574', pumped in 50 cubic feet of water ahead of cement. Filled hole to surface with 304 cu. ft. of slurry composed of Type C cement and 4% gel, B. J. Cementing Co.

11-17-63 Mixed and pumped 1720-1733 hours. Pulled out and filled hole with 121 cu. ft. of slurry (drill pipe displacement). Cement kept falling, closed rams and pumped in 41 cu. ft. of slurry with 0 pressure.

Ran in with 5-1/2" drill pipe hung at 93' and pumped in 91 cu. ft. of slurry before cement came to surface.

Closed drill pipe rams and pumped in 66 cu. ft. of slurry at 200 to 250 psi. Bled off and pulled drill pipe. Pumped in 63 cu. ft., did not fill hole. Waited 1-1/2 hours and pumped in 90 cu. ft. of slurry and dropped 2 sacks of perlite in cement while slurry was pumped in hole. Filled hole to surface at 2140 hours.

At 2240 hours, cement had lowered 10' inside of 13-3/8" casing. Filled hole, closed rams and squeezed away 13 cu. ft. of slurry at 300 psi maximum allowable pressure.

Pressure bled back to 250 psi and remained at such for 8 minutes. Pumped 1/2 cu. ft. of slurry and built up to 300 psi. At 0015 hours pressure had dropped to 225 psi. Squeezed away cement in 1/2 hour intervals maintaining 300 psi maximum pressure.

Shut well in at 300 psi at 0115 hours. Total slurry used was 1368 cu. ft. of Type C cement and 4% gel.

11-18-63 Shut in and nippled up for drilling cement out with mud.

11-19-63 Ran in with 9-7/9" bit and found cement 15' below KB (2' below GL). Drilled out cement to 580' with 9-7/8" bit using mud as circulating media. Nippled up to drill with air.

11-20-63 When drill pipe was removed fluid stood at approximately shoe of casing, indicating hole took no fluid.

Ran in to 120' and began unloading hole. Added soap and unloaded hole to 240' in short stages. Unloaded hole in 30' stages to 580'.

Closed blind rams and pumped in air through well head at 20 psi for 2 minutes. Increased air and built up pressure to 50 psi at 0415 hours and shut in. In one hour pressure had bled back to 41 psi. One valve was leaking and some pressure was being lost through blind rams. Tightened lines, valves, etc.

Built up pressure to 78 psi and after 5 minutes pressure had bled back to 75 psi. 0521 - 0526 hours.

Bled off all pressure, ran in with drill collars and one stand of drill pipe to test back pressure valve in drilling assembly. Built up pressure to 40 psi, remained at this pressure for 20 minutes. Well head gauge was opened and pressure dropped to 35 psi. A plastic bag placed on top of open drill pipe indicated that the back pressure valve was leaking. Test was approved by R. Burton and W. Allaire and orders were given to drill out cement and drill ahead. Finished test at 0730 hours.

Drilled out cement from 580' to 600' and drilled from 600' to 648' with a 9-7/8" bit using air-mist as circulating media. Injected 8 to 10 bbls. of water with 1/2 gal. soap per bbl. Survey at 642', 0°45' S 61° W.

11-21-63 Drilled ahead from 648' to 758' using air-mist, 6 to 8 bbls. of water/hr. and 1/2 gal. of soap/bbl. Surveys:

672' - 0°35' S 46° W.
704' - 0°50' N 88° W.
735' - 0°45' S 63° W.
765' - 1°00' S 64° W.

Drilling with 68 RPM, 18000# on bit.

11-22-63 Drilled with air-mist to 765'. Ran surveys and pulled out to core.

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11-22-63 (Con't.) Ran in with 6' X 4" Christensen standard running type core barrel with a set of 5-3/4" OD Bowen Jars and a 9-3/4" OD roller type reamer plus 9 - 7-1/2" OD drill collars. A 6' x 4" Christensen diamond core head was run on core barrel. Cored from 765' to 774' with 290 psi of air, soap and water. Mixture was 4 gal. of soap to 7 bbls of water, injection rate was 7 bbls/hr. Cored 9' and recovered 9'. Total hours coring, 4-1/2 hrs. or 2'/hr. of penetration rate. Extracted core, opened 6" core hole from 765' to 774' to 9-7/8" and drilled ahead to 803'. Checked surveys at 735, 765, 801 and 562'. Survey, 801', 0°55' S 62° W.

11-23-63 Drilled ahead to 840' using air-mist. 1/2 gal. of soap to 14 bbls. of water, injected at the rate of 6 to 8 bbls./hr.

Survey: 832' 1°07' S 82° W. Changed bits. Encountered a small flow of water at 843.

Survey: 859' 1°05' S 72° W. Drilled ahead to 864', dropped thru to 887' - badly fractured and no returns. Did not have to rotate bit for penetration from 865' - 887'; 890' - 895'. Picked 9-7/8" bit off bottom, lost 6' of hole. Drilled out to 896' with no returns. Drilled from 898' to 901' in 10 minutes.

11-24-63 Drilling with 2000 - 8000#. Pulled up 31' to run surveys, redrilled hole from 890' to 921'. Ran Rad Safe gamma probe. Drilled to 927' with no returns. Injected 3 bbls. of water with no returns. Poured 3 qts. of soap in drill pipe, no returns. Drilled ahead, had returns of 900 cfm of air, no cutting. Worked drill pipe every 5'. Increased injection rate to 8 gal. of soap to 1 bbl. of water. Circulated for returns. Changed injection to 10 gal. of soap to 14 bbls. of water. Injected at 1/2 bbl/hr. While drilling, had returns of air but no soap or mist. At 1830 hours had returns of small amount of soap. Reamed and worked tight spot to 930', drilled to 983 in badly fractured granite. Surveys:

890' - 0°50' S 76° W.
921' - 0°58' S 62° W.
953' - 1°25' S 52° W.

11-25-63 Ran Rad Safe probe in drill pipe. Pulled out of hole, air continued to blow out of hole at the rate of 3600 cfm. Continued to let air blow out of hole 0230 hours to 0730 hours. Reran Rad Safe probe to 888'. Opened 9-7/8" hole to 12-1/4" from shoe of 13-3/8" casing to 165'.

11-26-63 Opened 9-7/8" hole to 12-1/4" to 285'. Changed hole opener and reamed opened hole to 256'.

11-27-63 Opened hole from 9-7/8" to 12-1/4" from 256' to 572'.

Began injecting soap and water at 348' using 7 bbls. of water and 1 gal. of soap/hr. From 444' to 472' injected at the rate of 3-4 bbls. of water and 1 gal. of soap/hr.

11-28-63 Opened 9-7/8" hole to 12-1/4" from 572' to 753'. Injected soap and water at the rate of 4 bbls. per hr.

11-29-63 Opened 9-7/8" hole to 12-1/4" from 753' to 922'. Hole kept sloughing. Worked reamer thru tight spot from 913' to 933'. Difficulty making connection. Rigged up and ran Schlumberger Density log to 913'.

11-30-63 Ran in with 12-1/4" hole opener and pilot bit, trying to clean boulders out of hole from 900' to 922'. Bled down hole and ran Sandia Television camera. Picked up jars, 12-1/4" bit and reamed hole from 910' to 922', and opened hole to 940'. Continued to work pipe back and forth from 910' to 940' to remove broken granite that keeps falling into the hole. Pulled out.

12-1-63 When drill pipe was removed, left jars, 3 subs and 12-1/4" bit in hole. Mandrel on jars had twisted off at the bottom of threads. Waited on 5-3/4" slips to be flown in from Wyoming. Top of fish at 917', rigged up and ran TV camera, unable to get to top of fish.

Picked up jars, 5-3/4" overshot and worked tools down to fish. Pulled out and ran back in with overshot and bent single. Worked on fish, pulled out and found skirt badly bent. Fish down to 921'.

12-2-63 Sent for 8-5/8" skirt and knuckle joint. Ran in to top of fish tried to work over top of fish. No results. Picked up 12-1/4" bit, ran in and cleaned out to top of fish.

12-3-63 Drilled up boulders from 910' to 924'. Pulled out and ran in with fishing tools. Pulled out, ran in with 5" drill collars and 6-3/4" bit. Cleaned out and blew hole to 927'. Pulled out, ran knuckle guide and 8-3/4" skirt could not get over fish. Pulled out and ran in with 5" DC and 6-3/4" bit, cleaned out to 927'.

12-4 63 Pulled out, ran in with combination mill and 8-3/4" overshot, milling on top of fish. Pulled out to check tool. Ran in and drove mill and overshot over fish. Jarred fish loose and pulled out of hole.

Ran in with 9-7/8" bit and cleaned out to 983'. Pulled out and added 12-1/4" bit and reamer to drilling assembly.

12-5-63 Drilled up boulders from 940' to 983'. Worked 15' of kelly and 36' of drill pipe out of tight hole. Injected 4 bbls. of mud with 2 gal. of soap/hr. to try to make hole hold up and working pipe in and out from 920' to 970' using mud and soap as circulating media. Blowing hole to dry.

12-6-63 Working pipe thru tight hole. Injected slugs of soap and water at the rate of 2 bbls. of water and 10 gals. of soap. Injected slugs of water and soap until pressure build up and began to fall, then injected an additional slug of mixture to pull out. Pulled out and let hole blow down.

Ran TV camera and found hole bridge over with boulders at 901'.

Ran in with 9-7/8" bit and worked pipe thru bad spot at 932' to 939' with water and soap injected at the rate of 10 gals. of soap to 2 bbls. of water per hour. Pulled out and ran in with 12-1/4" bit, reamed and circulated from 938' to 982'.

12-7-63 Drilled up boulders from 923' to 938'. Injected soap and water at the rate of 4 bbls. of water with 10 gals. of soap/hr. Pulled out of hole to run 10-3/4" casing.

Ran 949.41' of 10-3/4, 40.5# J-55 casing with Baker guide shoe set at 937.61'. Casing would not go beyond 937.61'. Made up casing with power tongs and maintained 43000-45000 foot pounds of torque on make up on turned down collars, (11.25" Collar diameter). Pipe stopped at 353', 710', and 935'.

Cemented casing at 937.61' using B. J. Cementing Co. with 375 sacks of Type A cement and 2% CaCl mixed with 259 cu. ft. of water, total of 438.7 cu. ft. of slurry. Displace with one rubber plug, mixed 6 sacks of cement or 7 cu. ft. and pumped in on top of rubber plug. Pumped in 155 cu. ft. of water on top of plug and cement. (Casing calculated to take 522 cu. ft. of water to displace cement.)

Mixed cement 1415 - 1429 hours
Displaced 1436 - 1441 hours

Ran in with probe on Halliburton line and found rubber plug at 935'. Cement in place at 1500 hours. Standing cemented.

12-8-63 Ran Welex Bond Log to determine cement around casing. First run stopped on top of cement at 914'. Tried to pull casing with 10000# over casing weight, no movement, indicating some cement was around shoe of 10-3/4" casing. Raised BOP and set slips with 30000# of weight, cut off casing and nippled up well head. Cut off landing joint (24.56') ran in with 9-5/8" bit and found top of cement at 922'. Drilled out cement to 936.76' and reran Welex acoustic cement bond log to 931'. Log shows no cement around shoe of 10-3/4" casing.

12-9-63 Blew hole dry to 735'. Ran in with Welex tool and located fluid at 735'. Ran in with 4 - 1-11/16" link jits and shot 4 - .40" holes at 932' to 933'.. Pulled up and located fluid at 736'. Set tool in fluid at 738 and found no drop in fluid for 10 minutes. Rechecked fluid in 1 hour and found no drop. Ran tool to perforation and surged, pulled up and found no drop in fluid.

Ran in with drill pipe to 735' and filled casing with 380 cu. ft. of water using B. J. Cement truck. When returns were obtained, closed rams and pressured up with 400 psi gauge pressure. With 401 psi hydrostatic pressure - total 801 psi of pressure against perforations and found no break down in gauge pressure.

Blew hole dry to 935' and ran in with TV camera. Witnessed holes in casing. It is apparent there is a cement job around the casing, even though the bond log shows negative results.

Drilled out cement to 944', closed rams around drill pipe and regulated compressors sor a constant 75 psi air at surface for pressure test on cement around 10-3/4" casing.

Rigged up well head with a 30 psi, 1 pound increments, in annulus between 10-3" and 13-3/8" casing. A surface pressure of 75 psi remained constant while 30 psi. gauge remained at zero psi. Test remained on annulus between casing strings for 1 hour. Shut off compressors, checked back flow of air, Rad Safe reported negative results from air.

12-10-63 Drilled out cement with 9-5/8" bit from 949' to 983'. Drilled in fractured granite from 983' to 1070'. Blew hole down for low gamma probe and TV camera.

12-11-63 Ran gamma probe and TV camera. Ran in hole, drilling out bridges to 1070'. Pulled out and ran Schlumberger Temperature survey and high intensity gamma probe. Found fill at 1065'.

Laid down monel collar and ran in with 9-5/8" bit. Drilled from 1070' to 1082'. Hole fell in while drilling, worked pipe loose. Rocks continued to fall in on top of bit to 1086'. Worked pipe to break up boulders.

Rotary clutch burned out while working drill pipe, connecting links broken. Sent to Casper, Wyoming for complete new clutch.

12-12-63 Installed clutch at 1745 hours, injected 10 gals. of soap to 4 bbls. of water. Slugged hole with one 4 bbl. rate then added slowly. Shut off water and soap, pulled pipe loose, pulled out to check drilling assembly. Ran back in and drilled a 9-5/8" hole to 1115'.

12-13-64 Drilled boulders from 1076' to 1115'. Trouble making connections. Jars are installed on 6th drill collar. In order to make connections in rubble zone to 1175', mixed and injected 10 gals. of soap (no water) with air. Circulated and blew hole for 15-20 minutes after soap injection, then connection could be made. Drilled to 1340'.

12-14-63 Drilled 9-5/8" hole to 1355'. Blew hole for gamma and temperature probes. Ran Totco to 1351' - 2°. Worked pipe to rerun LRL temperature and gamma probe.

Checked annulus between 10-3/4" and 13-3/8" casing. Pressure on annulus indicated pressure to be one psi. Drilled 9-5/8" hole to 1391' stuck pipe and jarred loose. Ran Totco to 1391' - 1-1/2° and reran LRL temperature probe and gamma probe. Worked pipe out of tight hole.

12-15-63 Blowing hole and working pipe. Ran LRL logs. Began pulling out to run Homco sidewall sampler. Pipe was tight for 300'. After bit was removed, rams were closed. Noticed blind rams would not completely close. Upon examination of bowl, found that the 10-3/4" casing had been pulled up into bowl. Found 2 pieces of metal on jars when they were at surface.

Tried to reseat rotating drilling head. The head lacked 3' of seating. Contacted the Rad-Safe monitor and was informed there was too much explosive gas to remove the BOP and cut off casing.

Sandia requested that hole be completely bled down before remedial work is begun on 10-3/4" casing. Bled down well for 12 hours. Hole continued to bleed down at 1700 lineal feet per minute after 12 hours.

12-16-63 Bled hole until 0845 hours. Removed drilling head and let hole vent into Rad-Safe line.

Rigged up to run television camera, would not go into 10-3/4" casing. When blind rams were closed, casing had been pinched together enough that camera would not go below BOP. Picked up BOP and cut off 3.2' of 10-3/4" casing that was up inside of BOP.

Ran TV camera and found casing parted on 3rd joint. With close examination, threads in collar looked like there had been no serious damage. Collar looks ok but pin end of casing indicated damage.

Pulled casing from approximately 108'. Replaced bottom and top joint. Ran back in with casing end screwed into 10-3/4" collar. Tightened with 45,000# of torque and pulled casing string with 25,000# to check connection.

When 3rd joint was removed, the casing indicated that some part of the drilling assembly had caught under pin end and pulled it out of the collar.

Reset slips, cut off landing joint and nippled up.

12-17-63 Finished nippling up. Made up Homco sidewall sampler, nomel collar, jars and measured in hole. Drilled out bridges and boulders from 947' to 1255'. Bit began to torque badly. Pulled out of hole to check drilling assembly. Changed to Cobra bit, ran in and drilled bridges and boulders from 947' to 1298'. Hole is very bad from 1267' to 1298'.

Slugged with soap and one barrel of water, no change in hold conditions. Tried slugging with 2 gals. of soap and 7 bbls. of water, no change. Made connection by pumping in mixture as follows: Two gallons of soap to 14 bbls. of water. Pumped in 6 bbls. and hole tried to unload. When pressure on gauge started, pumped in 2nd slug, mixed as above. When pressure started dropping, pulled up and made connection. Pressure build up was to 200 psi maximum. Drilled to 1391' with this method of injection.

12-18-63 Cleaned out to 1391'. Condition hole for sidewall sampling. Installed sand line. Tried pulling dummy plug from sampler. Redressed retreaving tool, pulled plug and took first sample at 1327'. Pulled up to 1324' and tried 4 times to get sample. Sample tube showed 50 MR but nothing was found in tube. Pulled up to 1318', could not get tube out of tool, bottom of tool filled in with cuttings. Tried unplugging tool with air, pressure built up to 450 psi and remained constant. Pulled 120000 lbs to free pipe.

Sandia gave orders to pull out of hole and delete any further sidewall sampling. When Homco tool was removed from hole, recovered good sample from within sampling tool. Sampling tool was damaged beyond repair because of the bad hole conditions. Found 4' of cuttings inside of sampling tool.

Tried to run Sperry Sun multishots from 1391', film was burned, no Sperry Sun shots below 1288', temperature was 560°F at 1288'. Pulled out and surveys on 2 joint intervals. Surveys were as follows:

1391' - Totco	1°30'
1351' - Totco	2°00'
1300' - No picture	
1265' - Sperry Sun	2°00'S 5° E
1265' - Totco (Check Shot)	2°00'
1202' - Sperry Sun	0°50' S 10° E
1140' - Sperry Sun	1°40' S 1° W

(Con't.)

1078' - 2 runs with Sperry Sun - no picture
1078' - Totco 1° 45'
1025' - Totco 1° 45'
970' - Totco 1° 30'

12-19-63 Laid down pipe collars and tools. Washed down equipment with soap and water to decontaminate tools. All tools and equipment ok by Rad-Safe.

Picked up one 5-1/4" drill collar, new 6-3/4" Reed YHWR bit and run in on 3-1/2" drill pipe, 2-11/16" I.D. to 1171'. Worked pipe down to 1390.97 KB (1377.97' ground level. Baker back pressure valve installed on top of bit at 1389'.) Left approximately 3' of drill pipe sticking up above well head. Set weitht on bottom and made dummy run with Welex. Hit top of back pressure valve at 1389.5 KB (1376' gr. level.)

Made up 8" x 9-5/8" wooden plug and bolted around drill pipe. Plug was designed so that it would stop on top of 1st drill pipe tool joint below surface. Tool joint is at 26.76' below surface. Mixed neat cement and dumped down annulus. Filled to within one foot of surface using approximately 12 sacks of cement. Cement was in place at 1955 hours. Informed AEC as to time and amount of cement used.

Ran in with Welex link jet perforator and shot 3 - .49" hole at the middle of every joint below 940', perforated at the following depths:

KB Measurements	Ground Measurements
1373'	1360'
1345'	1312'
1315'	1302'
1285'	1272'
1256'	1243'
1235'	1222'
1195'	1182'
1165'	1152'
1134'	1121'
1106'	1093'
1075'	1062'
1045'	1032'
1014'	1001'
985'	972'
955'	942'
942'	929'

12-20-63 Finished perforating drill pipe at 0100 hours. Took off sand line and began Tearing down.

Installed valve and sampling connection on top of drillpipe so testing and sampling could be done in the future.

Rig released at 1600 hours.

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BITS

NO.	SIZE	TYPE	DEPTH IN	DEPTH OUT	HOURS	TOTA
1	11"	OWV	0	100'	54	10[illegible]
1A	17-1/2"	HO	0	98'		9[illegible]
2	9-7/8"	YE2GJ	100	183	53	[illegible]
3	9-7/8"	H7W	183	223	25	4[illegible]
4	9-7/8"	YE2G	223	600	82-3/4	37[illegible]
5	9-7/8"	W7R	DRILLING OUT CEMENT			58[illegible]
6	9-7/8"	YCCJ	600	765		
C-1	6	Diamond	765	774	4-1/2	[illegible]
6	9-7/8"	YCGJ	765	840	50-3/4	24[illegible]
7	9-7/8"	YCGJ	840	983	16-1/4	14[illegible]
1	12-1/4	HO	100	285	19	18
2	12-1/4	HO	100	222	6	12
3	12-1/4	HO	222	444	27	22
4	12-1/4	HO	444	850	24	40
5	12-1/4	HO	850	922	4-1/4	7
6	12-1/4	YHWR	910	940	6	3
7	12-1/4	YHWR	918	924	4-3/4	
1	6-3/4	YWH-2	FISHING			
2	6-3/4	YHW-R	FISHING			
8	9-7/8	YHW-2	915	940	CLEARING TO BOTTOM	
8	12-1/4	HW-J	940	983		[illegible]
9	12-1/4	HR	CLEANING OUT TO 983'			
1	9-7/8"	YHW-R	937'	999	23	[illegible]
2	9-5/8"	YCGR	999	1086	10-3/4	[illegible]
3	9-5/8"	YCG-R	1086	1391	25-1/4	3[illegible]
1	6-3/4	YHW-R	ON BOTTOM OF 3-1/2" DRILL PIPE.			

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Attachment B

Excerpts from the *Corrective Action Investigation Plan for Central Nevada Test Area CAU Nos. 417 and 443*

The sampling program for the CNTA mud pits has been designed to provide sufficient data to allow statistical determination of whether targeted analytes are present in the mud pits in concentrations that exceed preliminary action levels. This determination will be made using the procedures described in Chapter 6 of the EPA publication *Methods for Evaluating the Attainment of Cleanup Standards. Volume 1: Soils and Solid Media* (EPA 230/02-89-042. 1989). For each mud pit, the mean concentration (or activity for radionuclides in the UC-1 mud pit) and standard deviation of each targeted analyte detected in the mud pit soils will be used to calculate the number of samples necessary to make that determination at the 90 percent confidence level (equivalent to the decision error rate goal of 10 percent) using the following equation (equation 6.6 from the referenced document):

$$n_d = s^2\left(\frac{z_{1-\beta}+z_{1-\alpha}}{Cs-\mu_1}\right)^2$$

Where:

n_d = number of samples
s = standard deviation of the sample population
α = false positive rate
β = false negative rate
$z_{1-\alpha}$ = critical value for normal distribution with a probability of $1-\alpha$
$z_{1-\beta}$ = critical value for normal distribution with a probability of $1-\beta$
Cs = the cleanup standard (or action level)
μ_1 = mean concentration of contaminant

By using $z_{1-\alpha}$ and $z_{1-\beta}$ values (usually available from statistics text books) for $\alpha = \beta = 0.10$ (the 10 percent decision error rate goal for the project), the number of samples that need to be collected to make the determination at the 90 percent confidence level can be calculated. If the calculated number of samples is less than or equal to the number of samples actually collected, no additional samples would be required to support the decision with no more than a 10 percent chance of making a decision error. If the calculated number of samples is greater than the number actually collected, then either additional samples can be collected to meet the decision error goal, or the decision could be made with the level of confidence calculated for the number of samples collected.

The TPH analytical data collected in 1995 from the Central Mud Pit (Table 1) can be used to illustrate the process. A total of ten samples were collected from the surface and near-surface of the mud pit, four from the 0- to 3-inch depth interval (samples 1A, 3A, 4A, and 5A), one from the 3- to 6-inch depth interval (sample 2A), one from the 18- to 21-inch depth interval (sample 1B), and four from the 20- to 23-inch depth interval (samples 2B through 5B). Assuming that the top two feet of the drilling mud is homogeneous (i.e., there is no stratification of TPH contamination, and the analytical results are representative of the top two feet of mud), the data can be used to calculate how many samples would be required to determine whether TPH concentrations in the

Table 1
Central Mud Pit and UC-4 Mud Pit 1995 Analytical Results

Sample	Depth	TPH (mg/kg)	TCLP Cr (mg/L)
Central Mud Pit			
1A	0 - 3 in	680	23.0
2A	3 - 6 in	220	25.6
3A	0 - 3 in	840	15.7
4A	0 - 3 in	190	12.3
5A	0 - 3 in	610	14.5
1B	18 - 21 in	470	0.99
2B	20 - 23 in	150	2.20
3B	20 - 23 in	260	1.80
4B	20 - 23 in	290	1.29
5B	20 - 23 in	59	1.50
5C	5 ft 6 in - 6 ft	< 25	0.93
5D	6 ft - 6 ft 3 in	< 25	0.65
UC-4 Mud Pit			
6A	0 - 3 in	150	6.60
7A	0 - 3 in	96	6.80
8A	0 - 3 in	130	10.7
6B	20 - 23 in	140	0.96
7B	20 - 23 in	< 25	0.53
8B	20 - 23 in	< 25	10.8

top two feet of drilling mud exceed the TPH action level, with no more than a 10 percent chance of making a decision error (α and $\beta = 0.10$). The values for the equation variables are:

μ_1 = 376.9 mg/kg (the mean TPH concentration for the ten samples)
s = 258.77 mg/kg (the standard deviation for the ten samples)
Cs = 100 mg/kg (the preliminary action level for TPH)
$z_{1-\alpha}$ = 1.282 (for α=0.10)
$z_{1-\beta}$ = 1.282 (for β=0.10)

Using these values in the equation above, the number of samples needed to make the determination (n_d) at the specified confidence level is 5.74, rounded up to 6. Since 10 samples were collected, no additional samples are needed to make the determination with no more than a 10 percent chance of a decision error (the determination would be that the mean concentration of TPH in the uppermost two feet of drilling mud exceeds the preliminary action level for TPH). It should be noted that the equation is applicable to normally distributed data. Although the distribution of data for the mud pits is unknown, Gilbert (1987) indicates that the arithmetic mean (normal distribution) is a reasonable estimator of the true mean when the coefficient of variation (sample standard deviation divided by sample mean) is less than 1.2. Since the coefficient of variation for the above example is approximately 0.93, the assumption of normality appears to be reasonable.

It should be noted that the closer the mean concentration is to the action level, or the greater the standard deviation (or both), the greater the number of samples needed to make the determination. In addition, the false positive (α) and false negative (β) rates specified for the statistical calculations also affect the number of samples needed. As a result, the number of samples needed to make the determination for other mud pits may not be the same as the number needed for the top two feet of the Central Mud Pit.

<u>References</u>:

Gilbert, Richard O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold. New York, NY.

U.S. Environmental Protection Agency. 1989. *Methods for Evaluating the Attainment of Cleanup Standards, Volume 1: Soils and Solid Media*. EPA/230/02-89-042. Washington, DC.

Appendix C

Addendum 2: Responses to NDEP Comments on the Corrective Action Investigation Plan for Project Shoal Area CAU No. 416

COMMENT 1:

Pg. 2 The map shows the land withdrawal boundary. Has a document search been completed to establish the original entity that withdrew the land and for what purpose? Can DOE document the approval given to them to utilize the land for testing and the area in which this second withdrawal encompasses? Does the second withdrawal provide DOE with the access needed to remediate the entire Shoal Project site?

RESPONSE:

The U.S. Bureau of Land Management withdrew the land for the exclusive use of the U.S. Atomic Energy Commission under Public Land Order (PLO) No. 2771 (September 6, 1962), as amended by PLO No. 2834 (December 4, 1962). Both Public Land Orders were published in the Federal Register. Attachment 1 provides an excerpt from historical documentation that describes the land withdrawal.

The land still is withdrawn for the exclusive use of the DOE. All site work to be conducted as a part of the CAIP implementation will be within the withdrawn land boundary, so no access difficulties are anticipated.

COMMENT 2:

Pg. 3 NDEP is requesting a copy of the site-specific HASP.

RESPONSE:

The site-specific HASP currently is being finalized. A copy will be transmitted to NDEP when it is completed.

COMMENT 3:

Pg. 4 NDEP is requesting a copy of the Project Shoal Preliminary Site Characterization Report.

RESPONSE:

A copy of the Project Shoal Preliminary Site Characterization Report was transmitted to NDEP in mid June, 1996.

COMMENT 4:

Pg. 4 The shot cavity collapsed and left a 171 ft. in diameter chimney with a 36 ft. void at the top of the chimney. DOE needs to assess the stability of the ground in this area and if appropriate, evaluate the options available to secure or stabilize the void.

RESPONSE:

The stability of the chimney and void was evaluated by the AEC as a part of the evaluation of site disposal options. Attachment 2 provides an excerpt from historical documentation that discusses cavity stability. No additional studies of cavity stability are currently planned. However, DOE will implement institutional controls to limit access to the surface ground zero area. The specific details of these institutional controls will be provided in the Corrective Action Plan (CAP) for the CAU.

COMMENT 5:

Pg. 4 NDEP needs to review the classified document(s) to concur that the source term is all inclusive to the listed radionuclides of concern.

RESPONSE:

The classified document(s) are available for review by NDEP personnel with Q clearance.

COMMENT 6:

Pg. 6 In order to clean up waste sites under the "Housekeeping" program, DOE needs to identify the types of waste and provide justification for the CAS under this classification.

RESPONSE:

The Waste Pile/Oil Cans Corrective Action Site (CAS No. 57-98-01) consists of six (6) empty oil cans found near the ECH-A borehole during a recent (March 12, 1996) site visit. Additional site characterization is not considered to be necessary before these empty cans are removed from the site, which is consistent with the description of the housekeeping process presented in section 1.5.1 of Appendix VI to the FFACO.

COMMENT 7:

It appears that the decision for the emplacement shaft to be backfilled with the material in the muck pile has been made. How will the material be utilized, i.e., crushed, screened? Previous statements were made that other sources of available material were to be used. What happened to the BLM borrow pit option and has a cost analysis been performed?

RESPONSE:

If the remediation plan for the shaft had included installing a well in the shaft, other sources of backfill materials would have been necessary to ensure that the well was properly stemmed and sealed. However, the current plan does not include installing a well in the shaft, so the material in the muck pile is considered adequate for backfilling. Backfilling of the emplacement shaft is being addressed under a separate plan from the CAIP. This plan will be submitted to the State when it has been completed.

COMMENT 8:

Pg. 12 The assumption is made that the material present in the impoundment is a homogeneous mixture. What if during sample collection it is found not to be homogeneous? How will this condition modify the sample collection?

RESPONSE:

The sampling strategy for the impoundment soils will be revised in the field if the material present in the impoundment is found not to be homogeneous. Specifically, if the drilling mud is found to occur in a discrete layer(s) within the impoundment, the mud will be preferentially sampled and analyzed for TPH, total barium, and total chromium (potential mud additives).

COMMENT 9:

Pg. 14 In order to clearly determine the existing hydrogeological conditions at the site, an evaluation of the groundwater system must validate the present assumption that the shot cavity has filled with water.

RESPONSE:

Calculations of water infill rates following the nuclear test estimated that the cavity would fill approximately 10 years after the test (filled by 1973). A discussion of this, including references to the source documents, is provided on pages 3 and 4 of Appendix A of the CAIP. It is recognized that regardless of this estimate, the current hydrologic status of the cavity has not been measured. However, drilling directly into the shot cavity is very difficult due to the potential health and environmental problems that would result from high levels of radionuclide contamination. It is also not necessary from the standpoint of conservatively estimating contaminant transport. Flow of groundwater away from the cavity will be governed by regional hydrologic conditions (gradient, hydraulic conductivity, porosity) that will be estimated based on historic data and data from the new wells. If the cavity has not filled yet, that would only further delay any contaminant migration from the shot cavity, and also would indicate very non-transmissive hydrologic conditions, which would be favorable for containing the contaminants close to the site. For these reasons, the assumption that the shot cavity has filled with groundwater is believed to be conservative.

Although knowledge of the precise cavity conditions at resent is not considered necessary for transport predictions, understanding the position of the cavity in the hydrologic system is important, particularly the position of the cavity in relation to the groundwater divide beneath the Sand Springs Range. As discussed on page 14 of Appendix A to the CAIP, proposed well HC-4 was to be drilled if groundwater level data could not be obtained from the shaft. DRI's video logging of the shaft in late May 1996 did not encounter saturated conditions, so well HC-4 is now part of the drilling plan. The location of HC-4 has also been shifted slightly to the east to provide groundwater data closer to ground zero and hopefully address NDEP's concerns regarding near-field conditions. A map showing the new location for HC-4 is included as Attachment B.

COMMENT 10:

Pg. 18 "Remediation of the groundwater is not practical because the primary contaminant of concern (tritium) is not treatable/removable using any known treatment technologies". This statement is inaccurate. There are available technologies, however, based on our information, they are presently not cost-effective, which is not the same as nonexistent.

RESPONSE:

The addendum to the CAIP DQO section includes a revision to the text that indicates that there currently are no cost-effective technologies available for the treatment of tritium in groundwater. This revised text is in section 3.4.5.2 of the addendum.

COMMENT 11:

Pg. 21 The sampling program for the impoundment is vague. A better description of the sampling locations needs to be provided with rationale for the points that were chosen for sampling. For an example that was reviewer friendly to read and evaluate, please refer to the Corrective Action Investigation plan: Roller Coaster Lagoons and North Disposal Trench, Tonopah Test Range.

RESPONSE:

The sampling program for the PSA impoundment is described in detail in section 4 of the CAIP. The addendum to the CAIP DQO section includes revisions to several DQO steps that provide additional details and justification for the proposed sampling.

COMMENT 12:

Pg. 22 It is unclear why a 50% value has been chosen for quantification limits when the analytical method referenced already provides method detection and quantification limits.

RESPONSE:

The 50% values discussed in the CAIP are the measurement objectives for the study, not analytical method quantitation limits. As discussed on page 22 of the CAIP, the purpose of establishing measurement objectives at 50% of the preliminary action levels is to ensure that the analytical methods selected for the project are capable of meeting the quantitation limit needs for the project. The quantitation limits for the analytical methods selected for the project are presented in the "Analytical Reporting Limit" column of Tables 3-1 and 3-2 of the CAIP.

COMMENT 13:

Pg. 29 The third paragraph assumes vertical homogeneity. Consideration needs to be given if it is not the case.

RESPONSE:

See the response to comment 8, above.

COMMENT 14:

Pg. 37 As stated in the FFACO, NDEP should be receiving bi-weekly status on field activities.

RESPONSE:

Bi-weekly status reports for field activities will be submitted to NDEP when the Shoal field programs are implemented.

[illegible]

Attachment A

Excerpts from the
Site Disposal Report
Fallon Nuclear Test Site (Shoal)
Churchill County, Nevada

OFFICIAL USE ONLY

NVO-73

40406

SITE DISPOSAL REPORT

FALLON NUCLEAR TEST SITE

(SHOAL)

CHURCHILL COUNTY, NEVADA

ATOMIC ENERGY COMMISSION • UNITED STATES OF AMERICA •

MAY 1970

UNITED STATES ATOMIC ENERGY COMMISSION

NEVADA OPERATIONS OFFICE

STATUS VERIFIED UNCLASSIFIED

10/15/81
DATE

(g) BLM Stock Well, 4.2 miles east, 364 feet deep

(h) Frenchman Spring, 4.4 miles southeast, 3 feet deep

(3) Commercial Wells and Pipelines

There are no oil or gas wells within 20 miles of SGZ and the nearest pipeline terminates at Fallon, 30 miles to the northwest.

(4) AEC Drill Holes

Eight holes were drilled by the AEC supporting organizations for the SHOAL project. For location and status of these AEC holes see Figure 2 and Appendix I.b. Four hydrologic test holes are listed in Paragraph 3.1 C (2).

d. Land and Site Value

The land is presently used by Navy Auxiliary Air Station (NAAS) at Fallon, Nevada, in conjunction with the Bernard Bombing Target Area in accordance with the agreement between AEC/NVOO and the NAAS of January 1, 1966.

There is one active mine (Northern Dipper) within 10 miles, and the salt deposits located 5-1/2 miles northwest are commercially operated on a limited scale.

e. Acquisition

On November 24, 1961, the Albuquerque Operations Office (ALOO) of the AEC submitted an application to the BLM for withdrawal of public domain unimproved land for the proposed SHOAL project in Churchill County, Nevada. Withdrawal from public domain was authorized by Bureau of Land Management Permit No. 058078 and Public Land Order (PLO) No. 2771, dated September 6, 1962 (27 F.R.-9062), as amended by PLO No. 2834, dated December 4, 1962 (F.R. Doc. 62-9076) which assigned the land to the U. S. Atomic Energy Commission for its exclusive use.

Special Use Permit No. 058079, received on January 26, 1962, provided an additional 100 square miles surrounding the original withdrawn area for the purposes of survey, geological study, construction of necessary roads and exploratory drilling. "Right of Entry" was also granted by this permit to an area of 400 square miles enveloping the SHOAL area. Negotiations were completed between the AEC and the NAAS, Fallon, Nevada, for a small plot of land in Fairview Valley to be used for a seismic detection station.

Attachment B

Excerpts from the
Site Disposal Report
Fallon Nuclear Test Site (Shoal)
Churchill County, Nevada

SITE DISPOSAL REPORT

FALLON NUCLEAR TEST SITE

(SHOAL)

CHURCHILL COUNTY, NEVADA

MAY 1970

UNITED STATES ATOMIC ENERGY COMMISSION

NEVADA OPERATIONS OFFICE

both the granite body and metamorphic rock is overlain by Tertiary and Quaternary volcanic rocks, although not in the immediate SGZ area. The GZ and project area is within the granite uplift and there are northeast trending faults to the east and west. (See Figure 4.) Numerous aplite-pegmatite dikes cut the granite body. In turn, andesite and rhyolite dikes intrude the granite body, the metamorphic rocks and the aplite-pegmatite dikes. Tertiary and Quaternary alluvium and eolian deposits occupy the valleys to the east and west of the range.

> "Although the range is a north-south trending fault block, true north-south faults are rare; the range having been uplifted along a series of northwest- and northeast-trending faults which form a saw-tooth pattern in plan. The downdropped Fairview Valley block to the east contains over 5,000 feet of unconsolidated sediments; in contrast, the Four Mile Flat area to the west is a pediment, thinly veneered near the range with alluvium, which thickens to about 1,300 feet immediately south of the salt flats."[1]

c. Subsurface Cavity and Chimney

The nuclear explosive with a yield of 12.5 ± 0.5 kilotons produced a cavity which apparently collapsed immediately, leaving a rubble-filled chimney approximately 170 feet in diameter and approximately 460 feet high (according to Kouver, 1964). There is an approximate 36-foot high void within the top of the chimney. (See Figure 5.)

4.2 PHYSICAL PROPERTIES

a. Host Material

The host lithology consists of an intrusive granitic mass of grani to granodiorite composition, intruded by younger aplite-pegmatite, rhyolite and andesite dikes. The GZ granite is most commonly a po phyritic biotite granite with abundant large feldspar crystals. Locally, it is coarsely grained without the large crystals. The mineralogical composition is 45 to 70 percent feldspar, 25 to 40 p cent quartz, 5 to 10 percent biotite mica, and 1 percent or less c minerals.

Both the granite and granodiorite show typical spherical weatherin In addition, steeply dipping faults, joints, and shear zones with northwest and northeast orientation are prevalent.

b. Physical Stability

A stable, collapsed cavity exists at the SHOAL site. Bulking has provided physical stability by the "shrinkage stope" process, wel

[1]Reference 39, p. 24.

known to miners. This process consists of large blocks of ceiling material collapsing into the cavity and filling the available volume. The stoping process continues upward until the cavity void space has been distributed more or less evenly throughout the resulting chimney and in this situation a saucer-shaped void remains at the top in a configuration that normally will not permit further caving or in-fall.

c. Hydrology

The intrusive and metamorphic host rocks at the SHOAL site are of themselves nearly impermeable. The granitic rock has been broken up to such a degree by faults and fractures that the whole mountain mass may be regarded as a single hydrologic unit with relatively impermeable hydrologic properties similar to a very coarse gravel filled with clay and silt. Test and construction holes drilled at the SHOAL site indicate that ground water exists, and that regional water table can be found at about 970 feet below the surface. The piezometric surface slopes away from the SHOAL site, both westward toward Four Mile Flat and eastward toward Fairview Valley, because the site is near the apex of the recharge zone in the Sand Springs Mountain Range.

The metamorphic and intrusive rocks which comprise the Range have little capacity to transmit water. In hydrologic test holes which penetrated 300 or more feet of the saturated granite, low-pumping rates rapidly depressed water levels attesting to the low-transmissive capacity of the fractured rocks.

Figure 6 shows the locations of private water wells and springs. Appendix I.a tabulates the wells and springs in the vicinity of the SHOAL site.

Figure 2 shows AEC drill holes. Appendix I.b is a tabulation of the AEC drill holes, listing the responsible organizations and other factual data.

For additional information, refer to VUF-1001, Nevada Bureau of Mines Report of Geological, Geophysical, Chemical, and Hydrological Studies, and other documents referenced in Appendix II.

The shaft drifts and chimney-cavity area are all within the single essentially uniform media described above. The local area is a ground water divide and recharge area. (See Figure 7.) Surface water will move into the man-made voids and slowly through fractures. Water will later move downward and outward by a circuitous fracture path toward the alluvium of the valleys to the east and west.

d. Event Manifestations

Gross high-level radiation at the site was confined to the melt-rubble mixture at the bottom of the cavity. No venting of particulate debris occurred during or after shot time.

4.3 SECURITY ANALYSIS

As already discussed in Paragraph 3.3 b, SHOAL samples and analyses are classified and create a security problem. Therefore, for this reason, as well as health safety (discussed in Paragraphs 4.5 and 4.7 in which ground water movement calculations are given), an excavation and drilling exclusion area is required. The exclusion area lies between a level of plus 5,050 feet above mean sea level and plus 3,530 feet (i.e., between 180 feet and 1,700 feet below SGZ) and out to a horizontal distance of 3,300 feet from SGZ. Also included is any re-entry into drill holes or the shaft within the horizontal restrictions. This restricted area is shown on Figures 4 and 5 and becomes a part of the recommendations given in Paragraph 5.3.

4.4 STRUCTURAL SAFETY ANALYSIS

As stated in Paragraph 4.2 b, the SHOAL cavity collapsed immediately after detonation, with collapse moving upward until the bulking of the broken granite blocks provided a configuration of the void at the top that did not permit further in-fall. The area has a recent history of seismic activity; however, the present stability is not likely to be altered by earth tremors or ground water activity. Even if there should be some rearrangement of blocks in the chimney with some attendant subsidence, there are over 800 feet of granite in its natural state between the top of the chimney-cavity and the surface; thus, there should be no structural safety hazard.

Negligible consolidation of the chimney rubble might occur from large, nearby seismic activity, with consequent resumption of upward stoping. However, even a 20 percent compaction of the existing rubble would permit only another 20 to 30 feet maximum of ceiling in-fall. The present chimney should present no problem for physical stability and safety.

4.5 RADIOLOGICAL SAFETY ANALYSIS

Most of the nongaseous radioactive residue of the nuclear explosion was trapped in the melt portion at the bottom of the cavity or dispersed through the rubble chimney volume. The unfractured granite over the chimney has maintained its integrity as a radioactive shield; therefore, access to the radioactive melt can be achieved only by use of drilling equipment. Entry through the original shaft and drift has been effectively blocked by collapse of the shaft below 1,060 feet and by intervening sand plugs as well as the reinforced concrete cover slab sealing the shaft at the surface.

No radioactive materials were vented at shot time; however, minor radioactivity reached the surface during the postshot drill back. This release was mostly a gas under well-controlled conditions and was safely channeled into filters and traps. Soil and cuttings contaminated with

Appendix D

Addendum 3: Responses to NDEP Comments on the Corrective Action Investigation Plan for Project Shoal Area CAU No. 416 and Fluid Management Plan for the Project Shoal Area

COMMENT 1:
The CAIP contains a schedule in Section 3.6 which generally outlines site characterization timelines.

RESPONSE:
The PSA CAIP is to be modified as follows:

Replace Section 3.6 in its entirety with:
Field work will begin upon receipt of approval of this CAIP by NDEP. Upon receipt of approval of this plan, NDEP will be notified of the schedule start date for the field activities at least ten (10) working-days prior to the start of field activities, as reported on the FFACO Field Activity Report. The expected completion schedule, represented in working-days and assuming a 5-day work week, is:

- Day 0: Mobilize field staff to the site.
- Day 1: Mobilize construction crew for site preparation activities.
- Day 5: Complete the construction of drill pads, sumps, and access roadways.
- Day 6: Mobilize direct-push contractor
- Day 9: Complete direct-push sampling and mobilize drill crew
- Day 10: Commence drilling operations and demobilization of direct-push contractor
- Waste management samples will be collect from each sump upon completion of activities at each individual well site and the sampling results will be available within five (5) working-days from the day of sample shipment to the laboratory.
- Day 30 : Receive analytical results for the impoundment sampling
- Day 50: Quality assured analytical data available for the impoundment sampling
- Day 55: Complete drilling operations, thermal flowmeter/Chem-tool logging, wire-line geophysical logging, and well development.
- Day 56: Start groundwater sampling and installation of pressure transducers to monitor water levels.
- Day 61: Complete groundwater sampling.
- Day 62: Demobilize drill crew from the site.
- Day 72 : Receive analytical results from the groundwater sampling.

- Day 94: Quality assured data available for the groundwater sampling.
- Three (3) months after completion of drilling or when the groundwater level stabilizes, as defined in section 4.2, aquifer testing will begin.
- Complete aquifer testing two (2) weeks after start of testing.

Factors beyond DOE/NV's control, such as weather or delays in receipt of laboratory results may delay field activities. If such events occur, NDEP will be notified and a revised schedule submitted.

COMMENT 2:
FMP - inconsistencies or conflicts exist between CAIP and FMP or within the FMP related to IDW characterization and/or those management of those wastes.

RESPONSE:
The FMP has been substantially rewritten and portions of the CAIP amended to eliminate inconsistencies. More detail is provided in the comment responses below.

COMMENT 3:
The FMP provides a logic diagram as Figure 5-1 which implies sampling will be conducted to define when wastes are to be contained in the sump. The narrative on Page 7 (Section 3.1/3/2) states that only tritium monitoring will be conducted on site. Sampling of wastes going into the sump will only be conducted when the sump is full or when operations are completed. This condition asserts that waste decisions will not be made until sometime in the future after the wastes are generated. This is not consistent with Figure 5-1. Does this mean that all drilling material will be placed in the sump and waste determinations made at the end of the project allowing mixing to occur? This method of sampling is not consistent with the CAIP, which states that waste will be minimized. All of the drilling waste may not be hazardous, and in fact, it is implied, that initial material will most probably be inert solid waste. By depositing everything into the sump, the potential exists to make all sump wastes regulated. Trying to make appropriate waste determinations after all drilling wastes are blended could be difficult.

RESPONSE:
The FMP has been revised to incorporate on-site lead monitoring to minimize the potential for generation of hazardous or mixed waste and to incorporate both single- and double-lined sumps at each drill pad. Fluids shown through on-site monitoring to contain tritium or lead at concentrations greater than ten times the Nevada Drinking Water Standards will be routed to the double-lined sump to provide a greater degree of containment. Decisions to sample for tritium and lead and monitor these constituents on-site were based on process knowledge. After each well is drilled, the sump contents (of both the single- and double-lined sumps) will be sampled for all fluid management parameters and the samples analyzed by an off-site laboratory. A 14-day turnaround time will be requested from the laboratory. This will provide for timely confirmation of process knowledge and waste and fluid management decision-making.

In addition, the PSA CAIP is to be modified as follows:

Page 32 of 40, Section 4.0, Delete last sentence on page and replace with:
Fluids will be managed in accordance with the *Fluid Management Plan for the Project Shoal Area, Off-Sites Subproject* (FMP) (DOE, 1996b). Solid waste will be managed in accordance with Section 5.0 of this plan.

Replace Section 5.1 in its entirety with:
Characterization activities have been planned to minimize the amount of IDW generated. The planned field technique will generate minimal soil waste in the form of cuttings. Fluids will be managed under the FMP (DOE, 1996b) and will be screened on site for tritium and lead to minimize the potential for generation of mixed waste. Soil waste generated that does not require management as radioactive or RCRA-regulated waste will be left at the site and either closed in place under state of Nevada industrial landfill waiver requirements or used in site recountouring operations and/or construction of berms. Other waste, such as disposable sampling and personal protective equipment, will be segregated to the greatest extent possible to avoid generation of hazardous, radioactive, or mixed waste. Hazardous materials will be controlled minimize generation of hazardous or mixed waste.

<u>COMMENT 4</u>:
If the waste is found to be hazardous and RCRA regulated, by the time DOE makes this waste determination, after the completion of the project, they could be in violation of failure to provide adequate containment of accumulating wastes by a generator at a SAA, which exceeds 55 gallons and/or is stored longer than 90 days. The final report is not proposed to be completed to up to nine months. There are no proposal alternatives on how to manage waste or requests for approval to manage these wastes on site and no be construed to be a violation of RCRA, such as the request and case made for the SCEPs IDWs. DOE needs to provide clarification and document consistency on these issues.

<u>RESPONSE</u>:
The fluid management plan has been amended to clarify how fluids will be managed if they require management as hazardous, mixed, or radioactive waste. On-site lead monitoring will be conducted to minimize the probability of generating mixed or hazardous waste in the lined sumps. However, should this occur, operations will be halted, NDEP notified, and steps will be taken to containerize and appropriately manage the fluids and solids. The CAIP has been amended as stated below. It should be noted that it is expected that drilling each well will take about 3 days; upon completion of drilling, a sump sample will be collected for off-site analysis. The laboratory will be requested to meet a 14-day turnaround time for analyses. Therefore, DOE will be able to determine appropriate fluid disposition within 17 days of initial generation of fluid from each well. It is not expected that waste, if hazardous or mixed, would remain on site for longer than 90 days.

In addition, the PSA CAIP is to be modified as follows:

Replace Section 5.3 in its entirety with:

5.3 Fluid and Drilling Solids Management

Fluids generated from drilling operations will be contained in single- or double-lined sumps pending off-site laboratory characterization in accordance with the FMP (DOE, 1996b). Fluids emerging from the blooie line will be field screened for tritium and lead contamination. The on-site screening results will be used to determine whether fluids are routed to single- or double-lined sumps. Fluids containing contaminants in excess of five times the Nevada Drinking Water Standards (NDWS) for lead or tritium will be contained in lined sumps. If hazardous waste limits are not met or exceeded, the fluids will be allowed to evaporate in lined sumps. Fluids containing contaminants less than five times the NDWS may be routed to the ground surface. Solids and liners associated with fluids containing contaminants less than ten times the NDWS may be closed in place or used for site restoration and recountouring. Solids and liners associated with fluids containing radioactive contaminants greater than or equal to ten times the NDWS will be managed as low-level waste. Solids associated with fluids containing hazardous constituents at or above RCRA limits will be managed as hazardous (or mixed) waste if sampling and analysis of the solids demonstrates the presence of constituents at or above RCRA-regulated levels. Solids associated with fluids containing hazardous constituents greater than ten times the NDWS but less than RCRA-regulated levels will either be managed in place under the state of Nevada's industrial landfill regulations, or removed and managed at a permitted landfill. The state will be notified as to the ultimate disposition of solids generated from drilling operations.

If lead levels approach RCRA-regulated levels, drilling will stop and NDEP will be notified. The field screening and laboratory analytical strategy detailed in the FMP (DOE, 1996b) is designed to minimize the probability of generating hazardous or mixed waste and to minimize generation of low-level waste.

In addition, fluid samples will be collected of the sump contents to provide additional data for fluid management decision-making and to provide confirmation of process knowledge. The sump samples will be collected immediately after each well is drilled; a 14-day turnaround time will be requested for laboratory analyses. This will provide timely information for fluid management decision-making. Detailed fluid management and characterization strategy information is provided in the FMP (DOE, 1996b).

Drilling solids will be managed as sanitary, hazardous, mixed, or low-level waste, depending upon characterization results that implement the following decision process. Solids will be initially characterized by sampling and analyzing the fluids in accordance with the FMP (DOE, 1996b).

If hazardous constituents are present at or above RCRA-regulated levels, the liquids will be pumped from the sumps and placed in appropriate containers and transported to a permitted facility. The remaining solids will be sampled and analyzed to determine if hazardous constituents are present at or above RCRA-regulated levels. If so, the solids will be managed as hazardous waste and will be appropriately containerized and transported to a permitted facility within 90 days of generation. Containerization, transportation, treatment, storage, and disposal will be conducted in accordance with state and federal hazardous waste regulations. The waste may be transported to the Nevada Test Site permitted hazardous waste storage area or may be transported directly to a commercial, permitted, treatment, storage, and disposal facility.

If radioactive constituents are present at levels greater than those designated under DOE Orders, NDEP will be notified, and the liquids will be allowed to evaporate and the solids will be sampled and analyzed. If the solids are shown to be low-level waste, they will be appropriately containerized and stored at a designated Radioactive Materials Area pending disposal at the Nevada Test Site. The Radioactive Materials Area may be designated as a location at the PSA or the waste may be transported to a designated Radioactive Materials Area at the Nevada Test Site.

If both radioactive and hazardous constituents are present at levels such that the fluids and solids are considered mixed waste, NDEP will be notified and the liquids will be removed from the sump, placed in appropriate containers, and transported to the Nevada Test Site Area 5 Transuranic Waste Storage Pad. Mixed waste is that waste that contains hazardous constituents at or above RCRA-regulatory limits and radioactive constituents at or above limits established by DOE Orders. The remaining solids will be sampled to determine if mixed waste is present. If so, the solids will be removed, placed in appropriate containers, and transported to the Nevada Test Site Area 5 Transuranic Waste Storage Pad. The mixed waste will be stored, and a treatment plan developed, in accordance with the mutual consent agreement reached between the state of Nevada and DOE/NV for the storage of mixed waste generated by DOE's environmental restoration activities within the state of Nevada. The mixed waste will be removed from the PSA within 90 days of generation.

If the fluids are shown to contain only constituents below regulatory levels and DOE limits for radioactivity, the solids will be assumed to be uncontaminated and will be managed on-site under state of Nevada industrial landfill regulations. The solids and liner will be closed in place after evaporation of the fluids.

Background samples will be collected from the undisturbed locations within the surrounding area to provide information regarding naturally-occurring metals, such as arsenic, lead, and mercury. In order to determine if solids require management as sanitary, hazardous, or mixed waste, the background levels will be added to the NDWS or RCRA limits for characteristic waste to provide a regulatory limit or action level for those constituents. For example, if arsenic is shown to be present as a naturally-occurring leachable metal at 2 milligrams per liter, the regulatory limit for this constituent as a hazardous waste would be 7 milligrams per liter, rather than 5 milligrams per liter.

Sampling of the solids remaining in the sumps will be conducted by establishing a grid over each sump and collecting samples from random locations within the grid. The number of samples required will be dependent upon the volume of solids generated; a minimum of three samples will be collected per sump. The liner will be characterized through process knowledge; i.e., it will be assumed that the liner contains the same contaminants as the solids. In addition, if there is evidence of liner leakage, the underlying soils will be sampled and analyzed to determine if contamination is present. If so, NDEP will be notified and a plan developed to determine what remedial actions are required for the underlying soil.

Because of the above revisions to the CAIP, the following revisions are also required:

Throughout Text:

Replace:
(DOE, 1996)
With:
(DOE, 1996a)

List of Acronyms and Abbreviations

Add:

FMP Fluid Management Plan
NDWS Nevada Drinking Water Standards

Section 7.0, References

Replace:

U.S. Department of Energy, Nevada Operations Office. 1996. *Draft Project Shoal Preliminary Site Characterization Report, Shoal Site, Nevada.* Las Vegas, NV: IT Corporation.

With:

U.S. Department of Energy, Nevada Operations Office. 1996a. *Draft Project Shoal Preliminary Site Characterization Report, Shoal Site, Nevada.* Las Vegas, NV: IT Corporation.

Add:

U.S. Department of Energy, Nevada Operations Office. 1996b. *Fluid Management Plan for the Project Shoal Area, Off-Sites Subproject.* Las Vegas, NV.

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