February 28, 2011

Maryland Square Shopping Center, LLC
Herman Kishner Trust
c/o Mr. Tom Vandenburg
Dongell Lawrence Finney LLP
707 Wilshire Boulevard, Suite 4500
Los Angeles, California 90017

RE: **DRAFT CORRECTIVE ACTION PLAN FOR GROUNDWATER, MARYLAND SQUARE PCE SITE**
MARYLAND SQUARE SHOPPING CENTER
3661 SOUTH MARYLAND PARKWAY
LAS VEGAS, NEVADA
FACILITY ID NO. H-000086

Dear Mr. Vandenburg:

Enclosed please find one copy of the Draft Corrective Action Plan for Groundwater for the above referenced project as requested by the Nevada Division of Environmental Protection Bureau of Corrective Actions (BCA) in a letter dated January 11, 2011. This report is being provided to BCA in electronic Adobe Acrobat format on this date, February 28, 2011.

Should you have questions or require additional information, please do not hesitate to contact Robert Manriquez, Program Manager, at 619.321.6748, or myself at 775.333.8457. Thank you for your time and consideration in this matter.

Regards,

Tamara Pelham
CEM No. 1537, Exp. Sept. 11, 2012
Class A 60505

Robert L. Manriquez, PG
Program Manager

Enclosure(s) Draft Corrective Action Plan for Groundwater, Maryland Square PCE Site

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DRAFT CORRECTIVE ACTION PLAN FOR GROUNDWATER
MARYLAND SQUARE PCE SITE
3661 SOUTH MARYLAND PARKWAY
LAS VEGAS, NEVADA

SUBMITTED TO
NEVADA DIVISION OF ENVIRONMENTAL PROTECTION
BUREAU OF CORRECTIVE ACTIONS
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February 28, 2011

EXECUTIVE SUMMARY

This Corrective Action Plan (CAP) develops and evaluates potential remedies to clean up shallow groundwater contaminated with tetrachloroethene (PCE), also known as perchloroethene. The PCE contamination forms a dissolved-phase plume extending from the Maryland Square Shopping Center (the Property) to a residential neighborhood that lies downgradient. The extent of the PCE plume in shallow groundwater defines the site (Site).

The objectives of the CAP are to:

1. Identify and screen general remedial actions (GRA), technology types, and process options to remediate PCE-contaminated groundwater.
2. Combine process options into general Corrective Action Alternatives and evaluate the Corrective Action Alternatives against criteria identified in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).
3. Identify Corrective Action Alternatives, or specific components thereof, for further evaluation using bench-scale and pilot testing.

The identification and evaluation of Corrective Action Alternatives is intended to ensure that appropriate corrective action alternatives are developed and an appropriate corrective action is selected.

A baseline risk assessment predicting and quantifying potential human health risk will be presented in the final CAP after adequate data are obtained. Preliminary corrective action objectives (CAO) and preliminary numerical remediation standards were developed based on readily available information to guide the identification and evaluation of appropriate corrective actions. The preliminary CAOs and numerical remediation standards will be refined and finalized after completion of a baseline risk assessment and when a final corrective action is selected in a record of decision (ROD). The preliminary CAOs developed in the draft CAP are:

1. Prevent inhalation exposure of current residents to concentrations of PCE that exceed the remediation standard for residential indoor air.
2. Prevent use of shallow groundwater as a source of drinking water and remediate shallow groundwater where PCE concentrations exceed the remediation standard for groundwater.

The preliminary numerical remediation standard for shallow groundwater is 5.0 micrograms per liter (µg/L), equivalent to the maximum contaminant level (MCL).

General response actions (GRA) were identified using these preliminary CAOs and numerical remediation standards, and were evaluated based on implementability, effectiveness, and cost. Those technologies found to be viable based on these three criteria were subsequently assembled into Corrective Action Alternatives for detailed analysis based on eight NCP evaluation criteria: (1) overall protection of human health and the environment; (2) long-term effectiveness and permanence; (3) reduction in toxicity, mobility, and volume through treatment; (4) short-term effectiveness; (5) implementability; (6) cost; (7) state acceptance; and (8) community acceptance. The alternatives developed for detailed analysis include:

- Alternative 1 - No Action
- Alternative 2A - In Situ Chemical Oxidation of Hotspots and Residential Area, Institutional Controls (IC), Subslab Depressurization (SSD) Systems, and Monitored Natural Attenuation (MNA)
- Alternative 2B - In Situ Chemical Oxidation, ICs, SSD Systems, and MNA
- Alternative 3 - Permeable Reactive Barrier (PRB), ICs, SSD Systems, and MNA

- Alternative 4 – Sparge Curtain, ICs, SSD Systems, and MNA
- Alternative 5 – Extraction and Treatment, ICs, SSD Systems, and MNA
- Alternative 6 - In Situ Enhanced Bioremediation, ICs, SSD Systems, and MNA.

All of these alternatives incorporate ICs and SSD systems as well as MNA as a polishing step following the primary technology for remediation of groundwater. Based on the NCP criteria, the most promising primary technologies include in-situ chemical oxidation and the sparge curtain. These technologies are identified for bench-scale testing. Primary technologies with favorable bench-scale test results will undergo subsequent pilot testing. Given the concentrations of PCE in groundwater at the site, the subsurface conditions, and the various receptor pathways, it is likely that an integrated approach to remediation or a combination of general response actions will be required. If in-situ chemical oxidation or a sparge curtain is proven insufficient during testing, a zero-valent iron (ZVI) PRB, extraction and treatment, and/or enhanced bioremediation will be further evaluated. Until an adequate understanding of the environmental conditions and characteristics can be determined through bench-scale and pilot testing, the practical application or effectiveness of a particular Corrective Action Alternative to meet CAOs and numerical remedial standards cannot be confirmed.

Based on a review of the existing data, additional data are needed for adequate description and understanding as follows:

- Indoor air data are needed to evaluate current residential conditions and evaluate the efficacy of mitigation systems previously installed by the Nevada Department of Environmental Protection (NDEP).

- Soil properties have not been well characterized for the unsaturated and saturated heterogeneous soils across the Site. Insufficient physical, flow, and contaminant distribution data have been collected in the unsaturated and saturated zones beneath the Site.

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1.0 INTRODUCTION

The Maryland Square Tetrachloroethene (PCE) Site (the Site) is located near downtown Las Vegas, Nevada. The Site contains a dissolved PCE plume that extends from the location of the former Al Phillips the Cleaners (APTC), in the former Maryland Square Shopping Center (the Property) at 3661 South Maryland Parkway, to more than 4,000 ft east (downgradient) (Figure 1). PCE-contaminated groundwater was initially reported to the Nevada Department of Environmental Protection (NDEP) in a spill report dated November 29, 2000, by Converse Consultants (Converse). PCE-contaminated soils are present in the source area at the former APTC facility (Converse 2002; URS 2005, 2007b).

1.1 Purpose and Organization of the Report

This Corrective Action Plan (CAP) identifies and provides an initial evaluation of technologies to remediate shallow groundwater and to prevent PCE vapors from entering soil gas, thereby protecting indoor air quality in homes in the residential neighborhood overlying the PCE plume. The CAP describes existing information for the Site and presents a scope and schedule for remediation of PCE-contaminated groundwater.

The CAP summarizes past land uses across the Site and the results of previous investigations (Section 1), the physical setting (Section 2), the nature and extent of contamination (Section 3), and the fate and transport characteristics of the primary contaminant (PCE) and its breakdown products (Section 4). Section 5 references the need for a risk assessment. Preliminary remediation standards are described (Section 6), followed by a screening of possible general remedial actions (GRA) (Section 7). Section 8 is a detailed evaluation of seven alternatives for the remediation of shallow groundwater. Section 9 includes: (1) recommendations to fill data gaps, (2) a discussion of the need for bench pilot-scale testing to further assess the corrective action alternatives, and (3) a proposed schedule.

The objectives of the CAP are to:

1. Identify and screen GRAs, technology types, and process options to remediate PCE-contaminated groundwater and mitigate indoor air during groundwater remediation.
2. Combine process options into general Corrective Action Alternatives and evaluate the Corrective Action Alternatives against criteria identified in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).
3. Identify Corrective Action Alternatives, or specific components thereof, for further evaluation using bench-scale and pilot testing.

Corrective Action Alternatives are identified and preliminarily evaluated to ensure that an appropriate corrective action is selected. Given the heterogeneity of soil at the site, the groundwater's geochemistry, and the issues with vapor intrusion into residences, this CAP establishes a preliminary set of viable remedial alternatives for further evaluation through bench-scale and pilot-scale testing. Results from bench-scale testing will be used to develop a pilot test program to confirm field application and establish a design basis for remedial system implementation.

1.2 Site Background

APTC operated a dry cleaner facility in the Maryland Square Shopping Center at 3661 South Maryland Parkway, Las Vegas, Nevada from 1969 to 2000. The former APTC facility is on the west side of South Maryland Parkway, approximately 400 ft north of Twain Avenue, across the street from The Boulevard Mall (Figure 2).

The former APTC facility has been identified by NDEP as the source of PCE contamination that forms the Maryland Square PCE plume in the shallow groundwater (Figure 3). This dissolved-phase PCE plume extends downgradient of the former APTC facility, beneath the Boulevard Mall, residential properties, and

a golf course. A golf course irrigation well is located near the distal end of the PCE plume at a distance of approximately 3,200 ft east of the former APTC location.

1.2.1 Site Description

The Site is located in the Las Vegas Valley (Valley) approximately 1.6 miles northeast of Las Vegas McCarran International Airport. The surface topography at the Site gently slopes to the east (Figure 4). Current uses of the Site are commercial/industrial and residential. Residential properties are generally single-family homes.

1.2.2 Site History

The APTC facility was first developed in 1969 as a dry cleaning operation at the Property. APTC took over operation of the facility later that same year from the original operator, and continued to operate the dry cleaning facility until 2000. The facility was owned by the Maryland Square Shopping Center, LLC until the Clark County School District (CCSD) purchased the property in 2002. During a Phase II Environmental Site Assessment conducted in 2000 as part of the property transaction, PCE was detected in the groundwater at the southeast corner of the APTC facility (Converse 2000). A follow-up investigation identified PCE in soils beneath the operation area of the former APTC facility (Converse 2002). In 2004, National Dry Cleaner, Inc. (the owner of APTC) accepted financial responsibility for the investigation and remediation of PCE.

Maryland Square, LLC purchased the property from CCSD in June 2005, and demolished the former shopping center, including the concrete floor and foundation, in summer 2006. Currently, the site of the former shopping center is covered with asphalt, except for the former APTC facility, which is fenced and covered by uncapped native soil. The adjacent property use is commercial/industrial, with residential use (apartments) several hundred feet to the northwest, and an elementary school located about 450 ft upgradient to the west.

In July 2008, National Dry Cleaners, Inc. (the owner of APTC) filed for bankruptcy, and the financial responsibility for remediating the PCE defaulted to Maryland Square Shopping Center, LLC.

Boulevard Mall

The Boulevard Mall opened in 1968 and is the oldest enclosed Mall in the Valley, currently housing approximately 140 commercial occupants. During expansion of the Mall circa 1993, several structures located on the east side of Maryland Parkway and downgradient of the APTC facility were demolished. A three-level parking garage is currently located on the east side of the Mall next to JCPenney. A three-level parking garage is also located on the west side of the Mall adjacent to Macys.

Subsurface investigation efforts have included the installation of several monitoring wells across the Boulevard Mall property that are currently sampled and tested for PCE on a quarterly basis. The maximum PCE concentration reported in groundwater on the Boulevard Mall property was 5,310 μg/L at MW-13 in May 2005. The geologic profile logged during monitoring well installation(s) is generally characterized as sandy silt or clayey sand extending to approximately 19 feet bgs and sandy clay from 19 to 29 feet bgs within the saturated zone. Groundwater elevations fluctuate by as much as 15 or more feet across the site, which is demonstrated in the November 2010 groundwater monitoring results, wherein the groundwater elevation at monitoring well MW-6 was 1969.01 ft above mean seal level (amsl) and the groundwater elevation at monitoring well MW-19 was 1953.00 ft amsl.

Residential Areas

Construction of the residential neighborhoods to the east (downgradient) of the Boulevard Mall began in the early 1960s. Based on a review of historical aerial photos, the Property was undeveloped prior to construction of the residential neighborhoods. Traditional slab-on-grade homes are typical for the area.

Residences are on City of Las Vegas water that comes primarily from Lake Mead, although some City water (approximately 10 percent) is supplied from deep groundwater wells located in the northern portion of Las Vegas.

Las Vegas National Golf Course

The Las Vegas National Golf Course was constructed in 1961, and was originally called the Stardust Country Club. The golf course has at least two deep water wells (PW-1 and PW-2) located on the property for irrigation (Figure 3). According to the golf course management, more than 8 million gallons of fresh water are pumped from well PW-1 per week in the summer months. Groundwater samples from Well PW-1 have contained PCE at concentrations ranging from 130 µg/L in 2002 to 4.9 µg/L in 2006 (NDEP 2007). PW-1 is screened from 500 to 750 ft bgs in the deep aquifer. The irrigation well has an annular seal from the ground surface to 130 ft bgs. No details are known on the sampling procedures (such as duration of pumping prior to sampling).

1.2.3 Previous Investigations

A series of environmental investigations have been conducted across the Site since 2000 to assess groundwater, subsurface soils, and soil vapor migration. Several CAPs were also developed during this time; however, none proceeded beyond the initial investigation. Investigations were conducted by Converse Consultants from 2002 through 2004, and from 2008 to 2010, and by URS from 2005 through 2008. Reports relevant to preparation of the groundwater CAP include the following:

- Converse. *Phase I Environmental Site Assessment*. September 28, 1999.
- Converse. *Limited Phase II Subsurface Assessment*. August 22, 2000.
- Converse. *A Through K Data Research and Report*. August 22, 2001.
- Converse. *Additional Soil and Groundwater Investigation*. November 13, 2002.
- Converse. *Additional Soil and Groundwater Investigation*. May 16, 2003.
- Converse. *Preliminary Corrective Action Plan*. June 27, 2003.
- Converse. *Well Installation/Slug Testing/Groundwater Monitoring Report-4th Quarter 2003 and 1st Quarter 2004*. March 26, 2004.
- URS. *Report, Subsurface Investigation*. July 11, 2005.
- URS. *Source Removal Corrective Action Plan*. November 13, 2006.
- URS. *Quarterly Groundwater Sampling. December 2005.* February 6, 2005.
- URS. *Quarterly Groundwater Sampling and Additional Monitoring Well Installations. March 2006*. April 25, 2006.
- URS. *Quarterly Groundwater Sampling. June 2006*. July 31, 2006.
- URS. *Quarterly Groundwater Sampling. 3rd Quarter 2006*. November 14, 2006.
- URS. *Quarterly Groundwater Sampling. 4th Quarter 2006*, January 5, 2007.
- NDEP. *Groundwater Data from Golf Course Well PW-1,* February 2007.
- URS. *Quarterly Source Area Soil Assessment*. February 23, 2007.
- URS. *Quarterly Groundwater Sampling, 1st Quarter 2007,* April 2, 2007.
- URS. *Off-Site Soil Vapor Assessment Report*. April 13, 2007.

- URS. *Quarterly Groundwater Sampling , 2nd Quarter 2007,* July 25, 2007.
- URS. *Installation of Downgradient Groundwater Monitoring Wells,* November 26, 2007.
- URS. *Quarterly Groundwater Sampling , 3rd Quarter 2007,* December 6, 2007.
- URS. *Quarterly Groundwater Sampling , Fourth Quarter 2007,* January 16, 2008.
- URS. *Installation of Additional Downgradient Groundwater Monitoring Wells*, Letter Report, March 24. 2008.
- URS. *Quarterly Groundwater Sampling , First Quarter 2008,* April 14, 2008.
- Converse. *Groundwater Monitoring Report - 4th quarter 2008.* December 9, 2008.
- Converse. *Groundwater Monitoring Report - 1st quarter 2009.* April 15, 2009.

- Converse. *Groundwater Monitoring Report - 2nd quarter 2009.* July 21, 2009.
- Converse. *Groundwater Monitoring Report - 3rd quarter 2009.* October 9, 2009.
- TRC. *Groundwater Monitoring Well Investigation, Sampling and Capping.* December 9, 2009.
- Converse. *Groundwater Monitoring Report - 4th quarter 2009.* January 13, 2010.
- Converse. *Groundwater Monitoring Report - 1st quarter 2010.* April 14, 2010.
- Tetra Tech EM, Inc. (Tetra Tech). *Quarterly Groundwater Monitoring Report 2nd Quarter 2010.* July, 23, 2010.
- Tetra Tech. *Quarterly Groundwater Monitoring Report 3rd Quarter 2010,* October 22, 2010.
- Tetra Tech. *Quarterly Groundwater Monitoring Report 4th Quarter 2010,* January 21, 2011.

Quarterly groundwater monitoring has been conducted by various consultants at and downgradient of the Property since late 2005 to assess the extent of PCE contamination in groundwater. Most of the data consist of analytical data for groundwater samples collected from monitoring wells to define the distribution and extent of the dissolved-phase PCE plume in the shallow groundwater.

Data characterizing aquifer properties and soil gas for the Site are contained in three reports: an investigation by Converse (2004) and two investigations by URS (2005, 2007d). During the Converse 2004 investigation, slug tests were performed in six wells at the Site, along with some limited soil property tests on two soil samples (i.e., soil moisture, grain-size distribution, bulk density, and porosity).

The report for the Off-Site Soil Vapor Assessment (URS 2007d) provided analytical data for soil gas collected from multiple depths in 16 boreholes, along with soil geotechnical data for six soil samples. Table 6-1 in this 2007 report reported soil types ranging from clayey silt to sandy gravel. Analytical data for 32 soil vapor samples (plus four duplicate vapor samples) are presented in Table 6-2 of this 2007 report. Concentrations of PCE in these vapor samples ranged from nondetected to 170,000 micrograms per cubic meter (µg/m3). Based on a review of historical documents, data gaps that remain are identified and discussed in Section 9.0.

2.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The Valley covers roughly 1,600 square miles in southern Nevada, with the eastern edge extending to approximately 5 miles west of Lake Mead and the Colorado River. The Valley is bounded by mountain ranges that reach a maximum elevation of almost 12,000 ft above mean sea level (amsl) to the west. The Valley floor elevation ranges from about 3,000 ft in the west to 1,500 ft amsl in the east. (Zikmund 1996).

Precipitation on the Valley floor averages 4.16 inches per year as reported by the Western Region Climate Center (WRCC 2010). Most precipitation occurs during the months of July and August and during the winter (Wild 1990). Potential evapotranspiration ranges from 1 to 19 inches per month from winter to summer months (Shevenell 1996). Mountains surrounding the basin may receive as much as 20 inches of precipitation per year, usually as snowfall. Surface water flows in the Valley are tributary to Lake Mead through Las Vegas Wash (Brothers and Katzer 1988).

2.1 Regional Hydrogeology

The Valley is a structural basin filled with 3,000 to 15,000 ft of sediments in the Basin and Range Province of the northern Mojave Desert (Langenheim and others 1998). Plume (1984) divided the basin into three physiographic regions: mountain, piedmont, or alluvial apron and lowland. Groundwater generally flows southeast beneath Las Vegas Wash toward Lake Mead from recharge areas in the Spring Mountains in the west and the Sheep Range in the north (Figure 5) (Leising 2004).

In the west portion of the basin, sediments consist of coarse-grained sand and gravel alluvial fan deposits. In the lowland central and east portion of the basin, coarse alluvial sediments interfinger with fine-grained lacustrine and playa deposits (Plume 1989, Leising 2004). In the east central valley area, including the Site, coarse-grained sediments interfinger with heterogeneous playa deposits (e.g., sandy silt, silty sand, clayey sand, sandy clay, caliche) (Plume 1989, Leising 2004). Coarse material generally serves as aquifers, while the silts, clays, and caliche often act as confining layers (Zikmund 1996). The boundaries between aquifers and confining units (aquitards) in the basin fill are difficult to delineate due to the complexity of sediment distribution (Harrill 1976, Bernholtz 1993).

The hydrostratigraphic units of the Valley were redefined by Donovan (1996) and are presented here as defined by Leising (2004) and illustrated on Figures 6 and 7. The upper unit of heterogeneous sand, silt, and clay sediments in the central and eastern lowland area of the Valley is termed the Las Vegas Wash Aquitard. Based on well logs on file with Nevada Department of Water Resources (NDWR), this unit may be 100 ft thick in the area of the Site. The shallow groundwater system that has been investigated to define the distribution of the Site's PCE plume is within the upper 30 to 50 ft of the Las Vegas Wash Aquitard.

The Las Vegas Springs Aquifer underlies the Las Vegas Wash Aquitard and is subdivided into an upper unit (Las Vegas Creek Aquifer), a middle unit (Twin Lakes Aquitard), and a lower unit (La Madre Mountain Aquifer). The Las Vegas Creek Aquifer serves as the primary supply to domestic wells, and the La Madre Mountain Aquifer serves as the primary source for municipal supply wells. Based on well logs on file with NDWR, the depths to the upper and lower units of the Las Vegas Springs Aquifer within a few miles of the Site are estimated to be 100 to 200 ft bgs for the Las Vegas Creek Aquifer, and 550 to at least 750 ft bgs for the La Madre Mountain Aquifer. The Duck Creek Aquifer underlies the Las Vegas Springs Aquifer.

Recharge to the shallow groundwater system is attributed to: (1) upward vertical flow from the Las Vegas Springs Aquifer, (2) surface infiltration of runoff, and (3) over-irrigation (either agricultural or residential) (Bernholtz 1993). However, in some areas where water supply wells produce from the deeper aquifer, the vertical gradient has been reversed downward, and in some cases, shallow groundwater may be pumped and blended with groundwater from the deeper aquifer for irrigation and industrial uses (Zikmund 1996).

2.2 Site Geology

The geology of the Site consists of interbedded sequences of sand, sandy silt, sandy clay, and silty clay with frequent zones of caliche and intermixed gravel scattered throughout. Lithologic data are available in borehole logs from 33 monitoring wells installed at the Site between 2000 and 2008. The borehole logs and well construction diagrams for all monitoring wells at the Site are provided in Appendix A. Additional lithologic information was obtained from 29 soil borings drilled for subsurface characterization of the former APTC area, and from borings installed for active soil-gas sampling in and adjacent to the residential neighborhood. Figures 8 and 9 show cross sections prepared by URS (2007d) representing the downgradient area east of Algonquin Drive. Figure 8 shows that sediments along Algonquin Drive consist of gravelly sand and grade into silt in the area of wells MW-23 and MW-25, and then to clay at approximately 10 ft bgs in the area of wells MW-26 and MW-27. Figure 9 shows gravelly sand in the upper 5 to 10 ft along Algonquin Drive and silty sand in the upper 10 to 12 ft along Seneca Drive.

Total depth of monitoring wells at the Site vary from 20 to 50 ft, although most wells are completed at depths between 30 and 35 ft. Heterogeneous mixtures of lower permeability clays and silts (silty clay, sandy clay, clayey silt, and sandy silt) dominate the saturated intervals across most of the site. An apparent, alluvial stream-channel sand meanders through the area of the former APTC facility and portions of the Boulevard Mall in the upper 1 to 5 ft of the saturated zone, as evidenced in the borehole logs of wells MW-7, MW-8, MW-9, MW-10, MW-11, MW-12, MW-13, MW-14, MW-15, MW-20, MW-23 and MW-25. Sands exist in the lower portions of wells MW-12, MW-14, MW-20, MW-23, MW-25, MW-28, MW-30, and MW-31, as shown in the corresponding borehole logs.

The borehole logs for wells PT-1 and PT-2 at the National Golf Course indicate that below 80 ft bgs, the geology consists of interbedded red clay, sand, gravel, and caliche to at least 750 ft bgs.

2.3 Hydraulic Properties of the Shallow Groundwater System

Depth to groundwater generally varies between 9 to 28 ft bgs across the Site. Based on water level data obtained in June 2010, shallow groundwater flows east with a gradient that ranges from 0.0124 to 0.0132 ft/foot (Figure 10) (Tetra Tech 2010a). Historical groundwater elevations indicate the water table varied by several ft throughout the monitoring period from 2000 to 2011, as illustrated on Figure 11. The data show induced drawdown of the water table by pumping of well PW-1 at the National Golf Course during the months of June through October, with about 6 ft of drawdown in the nearest monitoring well (MW-27).

Converse (2004) conducted slug tests in monitoring wells MW-2, MW-3, MW-13, MW-15, MW-16, MW-19, and MW-20 in 2004 to estimate the hydraulic conductivity (K) representative of the Site. Calculated K values developed using the Bouwer-Rice Method (Bouwer and Rice 1976) ranged from 1.9 to 17 ft/day, whereas K values calculated using the Hvorslev Method (Hvorslev 1951) ranged from 0.8 to 6.4 ft/day.

Converse (2004) also measured total porosity and bulk density for two samples of sandy clay, yielding results of 49 to 57% for porosity, and 1.14 to 1.49 grams/cubic centimeter (g/cc) for bulk density. URS (2007d) conducted bulk density and grain size analyses for soil samples collected from three borings (SVB-5 at depths of 5.5 and 10 ft bgs, SVB-9 at depths of 3 and 8 ft bgs, and SVB-13 at depths of 8.5 and 18.5 ft bgs). Grain size ranged from clayey silt to sandy gravel, and bulk density ranged from 99.6 to 119 pounds per cubic foot or 1.6 to 1.91 g/cc.

Zikmund (1996) reported results from a study by Western Technologies (1991) to characterize basic hydraulic parameters for the shallow groundwater system in the Valley. Western Technologies tested 2- and 4-inch-diameter wells completed to depths of 25 to 30 ft bgs in downtown Las Vegas. The results of this study (summarized below) are considered representative of shallow groundwater characteristics in the downtown area (near the intersection of U.S. 95 and Interstate 15), approximately 3 miles north-northwest from the former APTC site:

- Yield — 0.15 to 8.5 gallons per minute (gpm)
- Average Transmissivity — 4.79×10^2 gallons per day/foot (gpd/ft)
- Horizontal Hydraulic Conductivity — 7 to 116 gallons per day/foot^2 (gpd/ft^2)

With the complex geology, the rate of groundwater flow within the shallow saturated zone varies, with preferentially higher flow rates within the gravelly sands and lower flow rates within silty to sandy clays. However, due to the frequent occurrence of scattered pea gravel and caliche within the mixed clays and silts, in combination with calcic water (which minimizes swelling of the clays), hydraulic conductivities within silty clay intervals may be relatively high (within the range of 0.01 to 1.0 ft/day) along predominant flow paths occurring along soil partings.

2.4 Geochemistry of the Shallow Groundwater System

Groundwater in the Las Vegas Wash Aquitard is generally brackish and considered non-potable. For example, total dissolved solids (TDS) range from 900 to 4,300 milligrams per liter (mg/L) in monitoring wells installed at the Site. Water quality in the Las Vegas Wash Aquitard generally degrades in an easterly, downgradient direction with increases of TDS, sulfate, and sodium. The elevated salinity results from evapotranspiration, dissolution of saline minerals in soils and rocks, and infiltration of irrigation water (Zikmund 1996). Groundwater in the Las Vegas Wash Aquitard in the area of the Site is a calcium-magnesium-sulfate water with a lesser bicarbonate component (Leising 2004). Some parts of the flow system also exhibit elevated concentrations of boron and nitrate (Zikmund 1996). Due to irrigation with chlorinated water from the local water system, chloroform and trihalomethanes may be found in the shallow groundwater (Leising 2004).

Groundwater samples were collected from eight wells and analyzed for concentrations of major anions (i.e., nitrate, sulfate, chloride, bicarbonate alkalinity), total iron, dissolved manganese, total organic carbon, and dissolved oxygen (URS 2005). Results generally agree with the regional geochemical characterization provided by Leising (2004). Sulfate is the dominant anion, with lesser concentrations of bicarbonate and chloride. Nitrate generally ranges from 4.5 to 7.3 mg/L in the shallow groundwater (URS 2005), and is attributed to the heavy use of fertilizers across the Valley (Leising 2004). Total organic carbon (TOC) in shallow groundwater at the Site ranges from 1.2 to 6.0 mg/L (URS 2005).

Field parameters (pH, temperature, specific conductance, turbidity, dissolved oxygen, and oxidation-reduction potential [ORP]) are routinely measured during quarterly groundwater monitoring. Most TDS measurements from across the Site are between 2,100 and 2,700 mg/L. URS (2005) reports detectable iron ranging from 1.2 to 38 mg/L and detectable manganese ranging from 0.0053 to 0.69 mg/L; however, turbidity is highly variable and can range from non-detectable to >999 Nephlometric Turbidity Units (NTU) due to the abundance of silt and clay in the saturated zone. Elevated concentrations of metals reported during prior investigations likely reflect the amount of turbidity (i.e., sediment) in the sample. Reported ranges of the field parameters are:

- pH — 4.67 to 7.41
- Temperature — 22 to 27.7 degrees Celsius (°C)
- Specific Conductance — 1.05 to 6.76 microsiemens/centimeter (mS/cm)
- Dissolved Oxygen — 0.07 to 7.27 mg/L
- ORP — -330 to +634 millivolts (mV)

Geochemical data from the Site and the regional characterization presented by Leising (2004) indicate the geochemistry of the shallow groundwater system of the Las Vegas Wash Aquitard is an aerobic environment that likely inhibits the growth of *Dehalococcoides* (DHC) bacteria. In the URS 2005 investigation, the presence of DHC bacteria was investigated and reported for two wells (MW-12 and MW-13); the results were below reportable counts. The relatively high concentration of sulfate in groundwater, with gypsum crystals in the subsurface soils, combined with elevated concentrations of nitrate and iron, suggest it would be difficult to induce reducing conditions that create the anaerobic geochemical environment needed to enhance either biodegradation or reductive dehalogenation of PCE and TCE. However, groundwater conditions at monitoring well MW-10 consistently exhibit a negative ORP that ranges from -140 to -330 mV. Negative ORP readings have also been observed periodically in MW-9 and MW-16, indicating the presence of localized areas where reducing conditions may persist. Given that groundwater at several additional well locations typically exhibits relatively low ORP values, in the range of 50 to 210 mV, it may be possible to use additives such as EHC® (a controlled-release, integrated carbon and soluble iron product) to achieve remediation of targeted areas of the Site. To confirm the efficacy or viability of this treatment technology, bench-scale testing or pilot testing would be necessary.

3.0 NATURE AND EXTENT OF CONTAMINATION

This section summarizes the distribution of contaminants in groundwater, soil and soil gas, and indoor air relevant to the objectives of this CAP.

3.1 Shallow Groundwater

The investigation of groundwater began in August 2000. Additional wells have been installed several times since 2000 to evaluate the extent of dissolved PCE in groundwater. Regularly scheduled monitoring of groundwater has been conducted since May 2005. Currently, 33 monitoring wells are installed at the Site, 31 of which are part of the monitoring program (Figure 3). Eleven wells in the residential area of the plume are monitored quarterly. Eleven wells in the area of the former APTC facility, the Boulevard Mall, and the southwestern residential area are monitored semi-annually. All 33 wells in the program are monitored during the 4th quarter monitoring event.

The PCE plume extends approximately 4,000 ft east from the APTC source to the east side of the National Golf Course (Figure 3). The plume width is estimated to be 700 ft at the widest extent near Spencer Street. The plume extends due east from the source, under the Boulevard Mall, then slightly curves to the north under the neighborhood between Cherokee Lane and Seneca Lane toward irrigation well PW-1, located within the Las Vegas National Golf Course. The plume east of PW-1 is estimated to extend 1200 ft. The center line of the plume is estimated to extend through MW-6, between MW-19 and MW-20, just north of MW-23 and MW-25, and approximately midway between MW-26 and MW-32 toward PW-1. PCE concentrations in the shallow groundwater along the centerline are estimated to be 2,500 to 3,000 μg/L near the Boulevard Mall, 1,500 to 2,000 μg/L near MW-18 and MW-23, and approximately 1,000 μg/L between MW-26 and MW-32. The concentration of PCE is below 100 μg/L at wells MW-30 and MW-31, located in the residential area in the central portion of the golf course. Based on the rate of dissolved PCE migration across 4,000 ft in approximately 30 to 40 years, the average migration rate of the leading edge of dissolved PCE is estimated to be 100 to 130 ft/year, assuming PCE releases began in 1969 at APTC. The plume has moved with normal groundwater flow, but is attenuated to roughly half the rate of groundwater. The plume likely only came within the capture zone of irrigation well PW-1 after 18 to 20 years of migration. PCE was initially reported in a sample collected from PW-1 at 8.1 μg/L in 1990.

Assuming a gradient of 0.013 ft/foot (Tetra Tech 2010a), an assumed average hydraulic conductivity of 15 ft/day (based on reported values provided in Section 2.3), and a porosity of 0.30, an annual, average groundwater flow rate of 237 ft/year for the shallow groundwater is derived. If the plume moved 100 to 130 ft/year, the PCE is attenuated at a factor of 1.8 to 2.4, which is within the expected range for PCE migration in a low degradation environment.

The plume migration initially would have been through the mixtures of fine sands and gravels as a preferential flowpath because of the higher hydraulic conductivity. The dissolved PCE then would have migrated into the silts and clays by diffusion and along soil partings (secondary porosity from differential stress cracks and desiccation partings that do not reseal due to the calcic water that minimizes clay swelling). Therefore, preferential flow paths likely allowed the leading edge of the plume to migrate 100 to 130 ft/year, while movement into and through the clay and silt units likely occurred at 1 to 20 ft/year. The plume at the Site is expected to be stable at its lateral extent, with remnants of later releases (such as periodic flushing/cleanout of the sump and drain lines) likely still moving through the plume as slugs (mobile hot spots of higher PCE concentration).

The PCE concentrations in the groundwater have fluctuated over time, with many wells exhibiting apparent decreases (Figure 12). In the upgradient portion of the plume, changes likely are due to movement of PCE slugs. For example, the concentration of dissolved PCE in MW-1 varied between 870 and 3,500 μg/L during 2000 to 2005, but decreased to below 1,000 μg/L by June 2007. The concentration of PCE in groundwater in MW-2 was at 3,000 μg/L in 2000 to 2002, and decreased to below 1,000 μg/L by June 2008. PCE concentrations in MW-6 decreased in late 2005, then increased over the

next 4 years and are currently near 2,500 μg/L. The groundwater in MW-13 had the highest PCE concentration ever reported (5,310 μg/L) in May 2005; since that time, the PCE concentrations have decreased to below 3,000 in 2007, and below 2,000 in 2010. MW-14 and MW-18 previously also had groundwater with PCE above 3,000 μg/L. PCE concentrations in groundwater at MW-14 were below 1,000 μg/L as of 2007, and in MW-18 have been below 2,000 μg/L since December 2006. PCE concentrations in groundwater in MW-23 have been below 2,000 μg/L since June 2007. PCE concentrations in wells MW-19, MW-20, MW-23, MW-25, MW-26, and MW-32 have all decreased to below 1000 μg/L. In the downgradient area of the plume, these decreases are likely due to lateral spreading of the plume by diffusion into the finer grained silts and clays.

The chemical results for PCE daughter products indicate limited if any degradation of PCE at the Site. Low levels of TCE and *cis*-1,2-dichloroethene (DCE) have been detected in wells MW-2, MW-5, and MW-6 (concentrations of about 0.5% of the PCE concentration). This is roughly the percentage that TCE occurs as a trace contaminant in industrial grade PCE. The highest concentrations of daughter products have been detected in samples from MW-6 (maximum TCE of 41 μg/L; maximum *cis*-1,2-DCE of 23 μg/L). Beginning in October 2008, low concentrations of TCE were regularly detected in 10 additional wells; this coincided with a change in the laboratory that was performing the analyses. The daughter product *cis*-1,2-DCE has been detected in a sample from one additional well besides the three wells near the source area; *cis*-1,2-DCE was reported twice in late 2005 in samples collected from MW-21.

3.2 Soil Gas

In 2007, URS collected soil gas samples from multiple depths in the central residential area along north-south transects along Spencer Street and along the eastern edge of the Boulevard Mall. Soil borings were advanced to 10 and 20 ft bgs at six locations along Spencer Street (Figure 13), at six locations in the eastern parking lot of the Boulevard Mall property, and at four locations along Ottawa Drive at Algonquin Drive (Figure 14). Borings were continuously cored, and then soil gas rods were inserted with upper sections of the hole grouted so that short-term-duration soil gas samples could be collected. A tracer gas (1,1-difluoroethane) was used to detect leaks in the sampling equipment.

The highest PCE concentration found in a soil gas sample along Spencer Street was 46,000 micrograms per cubic meter (μg/m^3) from 5 ft bgs at SVB-03 (Figure 13). The highest PCE concentration in a soil gas sample collected near the Boulevard Mall was 170,000 μg/m^3 from 20 ft bgs at SVB-14 (Figure 14). A total of 39 samples of soil gas were collected and analyzed; seven samples contained no detectable PCE. Of the 32 samples that contained detectable concentrations of PCE, significant amounts of the tracer gas were found in four samples, indicating leakage from the atmosphere and invalidating the results.

3.3 Indoor Air

The NDEP conducted neighborhood sampling events between fall 2007 and winter 2007-2008. During these events, 97 homes and two schools were sampled for PCE and related compounds in indoor air. Of the homes sampled, 15 homes exhibited PCE concentrations greater than the NDEP indoor air interim action level of 32 μg/m^3 (Broadbent & Associates [Broadbent] 2010).

Subslab depressurization (SSD) systems were installed at 14 homes, which were subsequently retested to assure that the systems successfully mitigated indoor air PCE concentrations. If indoor air PCE concentrations still exceeded the NDEP interim action level, the SSD systems were performance-tested (e.g., test the in-home pressure differential) and were modified to achieve PCE concentrations less than 32 μg/m^3 in indoor air. Subsequent sampling confirmed that homes with the SSD systems, after required modifications, exhibited PCE concentrations less than 32 μg/m^3 in indoor air (Broadbent 2010).

4.0 CONTAMINANT FATE AND TRANSPORT

Source Area

PCE was used in dry cleaning operations at the APTC facility from 1969 to 2000. Floor drains collected spills at the facility, which drained to a sump in the north central portion of the building. A "cooker" was operated in a half-basement on the north side of the building, and overflow from the cooker would drain to the sewer. The Property sewer line drained to the City sewer installed along the east margin of South Maryland Parkway, which drains north toward East Desert Inn Road. PCE may have migrated east of Maryland Parkway via the sewer line, with releases potentially occurring from leaks at the connection to city sewer lines.

Site data from the URS 2005 and 2007 source area investigations supported the contention that PCE had been released though the concrete floor drain, because the highest PCE concentrations were found adjacent to the sump (B-10 at 120 mg/kg; B-24 at 56 mg/L). The URS investigations, with the previous Converse (2002) data, involved 77 soil samples from 29 soil borings that delineate the extent of PCE in unsaturated soils beneath the former APTC facility. Soil sample results indicate the PCE wash seeped through the concrete drain and floor, continuing to migrate down through the soil until reaching groundwater. Maryland Square, LLC demolished the buildings of the former shopping center, including the concrete floor and foundation, in summer 2006.

Converse (2001, 2003a, 2004) and URS (2006b) installed a total of 15 wells in the APTC source area and about the Boulevard Mall parking garage to evaluate the extent of PCE in shallow groundwater. PCE concentrations in groundwater were detected between 2000 to 2005 at up to 3,500 µg/L in the source area. The dissolved PCE plume was observed east across South Maryland Parkway, and was found to have dispersed laterally (north-south) to a width of 300 ft at the edge of the property along South Maryland Parkway, and a width of approximately 600 ft at the Mall (east of the parking garage). The lateral spread may have been due to the influence of the utility lines along the South Maryland Parkway. As of 2010, PCE in groundwater in the source area had decreased to concentrations below 430 µg/L (Tetra Tech 2011).

The Extended Shallow Groundwater Plume

An additional 18 wells were installed east of the Boulevard Mall in the 2005 investigation and subsequent investigations (URS 2006a, 2007f, and 2008b) that established the extent of the plume to the east side of the National Golf Course, an approximate distance of 4,000 ft from the source area (Figure 3). The plume at the widest transect is estimated to be 700 ft near Spencer Street, approximately 3,000 ft from the APTC source. As of late 2010, PCE concentrations in the shallow groundwater along the centerline of the plume were estimated to be 2,500 to 3,000 µg/L near the Boulevard Mall, 1,500 to 2,000 µg/L near MW-18 and MW-23, and about 1,000 µg/L between MW-26 and MW-32. The PCE concentrations decrease quickly north and south of the centerline of the plume to below 5 µg/L within 300 to 400 ft. The plume at the Site is assumed to be stable at its eastern extent. Slugs with higher concentration of PCE from releases in the late 1990s (such as from flushing/cleanout of the sump and drain lines) are likely still moving through the central area of the plume.

Deep Groundwater

The golf course operates two irrigation wells, PW-1 and PW-2. Dissolved PCE has been detected at concentrations ranging from 130 µg/L in 2002 to 4.9 µg/L in 2006 (NDEP 2007) in water from PW-1, the western irrigation well (Figure 3). PW-1 is screened from 500 to 750 ft bgs in the deep aquifer, although the filter pack extends to 130 ft bgs. The grout seal extends from 130 ft bgs to the surface. According to the property management, more than 8 million gallons of fresh water are pumped from well PW-1 per week in the summer months. The path of the PCE to the production zone of the well is unknown; it could be through a failure of the well seal or through vertical migration below the 130-foot depth of the seal.

Migration and Retention of PCE

As presented in Section 3.1, the shallow groundwater flow across the site is from west to east at an estimated average annual flow rate of 237 ft/yr. Based on the dissolved PCE plume migrating about 4,000 ft in 30 to 40 years, the average migration rate of the leading edge of the PCE plume is estimated to be 100 to 130 ft/year, with an attenuation factor of 1.8 to 2.4.

The PCE plume is believed to have initially migrated through the preferential path of the sand and gravel portions of the Las Vegas Wash Aquitard (the shallow groundwater system). Although these intervals are poorly sorted, with up to 30% silt or clay present, these sand/gravel facies are the higher permeable portions of the aquitard and would allow migration at the required rates to produce the plume dimensions observed by 2008, and as indicated by the PCE detected at PW-1 in 1990.

However, a large amount of the aquitard at the Site also consists of heterogeneous clays and silts (silty clay, sandy clay, silty sand, and clayey sand). Dissolved PCE in groundwater will move by advective transport and diffusion into the portions of these facies that have greater silt and sand content and where secondary porosity has developed along soil partings from differential stress cracks and seasonal desiccation. This inflow into the finer grained units may occur at rates of 1 to 20 ft or more each year. PCE in these silt and clay units may be retained for a very long time, as little degradation is evident from the monitoring data. Rebound of PCE into groundwater may occur from the diffusion of PCE that is entrained in these finer grained sediments after the application of many available remedial treatment technologies.

Biodegradation and Treatment of PCE

An evaluation of groundwater monitoring data suggests very little if any degradation of PCE occurs within the shallow groundwater system. Concentrations of PCE have likely persisted for at least 40 years at the Site, during which time daughter products TCE and *cis*-1,2-DCE have been detected only at low concentrations that are within the range of concentrations of impurities in industrial grade PCE used in dry cleaner operations.

The site chemistry is strongly aerobic across most of the site, although there may be pockets of anaerobic zones, as exemplified by conditions near well MW-10 that exhibits a negative ORP range of -140 to -330 mV. Biodegradation of PCE occurs under anaerobic conditions through the bioactivity. URS (2005) submitted two groundwater samples to ascertain the population of DHC bacteria; however, the presence of DHC bacteria was not evident. Aerobic conditions inhibit the growth of DHC bacteria. In addition, as sulfate is present in the groundwater at relatively high concentrations, artificially inducing reducing conditions will produce high concentrations of sulfide that will also inhibit DHC bacteria. Therefore, inducing reducing conditions by injecting only electron donors (such as HRC®) is not likely to be effective. However, electron donors combined with zero-valent iron (ZVI) have had some success in high sulfate groundwater. This suggests that induced reductive dehalogenation using a product such as EHC® may be possible. This may be cost-effective in areas where the ORP is no higher than 200 mV. Bench-scale and pilot-scale testing would be necessary to evaluate the feasibility of this treatment option.

5.0 HUMAN HEALTH RISK ASSESSMENT

It is anticipated that the results of a baseline risk assessment predicting and quantifying potential risk from indoor air exposure, as well as other potentially complete exposure pathways, will be presented in the final CAP after adequate data are obtained.

6.0 IDENTIFICATION OF PRELIMINARY CORRECTIVE ACTION OBJECTIVES AND REMEDIATION STANDARDS

Preliminary corrective action objectives (CAO) and preliminary numerical remediation standards are assigned to protect human health and the environment, and are used to guide the evaluation of potential corrective actions. The preliminary CAOs and numerical remediation standards used for this site were established to address site-specific chemicals of concern (COC), affected media, and potential exposure pathways.

Preliminary CAOs address potential risks to human health and the environment. The following CAOs are specified:

1. Prevent inhalation exposure of current residents to concentrations of PCE that exceed the remediation standard for residential indoor air.
2. Prevent use of shallow groundwater as a source of drinking water and remediate shallow groundwater where PCE concentrations exceed the remediation standard for groundwater.

These preliminary CAOs will be refined after completion of a human health risk assessment that will be presented in the final CAP. CAOs will become final when the corrective action is selected in a record of decision.

The development of preliminary numerical remediation standards involves four steps:

1. Identification of potentially applicable regulatory standards promulgated under *Nevada Administrative Code* (NAC) 445A.226, et seq., as amended under Adopted Regulation R189-08, that contain health or risk-based numerical values or requirements.
2. Calculation of risk-based concentrations in the absence of promulgated regulatory standards.
3. Identification of laboratory practical quantitation limits (PQL).
4. Comparison of the concentrations identified through the previous steps.

The first step identifies potential regulatory standards potentially applicable to a release from the Property. NAC 445A.22735 establishes action levels for groundwater. These groundwater action levels are either maximum contaminant levels (MCL) established under the Safe Drinking Water Act, (and adopted by reference at NAC 445A.22735(1)(b)), or background concentrations if these exceed the MCL. If a MCL has not been established for a hazardous substance, hazardous waste, or regulated substance, provisions for using background concentrations or an appropriate concentration based on protection of public health and safety and the environment (risk) can be invoked to derive relevant action levels (NAC 445A.22735).

A MCL for PCE of 5 µg/L has been established under the Safe Drinking Water Act. MCLs and drinking water standards promulgated under the Safe Drinking Water Act are standards applicable to public water supplies “at the tap,” at the point of end use. A drinking water standard, like the MCL, may not be appropriate for the shallow groundwater at the Site if naturally occurring groundwater quality is so poor it is not likely to serve as a potential source of drinking water. Furthermore, Section 14 of Revised Proposed [and adopted] Regulation R189-08, issued by the NDEP Bureau of Corrective Actions, prescribes the criteria required to conclude remedial activity, that relies, in part, on source control; interruption to, or remediation of, exposure pathways; and the likely use of groundwater based on quality characteristics. However, groundwater is “waters of the state,” (NRS 445A.415) and NDEP asserts that regulations require “no degradation” of waters of the state (NDEP 2011). No promulgated numerical standards apply to concentrations of PCE in indoor residential air.

The second step identifies potential site-specific, risk-based concentrations. Risk-based concentrations are typically calculated in the absence of promulgated regulatory requirements for protection of a

particular receptor or exposure pathway in a given medium. Risk-based concentrations for groundwater will be calculated, if necessary, for groundwater exposure pathways identified as complete or potentially complete in the human health risk assessment to be completed as part of the final CAP. NDEP's interim action level of 32 µg/m^3 for PCE is a risk-based concentration protective of residential receptor exposure to PCE in indoor air at a cancer risk level of 10^{-4}. A cancer risk level of 10^{-6} correlates to PCE concentration in indoor air of 0.32 µg/m^3.

The third step involves consideration of laboratory PQLs. The PQL is the lowest concentration that can be reliably measured within specified limits of precision and accuracy by individual analytical methods under routine laboratory conditions. PQLs are based on a general estimate for an analytical method, and not a determination for individual chemicals. Numeric remediation standards cannot be set below the laboratory PQL because concentrations lower than the PQL cannot be reliably measured. The laboratory PQL for PCE in water is 0.5 µg/L. The laboratory PQL for PCE in indoor air varies by laboratory and analytical method but is generally less than 10 µg/m^3. NDEP's indoor air sampling program achieved an average detection limit for PCE in indoor air of 5.6 µg/m^3 (NDEP 2011). Laboratory PQLs are not low enough to detect PCE concentrations in indoor air of 0.32 µg/m^3.

The final step compares the values generated by the previous steps. The only numbers generated in the previous three steps for PCE in groundwater were the MCL, identified as the Nevada regulatory standard under NAC 445A.22735, and the laboratory PQL. The MCL for PCE (5.0 µg/L) is used in the draft CAP as the preliminary remediation standard for groundwater because it is higher than the laboratory PQL, and it is a regulatory standard that can be reliably measured.

The numbers generated in the previous three steps for PCE in indoor air were NDEP's interim action level (a risk-based concentration of 32 µg/m^3 associated with a risk factor of 10^{-4}), a risk-based concentration correlating to the 10^{-6} risk level (0.32 µg/m^3), and the laboratory PQL. These preliminary values will be refined after completion of a human health risk assessment, which will be presented in the final CAP. Numerical remediation standards will become final when the corrective action is selected in a record of decision.

7.0 IDENTIFICATION OF SCREENING TECHNOLOGIES

This section presents GRAs, remedial technologies, and process options evaluated to address shallow groundwater above the remediation standard. In general, the same or similar GRAs, remedial technologies, and process options are applicable in the source area, Boulevard Mall, and residential areas; therefore, these areas have been combined for evaluation. Remedial technologies and process options are developed and screened based on implementability, effectiveness, and cost (United States Environmental Protection Agency [EPA] 1988). After the remedial technologies are evaluated, they are combined into corrective action alternatives.

Soil in the source area is being addressed as part of the CAP for Source Area Soil (Tetra Tech 2010). The CAP for Source Area Soil recommends excavation of soil (to groundwater, which is found at approximately 18 ft bgs) containing concentrations of PCE in excess of the residential EPA Region IX Residential Regional Screening Level (RSL) of 550 micrograms per kilogram (µg/kg) for residential soil; disposal of the soil in a permitted off-site hazardous waste landfill; and addition of a chemical oxidant to the footprint of the excavation as the preferred corrective action alternative. After excavation and disposal, the open excavation provides an opportunity for additional treatment of PCE using chemical oxidation in soil and groundwater below the excavation. Data obtained from corrective action in the source area can be subsequently used to evaluate effectiveness of chemical oxidation as part of remedy selection for groundwater.

7.1 General Response Actions

GRAs were derived from engineering judgment and experience with corrective actions proven successful for remediation of dissolved phase PCE in groundwater. The following GRAs were identified to achieve the preliminary remediation standard for groundwater in the source, Boulevard Mall, and residential areas:

- No Action – Required for consideration.
- Institutional controls (IC) – land-use and groundwater-use restrictions.
- Engineering controls – mitigation measures like vapor barriers, SSD systems, and well abandonment.
- Monitored natural attenuation (MNA) – Organic contaminants are allowed to naturally attenuate via biodegradation, diffusion, dilution, or adsorption.
- Treatment – in situ and ex situ treatment and monitoring of groundwater contamination.
- Containment – capping and vertical barriers to contain the contamination.

Process options for these GRAs are evaluated below.

7.2 Identification, Screening, and Evaluation of Technology Types and Process Options for the Source, Boulevard Mall, and Residential Areas

This section analyzes the technology types and process options for each GRA in terms of three broad screening evaluation criteria: effectiveness, implementability, and cost (EPA 1988). Potentially applicable GRAs identified for groundwater consist of (1) No Action, (2) ICs, (3) engineering controls, (4) MNA, (5) treatment, and (6) containment. Process options for containment were not retained after the initial screening based on difficulty of implementation and ineffectiveness. The five remaining GRAs are discussed in this section. Given the concentrations of PCE in groundwater at the Site, the subsurface conditions, and the various receptor pathways, it is likely that an integrated approach to remediation or a combination of general response actions will be required.

The screening of process options incorporating the remedial technology types for these GRAs is provided in Table 7-1. The rationale for eliminating process options from further evaluation is also presented in the table, and eliminated process options are not discussed further.

No Action

The NCP requires that the No Action alternative be carried through the detailed analysis of alternatives. Under this GRA, no corrective action is taken. Groundwater would be left without implementing ICs, engineering controls, removal, treatment, containment, or other mitigating actions. Because groundwater poses a potential risk to human health of current and future residents, the no-action response is not an effective alternative. As quarterly groundwater and annual air monitoring are ongoing at the Site, these monitoring costs were included as part of the no-action alternative.

Institutional Controls

ICs can effectively prevent human contact with PCE in groundwater and can include access restrictions and deed restrictions executed by legal and/or administrative mechanisms. The main risk for exposure to contaminants is through vapor intrusion in buildings and residences at the Site. Exposure to volatile contaminants can be prevented with ICs requiring engineering controls on existing and/or newly constructed buildings and residences.

Groundwater at the site is not a source of drinking water due to poor water quality; however, groundwater is considered “waters of the state,” and regulations require “no degradation” of waters of the state. Domestic water supply wells at the Site are not permitted by the Department of Conservation and Natural Resources, Division of Water Resources. However, some residents or businesses may continue to pump and use shallow groundwater without regulatory or municipal authorization (existing wells are to be abandoned when the business or residence is connected to the municipal water supply). ICs may mitigate unauthorized use and exposure to shallow groundwater by virtue of education and awareness; however, unauthorized or unlawful uses of groundwater cannot be reasonably precluded through ICs or other administrative or engineering controls.

When used properly and as intended, ICs are effective, implementable, and low cost. Therefore, ICs were retained for development and evaluation of corrective action alternatives.

Engineering Controls

Engineering controls can effectively mitigate vapor intrusion and prevent human contact with PCE in groundwater when used in conjunction with ICs. Process options pertaining to vapor intrusion mitigation were evaluated during the initial screening process, including: epoxy coating or subslab vapor barrier for future construction, SSD systems, and raised floor systems for future construction. SSD systems are being used effectively to mitigate vapor intrusion at 14 residences. Given the effectiveness of SSD systems currently in use at the Site, this process option was retained. Subslab vapor barriers could be effective for future construction; therefore, this process option also was retained. Because (1) the location and status of unauthorized groundwater wells is unclear and (2) shallow groundwater is not a designated source of drinking water, engineering controls (e.g. individual wellhead treatment units) addressing individual unauthorized groundwater wells were not considered.

TABLE 7-1

GENERAL RESPONSE ACTIONS AND PROCESS OPTIONS FOR GROUNDWATER ABOVE PRELIMINARY REMEDIATION STANDARD

General Response Action	Remedial Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Comment
No Action	Not applicable (NA)	NA	No actions are taken at the site.	Low	Easy	Low	Retained for comparison purposes.
Institutional Controls	Deed Restrictions	Deed Restrictions	Could include well restrictions, testing for indoor air quality, and requirement for individual home air treatment units.	Moderate	Moderate	Low	Potentially applicable in conjunction with other GRAs. Residents impacted by vapor intrusion have individual subslab depressurization (SSD) systems.
	Access Restrictions	Access Restrictions	Currently, homes are on municipal water; could include abandonment of unauthorized wells.	Moderate	Easy	Low	Potentially applicable in conjunction with other GRAs.
Engineering Controls	Vapor Barriers	Epoxy Coating	The floor of the building is sealed with an epoxy-based sealant, providing a physical barrier to vapor migration into buildings.	Low – Moderate	Easy - Moderate	Low – Moderate	Poor performance record; most effective when implemented in conjunction with subslab depressurization. It is difficult to ensure that all cracks are sealed, and sealant itself cracks over time.
		Subslab Vapor Barrier	An impermeable vapor barrier is placed below the building's foundation before construction.	Moderate	Easy - Moderate	Low – Moderate	Potentially applicable for new buildings/residences. Important to ensure material is compatible with contaminant. May be used in conjunction with subslab depressurization for improved effectiveness
		Subslab Depressurization	Blowers and vapor collection points are installed below the building to prevent vapor intrusion.	Moderate – High	Easy - Moderate	Low – Moderate	Currently used at 14 residences at the Site.
		Raised-Floor System	A new sub floor and depressurization system is installed between the floors to maintain a negative pressure gradient and prevent vapor intrusion.	Moderate – High	Moderate	High	Effective for buildings where subslab depressurization is not implementable. Difficult to implement in existing buildings; reduces the functionality of the structure.
	Wellhead Treatment	Well Abandonment	Abandon unauthorized wells to prevent exposure to tetrachloroethene (PCE) in groundwater.	High	Easy	Low	Location and status of potential residential groundwater wells is being assessed; additional information is required.
		Granular Activated Carbon (GAC) Treatment Unit	Utilize individual GAC units to treat PCE at individual wells.	High	Easy	Low	Location and status of potential residential groundwater wells is being assessed; additional information is required.
Monitored Natural Attenuation (MNA)	MNA	MNA	Monitor wells to track natural declines of contaminants that occur with source removal. Organic contaminants are allowed to naturally attenuate via biodegradation, dispersion, dilution, or adsorption	Low	Easy	Low	Potentially applicable in conjunction with other GRAs. Preliminary assessment of site conditions shows limited evidence of biodegradation; requires long-term monitoring to assess recovery rates and success.
Treatment	In Situ Biological Treatment	Enhanced Bioremediation	The activity of naturally occurring or augmented (bioaugmentation) microbes is stimulated (biostimulation) by circulating electron donors, electron acceptors, or nutrients, through contaminated groundwater to enhance in situ biological degradation of organic contaminants.	Moderate – High	Moderate - Difficult	Moderate – High	Potentially applicable. High sulfate concentration in groundwater may reduce effectiveness. May be difficult to implement in situ; nutrients and other amendments are difficult to deliver. Aquifer shows no signs of ongoing biodegradation.
		Phytoremediation	Plants are used to remove, transfer, stabilize, and destroy contaminants in groundwater	Low	Difficult	Moderate	Not effective for deeper groundwater.
	In Situ Physical/Chemical Treatment	Air Sparging/Soil Vapor Extraction	Inject air into the saturated subsurface to volatilize organic contaminants in groundwater. May be used in conjunction with soil vapor extraction, where a vacuum is applied to soil to induce controlled air flow and remove volatile and semivolatile contaminants from the unsaturated zone.	Moderate – High	Moderate	Moderate – High	Potentially applicable. Design and effectiveness of system depends on geology and depth of contaminants; operations and maintenance (O&M) intensive. Air stream may require treatment.
		In Situ Thermal Treatment	The subsurface is heated to vaporize VOCs; vaporized contaminants can then be removed from the unsaturated zone by vacuum extraction and treated.	Moderate – High	Difficult	High	Typically a source control technology used for gross mass reduction. Success and required treatment time depend heavily on site-specific characteristics such as soil type, contaminant characteristics and concentrations, geology, and hydrogeology; volatilized VOCs are difficult to capture and may accumulate in buildings or follow preferential pathways; may require a large number of wells. Effective for VOCs; depends on the ability to capture vaporized contaminants.
		Permeable Reactive Barriers	A permeable wall is created (often zero-valent iron) to treat contaminated groundwater while groundwater passively flows through.	High	Moderate – Difficult	High	Potentially applicable. Limited to subsurface lithology that has a continuous aquitard; can be difficult to install at depths greater than conventional trenching equipment. Possibility of precipitate formation due to site geochemistry.

TABLE 7-1 (CONTINUED)

GENERAL RESPONSE ACTIONS AND PROCESS OPTIONS FOR GROUNDWATER ABOVE PRELIMINARY REMEDIATION STANDARD

General Response Action	Remedial Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Comment
Treatment (continued)	In Situ Chemical Treatment	In Situ Chemical Oxidation	Chemicals (such as ozone, potassium permanganate, or Fenton's reagent) are injected into the contaminated groundwater to oxidize the contaminants	Moderate – High	Moderate – Difficult	Moderate – High	Potentially applicable. Depends on site geology, which may inhibit adequate dispersion of injected chemicals; multiple injections may be necessary to achieve remediation goals. Could add total dissolved solids (TDS) within the aquifer.
		In Situ Chemical Reduction	Chemicals (such as zero-valent iron) are injected into the contaminated groundwater to chemically reduce the contaminants	Moderate – High	Moderate – Difficult	Moderate – High	Potentially applicable. Depends on site geology, which may inhibit adequate dispersion of injected chemicals; multiple injections may be necessary to achieve remediation goals.
		Permeable Reactive Barriers	A permeable wall is created (often zero-valent iron) to treat contaminated groundwater while groundwater passively flows through.	High	Moderate – Difficult	High	Potentially applicable. Limited to subsurface lithology that has a continuous aquitard; can be difficult to install at depths greater than conventional trenching equipment. Possibility of precipitate formation due to site geochemistry.
		Ozone Sparging	Inject ozone into the saturated subsurface to treat organic contaminants in groundwater.	Moderate – High	Moderate	Moderate – High	Potentially applicable. Design and effectiveness of system depends on geology, depth of contaminants, and dispersion of ozone; operations and maintenance (O&M) intensive.
Removal/ Treatment	Ex Situ Physical/Chemical Treatment	Extraction and Treatment	Contaminated groundwater is removed by pumping, and contaminants are removed or destroyed ex situ through treatment such as advanced oxidation processes, air stripping, GAC adsorption, ion exchange, or separation	Moderate – High	Moderate	High	Potentially applicable. Effective for organic compounds; often generates a secondary waste stream; may leave significant concentrations of chemicals of concern (COC) behind as the aquifer is dewatered. Aquifer has exhibited slow recharge of groundwater indicating low hydraulic conductivity; may be difficult to implement; long remedial time frame. TDS may require additional treatment prior to discharge.
		Dual-Phase Extraction	A high vacuum system is used to extract liquid and vapor from the subsurface; liquid and vapor are then separated and treated.	Moderate - High	Moderate – Difficult	High	Requires both water treatment and vapor treatment; more applicable to light non-aqueous phase liquids (petroleum releases) than to chlorinated solvent releases
Containment	Capping	Asphalt.	Pave with asphalt over areas of contamination. Can be used to minimize vapor intrusion and infiltration.	Moderate	Easy	Low – Moderate	May prevent vapor intrusion into areas that are not developed; will not reduce concentrations in groundwater or reduce vapor intrusion into buildings that have already been constructed.
		Concrete	Place concrete over areas of contamination. Can be used to minimize vapor intrusion and infiltration	Moderate	Easy	Low – Moderate	May prevent vapor intrusion into areas that are not developed; will not reduce concentrations in groundwater or reduce vapor intrusion into buildings that have already been constructed.
		Compacted Clay & Soil	Place compacted clay and soil over areas of contamination. Can be used to minimize vapor intrusion and infiltration	Moderate	Easy	Low – Moderate	May prevent vapor intrusion into areas that are not developed; will not reduce concentrations in groundwater or reduce vapor intrusion into buildings that have already been constructed.
	Vertical Barriers	Grout Curtain	Pressure injection of grout in a regular pattern of drilled holes.	Moderate	Difficult	High	Contamination has already moved off site; containment technologies would be ineffective in treating the entire plume but could be used to isolate the source area.
		Slurry Wall.	Trench around area of contamination is filled with bentonite slurry	Moderate	Difficult	High	Contamination has already moved off site; containment technologies would be ineffective in treating the entire plume but could be used to isolate the source area.

Notes:
Gray shading indicates a technology or process option was eliminated from consideration.
Effectiveness and cost scales defined as low, medium, and high.
Implementability scale defined as easy, moderate, and difficult.

Monitored Natural Attenuation

MNA "… refers to the reliance on natural attenuation processes (within the context of a carefully controlled and monitored clean-up approach) to achieve site-specific remedial objectives within a time frame that is reasonable compared to other methods. The 'natural attenuation processes' at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil and groundwater. These in situ processes include: biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization, transformation, or destruction of contaminants (EPA 1997).

MNA was not retained for further evaluation as a stand-alone technology in the corrective action alternatives. MNA alone would not reduce the concentrations of PCE within a reasonable timeframe and would not be sufficient to prevent the expansion or migration of the groundwater contaminants. As described in Section 4, very little if any degradation of PCE occurs within the shallow groundwater system. As such, any natural attenuation of contaminant concentrations would likely be due to processes other than biological degradation. Because it may be physically impossible to actively treat all areas of the plume to completion, abiotic MNA may further reduce the concentrations of contaminants to complete the attainment of corrective action goals. Therefore, MNA was retained as part of a groundwater treatment train, in conjunction with a more aggressive primary treatment technology.

Treatment

Treatment processes directly reduce the toxicity, mobility, or volume of contaminants. The following in situ treatment process options were evaluated and retained during the screening process: in situ chemical oxidation, sparge curtain (air sparging in conjunction with soil vapor extraction (SVE) or ozone sparging), PRB using in situ chemical dechlorination, and enhanced bioremediation. Extraction and treatment was retained as an ex situ process option. Technologies screened out can be identified in Table 8-1.

<u>In Situ Chemical Oxidation</u>

In situ chemical oxidation involves injection of chemical oxidants into the groundwater to oxidize and degrade the PCE. Chemical oxidation has been shown to destroy PCE and its breakdown products both in the laboratory and in the field. The most commonly used oxidants for in situ chemical oxidation are hydrogen peroxide, Fenton's reagent, potassium (or sodium) permanganate, ozone, and sodium persulfate. In situ chemical oxidation can effectively treat PCE, and the costs are expected to be moderate to high. Chemical oxidation is implementable; however, success implementing the technology depends on site geology because it influences the ability to distribute the oxidant within the treatment zone. Chemical oxidant is typically injected via direct push; however, given the presence of caliche at the site, permanent injection wells would be installed with a drill rig, allowing for repeat applications of the chemical oxidant.

Bench-scale and pilot testing should be conducted to determine the effectiveness of chemical oxidation and the associated soil oxidant demand (SOD), as well as the radius of influence (ROI) achievable under injection. In addition, careful planning and control is needed when injecting near residences or underground utilities that could provide preferential pathways; however, given that the depth to groundwater in most cases is below 17 ft bgs, preferential pathways via utility corridors are not likely. A contingency plan to detail precautions that would be taken to ensure the safe application of chemical oxidant at the Site is warranted.

In Situ Chemical Reduction

Implementation of in situ chemical reduction is similar to in situ chemical oxidation. Chemicals are injected into groundwater to degrade PCE abiotically through reductive dechlorination. Typically zero-valent iron (ZVI) or ZVI combined with a carrier (e.g., clay or granular activated carbon [GAC]) are employed.

Although in situ chemical reduction can effectively treat PCE; the costs are expected to be moderate to high. Chemical reduction is implementable; however, success implementing the technology depends on site geology because it influences the ability to distribute the chemical within the treatment zone. Elevated sulfate concentrations in groundwater may influence the cost and performance of this technology. While some have suggested that ZVI can directly reduce sulfate to sulfide, it is more commonly noted that reduction of sulfate is biologically mediated (Environmental Technologies, Inc. [ETI] 2007). Introducing ZVI into groundwater would produce reducing conditions that would allow anaerobic bacteria to thrive. If sulfate reducing bacteria are present, they would reduce dissolved sulfate to sulfide, which would in turn react with ZVI and potentially result in some passivation of the ZVI surface. In such cases, it becomes necessary to provide more ZVI to compensate for this loss of reactive surface. Consequently, sulfate is an important anion and must be carefully considered when present at such elevated concentrations. However, elevated concentrations of dissolved sulfate do not automatically disqualify ZVI as a potential treatment option. Studies have shown that ZVI can still effectively treat chlorinated ethenes such as PCE in the presence of elevated sulfate concentrations. ETI has performed column tests on groundwater from various sites containing up to 6,000 mg/L of sulfate with little or no interference from sulfate (ETI 2007).

Reducing agent is typically injected via direct push, but given the presence of caliche at the site, a drill rig would be required. If field application is to be further considered, bench-scale and pilot tests should be conducted to determine the effectiveness of chemical reduction, the influence of site-specific geochemistry, the effects of sulfate and electron acceptor concentrations on cost, and the ROI for injection. Careful planning and control is needed when injecting near residences or underground utilities that will provide preferential pathways; however, given the depth to groundwater in most cases is below 17 ft bgs, preferential pathways via utility corridors are not likely.

Sparging

Air sparging (AS) combined with soil vapor extraction (SVE) is often used for the treatment of volatile organic compounds (VOC) in groundwater. Air sparging is an in situ technology that injects air into the saturated zone below or within the chemical plume through a system of injection wells. Injected air flows vertically and horizontally through permeable (interconnected) void spaces within the geologic media. As air is driven through these void spaces, it strips, desorbs, and partitions chlorinated solvents from the geologic media and groundwater into the vapor phase. The function of the SVE system is to capture and extract VOCs migrating into and through the vadose zone by applying a negative pressure, or vacuum, to the subsurface.

A blower applies the subsurface vacuum through a network of extraction wells installed within the contaminated area. The pressure gradient that results from the applied vacuum induces air flow through the vadose zone to the extraction points, and the soil gas containing vapor-phase contaminant(s) is removed. VOCs in blower effluent are typically removed or destroyed before treated air is discharged to the atmosphere. The effectiveness of these technologies depends on the subsurface geology. Pilot tests should be conducted to determine the effectiveness of AS/SVE, as well as the ROI for injection and extraction. Because AS/SVE may increase vapors present beneath homes, implementation in residential

areas should consider if SVE can effectively capture vapors produced by sparging and prevent their migration into indoor air.

Ozone sparging is similar to air sparging in that ozone is injected into the saturated zone below or within the chemical plume through a system of injection wells. However, the primary remedial mechanism is in-situ reaction and not physical removal of contaminants. The ozone dissolves in the groundwater and oxidizes dissolved contaminants, ultimately producing carbon dioxide and water.

Sparging technologies may be applicable in source areas, areas of higher PCE concentrations, or as a curtain east of the Boulevard Mall to intersect and treat the plume before it flows under the residential neighborhood. Pilot tests should be conducted to determine the effectiveness of sparging, ozone treatment, and/or SVE and associated ROIs.

Permeable Reactive Barrier

PRBs can be used to intercept and treat PCE in groundwater. PRBs consist of engineered zones that are installed in the subsurface perpendicular to the flow path of a groundwater plume. As groundwater flows through the PRB, contaminants are removed or treated. Often a reactive material, typically ZVI, is utilized to treat groundwater (however, a biologically active wall could be utilized as well). Depending on the type of PRB, they are typically installed by excavation into the saturated zone followed by backfilling the trench with the reactive material; however, drilling, hydraulic fracturing, and pressurized injection can also be used to install a PRB.

Subsurface geology can influence the performance and longevity of PRBs. If carbonate or other solid-phase precipitates form within the PRB, hydraulic conductivity and reactivity (treatment efficiency) may diminish. Bench-scale treatability testing would be necessary to evaluate the likelihood of precipitate formation, and pilot testing should be conducted to help evaluate installation procedures and determine how the PRB would perform at the site. Additional information on chemical reduction through use of ZVI is presented above.

Enhanced Bioremediation

In situ bioremediation involves microbial degradation of contaminants in groundwater. As described in Sections 2 and 4, bioremediation is not likely occurring at an appreciable rate at the Site. Microbial populations require a source of carbon, an electron donor, an electron acceptor, nutrients, a suitable temperature and pH range, and other favorable environmental conditions. Enhanced in situ bioremediation systems are designed to stimulate the biodegradation of chlorinated solvents by manipulating these conditions or requirements in the subsurface (biostimulation). Some systems further augment biodegradation by adding naturally occurring or engineered microorganisms particularly suited for the breakdown of certain chemicals (bioaugmentation).

Enhanced in situ bioremediation systems for groundwater use various delivery mechanisms, degradation mechanisms, and nutrient/biological amendments that depend on site-specific characteristics. DHC bacteria have not been found at the Site; therefore, bioaugmentation would likely be required. The absence of DHC is likely due to the predominantly aerobic conditions in the aquifer. However, given that the ORP of groundwater in many of the wells is generally in the range of 50 to 210 mV, it should be cost-effective to artificially create reducing conditions. In addition, because sulfate is present in the groundwater at high concentrations, sulfate reducing bacteria will produce high concentrations of sulfide, which might inhibit DHC. Therefore, biostimulation through injection of electron donors alone is not likely to be effective. This is evident in the poor performance of HRC® that has been used as a biostimulant at sites in the Las Vegas area (NDEP 2009). However, electron donors combined with ferrous gluconate

have had some success in high sulfate groundwater. This may be because dissolved sulfide concentrations are reduced through reaction with dissolved iron. This suggests that reductive dechlorination using iron containing product such as EHC® or an alternate electron donor combined with ferrous gluconate might be possible. Should an integrated remedial approach involve the use of enhanced bioremediation, bench-scale testing is required to determine the most effective form of enhancement and/or augmentation.

Extraction and Treatment

Extraction and treatment is an ex situ remediation technology whereby groundwater is removed from the subsurface through a network of extraction wells. Extracted water is pumped to a treatment facility where the dissolved contaminants are removed. Air stripping and GAC are typical removal strategies for chlorinated solvents.

The geology of the Site consists of interbedded sequences of sand, sandy silt, sandy clay, and silty clay with frequent zones of caliche and intermixed gravel scattered throughout. Heterogeneous mixtures of lower permeability clays and silts dominate the saturated intervals across most of the site. As presented in Section 2.2, an alluvial stream-channel sand meanders through the area of the former APTC facility and portions of the Boulevard Mall in the upper 1 to 5 ft of the saturated zone. In the central area of the site along the path of the plume, sands exist in the saturated lower portion of intervals screened by the wells. The geology of the well borings indicates that the sand intervals have limited lateral extent as typical of stream channel deposits. The change in facies from sand to silt and clay along the margin of the channel deposits create hydraulic boundaries which limit the extent of the production or capture zone of wells.

Soil samples collected from the Site indicate the sand intervals frequently contain appreciable silt or clay (as much as 30 to 40%). Hydraulic tests at the site and in nearby areas of the City of Las Vegas indicate hydraulic conductivities likely range from 0.8 to 20 ft/day or 6 to 150 gpd/ft^2. Assuming saturated intervals of 25 ft and 20 ft of available drawdown, the yields of individual wells may range from 1 to 20 gpm, with sandy zones at the higher rates and silts at the lower rates. However, considering the numerous hydraulic barriers and limited unit thicknesses created by the heterogeneous conditions, and superposition effects from the influence of adjacent extraction wells, steady state production rates can be expected to be significantly lower-in the range of 0.2 to 8 gpm. The sand zones will likely be depleted relatively quickly, with the capture zone of the well field likely being dewatered. The use of injection wells to return treated water to the groundwater system can help minimize the potential negative effects of a remedial production well field. Although greater production rates can be achieved by installing the wells to depths of 50 to 60 ft bgs in the Las Vegas Wash Aquitard, such well construction may only lead to greater dewatering of the shallow groundwater system. The well system would likely operate intermittently. Saturated clays at the Site would likely dewater and may shrink, potentially resulting in subsidence in the residential and Boulevard Mall areas.

Production tests should be conducted within several silt, sand and gravel units at the Site to evaluate whether pump and treat is a viable alternative for remediation of groundwater at the Site. Current data indicate that Site conditions are not conducive to this option as the primary remedial approach.

Furthermore, treatment by air stripping or GAC will generate a secondary waste stream, and high TDS concentrations in the treated wastewater discharge may present complications due to water quality standards and policies imposed by the Colorado River Basin Salinity Forum. If TDS must be removed from treated water before surface discharge, disposal, or reinjection, costs will be high. Despite these practical constraints, extraction and treatment may be effective as a hydraulic control; therefore, the technology was retained for further consideration.

8.0 DEVELOPMENT AND DETAILED ANALYSIS OF ALTERNATIVES

Preliminary CAOs and numerical remediation standards were identified in Section 6 of the draft CAP. Corrective action alternatives were developed and evaluated based on the CAOs and numerical remediation standards. Additional data acquisition is necessary to evaluate current site conditions (delineation of the 5 µg/L plume and geophysical parameters), evaluate risks, and more fully assess the viability of the cleanup applications (bench-scale and pilot scale testing and groundwater modeling to assess the efficacy of extraction and treatment). These sampling data will also be used to ultimately satisfy provisions for terminating remediation established under Adopted Regulation R189-08, Section 14 (NAC 445A.22725) and Section 15 (NAC 445A.22745).

This section identifies corrective action alternatives for groundwater and provides a detailed analysis of each corrective action alternative. The alternatives were developed and screened based on the requirements of NAC 445A.2271; guidance issued and offered by NDEP; and in a manner consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA); the National Oil and Hazardous Substances Pollution Contingency Plan (NCP); and *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988).

The following groundwater alternatives were developed for analysis in this CAP:

- Alternative 1 – No Action
- Alternative 2A – In Situ Chemical Treatment of Hotspots and Residential Area, ICs, SSD Systems, and MNA
- Alternative 2B – In Situ Chemical Treatment, ICs, SSD Systems, and MNA
- Alternative 3 – Permeable Reactive Barrier, ICs, SSD Systems, and MNA
- Alternative 4 - Sparge Curtain, ICs, SSD Systems, and MNA
- Alternative 5 – Extraction and Treatment, ICs, SSD Systems, and MNA
- Alternative 6 – In Situ Enhanced Bioremediation, ICs, SSD Systems, and MNA.

The following sections describe the evaluation criteria (Section 8.1), describe and evaluate the corrective action alternatives for groundwater (Sections 8.2.1 through 8.2.7), and provide a comparative analysis of the alternatives based on the evaluation criteria (Section 8.3). General assumptions made in developing cost estimates for the alternatives are presented in Appendix B.

8.1 Evaluation Criteria

The NCP details the expectations for remedy selection in 40 *Code of Federal Regulations* (CFR) § 300.430 (a)(1)(iii), and these are described below. Each corrective action alternative was developed and evaluated according to seven evaluation criteria. After additional data are obtained, the risk assessment and development and assessment of the treatment alternatives can be refined. Section 9 of this CAP proposes bench-scale and pilot studies that will allow for better assessment of effectiveness and cost based on site-specific conditions.

Overall Protection of Human Health and the Environment

This criterion assesses whether each alternative adequately protects human health and the environment. The overall assessment of protection draws on evaluations of long-term effectiveness and permanence and short-term effectiveness. Protectiveness focuses on how risks are reduced, eliminated, or controlled

by each alternative. Risk reductions are associated with the effectiveness of an alternative in meeting the preliminary remediation standard. This criterion is considered a threshold that the selected alternative must meet. Given no pathway for exposure of ecological receptors to groundwater at the Site, only human health was considered as part of this evaluation.

Long-Term Effectiveness and Permanence

Each alternative is evaluated in terms of risk remaining at the site after the preliminary remediation standard has been met. The primary focus of this evaluation is on extent and effectiveness of controls used to manage the risk posed by treatment residuals or untreated wastes. This criterion addresses the long-term adequacy, reliability, and permanence of the corrective action.

Components of this analysis include the following:

- Expected long-term reduction in risk posed by the site
- Level of effort needed to maintain the corrective action and monitor the area for changes in site conditions
- Compatibility of the corrective action with planned future use of the site.

Reduction in Toxicity, Mobility, and Volume through Treatment

This evaluation criterion addresses the statutory preference for treatment options that permanently and significantly reduce toxicity, mobility, or volume of the contaminants. This preference is satisfied when treatment reduces the principal threats through the following:

- Destruction of toxic contaminants
- Reduction in contaminant mobility
- Reduction of the total mass of toxic contaminants
- Reduction of total volumes of contaminated media.

Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until the preliminary remediation standard is met. Under this criterion, alternatives are evaluated in terms of their effects on human health and the environment during implementation of the corrective action. The following factors are considered:

- Protection of the community during the corrective action, including protection from effects of potential releases from the site, transport of contaminated materials, and air-quality impacts from on-site treatment
- Exposure of the workers during construction
- Potential environmental impacts of the corrective action, and effectiveness and reliability of protective measures
- Time required to achieve the remediation standard. It should be noted that current knowledge of the site parameters and hydrologic and engineering judgment has been used to assume remediation timeframes for each of the alternatives. Bench-scale and pilot testing will be conducted to confirm site-specific conditions, and the remedial design will be based on physical data. Groundwater modeling that interprets field measurements and observations, and enhances understanding of site-specific parameters and remediation scenarios will be

conducted for the site when adequate data are obtained. Modeling and bench-scale and pilot studies will refine projected corrective action timeframes.

Implementability

This criterion addresses the technical and administrative feasibility of implementing an alternative, and availability of various services and materials required during its implementation. Factors considered in assessing this criterion include the following:

Technical feasibility

- Construction and operation − technical difficulties and unknowns associated with construction and operation of a technology
- Reliability of the technology − likelihood that technical problems associated with implementation would lead to schedule delays
- Ease of undertaking additional corrective actions
- Ability to monitor effectiveness of the corrective action

Availability of materials

- Availability of adequate off-site treatment, storage capacity, and disposal capacity and services
- Reliability of the technology − likelihood that technical problems associated with implementation would delay the schedule
- Availability of services and materials
- Availability of prospective technologies

Administrative feasibility

- Implementability within current and future development scenarios
- Activities needed to coordinate with other offices and agencies
- Ability and time required to obtain any necessary approvals and permits from those agencies.

Cost

The cost analysis for each alternative is based on estimates of capital, annual operation and maintenance (O&M), and periodic cost elements in combination with a calculation of net present value of these cost elements. Capital costs consist of direct and indirect costs. Direct costs include purchase of equipment, contractor and subcontractor labor, and materials necessary to construct the corrective action alternative. Indirect costs include those for engineering, legal, construction management, and other technical and professional services such as testing and monitoring. Annual O&M costs for each alternative include maintenance materials, supplies, and utilities, as well as operating labor. Periodic costs are those that occur only once every few years. These costs may be capital or O&M, but because they are periodic, are considered separately from other capital and O&M costs. Costs were estimated for 30 years even if the alternative was projected to take longer.

Cost estimates for the corrective action alternatives are generally based on costs derived from the following sources:

- Historical cost data
- Estimates from similar projects
- Engineering judgment
- Site-specific quantities and information
- Vendor quotes and estimates.

The present value analysis is a method to evaluate expenditures, either capital or O&M, that occur over different periods extending into the future. The discount rate used for this project is 5 percent, the suggested rate for projects extending at least 30 years into the future. This discount rate was used for all present value analyses, regardless of actual future project duration. A present value analysis of each alternative is presented in Appendix B of this document.

The accuracy of the cost estimate for each alternative is intended to be within the range of plus 50 percent to minus 30 percent of actual costs (EPA 1988). However, additional site-specific data are required to fully assess and estimate costs for the alternatives. The level of detail employed in developing these estimates is considered appropriate for making choices among alternatives, but the cost estimates are not intended for use in detailed budgetary planning. Costs for each alternative are compiled in Appendix B. Upon completion of future bench-scale and pilot studies, additional information regarding design of corrective actions will allow further refinement of the cost estimates.

NDEP Acceptance

NDEP's concerns regarding the proposed corrective action alternatives may not be fully assessed until comments on this and future documents are received. NDEP has indicated its concern with the viability of in situ reductive treatment and enhanced bioremediation, given the Site's geochemistry (NDEP 2011). The Site's geochemistry, in particular high TDS and sulfate concentrations, may make implementation of in situ reductive treatment and enhanced bioremediation challenging; however, it is not considered a fatal flaw. The viability of these technologies with respect to site-specific conditions including the geochemistry will be further evaluated in this document and through subsequent bench-scale and pilot testing as appropriate.

Community Acceptance

This involves assessment of community support for, reservations about, or opposition to various components of the alternatives. This criterion will be evaluated after comments on the proposed plan have been received from the community. Community comments and concerns will be considered before final decisions are made on the corrective actions.

8.2 Descriptions and Individual Analyses of Alternatives

8.2.1 Alternative 1: No Action

The No Action alternative is required for analysis according to the NCP (40 CFR § 300.430[e][6]). The No Action alternative is the baseline alternative against which to judge the effectiveness of all other corrective action alternatives. Under the No Action alternative, no corrective actions would be conducted at the site. It was assumed that current groundwater and indoor air monitoring would continue for 30 years. No additional attempts would be made to control the vapor intrusion of PCE to indoor air.

Overall Protection of Human Health

Groundwater poses a risk to human health through the vapor intrusion pathway. This alternative would not reduce, eliminate, or control the potential risk; therefore, Alternative 1 is not protective of human health.

Long-Term Effectiveness and Permanence

Under Alternative 1, groundwater contamination at concentrations above the remediation goal would not be addressed. No controls to prevent exposure, and no long-term management measures such as ICs, would be implemented. Therefore, Alternative 1 would not provide a long-term effective solution for the permanent protection of human health.

Reduction in Toxicity, Mobility, and Volume through Treatment

Alternative 1 would not reduce the toxicity, mobility, or volume of hazardous substances because no action would be taken at the site. PCE in groundwater would not be treated, contained, or removed.

Short-Term Effectiveness

The following four factors are considered as part of the short-term effectiveness criterion. These are assessed below for Alternative 1:

- No corrective actions would occur; the current risks would remain. The on-site community may be exposed to additional risks from groundwater if higher concentrations migrated under the residential neighborhood and increased the number of residences with indoor air above the interim action level.
- Workers conducting groundwater sampling may be exposed to health risks during implementation of Alternative 1. Because no corrective actions would be taken, construction workers would not be exposed to human health risk due to the implementation of the alternative; however, construction workers in the area may be exposed incidentally while doing work at the Site.
- No adverse environmental impacts would result from implementation of Alternative 1 because no corrective action would be taken.
- No time would be required to complete Alternative 1 because no action would be taken; however, groundwater would remain contaminated as PCE mass flows off site. Groundwater modeling with site-specific parameters could predict the timeframe associated with this process. For purposes of this assessment, groundwater and air monitoring were considered to continue for 30 years, the typical maximum timeframe for cost estimate purposes, although contamination would likely remain onsite for significantly longer.

Implementability

No Action, including implementation of ICs or construction and operation of a remedial system, would be required to implement this alternative. Therefore, Alternative 1 would be easily implemented.

Cost

No capital costs are included. O&M costs associated with quarterly groundwater and annual indoor air monitoring would total $3,840,000 for the assumed 30-year lifespan.

State Acceptance

Presumably, Alternative 1 would not be acceptable to the NDEP.

Community Acceptance

Presumably, Alternative 1 would not be acceptable to the community.

8.2.2 Alternative 2A: In Situ Chemical Oxidation of Hotspot and Residential Area, Institutional Controls, Subslab Depressurization Systems, and MNA

Alternative 2A combines in situ chemical oxidation of the plume hotspot and the plume upgradient of the residential area, ICs, the SSD systems, and MNA. Under this alternative, a chemical oxidant is injected into the subsurface in the plume hotspot to treat the greatest mass of PCE, and in a line of injection wells perpendicular to the plume upgradient of the residential area to treat groundwater as it flows into the residential area. Abiotic MNA occurring as a residual effect of treatment and subsurface alteration could further reduce concentrations of PCE in groundwater. ICs and SSDs would protect residents from PCE in indoor air until groundwater is treated to protective levels.

For this CAP, the oxidant selected for injection is potassium permanganate; however, bench-scale testing may determine that a different oxidant is preferable based on site-specific conditions. Potassium permanganate was chosen for this CAP because it is generally more stable and easier to handle than hydrogen peroxide or ozone; is effective over a large pH range (3.5 to 12); can persist in the soil for several months; and is the most effective for the site contaminants. Potassium permanganate is typically provided as a solid. The assumptions made for the purposes of this CAP and costing are detailed in Appendix B.

Injection would occur over the top 20 ft of the shallow aquifer in the plume hotspot (concentrations of PCE greater than 1,000 µg/L) and upgradient of the residential area and in a line perpendicular to the plume (in the Boulevard Mall eastern parking lot). The injection wells in the hotspot would likely require four rounds of injection of potassium permanganate, and 10 years of annual injections uppgradient of the residential area. However, additional injection may be required based on the rate of PCE desorption from the soil matrix. The assumptions made for the purposes of this CAP and costing are detailed in Appendix B.

Bench-scale testing will determine reagent effectiveness, dosing rates, and potential geochemical interference at the Site. High TDS or reagent demand at the site may be problematic. If bench-scale testing is successful, pilot studies could be conducted in the area before full-scale implementation of in situ chemical treatment to establish effective dosage rates, the distance the reagent can be expected to travel underground (ROI), optimal well spacing, and the injection pumping rates. These tests will also allow for refinement of costs. The bench-scale and pilot studies will also evaluate the potential increase in TDS or loss of permeability in the subsurface.

Fourteen SSD systems are currently in use at the site, effectively protecting residents of those 14 properties from risk caused by vapor intrusions of PCE into indoor air. If new SSD systems are required in other properties as determined by indoor air sampling, they would be installed. These systems would stay in place until groundwater concentrations decrease to levels protective of indoor air. ICs could be utilized to ensure the continued operation of SSD systems.

After in situ chemical treatment, residual abiotic MNA activity occurring after subsurface remedial treatment may further diminish residual PCE concentrations. Upon completion of data gathering and pilot testing, groundwater modeling could be used to more accurately predict the timeframe in which remediation standards would be met.

Before, during, and after treatment, groundwater would be monitored to evaluate the effectiveness of the alternative and whether the remediation standard has been met. Indoor air sampling would be maintained until groundwater concentrations decrease to levels established through subsequent risk assessment to be protective of indoor air.

More specific assumptions for costing the alternatives are listed in Appendix B.

Overall Protection of Human Health

Alternative 2A protects human health and the environment because groundwater that poses an unacceptable risk to human health would be remediated using in situ chemical oxidation. The injection of a reagent would reduce concentrations of PCE in groundwater to below the preliminary remediation standards. While the level of contaminants decrease in groundwater (occurring quickly with chemical treatment), residents would be protected from the risk of PCE in indoor air by the previously installed SSD systems, which would be operated until groundwater concentrations decrease to levels protective of indoor air.

Long-Term Effectiveness and Permanence

PCE in groundwater would be permanently treated in situ with chemical oxidation. Groundwater monitoring would be conducted to determine that the concentrations of VOCs are reduced to below the preliminary remediation standards and would not pose a long-term risk to human health. No long-term activities would be required to maintain the effectiveness of this alternative.

Reduction in Toxicity, Mobility, and Volume through Treatment

This alternative includes treatment of the VOCs in groundwater. Chemical oxidation would reduce the toxicity and volume of contamination in the groundwater.

Short-Term Effectiveness

Four factors considered as part of the short-term effectiveness criteria are assessed below for Alternative 2A:

- Alternative 2A would present minimal risks to the community because the corrective action would be applied in situ in commercial areas. Drilling and injection equipment would be required to implement this alternative; however, risk to the community could be minimized through exclusion zones and other typical safety measures. Injections would not occur in close proximity to residences, and given that the depth to groundwater in most cases is below 17 ft bgs, preferential pathways via utility corridors are unlikely. A contingency plan to detail precautions that would be taken to ensure the safe application of chemical oxidant at the Site is warranted.
- On-site workers may be exposed to risks while installing injection or monitoring wells, handling the chemicals for injection, or sampling contaminated groundwater; these risks would be minimized by proper handling and housekeeping, and by use of appropriate personal protective equipment. Remediation activities would be carried out under a health and safety program designed to minimize worker exposure.
- Environmental impacts in the injection areas could be minimized through bench-scale and pilot testing, engineering controls, and proper design. While initial injection of chemical oxidant may release sorbed PCE into the aquifer, this PCE would subsequently be destroyed after reacting with the oxidant. The oxidation of trivalent chromium to hexavalent chromium and its consequent mobilization is not anticipated at this Site; however, as is common with chemical oxidation, even if hexavalent chromium is formed, it will return to its trivalent state as soon as it migrates out of the treatment zone. Oxidation and mobility of metals will be evaluated during bench-scale testing. Chemical treatment may increase TDS in the aquifer, and oxidants like permanganate can reduce permeability over time due to precipitation of manganese dioxide.
- The corrective action is estimated to take 30 years with four rounds of injections in the plume hotspot and 10 rounds upgradient of the residences. For cost estimating purposes, it was assumed that the SSD systems could be turned off after 10 years. Site-specific testing and groundwater modeling would refine these estimates of remediation time.

Implementability

Three factors considered as part of the implementability criteria are assessed below for Alternative 2A:

- The alternative is considered technically feasible; however there are several considerations. Well installation, chemical injection, groundwater and indoor air monitoring, and installation of SSD systems are fairly routine activities. Bench-scale and pilot testing would be required to assess the effectiveness of chemical treatment and the impact of site-specific conditions on effective dosage, ROI, and well spacing. Hydrogeology between the existing monitoring wells is not well defined, and potential impermeable lenses in the aquifer may influence injection. Groundwater velocities of 0.5 to 1 foot per day are assumed based on previous site data. However, faster velocities have been associated with sand and gravel areas found in the subsurface of the Site; flow at higher rates (e.g., 2 to 4 ft per day) may cause the chemical to wash out of the system too quickly. The number of injection points may increase significantly if the estimated ROI of the injection is not achieved. The potential loss of permeability, mobilization of metals, or transformation of chemicals would be monitored during the pilot study and may affect the implementability and effectiveness of chemical treatment. Problems with site access or drilling issues could impact the schedule.

- The materials required for implementation of chemical treatment and any additional SSD system installation are readily available. Services for well installation, chemical injection, groundwater and indoor air monitoring, and SSD system installation are also readily available.

- The alternative is considered administratively feasible. A permit for injection of chemical oxidant would be required.

Cost

The capital cost of Alternative 2A would be $1,070,000. The present value of O&M costs, including groundwater and indoor air monitoring, would be $4,060,000. The total present value cost for Alternative 2A would be $7,100,000.

State Acceptance

This criterion will be further evaluated after comments on this CAP have been received from NDEP. However, the NDEP has expressed initial reservations regarding the environmental impacts of this alternative and indicated that it will require a contingency plan (NDEP 2011).

Community Acceptance

This criterion will be evaluated after comments on the proposed plan have been received from the community. Community comments and concerns will be considered before final decisions are made on the corrective actions.

8.2.3 Alternative 2B: In Situ Chemical Oxidation, Institutional Controls, Subslab Depressurization Systems, and MNA

Alternative 2B combines in situ chemical oxidation, ICs, the SSD systems, and MNA. Under this alternative, a chemical oxidant injected into the subsurface over the areal extent of the plume would chemically treat the groundwater at concentrations exceeding 100 µg/L. ICs and SSDs would protect residents from PCE in indoor air until groundwater is treated to protective levels. Given the developed nature of the Site and difficulty injecting into the entire plume due to buildings and private residences, chemical treatment would be unlikely to treat all groundwater to below the remediation standard;

therefore, after in situ chemical treatment has decreased concentrations of PCE at the site, abiotic MNA would be relied on to further decrease PCE concentrations.

In situ chemical oxidation (by potassium permanganate) would be applied to groundwater with concentrations of PCE exceeding 100 µg/L where practicable at the Site, including at the Property; in streets, public right of ways, and parking lots at the Boulevard Mall; and in streets and public right of ways within residential areas. Given the depth to groundwater, injectate migration via utility corridors is not expected; however, careful planning would accommodate conservative safety requirements. It was assumed that all injection wells would require three rounds of injection of potassium permanganate. However, additional injection may be necessary depending on the rate of PCE desorption from the soil matrix. Chemical oxidant or a reducing agent would not be directly injected beneath buildings or private residences. The assumptions made for the purposes of this CAP and costing are detailed in Appendix B. Bench-scale and pilot testing are required. See the description of Alternative 2A in Section 8.2.2 for additional description of chemical treatment and testing requirements.

SSD systems, ICs, groundwater and indoor air monitoring, and MNA would be similar to the descriptions detailed in Alternative 2A in Section 8.2.2. If new SSD systems are required as determined by indoor air sampling, they would be installed. SSD systems would stay in place until groundwater concentrations decrease to levels protective of indoor air. ICs could be employed to ensure continued operation of SSD systems. After chemical treatment, MNA would be relied on to decrease residual PCE concentrations below the remediation standard. Indoor air sampling would be maintained until groundwater concentrations decrease to levels protective of indoor air (assumed to be 2 years).

More specific assumptions made for costing the alternatives are listed in Appendix B.

Overall Protection of Human Health

Alternative 2B protects human health and the environment because groundwater that poses an unacceptable risk to human health would be treated. The injection of an oxidant would reduce concentrations of PCE in groundwater to below the preliminary remediation standards. While the level of contaminants decrease in groundwater (quickly occurring with chemical treatment), residents would be protected from the risk of PCE in indoor air by the previously installed SSD systems, which would be operated until groundwater concentrations decrease to levels protective of indoor air.

Long-Term Effectiveness and Permanence

PCE in groundwater would be permanently treated in situ. Groundwater monitoring would be conducted to determine that the concentrations of VOCs are reduced to below the preliminary remediation standards and would not pose a long-term risk to human health. No long-term activities would be required to maintain the effectiveness of this alternative.

Reduction in Toxicity, Mobility, and Volume through Treatment

This alternative includes treatment of the VOCs in groundwater. Chemical treatment would reduce the toxicity and volume of contamination in the groundwater.

Short-Term Effectiveness

Four factors considered as part of the short-term effectiveness criteria are assessed below for Alternative 2B:

- Alternative 2B would present low-level risks to the community because the corrective action would be applied in situ in all areas of the Site. PCE sorbed to soil may be released and require treatment. Drilling and injection equipment would be required to implement this alternative;

however, risk to the community could be minimized through exclusion zones and other typical safety measures. Careful planning should be used when injecting near residences or underground utilities that could provide preferential pathways; given the depth to groundwater is in most cases below 17 ft bgs, preferential pathways via utility corridors are unlikely. A contingency plan detailing precautions that would be taken to ensure the safe application of chemical oxidant at the Site is warranted.

- On-site workers may be exposed to risks while installing injection or monitoring wells, handling the chemical for injection, or sampling contaminated groundwater; these risks would be minimized by proper handling and housekeeping and use of appropriate personal protective equipment. Remediation activities would be carried out under a health and safety program designed to minimize worker exposure.
- Environmental impacts in the injection areas could be minimized through bench-scale and pilot testing, engineering controls, and proper design. Displacement of contaminated groundwater by site-wide injections may be problematic and increase the treatment area. While initial injection of chemical oxidant may release sorbed PCE into the aquifer, this PCE would subsequently be destroyed after reacting with the oxidant. The oxidation of trivalent chromium to hexavalent chromium is not anticipated at this Site; however as is common with chemical oxidation, even if hexavalent chromium is formed, it will return to its trivalent state as soon as it migrates out of the treatment zone. Bench-scale and/or pilot tests should additionally evaluate the potential to displace groundwater containing dissolved PCE and provide a basis to specify proper engineering controls to mitigate this ramification. Chemical treatment may increase TDS in the aquifer, and oxidants like permanganate can reduce permeability over time due to precipitation of manganese dioxide.
- The first phase of the corrective action is estimated to take 2 years with three rounds of injections. An additional 5 years of MNA and groundwater monitoring would be required to evaluate the reduction in concentrations of VOCs and monitor for rebound of VOCs. It was assumed for cost estimating purposes that the SSD systems could be turned off after the second round of chemical injection. Site-specific testing and groundwater modeling would refine these estimates of remediation time.

Implementability

Three factors considered as part of the implementability criteria are assessed below for Alternative 2B:

- The alternative is considered technically feasible; however there are several considerations. Well installation, injection, groundwater and indoor air monitoring, and installation of SSD systems are fairly routine activities. Bench-scale and pilot testing would be required to assess the effectiveness of chemical treatment and the impact of site-specific conditions on effective dosage, the ROI, and well spacing. Access to injection locations may be an issue. The hydrogeology between the existing monitoring wells is not well defined, and potential impermeable lenses in the aquifer may influence injection. Groundwater velocities of 0.5 to 1 foot per day are assumed based on previous site data. However, faster velocities have been associated with sand and gravel areas found in the subsurface of the Site; flow at higher rates (e.g., 2-4 ft per day) may cause the chemical to wash out of the system too quickly. The number of injection points may increase significantly if the estimated ROI of the injection is not achieved. The potential loss of permeability, mobilization of metals, or transformation of chemicals would be monitored during the pilot study and may affect the implementability and effectiveness of chemical treatment. Careful planning should be used when injecting near residences or underground utilities that would provide preferential pathways. Problems with site access or drilling issues could impact the schedule.

- Materials required for implementation of chemical treatment and any additional SSD system installation are readily available. Services for well installation, chemical injection, groundwater and indoor air monitoring, and SSD system installation are also readily available.

- The alternative is considered administratively feasible. A permit for injection of the chemical oxidant would be required.

Cost

The capital cost of Alternative 2B would be $4,660,000. The present value of O&M costs, including groundwater and indoor air monitoring, would be $18,550,000. The total present value cost for Alternative 2B would be $23,210,000.

State Acceptance

This criterion will be further evaluated after comments on this CAP have been received from NDEP. However, NDEP has indicated that widespread injection especially in the residential area is likely unacceptable due to safety concerns (NDEP 2011).

Community Acceptance

This criterion will be evaluated after comments on the proposed plan have been received from the community. Community comments and concerns will be considered before final decisions are made on the corrective actions.

8.2.4 Alternative 3: Permeable Reactive Barrier, Institutional Controls, Subslab Depressurization Systems, and MNA

Alternative 3 combines a PRB, ICs, the SSD systems, and MNA. Under this alternative, a ZVI PRB would be installed upgradient of the residential area to treat contaminated groundwater as it flows into the residential area. Abiotic MNA would further reduce concentrations of PCE in groundwater and would be monitored. ICs and SSDs would protect residents from PCE in indoor air until groundwater is treated to protective levels.

For the CAP, it was assumed that the ZVI PRB would be placed via trenching across 20 ft below the top of the shallow saturated zone. Given the estimated installation depth, trenching may be challenging. The PRB could also be installed via hydraulic fracturing and injection if this method is found preferable. The PRB would stretch across the plume and treat groundwater with PCE concentrations exceeding 5 µg/L, the preliminary remediation standard. Groundwater monitoring wells would be installed at the leading edge and downgradient edge of the PRB to measure effectiveness. The assumptions made for the purposes of this CAP and costing are detailed in Appendix B.

Bench-scale and pilot testing would determine the effectiveness, dosing rates, and any geochemical interference at the Site. High sulfate concentrations at the Site may impact barrier performance. If sulfate is reduced to sulfide it would react with the ZVI and reduce the available reactive surface. Additional ZVI may have to be provided to compensate for this. When sulfate reduction occurs in PRBs, it is generally observed in the first few inches of the barrier. Precipitation of iron sulfides (FeS and FeS_2) would reduce permeability of the barrier over time. If bench-scale testing reveals the possibility for such precipitation, other treatment media could be used upgradient of the PRB to remove sulfate. If bench-scale testing is successful, pilot studies would be conducted in the area before full-scale implementation to verify applicability of bench-scale results to field conditions. These tests would also allow for refinement of costs. The costing purposes installation of a replacement PRB was assumed after 30 years.

SSD systems, ICs, groundwater and indoor air monitoring, and MNA are similar to the descriptions detailed in Alternative 2A in Section 8.2.2. If new SSD systems are required as determined by indoor air sampling, they would be installed. SSD systems would stay in place until groundwater concentrations decrease to levels protective of indoor air. ICs could be utilized to ensure continued operation of SSD systems. In addition to treatment by the PRB, residual MNA may be observed to further diminish PCE mass at concentrations below the remediation standard. For cost estimating purposes, it was assumed that groundwater monitoring would be necessary for 30 years. Indoor air sampling would be maintained until groundwater concentrations in the residential area decrease to levels protective of indoor air (assumed to be 10 years).

More specific assumptions made for costing the alternatives are listed in Appendix B.

Overall Protection of Human Health

Alternative 3 protects human health and the environment because groundwater that poses an unacceptable risk to human health would be treated by reductive dechlorination by ZVI within the PRB. The PRB would reduce concentrations of PCE in groundwater downgradient of the PRB to below the preliminary remediation standards. While the level of contaminants decreases in groundwater, residents would be protected from the risk of PCE in indoor air by the previously installed SSD systems, which would be operated until groundwater concentrations decrease to levels protective of indoor air.

Long-Term Effectiveness and Permanence

PCE in groundwater would be permanently treated in situ. Groundwater monitoring would be conducted to confirm that concentrations of PCE are reduced to below preliminary remediation standards and would not pose a long-term risk to human health. PRBs tend to be low maintenance, but depending on site characteristics, some PRBs require replacement (replacement was assumed after 30 years of life, but it could be earlier if precipitation is an issue). Bench-scale testing should provide adequate information regarding the expected life of the PRB.

Reduction in Toxicity, Mobility, and Volume through Treatment

This alternative includes treatment of the VOCs in groundwater. The PRB would reduce the toxicity and volume of contamination in the groundwater.

Short-Term Effectiveness

Four factors considered as part of the short-term effectiveness criteria are assessed below for Alternative 3:

- Alternative 3 would present minimal risks to the community because the corrective action would be applied in situ. Excavation or drilling and injection equipment would be required to implement this alternative; however, risk to the community could be minimized through exclusion zones and other typical safety measures.
- On-site workers may be exposed to risks while emplacing the PRB, handling the ZVI, or sampling contaminated groundwater. These risks would be minimized by proper handling and housekeeping and use of appropriate personal protective equipment. Remediation activities would be carried out under a health and safety program designed to minimize worker exposure.
- Environmental impacts of the PRB would be minimal because the remediation is in situ.
- The corrective action is estimated to take 30 years. For cost estimating purposes it was assumed that the SSD systems could be turned off after 10 years. Site-specific testing and groundwater modeling would refine these estimates of remediation time.

Implementability

Three factors considered as part of the implementability criteria are assessed below for Alternative 3:

- The alternative is considered technically feasible. PRB installation, groundwater and indoor air monitoring, and SSD system installation are fairly routine activities. Given the estimated installation depth of approximately 18 to 38 ft bgs, trenching may be challenging. The PRB could also be installed via hydraulic fracturing and injection if this method would be found preferable (pilot testing would be required to determine the ROI and effectiveness of hydraulic fracturing and injection in the formation). Bench-scale and pilot testing would be required to assess the effectiveness of the technology and the impact of site-specific conditions. Potential loss of permeability and sulfate reduction would be monitored during the pilot study, and may affect implementability and effectiveness. Problems installing the PRB could impact the schedule.

- Materials required for the PRB and any additional SSD system installations are readily available. Services for PRB installation, groundwater and indoor air monitoring, and SSD system installation are also readily available.

- The alternative is considered administratively feasible. If the wall is installed by injection, a permit would be required.

Cost

The capital cost of Alternative 3 would be $2,800,000. The present value of O&M costs, including groundwater and indoor air monitoring, would be $5,340,000. The total present value cost or Alternative 3 would be $8,140,000.

State Acceptance

This criterion will be further evaluated after comments on this CAP have been received from NDEP. However, NDEP has indicated that this technology does not seem viable given sulfate conditions at the Site (NDEP 2011). While high sulfate and electron acceptor concentrations at the Site would require the addition of more ZVI, chemical reducing agents have been utilized effectively at sites with high sulfate. The feasibility of this alternative and the effect of sulfates can quickly be determined through bench-scale testing.

Community Acceptance

This criterion will be evaluated after comments on the proposed plan have been received from the community. Community comments and concerns will be considered before final decisions are made on the corrective actions.

8.2.5 Alternative 4: Sparge Curtain, Institutional Controls, Subslab Depressurization Systems, and MNA

Alternative 4 combines sparging wells upgradient of the residential area (in a sparge curtain), ICs, the SSD systems, and MNA. This alternative could be implemented in two different ways, the use of ozone sparging for in situ treatment or AS/SVE. Data obtained during pilot scale testing would provide additional information necessary to help choose the more effective and efficient sparging method. For consideration on this alternative, it was assumed that air would be injected into the groundwater in a line of AS wells perpendicular to the plume, creating a sparge curtain to strip PCE in groundwater as it flows into the residential area. SVE wells would be utilized to extract the PCE-laden sparged air as it migrates upwards into the vadose zone. Clean water would flow from the downgradient edge of the sparge curtain. With the source area cut off, MNA would reduce concentrations of PCE in groundwater downgradient of the

curtain. ICs and SSDs would protect residents from PCE in indoor air until groundwater is treated to protective levels.

Sparging, injection of air into the aquifer, would occur over the top 20 ft of the shallow aquifer. AS wells would be placed perpendicular to groundwater flow west of the residential area (in the eastern Boulevard Mall parking lot) to treat groundwater flowing into the residential area. The sparge curtain would stretch across the plume and treat concentrations of PCE currently greater than 5 µg/L. SVE wells would be utilized to capture PCE-laden sparged air.

The treatment system would conceivably be installed under the eastern mall parking lot (and the system could be expanded to treat other areas with high PCE concentrations). The parking lot would help trap vapors in the subsurface for capture. For cost estimating purposes, it was assumed that PCE in the effluent gas would be removed by two vapor-phase GAC units in series before discharge to the atmosphere; however, another form of treatment may be used if found economically preferable. An air permit would be required for the SVE system. Also, an assumed 30 years of treatment would be required as contaminated groundwater flows toward the residences. O&M of the system would include weekly air monitoring to assure attainment of discharge standards associated with an air quality permit.

A pilot test should be considered to better determine AS/SVE design parameters, including the ROI of the AS and SVE wells, stripping effectiveness based on site geology, vapor capture effectiveness, and likely influent concentrations. These tests would also allow for refinement of costs. The assumptions made for the purposes of this CAP and costing are detailed in Appendix B. If implementation proves favorable, additional system expansion to reduce remedial timeframes may be considered.

SSD systems, ICs, groundwater and indoor air monitoring, and MNA are similar to the descriptions detailed in Alternative 2A in Section 8.2.2. In addition to the AS/SVE treatment, abiotic MNA could be relied on to decrease PCE concentrations below the remediation standard. For cost estimating purposes, it was assumed that groundwater monitoring would be necessary for 30 years. Indoor air sampling would be maintained until groundwater concentrations decrease to levels protective of indoor air (assumed at 10 years).

More specific assumptions made for costing the alternatives are listed in Appendix B.

Overall Protection of Human Health

Alternative 4 protects human health and the environment because PCE that poses an unacceptable risk to human health would be removed from groundwater and treated. Sparing would reduce concentrations of PCE in groundwater in the residential area to below the preliminary remediation standards. While the level of contaminants decrease in groundwater (occurring fairly quickly in the residential area), residents would be protected from the risk of PCE in indoor air by the previously installed SSD systems, which would be operated until groundwater concentrations decrease to levels protective of indoor air.

Long-Term Effectiveness and Permanence

PCE would be removed from groundwater, captured from the air stream, and treated. Groundwater monitoring would be conducted to determine that the concentrations of PCE are reduced to below the preliminary remediation standards and would not pose a long-term risk to human health. Air monitoring of the SVE treatment system discharge would be conducted to ensure PCE would not be released at unacceptable levels to the atmosphere.

Reduction in Toxicity, Mobility, and Volume through Treatment

This alternative includes removal of VOCs in groundwater and subsequent treatment. Sparging would reduce the toxicity, volume, and mobility of contamination.

Short-Term Effectiveness

Four factors considered as part of the short-term effectiveness criteria are assessed below for Alternative 4:

- Alternative 4 would present minimal risks to the community. Soil gas monitoring should be conducted to verify that the SVE system is capturing soil gas with elevated concentrations of PCE. Drilling and injection equipment would be required to implement this alternative; however, risk to the community could be minimized through exclusion zones and other typical safety measures.
- On-site workers may be exposed to risks while installing AS and SVE wells, or sampling contaminated groundwater; these risks would be minimized by safety procedures and use of appropriate personal protective equipment. Remediation activities would be carried out under a health and safety program designed to minimize worker exposure.
- Environmental impacts would be minimal.
- The corrective action is estimated to take 30 years. For cost estimating purposes it was assumed that the SSD systems could be turned off after 10 years of AS/SVE operation.

Implementability

Three factors considered as part of the implementability criteria are assessed below for Alternative 4:

- The alternative is considered technically feasible; however there are several considerations. AS/SVE well installation, and groundwater, soil gas, and indoor air monitoring are fairly routine activities. Pilot testing would be required to assess the effectiveness of AS/SVE versus ozone sparge wells, the impact of site-specific conditions, and the ROI and well spacing of the wells. Hydrogeology between the existing monitoring wells is not well defined, and potential impermeable lenses in the aquifer may influence sparging and capture. Careful planning should be used when sparging near residences or underground utilities that would provide preferential pathways. Problems with site access or drilling issues could impact the schedule.

- Materials required for implementation of sparging and any additional SSD system installation are readily available. Services for well installation and for groundwater, soil gas, and indoor air monitoring are also readily available.

- The alternative is considered administratively feasible. An air permit for the SVE system would be required. Site-specific testing and groundwater modeling would refine these estimates of remediation time.

Cost

The capital cost of Alternative 4 would be $770,000. The present value of O&M costs, including groundwater and indoor air monitoring, would be $6,030,000. The total present value cost for Alternative 4 would be $6,800,000.

State Acceptance

This criterion will be further evaluated after comments on this CAP have been received from NDEP.

Community Acceptance

This criterion will be evaluated after comments on the proposed plan have been received from the community. Community comments and concerns will be considered before final decisions are made on the corrective actions.

8.2.6 Alternative 5: Extraction and Treatment, Institutional Controls, Subslab Depressurization Systems, and MNA

Alternative 5 combines groundwater extraction and treatment, ICs, the SSD systems, and MNA. Under this alternative, groundwater would be removed from the subsurface and treated; residual MNA would be monitored to assess inherent, post-treatment activity that may drive further reductions of PCE concentrations in groundwater. ICs and SSD systems would protect residents from PCE in indoor air until groundwater is treated to protective levels.

Groundwater would be extracted from within the plume, treated to remove PCE, then re-injected outside the plume. Extraction and injection wells would be installed where possible and would cover the entire plume. An estimated 14 extraction wells and 15 injection wells would be needed. Two treatment systems (one located in the mall parking lot and the other on the golf course property) would be considered. Treated water would be delivered to injection wells surrounding the PCE plume. It is expected that wells in residential areas would be installed in right of ways. The wells would be screened in the top 20 ft of the shallow aquifer. A number of applicable treatment trains for the extracted groundwater include but are not limited to aqueous GAC units, ultraviolet (UV) oxidation, and air stripping followed by vapor-phase GAC units. For this CAP, it was assumed that GAC would be utilized to treat the extracted groundwater. It was also assumed that extracted groundwater could be reinjected after treatment to remove PCE but without treatment to reduce TDS. Some or all treated water may also be discharged to the sewer or supplied for irrigation if these options are later found to be more cost-effective. The assumptions made for the purposes of this CAP and costing are detailed in Appendix B.

Pumping tests, as well as bench-scale and pilot tests, would be required to determine the effectiveness of the alternative, aquifer characteristics, design criteria, and best suited water treatment techniques. These tests would also allow for refinement of costs. Given the geology at the Site, there will likely be localized dewatering of the formation at each extraction well. The sorbed PCE in the dewatered zone could re-contaminate groundwater when pumping stops. To reduce the impact of this phenomenon, it is expected that pumping will be pulsed rather than continuous. This aquifer has exhibited slow recharge of groundwater, indicating low hydraulic conductivity, which may make this technology difficult to implement and lead to a long remedial timeframe. The remedial duration is calculated at more than 40 years based on basic equilibrium partitioning and required pore volume exchanges. However, it is expected that the actual remedial duration will be much longer because of aquifer material heterogeneity and the tendency for fine-grained materials to be cleaned up slowly. Groundwater modeling should be completed to determine well placement. These tests would also allow for refinement of costs.

The potential for dewatering to compromise the geotechnical stability of subsurface clay and silt lithologic zones will also require careful evaluation to ensure protection of surface structures and infrastructure. Discharge or reinjection of treated groundwater may be problematic due to elevated concentrations of TDS in extracted groundwater. Re-injecting groundwater containing elevated TDS (even if from the same groundwater source) or conducting surface discharge is limited by regulation and may not be permitted.

SSD systems, ICs, groundwater and indoor air monitoring, and MNA are similar to the descriptions detailed in Alternative 2A in Section 8.2.2. In addition to extraction and treatment, MNA would be relied on to decrease residual PCE concentrations below the remediation standard. For cost estimating purposes, it was assumed that groundwater monitoring would be necessary for 30 years. Indoor air

sampling would be maintained until groundwater concentrations decrease to levels protective of indoor air (assumed at 10 years).

More specific assumptions made for costing the alternatives are listed in Appendix B.

Overall Protection of Human Health

Alternative 5 protects human health and the environment because groundwater that poses an unacceptable risk to human health would be extracted from the aquifer and treated. Extraction and treatment and MNA would be expected to eventually reduce concentrations of PCE in groundwater to below the preliminary remediation standards. However, as noted, this is expected to take over 40 years. While the level of contaminants decrease in groundwater, residents would be protected from the risk of PCE in indoor air by the previously installed SSD systems, which would be operated until groundwater concentrations decrease to levels protective of indoor air.

Long-Term Effectiveness and Permanence

PCE would be removed with groundwater and treated. Groundwater monitoring would be conducted to determine that the concentrations of VOCs are reduced to below the preliminary remediation standards and would not pose a long-term risk to human health.

Reduction in Toxicity, Mobility, and Volume through Treatment

This alternative includes removal of PCE in groundwater and subsequent treatment. It would reduce the toxicity and volume of contamination.

Short-Term Effectiveness

Four factors considered as part of the short-term effectiveness criteria are assessed below for Alternative 5:

- Alternative 5 would present minimal to moderate risks to the community. Drilling and trenching equipment would be required to implement this alternative; however, risk to the community could be minimized through exclusion zones and other typical safety measures. There would be a high level of drilling and trenching, which would disrupt surface activities in the area and would lead to physical hazards. Groundwater would be extracted from the subsurface and pumped through piping to a treatment area; appropriate security, signs, and warnings could protect the community from accidental contact with the contaminated water.
- On-site workers may be exposed to physical and chemical risks while installing the wells, piping, electrical system, treatment plant, system operation and maintenance, or sampling contaminated groundwater; these risks would be minimized by safety procedures and use of appropriate personal protective equipment. Remediation activities would be carried out under a health and safety program designed to minimize worker exposure.
- Environmental impacts would be minimal and would include potential increases to Site TDS if reinjection is used.
- For cost estimating purposes, a lifetime of 30 years was assumed; it was also assumed that the SSD systems could be turned off after 10 years of operation. Site-specific testing and groundwater modeling would refine these estimates of remediation time.

Implementability

Three factors considered as part of the implementability criteria are assessed below for Alternative 5:

- The alternative is considered technically feasible. Well installation, treatment of PCE-contaminated water, and groundwater and indoor air monitoring are fairly routine activities. Pilot and pump testing and subsequent groundwater modeling would be required to assess site-specific conditions and determine spacing of the extraction wells. Dewatering may lead to subsidence issues. Hydrogeology between the existing monitoring wells is not well defined, and potential impermeable lenses in the aquifer may influence hydraulic capture. The high TDS may lead to precipitate formation and fouling of the extraction and treatment equipment, which can be costly. Problems with site access or drilling issues could impact the schedule.

- Materials required for implementation of the extraction and treatment system and for any additional SSD system installation are readily available. Services for well installation and for groundwater and indoor air monitoring are also readily available.

- The alternative is considered administratively feasible. A Groundwater Discharge Permit for re-injection or a National Pollutant Discharge Elimination System (NDPES) permit for surface discharge of treated groundwater would be required. Regulatory limitations applicable to the discharge of TDS mass to surface water or groundwater may adversely affect the permissibility or permit options associated with this treatment strategy such that this alternative becomes inhibited.

Cost

The capital cost of Alternative 5 would be $1,740,000. The present value of O&M costs, including groundwater and indoor air monitoring, would be $8,710,000. The total present value cost for Alternative 5 would be $10,450,000.

State Acceptance

This criterion will be evaluated after comments on this CAP have been received from NDEP. However, the NDEP has indicated preference of a more modest extraction and treatment system in the east Boulevard Mall parking lot and near the golf course wells (NDEP 2011); however, this would mainly be effective as hydraulic capture.

Community Acceptance

This criterion will be evaluated after comments on the proposed plan have been received from the community. Community comments and concerns will be considered before final decisions are made on the corrective actions.

8.2.7 Alternative 6: In Situ Enhanced Bioremediation, Institutional Controls, Subslab Depressurization Systems, and MNA

Alternative 6 combines enhanced in situ bioremediation, ICs, the SSD systems, and MNA. Under this alternative, enhanced bioremediation would be employed in areas of the plume hotspot and upgradient of the residential area to treat groundwater as it flows into the residential area (where the aquifer conditions are amenable to reductive dechlorination as described in Section 4). ICs and SSDs would protect residents from PCE in indoor air until groundwater is treated to protective levels. MNA would be relied on to further decrease concentrations of remaining contamination found in groundwater.

Enhanced bioremediation would be applied through injection of substrates or microbes in the plume hot spot where practicable based on preferable ORP values and where logistically practicable, including at the Property and in streets, public right of ways, and parking lots in the Boulevard Mall. For the purposes of this study it was assumed biostimulaltion and bioaugmentation would be required (bench-scale testing would determine the level of enhancement required). Biostimulation would also be conducted upgradient

of the residences in the Boulevard Mall's eastern parking lot. Amendments would be injected into the top 20 ft of aquifer at the site. The assumptions made for the purposes of this CAP and costing are detailed in Appendix B.

Bench-scale testing would be required to determine the technology's effectiveness, including substrate requirements, need for bioaugmentation, dosing rates, and potential geochemical interference at the Site. The high sulfate concentration found at the site would increase the amount of substrate required. If bench-scale testing is successful, pilot studies would be conducted in the area before full-scale implementation to establish the effective dosage rates, ROI, the optimal well spacing, breakdown products, and potential for degradation to stall. These tests would also allow for refinement of costs. The bench-scale and pilot studies would also evaluate any potential increase in TDS or loss of permeability in the subsurface. Based on the aquifer characteristics, very few biostimulants have potential to be effective,

SSD systems, ICs, groundwater and indoor air monitoring, and MNA are similar to the descriptions detailed in Alternative 2A in Section 8.2.2. In conjunction with bioremediation, MNA would be relied on to decrease residual PCE concentrations below the remediation standard. For cost estimating purposes it was assumed that groundwater monitoring would be necessary for 30 years. Indoor air sampling would be maintained until groundwater concentrations decrease to levels protective of indoor air (assumed at 10 years).

More specific assumptions made for costing the alternatives are listed in Appendix B.

Overall Protection of Human Health

Alternative 6 protects human health and the environment because groundwater that poses an unacceptable risk to human health would be treated through enhanced bioremediation. Biodegradation would reduce concentrations of PCE in groundwater to below the preliminary remediation standards. While the level of contaminants decrease in groundwater, residents would be protected from the risk of PCE in indoor air by the previously installed SSD systems, which would be operated until groundwater concentrations decrease to levels protective of indoor air.

Long-Term Effectiveness and Permanence

PCE in groundwater would be permanently treated in situ. Groundwater monitoring would be conducted to determine that the concentrations of VOCs are reduced to below the preliminary remediation standards and would not pose a long-term risk to human health. No long-term activities would be required to maintain the effectiveness of this alternative.

Reduction in Toxicity, Mobility, and Volume through Treatment

This alternative includes treatment of the VOCs in groundwater. Enhanced bioremediation would reduce the toxicity and volume of contamination in the groundwater.

Short-Term Effectiveness

Four factors considered as part of the short-term effectiveness criteria are assessed below for Alternative 6:

- Alternative 6 would present minimal risks to the community because the corrective action would be applied in situ. Drilling and injection equipment would be required to implement this alternative; however, risk to the community could be minimized through exclusion zones and other typical safety measures. Initially, concentrations of PCE breakdown products would

increase as microbial degradation occurs. Proper design would minimize the likelihood of the degradation stalling before complete breakdown of the compounds.

- On-site workers may be exposed to risks while installing injection or monitoring wells, handling the substrate for injection, or sampling contaminated groundwater; these risks would be minimized by proper handling and housekeeping and use of appropriate personal protective equipment. Remediation activities would be carried out under a health and safety program designed to minimize worker exposure.
- Environmental impacts in the injection areas would be minimal because the remediation is in situ. However, the biostimulation may increase TDS in the aquifer. Site-specific testing and groundwater modeling would refine these estimates of remediation time.
- The corrective action is estimated to take 30 years with two injections in the plume hotspot and three injection rounds upgradient of the residences. For cost estimating purposes it was assumed that the SSD systems could be turned off after 10 years.

Implementability

Three factors considered as part of the implementability criteria are assessed below for Alternative 6:

- The alternative is considered technically feasible; however there are several considerations. Well installation, injection, groundwater and indoor air monitoring, and installation of SSD systems are fairly routine activities. Bench-scale and pilot testing would be required to assess the effectiveness of the treatment technologies, need for bioaugmentation, and impact of site-specific conditions on the dosage, the ROI, and well spacing. Hydrogeology between the existing monitoring wells is not well defined, and potential impermeable lenses in the aquifer may influence the injection. High sulfates may be problematic and require additional substrate; given sulfate concentrations at the Site, EHC is likely one of the few substrates that will be effective. Potential transformation of chemicals and residual breakdown products would be monitored during the pilot study and may affect implementability and effectiveness of the alternative. Problems with site access or drilling issues could impact the schedule.

- Materials required for implementation of enhanced bioremediation and any additional SSD system installation are readily available. Services for well installation, injection, groundwater and indoor air monitoring, and SSD system installation are also readily available.

- The alternative is considered administratively feasible. A permit for injection of the substrates or microbes would be required.

Cost

The capital cost of Alternative 6 would be $1,240,000. The present value of O&M costs, including groundwater and indoor air monitoring, would be $15,090,000. The total present value cost for Alternative 6 would be $16,330,000.

State Acceptance

This criterion will be further evaluated after comments on this CAP have been received from NDEP. However, NDEP has indicated that high sulfate concentrations at the Site may make this alternative unviable (NDEP 2011). While high sulfate and electron acceptor concentrations at the Site would require the addition of more EHC, this alternative may be viable. The feasibility of this alternative and the effect of sulfates can quickly be determined through bench-scale testing.

Community Acceptance

This criterion will be evaluated after comments on the proposed plan have been received from the community. Community comments and concerns will be considered before final decisions are made on the corrective actions.

8.3 Comparison of Corrective Action Alternatives

This section compares the groundwater corrective action alternatives using the seven criteria to assess relative performances of the alternatives. State acceptance is based on comments received to date (NDEP 2011), and community acceptance will be evaluated after comments on this CAP have been received from NDEP and comments on the proposed plan have been received from the community. The preferred alternative for soil and groundwater will be selected in the proposed plan after:

- Data gaps are filled.
- The risk assessment is complete.
- The CAP is finalized.
- Bench-scale and pilot testing have been completed.
- A corrective action alternative is recommended in the Corrective Action Report.

Table 8-1 presents a comparative summary of the alternatives and evaluation criteria. Table 8-2 provides a simplified comparative summary of advantages and disadvantages of each technology.

TABLE 8-1

COMPARISON OF ALTERNATIVES SUMMARY

Alternative	Description	Overall Protection of Human Health	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-Term Effectiveness	Implementability	Cost	State Acceptance	Community Acceptance
1	No Action	Low − The no action alternative is not protective of human health.	Low − The no action alternative is not effective.	Low − The no action alternative does not reduce the toxicity, mobility, or volume of contaminants.	Low - Minimal risk to the residents as there is no implementation but increased risk if PCE concentrations in groundwater and indoor air increase. It is assumed monitoring would be required for 30 years.	Easy − This alternative is technically implementable,	Capital Costs: None O&M Costs: $3,840,000	The no action alternative would likely be unacceptable to NDEP and the community.	Low − The no action alternative would likely be unacceptable to the community.
2A	In Situ Chemical Oxidation of Hotspots and Residential Area, Institutional Controls, SSD Systems, and MNA	High − Residents are protected from PCE in indoor air until groundwater concentrations are decreased by in situ chemical treatment. Treatment would rapidly decrease concentrations in the plume hotspot and in the residential area.	High − PCE will be destroyed through in situ chemical treatment. Several injections of chemical are likely.	High − The toxicity and volume of contaminants would be reduced through chemical treatment.	High − Minimal risk as the corrective action is applied in situ. Precautions can be taken to prevent exposure of workers and the community during implementation. Environmental impacts are expected to be low. It is assumed the SSD systems could be turned off after approximately 10 years.	Moderately Difficult − This alternative is considered technically feasible, and materials required are readily available. A bench-scale and pilot test should be conducted to better determine efficacy, geochemical interferences, and design parameters. The higher flow rate in sand and gravel channels may cause problems. This alternative is administratively feasible. An underground injection permit would be required for chemical application.	Capital Costs: $1,070,000 O&M Costs: $6,030,000 Total: $7,100,000	NDEP has expressed concerns regarding the environmental impacts of this alterative (NDEP 2011).	This criterion would be evaluated after comments on the proposed plan have been received from the community.
2B	In Situ Chemical Oxidation, Institutional Controls, SSD Systems, and MNA	High − Residents are protected from PCE in indoor air until groundwater concentrations are decreased by in situ chemical treatment. Treatment would rapidly decrease concentrations in the plume.	High − PCE will be destroyed through in situ chemical treatment. Several injections of chemical are likely.	High − The toxicity and volume of contaminants would be reduced through chemical treatment.	High − Minimal risk as the corrective action is applied in situ. Precautions can be taken to prevent exposure of workers and the community during implementation. Environmental impacts are expected to be low to moderate. It is assumed the remediation goal would be reached in approximately 5 years.	Moderately Difficult − This alternative is considered technically feasible, and materials required are readily available. A bench-scale and pilot test should be conducted to better determine efficacy, geochemical interferences, and design parameters. The higher flow rate in sand and gravel channels may cause problems. It may be difficult given structures and utilities to inject chemical oxidant into the entire plume. This alternative is administratively feasible. An underground injection permit would be required for chemical application.	Capital Costs: $4,660,000 O&M Costs: $18,550,000 Total: $23,210,000	NDEP has expressed concerns regarding the feasibility and safety of this alternative. (NDEP 2011).	This criterion would be evaluated after comments on the proposed plan have been received from the community.
3	Permeable Reactive Barrier, ICs, SSD, Systems, and MNA	High − Residents are protected from PCE in indoor air until groundwater concentrations are decreased by reductive dechlorination. Treatment would rapidly decrease concentrations in the residential area.	High − PCE will be destroyed through reductive dechlorination. Once installed, the PRB should last for the lifetime of the project.	High − The toxicity and volume of contaminants would be reduced through reductive dechlorination.	High − Minimal risk as the corrective action is applied in situ. Precautions can be taken to prevent exposure of workers and the community during implementation. Environmental impacts are expected to be low to moderate; however this alternative may increase TDS in the aquifer. It is assumed the SSD systems could be turned off after approximately 10 years.	Moderately Difficult to Difficult − This alternative is considered technically feasible, and materials required are readily available. The depth to groundwater makes conventional trenching more challenging. A bench-scale and pilot test should be conducted to better determine efficacy, geochemical interferences, precipitate formation, and design parameters. The high TDS may lead to precipitate formation. This alternative is administratively feasible. A permit may be required if the PRB is injected.	Capital Costs: $2,800,000 O&M Costs: $5,340,000 Total: $8,140,000	NDEP has expressed concerns regarding the viability of this treatment technology due to high sulfate concentrations.	

TABLE 8-1

COMPARISON OF ALTERNATIVES SUMMARY (CONTINUED)

Alternative	Description	Overall Protection of Human Health	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume through Treatment	Short-Term Effectiveness	Implementability	Cost	State Acceptance	Community Acceptance
4	Sparging, ICs, SSD Systems, and MNA	High − Residents are protected from PCE in indoor air until groundwater concentrations are decreased by chemical treatment. Treatment would rapidly decrease concentrations in the residential area.	Moderate to High − PCE will be removed through sparging. Sparging systems tend to be O&M intensive. Air from the SVE will require treatment to remove PCE.	High − The toxicity, volume, and possibly mobility of contaminants would be reduced through removal and treatment.	Moderate to High − Air contaminated with PCE would be brought above ground; however, precautions can be taken to prevent exposure of workers and the community during implementation. Design would need to ensure PCE vapors are captured and do not enter the residential area. Environmental impacts are expected to be low. It is assumed the SSD systems could be turned off after approximately 10 years.	Moderately Difficult − This alternative is considered technically feasible, and materials required are readily available. A pilot test should be conducted to better determine design parameters and ensure PCE vapor capture by the SVE system. This alternative is administratively feasible. An air quality permit would be required.	Capital Costs: $770,000 O&M Costs: $6,030,000 Total: $6,800,000	NDEP has provided few comments on this alternative (NDEP 2011).	This criterion would be evaluated after comments on the proposed plan have been received from the community. (It should be noted that AS/SVE systems tend to create noise, which may be objectionable to some residents.)
5	Extraction and Treatment, ICs, SSD Systems, and MNA	High − Residents are protected from PCE in indoor air until groundwater concentrations are decreased by extraction and treatment. Treatment would decrease concentrations in the plume over time.	Moderate − PCE will be removed from the aquifer. Extraction and treatment tends to require an extended timeframe to remove contaminants.	High − The toxicity, volume, and mobility of contaminants would be reduced through removal and treatment.	High − Groundwater contaminated with PCE would be brought above ground; however, precautions can be taken to prevent exposure of workers and the community during implementation. Environmental impacts are expected to be low. It is assumed the remediation goal would be reached in over 40 years, and SSD systems could be turned off after approximately 10 years.	Moderately Difficult to Difficult − This alternative is considered technically feasible, and materials required are readily available. Groundwater capture can be challenging and the aquifer may dewater in areas with a tight formation; groundwater modeling would be required. Dewatering may lead to subsidence. The high TDS may lead to fouling of the extraction and treatment equipment. Pump and soil tests should be conducted to better determine effectiveness, well placement, and design parameters. Discharge of water with TDS may also be an issue. This alternative is administratively feasible. A NPDES permit would be required.	Capital Costs: $1,740,000 O&M Costs: $8,710,000 Total: $10,450,000	NDEP has expressed interest in use of extraction and treatment (NDEP 2011).	This criterion would be evaluated after comments on the proposed plan have been received from the community.
6	In Situ Enhanced Bioremediation, ICs, SSD Systems, and MNA	High − Residents are protected from PCE in indoor air until groundwater concentrations are decreased by bioremediation. Treatment would decrease concentrations in the plume hotspot and in the residential area.	High − PCE will be destroyed through microbial degradation. Multiple injections of microorganisms (bioaugmentation) or substrates (biostimulation) may be required.	The toxicity and volume of contaminants would be reduced through microbial degradation.	High − Precautions can be taken to prevent exposure of workers and the community during implementation. Concentrations of PCE breakdown products would initially increase. Environmental impacts are expected to be low; however this alternative may increase TDS in the aquifer. It is assumed the SSD systems could be turned off after approximately 10 years.	Difficult − This alternative is considered technically feasible. Bioremediation can be more sensitive to environmental conditions than other technologies. Materials required are readily available. A bench-scale and pilot test should be conducted to determine the effectiveness of the microbial degradation process, geochemical interferences, and design parameters. The high sulfate conditions at the site may be an issue. This alternative is administratively feasible. An underground injection permit would be required for substrate and/or microbe application.	Capital Costs: $1,240,000 O&M Costs: $15,090,000 Total: $16,330,000	NDEP has expressed concerns regarding the viability of this treatment technology due to high sulfate concentrations.	This criterion would be evaluated after comments on the proposed plan have been received from the community.

Notes:

AS Air sparge
GAC Granular activated carbon
NDEP Nevada Department of Environmental Protection
O&M Operation and maintenance
PRB Permeable reactive barrier
SVE Soil vapor extraction
CAP Corrective action plan
MNA Monitored natural attenuation
NPDES National Pollutant Discharge Elimination System
PCE Tetrachloroethene
SSD Subslab Depressurization
TDS Total dissolved solids

TABLE 8-2

SUMMARY OF TECHNOLOGY ADVANTAGES AND DISADVANTAGES

Technology	Advantages	Disadvantages
In Situ Chemical Oxidation	• Potential for short treatment timeframe • In situ • Proven for treatment of PCE	• Only effective if oxidant reaches PCE, which may be difficult given development at the Site • Potential for injection issues • Will require multiple injections • NDEP concerned with safety
ZVI Permeable Reactive Barrier,	• Passive • In situ • Proven for treatment of PCE	• Elevated sulfates will require additional ZVI • Installation of the wall may be challenging given the depth to groundwater • Expensive • NDEP questions the effectiveness of reduction at this Site
Sparging,	• In situ • Proven for treatment of PCE • Use as a sparge curtain, and could expand to treat areas with higher concentrations	• O&M intensive • Need to control vapors
Extraction and Treatment,	• Proven for treatment of PCE • Preferred by NDEP	• Long remediation timeframe estimated over 40 years. • Will likely cause aquifer dewatering which may lead to subsidence • Expensive • O&M intensive • High sulfates/TDS in aquifer will increase costs
In Situ Enhanced Bioremediation,	• Innovative • In situ	• Biodegradaion is not occurring at the Site • Not many substrates will work; would likely need to include bioaugmentation • NDEP does not support this technology at this Site • Potential for injection issues • Will require multiple injections

Notes:
NDEP Nevada Department of Environmental Protection
O&M Operation and maintenance
ZVI Zero-valence iron
TDS Total dissolved solids
PCE Tetrachloroethene

9.0 RECOMMENDATIONS

This section provides a list of data needs and field activities recommended for obtaining needed data. These data gaps disallow a sufficient understanding of the Site conditions pertinent to: (1) development of a human health risk assessment, (2) a complete evaluation of remedial alternatives, and (3) confirmation of site parameters essential for development of a final remedial design.

9.1 Data Needs

The extent of groundwater contamination and how it impacts soil gas and indoor air are not fully defined in the downgradient areas of the plume, north of Cherokee Lane in the residential neighborhood and across the golf course. The pathways of potential concern relate to volatilization of PCE from groundwater to soil gas and its transport to indoor air in homes and businesses. A work plan is being developed for an investigation to determine the extent of PCE in groundwater and better understand the volatilization of PCE from groundwater into soil gas and its migration and transport into indoor air. Data expected to be obtained via that effort are needed to prepare the risk assessment and develop mitigation measures for residential indoor air. Additional data representing hydraulic flow parameters for the diverse range of soil types at the Site are needed for evaluation of the remedial alternatives and development of the remedial design. Data gaps and additional data acquisition activities are as follows:

- Indoor air data are needed to evaluate current residential conditions and evaluate the efficacy of mitigation systems previously installed by NDEP:
    - Indoor air sampling and subslab sampling in the residential area are needed to verify results from previous investigations, re-assess how well previous data represent current conditions at the Site, and establish a baseline for monitoring remedial progress.
    - Similar indoor air and subslab data are needed for the Boulevard Mall to determine whether engineered control systems are needed to mitigate indoor air in order to address potential risks under current conditions.
- Soil properties have not been well characterized for the unsaturated and saturated heterogeneous soils across the Site. Insufficient physical, flow, and contaminant distribution data have been obtained in the unsaturated and saturated zones beneath the Site:
    - Additional soil testing (standard measurements of porosity, grain size distribution, organic carbon, and bacterial analyses) is needed to better understand the geotechnical properties and lithologic conditions of the heterogeneous subsurface soils as related to flow dynamics, contaminant transport, and vapor migration; this information is necessary to assist in evaluating remedy selection and development and implementation of the remedial design.

9.2 Bench-Scale and Pilot Testing

Given the concentrations of PCE in groundwater at the site, the subsurface conditions, and the various receptor pathways, an integrated approach to remediation or a combination of general response actions likely will be required. In Section 8, alternatives were assessed for their overall protection of human health; long-term and short-term effectiveness; reduction in toxicity, mobility, and volume through treatment; implementability; and cost. Based on preliminary evaluations of alternatives for the Site, bench-scale or pilot tests should be conducted to evaluate the potential of a corrective action to meet project needs. Tests for air permeability, ROI, and groundwater production are needed. Production tests are necessary to understand the flow capacity and area of influence in the variety of soil types that exist at the Site, and to predict the locations and effects of the complex flow boundary conditions for developing the remedial design for a groundwater remedy. Currently, the most promising technologies evaluated

include chemical oxidation and sparging. If bench-scale tests are successful, the results should be used to aid in design of pilot studies as needed. A Pilot Study Work Plan will be developed detailing the requirements, objectives, layout, and schedules for the progression of tests to be conducted for further refining the selected alternative(s) for the Site.

If testing for chemical oxidation and sparging technologies proves unsuccessful or insufficient as an overall strategy for treatment of the Site, additional testing for a ZVI PRB, extraction and treatment, and enhanced bioremediation will be considered. The following provides details on bench-scale testing and a speculative outline of what some of these pilot tests might include.

In-Situ Chemical Oxidation

In situ chemical oxidation requires bench-scale testing to determine the stoichiometry involved in chemical demands for the Site soil and groundwater, and the type of chemical and other additives that are suitable. If bench-scale testing is successful, pilot testing is needed to evaluate the effectiveness of the chemical for remediating the contaminant to acceptable levels, and to obtain data for full-scale implementation evaluation including ROI, degradation byproducts, and persistence in the aquifer. Data from post-pilot test monitoring will assist in determining whether periodic injections would be necessary following rebound.

Sparging

A pilot test would determine the effectiveness of sparging and evaluate the benefits of ozone sparging versus AS/SVE. The ROIs of the both injection and extraction wells would be determined for full-scale implementation. In addition, the test would help predict influent PCE concentrations in order to develop appropriate air treatment strategies.

9.3 Path Forward

The perceived process to effectively and efficiently advance corrective action evaluation and implementation is:

Task	Schedule
1. Provide bench-scale test protocols.	April 15, 2011
2. Complete bench-scale testing.	May 31, 2011
3. Submit summary report bench-scale test results and proposed pilot study protocol(s).	June 30, 2011
4. Execute pilot study field efforts.	August 31, 2011
5. Finalize the CAP for Groundwater (assumes data for indoor air and PCE plume delineation have been obtained and analyzed in a risk assessment).	September 30, 2011
6. Maintain operation of pilot study systems and propose appropriate expansion, as needed, within a remedial design/remedial action (RD/RA) plan.	November 15, 2011
7. Upon approval of the RD/RA, implement full-scale corrective action.	January 2012

Schedule dates are subject to change based on NDEP concurrence and subsequent project developments.

10.0 BIBLIOGRAPHY

Bernholtz, A.J., 1993, *Estimation of leakage between shallow and principal aquifers in the Las Vegas Valley Water District's Main Well Field, Las Vegas Nevada*: University of Nevada, Las Vegas, unpublished M.S. thesis, 88 p.

Bouwer, H. and R.C. Rice. 1976. "A Slug Test for Determining Hydraulic Conductivity of unconfined Aquifer with Completely or Partially Penetrating Wells," Water *Resources Research*, V. 12, No. 3, pp. 423-428.

Broadbent & Associates Inc. (Broadbent). 2010. *Indoor Air Mitigation and Sampling Report, for the Maryland Square PCE Site, Las Vegas, Nevada*. March.

Brothers, K. and T. Katzer. 1988. *Ground-Water Chemistry Changes Resulting from Stressed Aquifer Systems in Las Vegas Valley, Nevada*. Las Vegas Valley Water District. In cooperation with the Nevada Division of Environmental Protection. Carson City, Nevada. 53 pages.

Colorado River Basin Salinity Control Forum. 2008. *2008 Review Water Quality Standards for Salinity Colorado River System*. July.

Converse Consultants (Converse). 1999. *Phase I Environmental Site Assessment, Maryland Square Shopping Cente*r, 3661 South Maryland Parkway, Las Vegas, NV. September 28.

Converse. 2000. *Limited Phase II Subsurface Assessment*. August 22.

Converse. 2001. *A Through K Data Research and Report*. August 22.

Converse. 2002. *Additional Soil and Groundwater Investigation*. November 13.

Converse. 2003a. *Additional Soil and Groundwater Investigation*. May 16.

Converse. 2003b. *Preliminary Corrective Action Plan*. June 27.

Converse. 2004. *Well Installation/Slug Testing/Groundwater Monitoring Report - 4th Quarter 2003 and 1st Quarter 2004.* March 26.

Converse. 2008. *Groundwater Monitoring Report - 4th Quarter 2008*. December 9.

Converse. 2009a. *Groundwater Monitoring Report -1st Quarter 2009*. April 15.

Converse. 2009b. *Groundwater Monitoring Report -2nd Quarter 20*09. July 21, 2009

Converse. 2009d. *Groundwater Monitoring Report -3rd Quarter 2009*. October 9.

Converse. 2010a. *Groundwater Monitoring Report -4th Quarter 2009*. January 13.

Converse. 2010b. *Groundwater Monitoring Report -1st Quarter 2010*. April 14.

Donovan, D.J. 1996. *Hydrostratigraphy and Allostratigraphy of the Cenozoic Alluvium in the Northwestern Part of Las Vegas Valley, Clark County, Nevada*. Master Thesis. Department of Geosciences. University of Nevada – Las Vegas, NV. 199 pages.

Environmental Technologies Inc. (ETI). 2007. *Effects of Sulphate and Sulfide on Granular Iron Permeable Reactive Barrier Performance*. Technical Note 2.09. Waterloo. Ontario.

Harrill, J.R. 1976. Pumping and depletion of ground –water storage in Las Vegas Valley, Nevada 1955-74: Nevada Department of Conservation and Natural Resources Division of Water Resources. *Water Resources Bulletin* No. 44. 69 p.

Hvorslev, J.M. 1951. *Time Lag and Soil Permeability in Ground-Water Observations*, Bulletin No. 36, U.S. Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. 50 pages.

Langenheim, V.E., J. Grow, J. Miller, J.D. Davidson, and E. Robinson. 1998. "Biodegradation of Disinfection Byproducts as a Potent Removal Process During Aquifer Storage and Recovery." *Journal of the American Water Resources Association*. V. 36, n.4, pp. 861-867.

Leising, J.F. 2004. *Chemical Conditions in the Primary Producing Aquifers and Portions of the Shallow Groundwater System of the Las Vegas Valley in 2000*. Southern Nevada Water Authority. March.

Nevada Division of Environmental Protection (NDEP). 2007. Groundwater Data from Golf Course Well PW-1, February.

NDEP. 2009. "Limited Site Investigation and Quarterly Monitoring Work Plan: Hudson Cleaners, Somerset Shopping Center." Letter to Mr. Albert Marquis, Esq. March 23.

NDEP. 2011. Draft Corrective Action Plan for Groundwater, Maryland Square Shopping Center. Letter and attachments to Mr. Irwin Kishner and Mr. Tim Swickard. January 11.

Plume, R.W. 1984. *Ground-Water Conditions in Las Vegas Valley, Clark County, Nevada*. U.S. Geological Survey Open-File Report 84-130. 25 pages.

Plume, R.W. 1989. *Ground-Water Conditions in Las Vegas Valley, Clark County, Nevada: Part I. Hydrogeologic Framework*. U.S. Geological Survey Water Supply Paper 2320-A. 14 pages.

Shevenell, L. 1996. *Statewide Potential Evapotranspiration Maps for Nevada*. Nevada Bureau of Mines and Geology, Report 48. Mackay School of Mines, University of Nevada – Reno. 32 pages.

Tetra Tech, Inc. (Tetra Tech). 2010a. *Quarterly Groundwater Monitoring Report, 2nd Quarter 2010*. July 23.

Tetra Tech. 2010b. *Corrective Action Plan for Source Area Soil, Maryland Square Shopping Center*. December 14.

Tetra Tech. 2010c. *Quarterly Groundwater Monitoring Report 3rd Quarter 2010.* October 22.

Tetra Tech. 2011. *Quarterly Groundwater Monitoring Report 4th Quarter 2010.* January 21.

TRC Solutions, Inc. (TRC). 2009. *Groundwater Monitoring Wells Investigation, Sampling and Capping, The Boulevard Mall, 3528 South Maryland Parkway, Las Vegas, NV.* December 9.

URS Corporation (URS). 2005. *Report, Subsurface Investigation*. July 11.

URS. 2006a. *Quarterly Groundwater Sampling. December 2005*. February 6

URS. 2006b. *Quarterly Groundwater Sampling and Additional Monitor Well Installations. March 2006*. April 25.

URS. 2006c. *Quarterly Groundwater Sampling. June 2006*. July 31

URS. 2006d. *Source Removal Corrective Action Plan*. November 13.

URS. 2006e. *Quarterly Groundwater Sampling. 3rd Quarter 2006*. November 14.

URS. 2007a. *Quarterly Groundwater Sampling. 4th Quarter 2006.* January 5.

URS. 2007b. *Quarterly Source Area Soil Assessment*. February 23.

URS. 2007c. *Quarterly Groundwater Sampling, 1st Quarter 2007*. April 2.

URS. 2007d. *Offsite Soil Vapor Assessment Report*. April 13.

URS. 2007e. *Quarterly Groundwater Sampling , 2nd Quarter 2007*. July 25.

URS. 2007f. *Installation of Downgradient Groundwater Monitoring Wells*. November 26.

URS. 2007g. *Quarterly Groundwater Sampling , 3rd Quarter 2007*. December 6.

URS. 2008a. *Quarterly Groundwater Sampling , 4th Quarter 2007*. January 16.

URS. 2008b. *Installation of Additional Downgradient Groundwater Monitoring Wells*, Letter Report. March 24.

URS. 2008c. *Quarterly Groundwater Sampling , First Quarter 2008*, April 14.

U.S. Environmental Protection Agency (EPA). 1988. *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final*. EPA 540/P-91/001, Office of Solid Waste and Emergency Response (OSWER) 9355.3-11. October.

EPA, 1997. *Use of Monitored Natural Attenuation at Superfund RCRA Corrective Action and Underground Storage Tank Sites*. OSWER Directive 9200.4-17. November.

Western Regional Climate Center (WRCC). 2010. Online Address: http://www.wrcc.dri.edu/

Western Technologies. 1991. *Phase II Groundwater Evaluation, Proposed Downtown Park System*. Las Vegas, Nevada, Project No. 4121K202 Prepared for Atlandia Design. 23 pages.

Wild, S.W., Jr. 1990. *Hydrogeology and Hydrogeochemistry of the Shallow Alluvial Aquifer Zone, Las Vegas, Nevada*. M.S. Thesis. Department of Geoscience, University of Nevada - Las Vegas. 203 pages.

Zikmund, K.S. 1996. *Extent and Potential use of the Shallow Aquifer and Wash Flow in Las Vegas Valley, Nevada.* Southern Nevada Water Authority.

FIGURES

0 500 1,000 Feet

Approximate Scale in Feet

MARYLAND SQUARE SHOPPING CENTER
3661 South Maryland Parkway
Las Vegas, Nevada

FIGURE 1
Location Map

TETRA TECH

S:\Projects Directory\Private Sector - Other Offices\Maryland Square\Groundwater Cap\Figure 1.mxd troy.fegter

Source: Clark County Assessors Web Site

Scale: 0Feet 200 Feet

N

MARYLAND SQUARE SHOPPING CENTER
3661 South Maryland Parkway
Las Vegas, NV

Figure 2

Al Philips the Cleaner
Former Facility Location

TETRA TECH

Modified from URS 2007

Legend

- Monitoring Well Location
- Production Well Location
- 1100 PCE Concentration (ug/L)
- NS Not Sampled
- ND Non-detect
- ug/L Micrograms per Liter

PCE Contour (ug/L)

- 100
- 500
- 1000
- 1500
- 2000
- 2500

Notes: 1. Contours do not recognize unusually low PCE concentrations quantified at MW-19 and MW-20.
2. PCE data and contours are from the November 2010 monitoring event.

N W E S

0 250 500 Feet

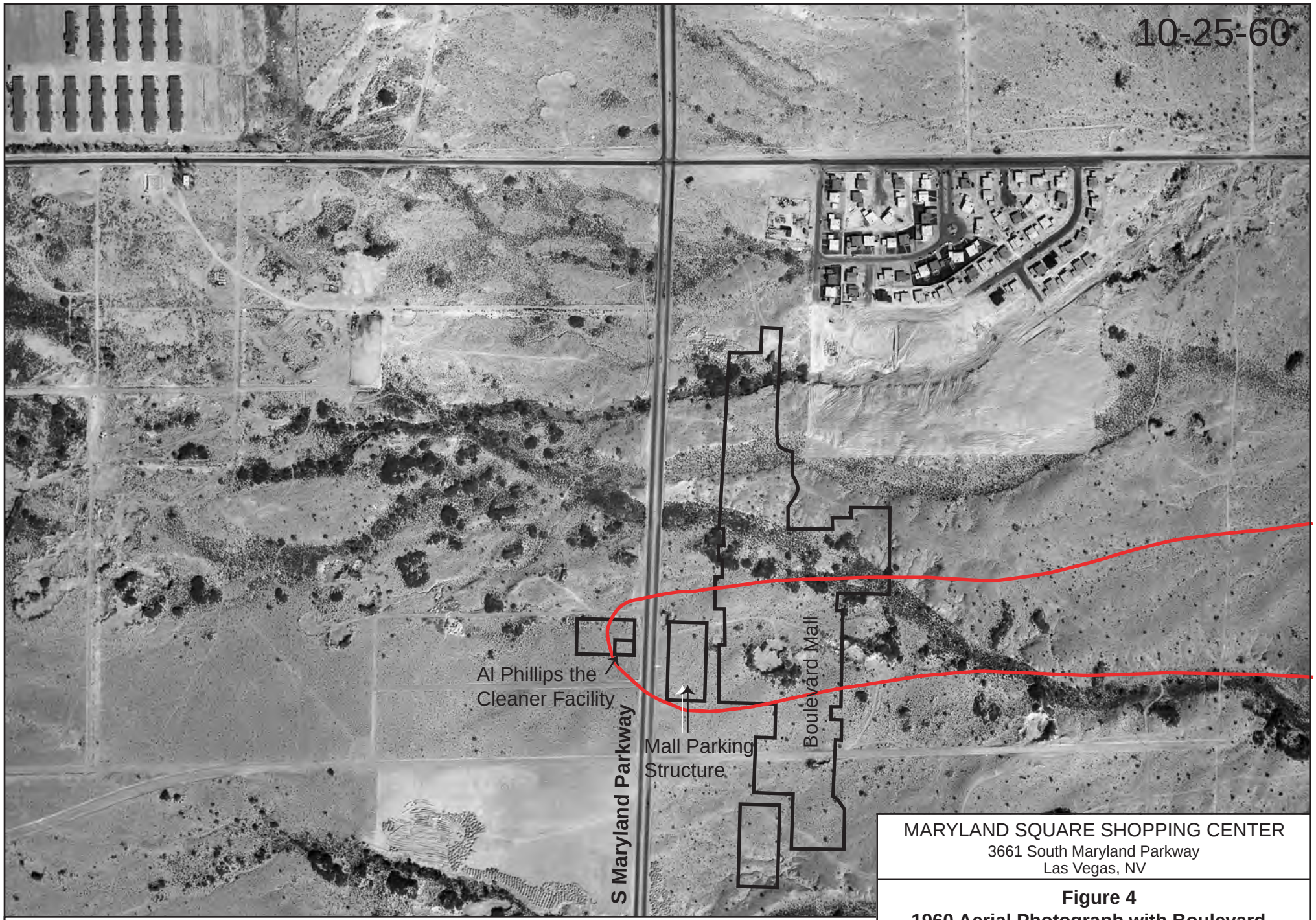
Approximate Scale in Feet

MARYLAND SQUARE SHOPPING CENTER
3661 South Maryland Parkway
Las Vegas, Nevada

FIGURE 3
PCE CONCENTRATION MAP

TETRA TECH

S:\Projects Directory\Private Sector - Other Offices\Maryland Square\Groundwater Cap\Figure 3.mxd troy.fegter



PCE Contour

PCE Tetrachloroethylene

μg/L Micrograms per Liter

Photograph Courtesy of Cooper Aerial Photo

N

0 250 500

Feet

MARYLAND SQUARE SHOPPING CENTER

3661 South Maryland Parkway

Las Vegas, NV

Figure 4

1960 Aerial Photograph with Boulevard Mall Footprint

TETRA TECH

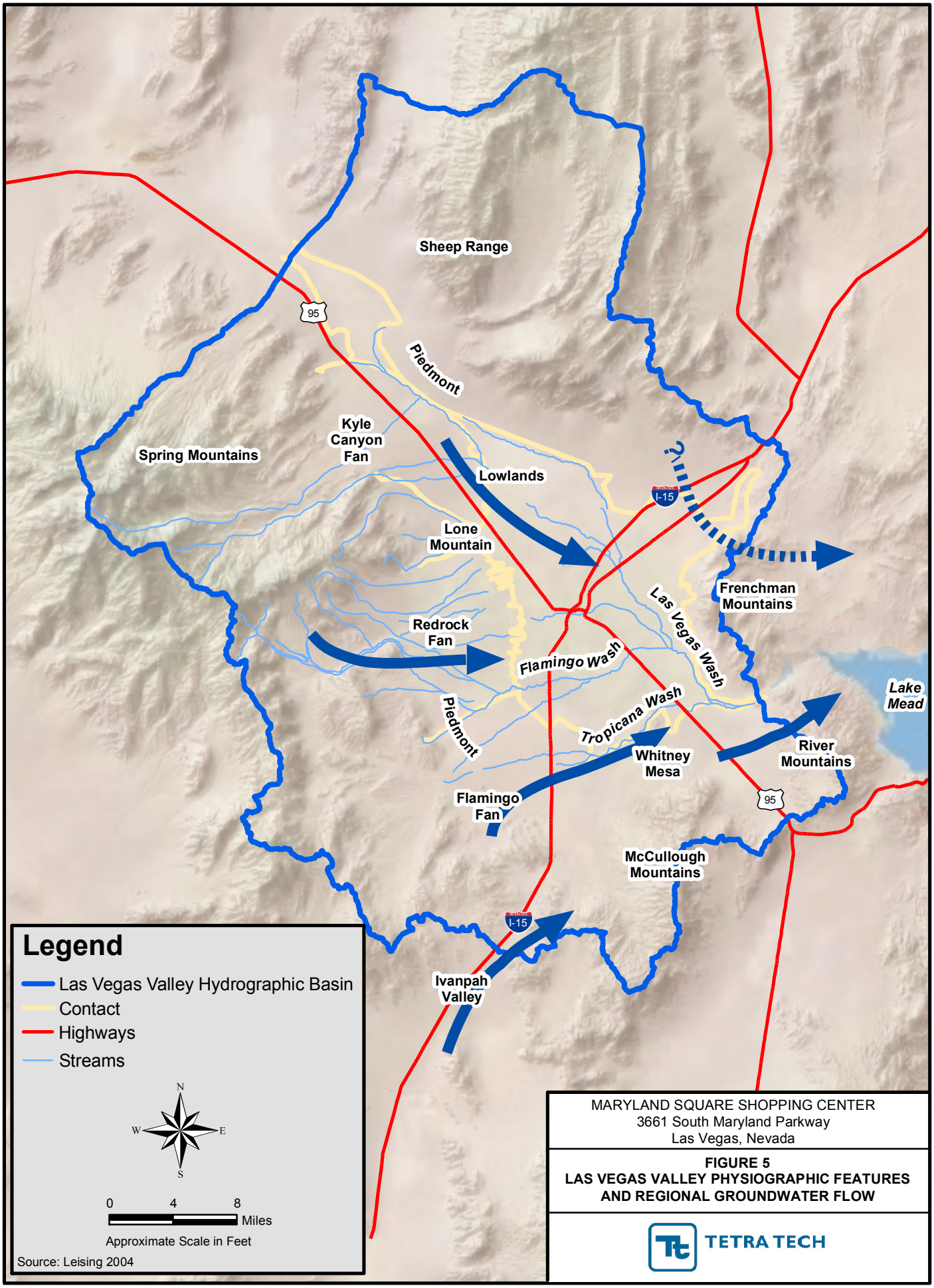


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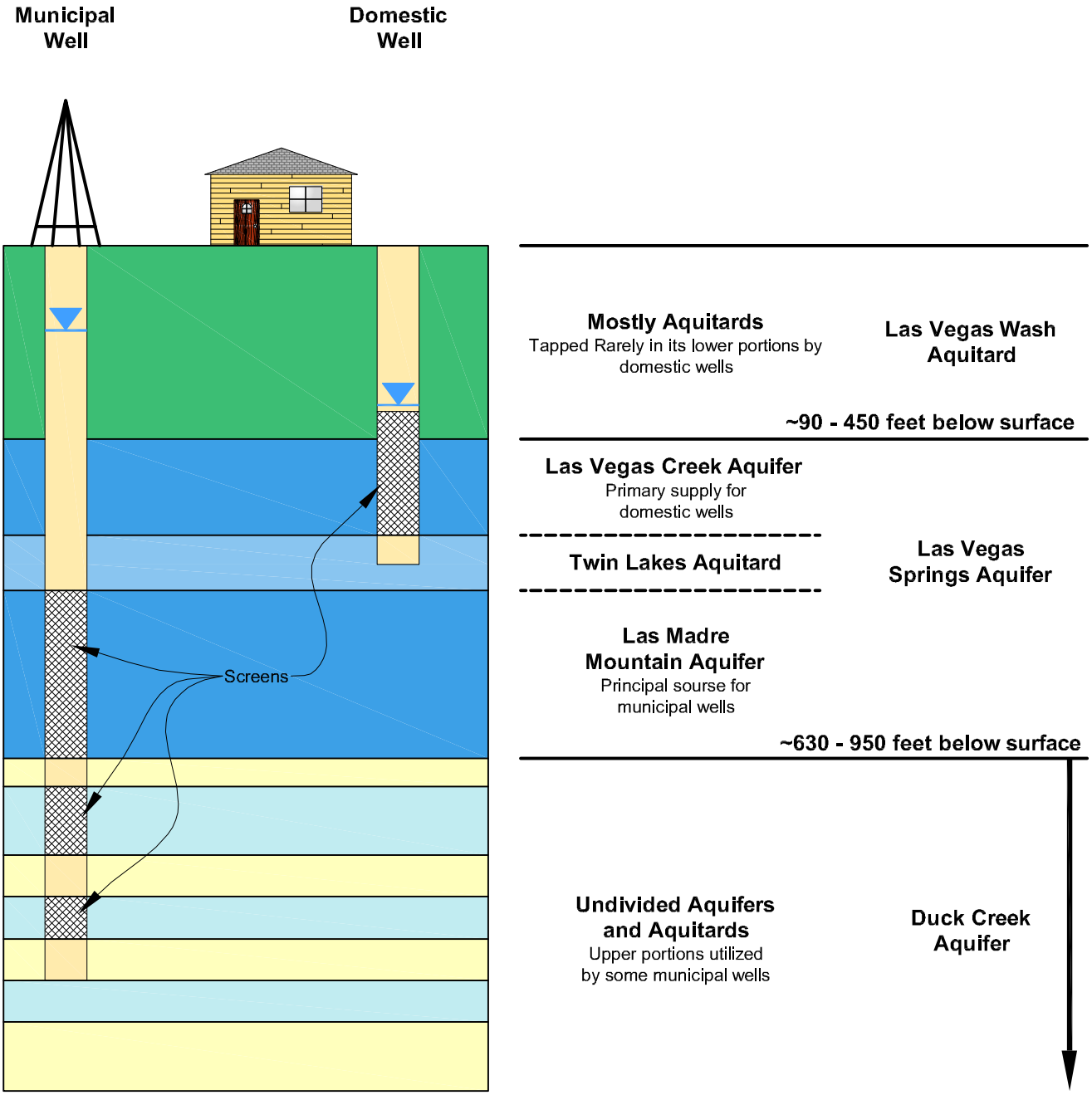
FIGURE 5
LAS VEGAS VALLEY PHYSIOGRAPHIC FEATURES AND REGIONAL GROUNDWATER FLOW

TETRA TECH



Not to Scale

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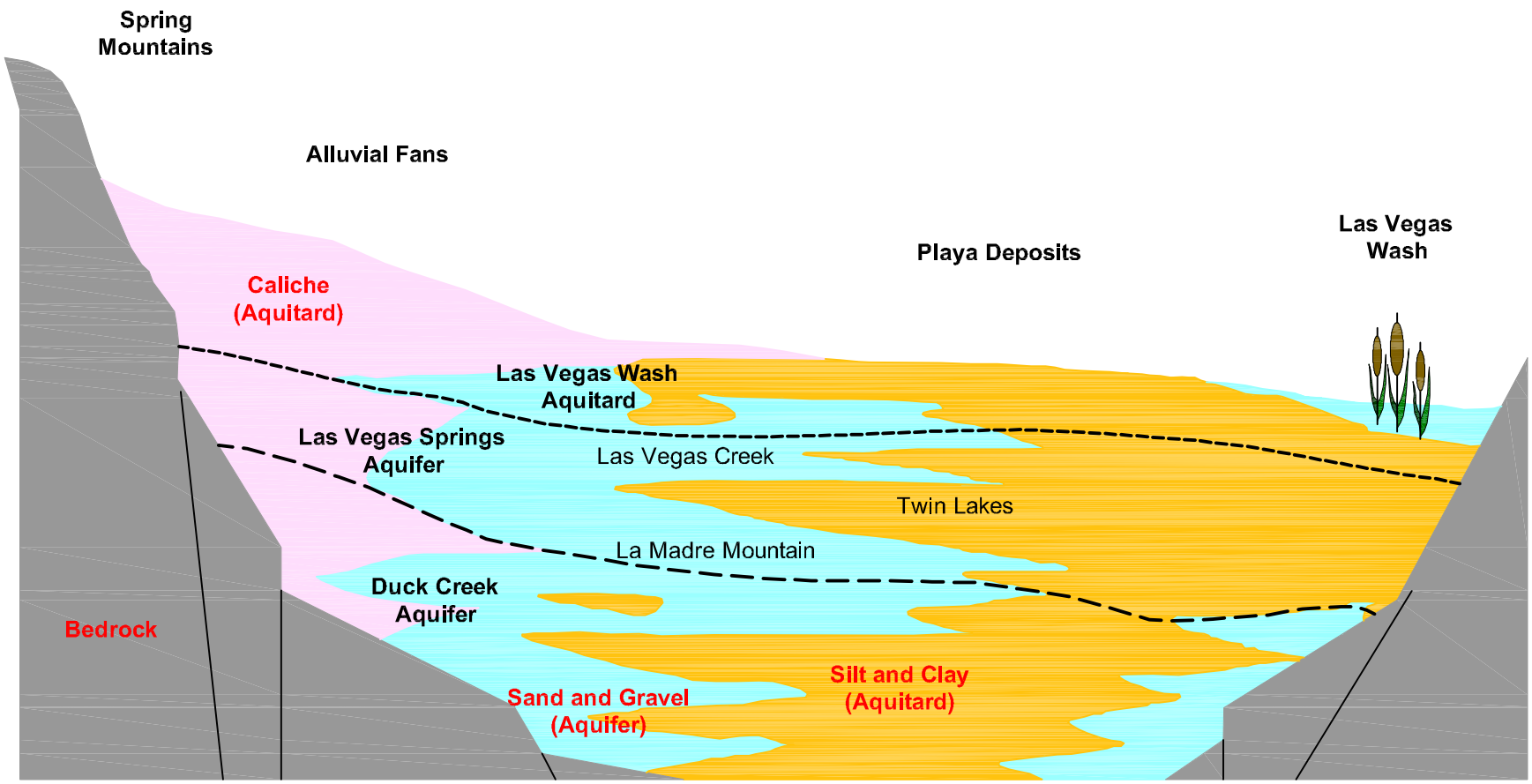
3661 South Maryland Parkway
Las Vegas, Nevada

FIGURE 6
HYDROGEOLOGIC UNITS OF THE LAS VEGAS VALLEY

TETRA TECH

Source: Modified from Leising 2004



Not to Scale

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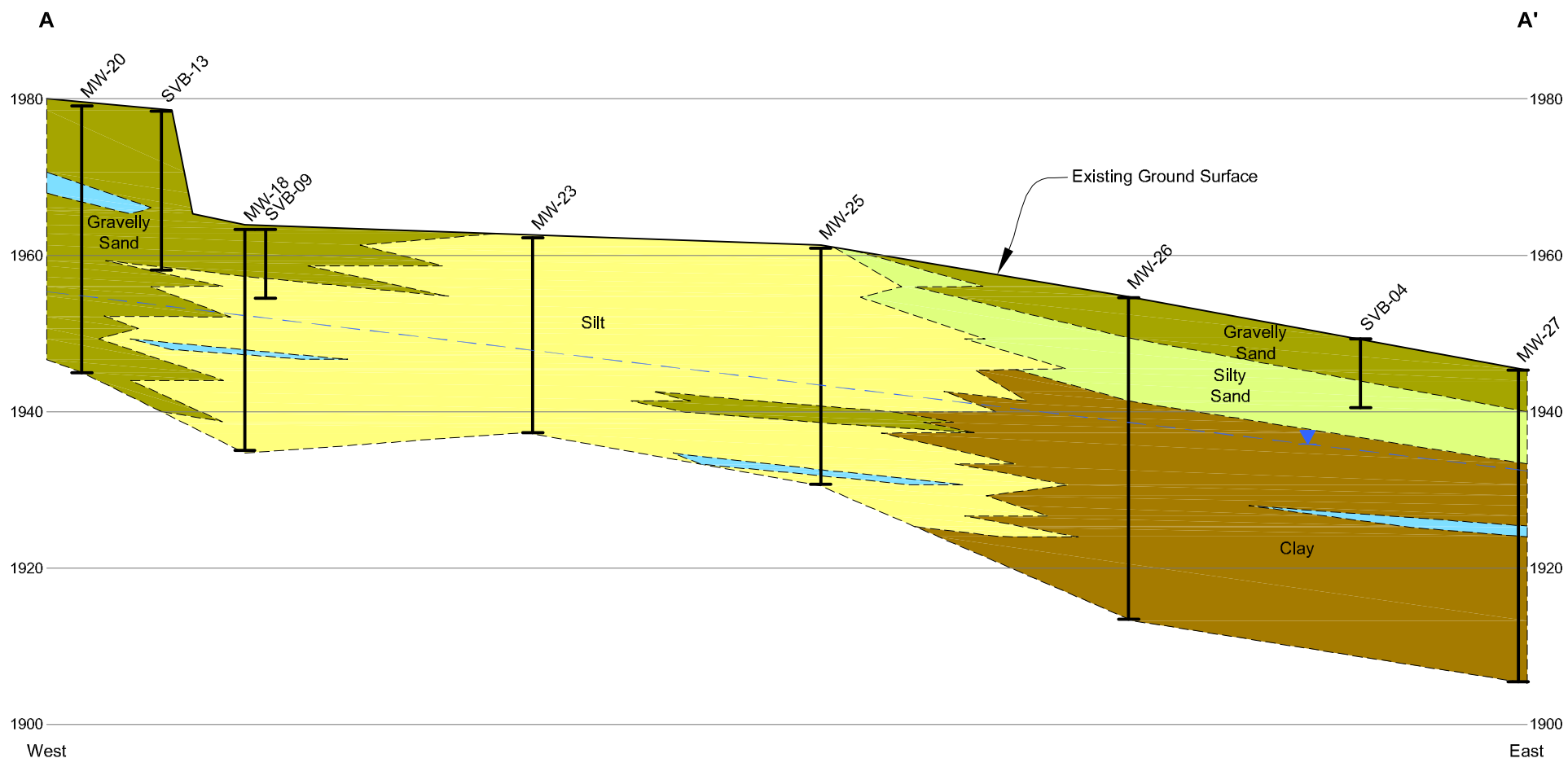
FIGURE 7
GENERALIZED CROSS SECTION OF THE LAS VEGAS VALLEY

TETRA TECH

Source: Leising 2004



Legend

- Approximate April 2007 Groundwater Surface
- Gravelly Sand
- Caliche
- Silty Sand
- Silt
- Clay

0 100 200
Horizontal Scale in Feet

0 10 20
Vertical Scale in Feet

Source: URS 2007

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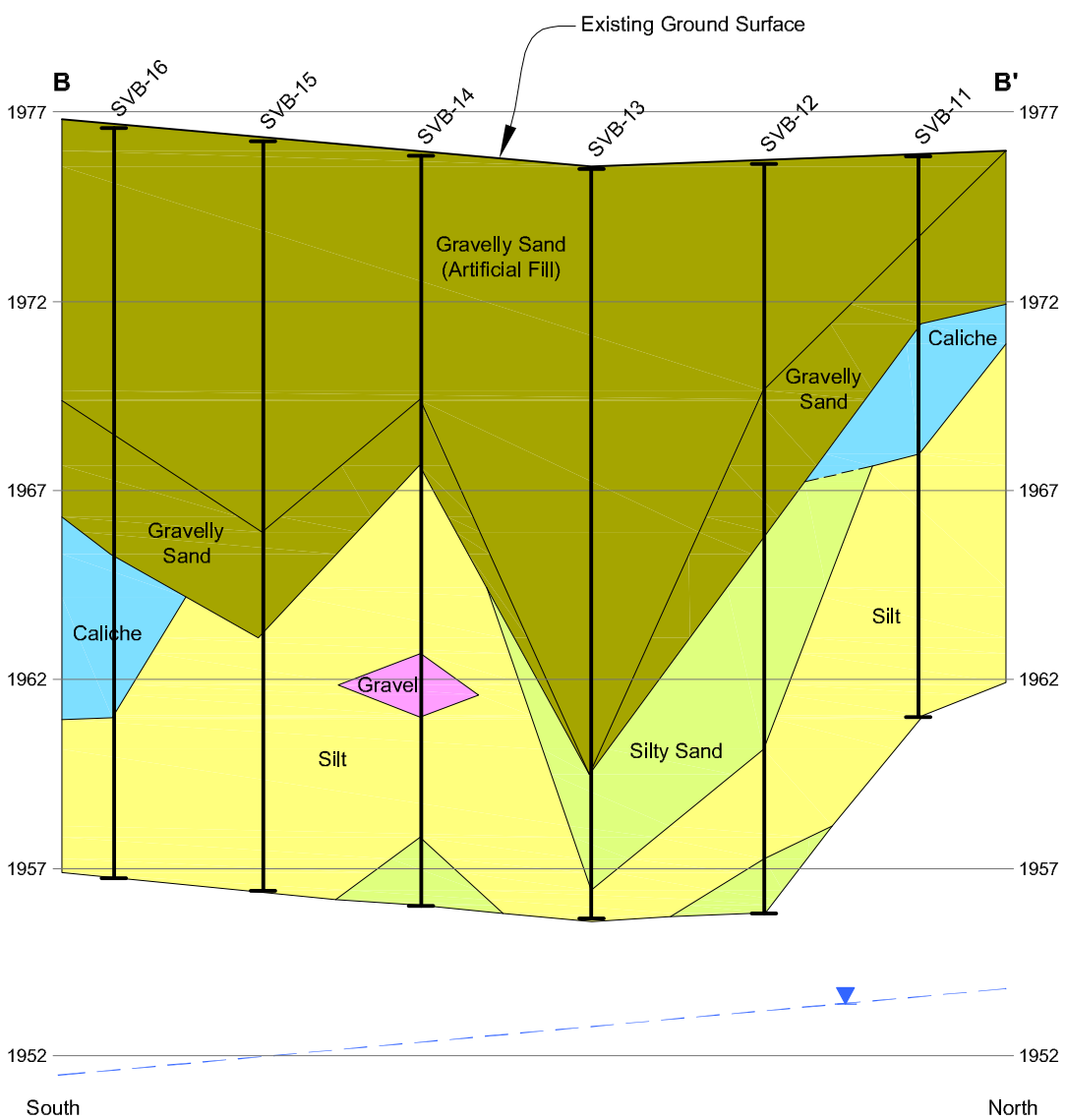
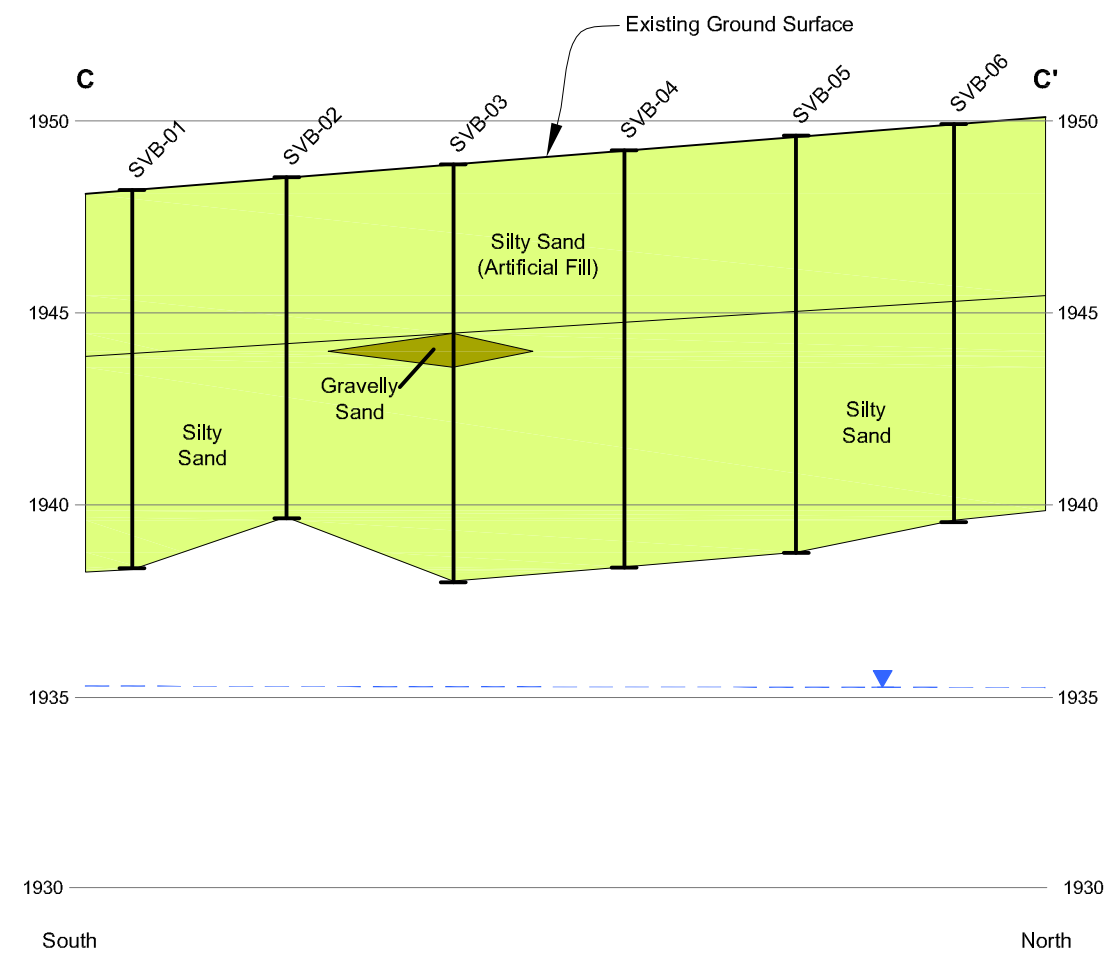
FIGURE 8
GEOLOGIC CROSS SECTION A - A'

TETRA TECH





Legend

- Approximate April 2007 Groundwater Surface
- Gravelly Sand
- Caliche
- Silty Sand
- Silt
- Gravel

Source: URS 2007

0 35 70
Horizontal Scale in Feet

0 2.5 5
Vertical Scale in Feet

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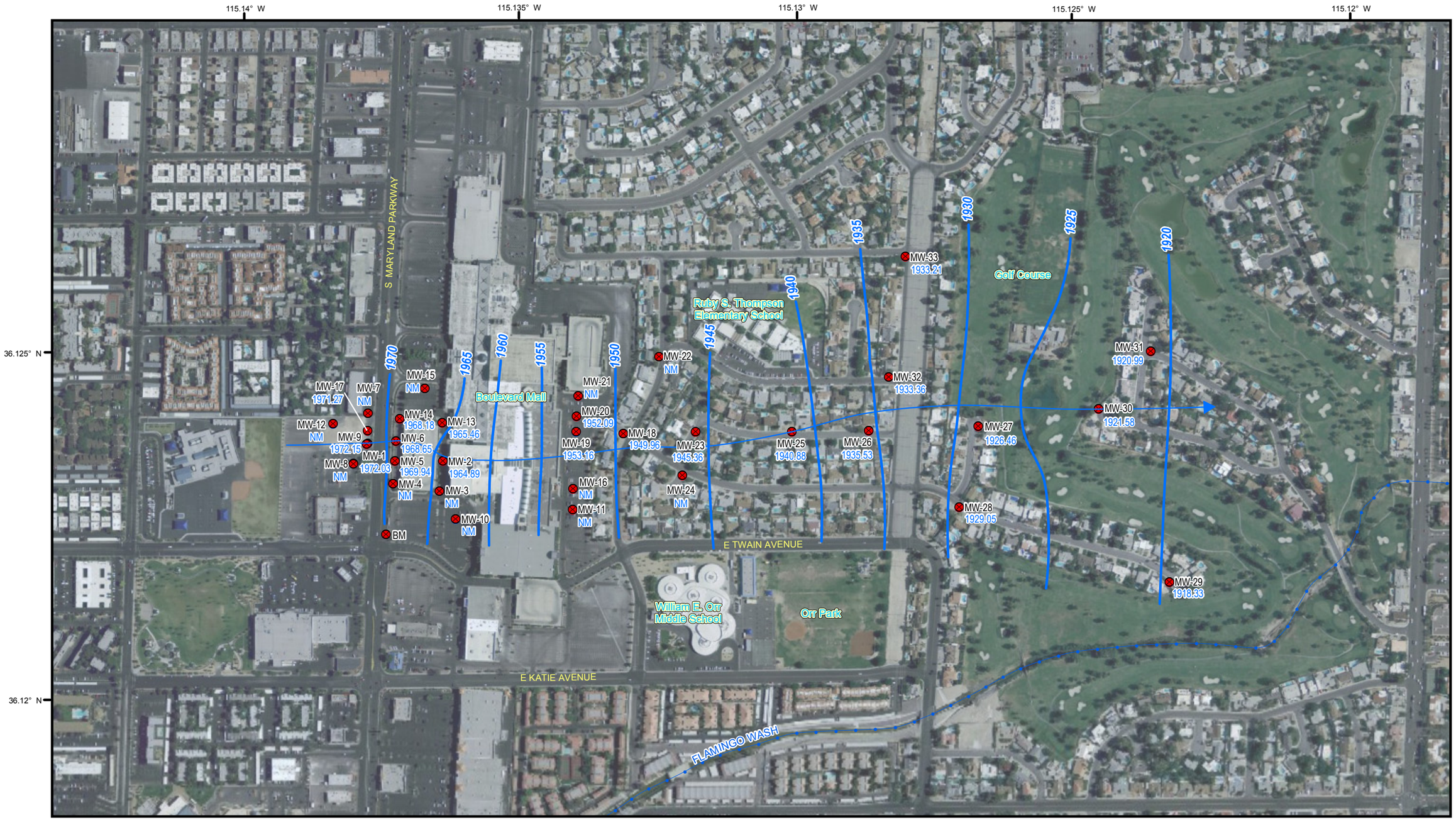
FIGURE 9
GEOLOGIC CROSS SECTIONS B - B' AND C - C'

TETRA TECH



Legend

- Monitoring Well Location
- Groundwater Elevation Contour (5 ft Intervals)
- Direction of Groundwater Flow
- 1965.46 Groundwater Elevation (ft amsl)
- NM Not Measured
- ft amsl Feet Above Mean Sea Level

N
W E
S

0 250 500 Feet
Approximate Scale in Feet

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FIGURE 10
SHALLOW GROUNDWATER POTENTIOMETRIC MAP
OCTOBER 2010

TETRA TECH

S:\Projects Directory\Private Sector - Other Offices\Maryland Square\Groundwater Cap\Figure 11.mxd troy.fegter

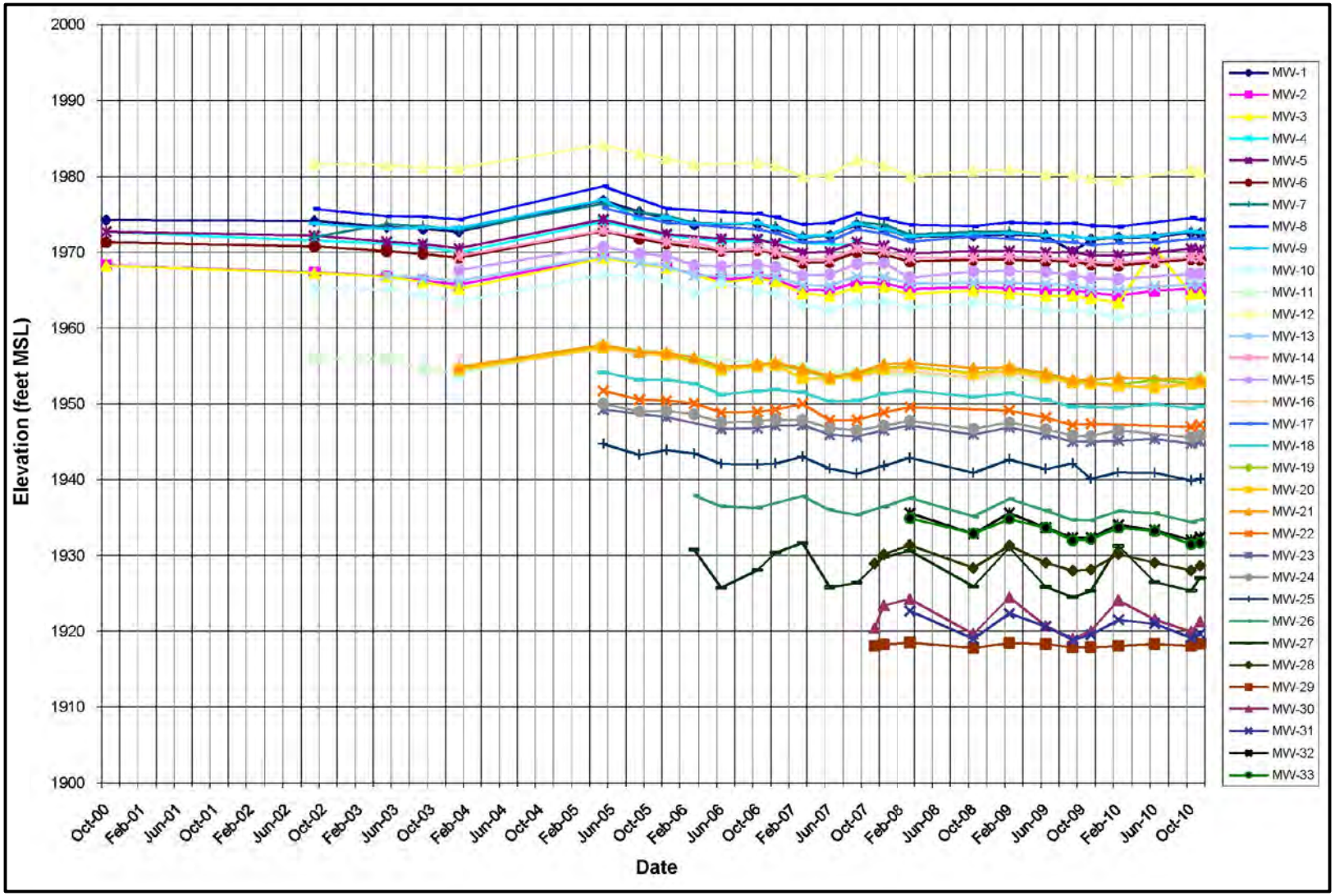

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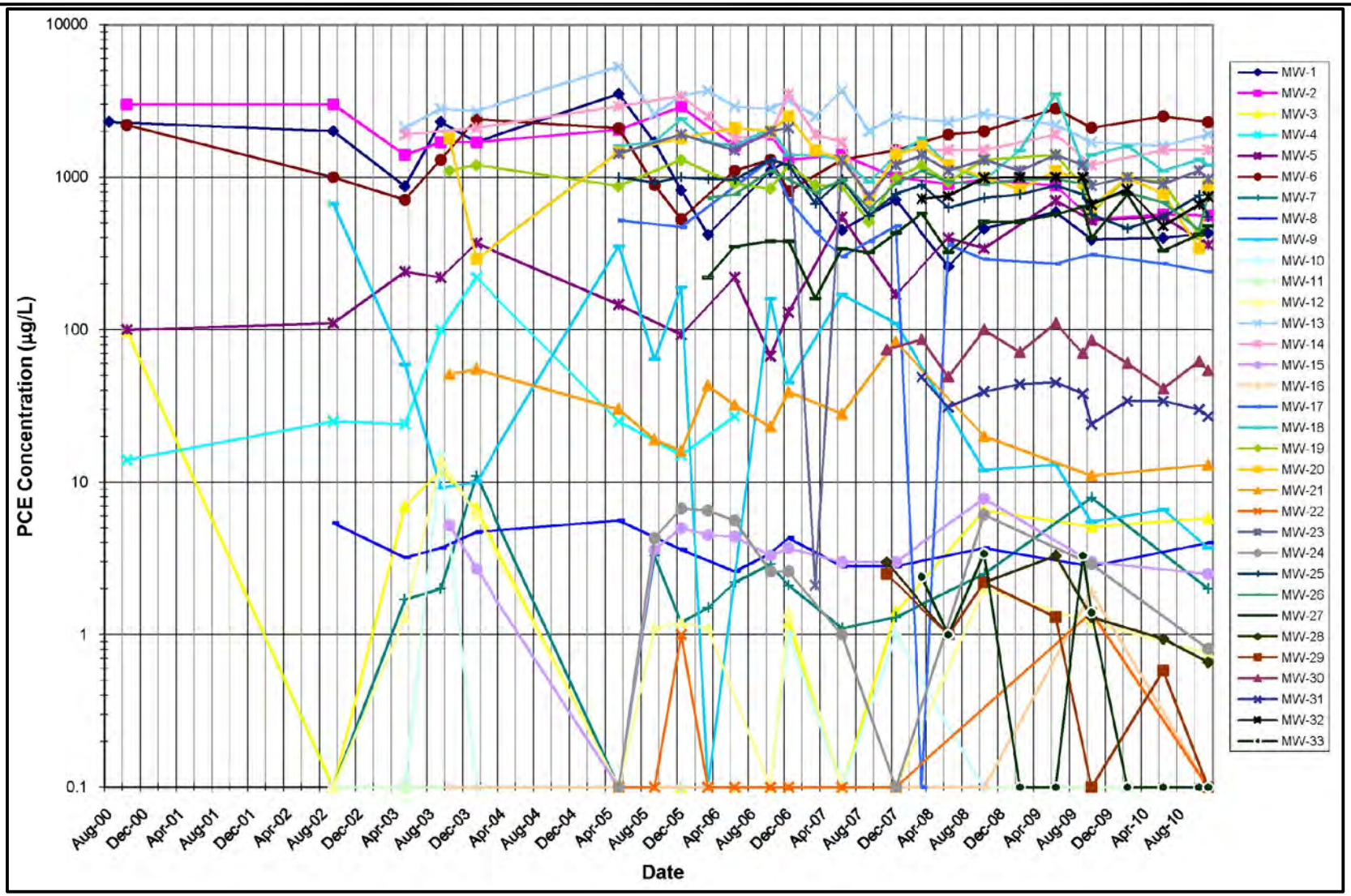
FIGURE 11
GROUNDWATER ELEVATION OVER TIME

TETRA TECH

Source: Modified from URS 2008



Note: Nondetected results are shown in the chart by a concentration of 0.1 ug/L.

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FIGURE 12b
GROUNDWATER PCE CONTAMINATIONS OVER TIME

TETRA TECH

Summary of PCE Soil Vapor Concentrations

Sample Number	Sample Depth[1]	Soil Type	Soil Vapor Concentrations µg/L	µg/m[3]	ppbv
SVB-01-05	5	Silty Sand (Af)	2.5	2,500	369
SVB-02-04	4	Silty Sand (Af)	3.0	3,000	443
SVB-02-10	10	Silty Sand	ND	ND	ND
SVB-03-05	5	Silty Sand (Af)	46	46,000	6,786
SVB-03-12	12	Silty Sand	0.8	800	118
SVB-04-05	5	Sand (Af)	0.4	400	59
SVB-04-12	12	Silty Sand	1.0	1,000	148
SVB-05-08	8	Silty Sand	25	25,000	3,688
SVB-05-98[2]	8	Silty Sand	17	17,000	2,508
SVB-05-13	13	Silty Sand	1.1	1,100	162
SVB-06-08	8	Silty Sand	ND	ND	ND
SVB-06-12	12	Silty Sand	12	12,000	1,770

Legend

- Approximate Location of Monitoring Well Installed by URS Showing Concentration (µg/L) of PCE in Groundwater. Analytical Data from October and December 2006.
- Approximate Location of Soil Vapor Sampling Borehole Showing Concentration (µg/m[3] and ppbv) of PCE in Soil Vapor Collected from Shallow and Deeper Soil Above Groundwater.
- Approximate Concentration Contour of PCE in Groundwater

PCE tetrachloroethene

ND Analyte not detected at or above the reporting limit

µg/L Micrograms per liter

µg/m[3] Micrograms per cubic meter

ppbv Parts per billion by volume

(1) Depth in feet (ft) below ground surface

(2) Soil Sample SVB-05-98 is a duplicate for sample SVB-05-08

N
W E
S

0 50 100 Feet

Approximate Scale in Feet

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FIGURE 13
SOIL VAPOR PCE CONCENTRATIONS ALONG SPENCER STREET

TETRA TECH

Sources: Clark County Assessors Web Site, URS 2007

S:\Projects Directory\Private Sector - Other Offices\Maryland Square\Groundwater Cap\Figure 14.mxd troy.fegter

Summary of PCE Soil Vapor Concentrations

Sample Number	Sample Depth(1)	Soil Type	Soil Vapor Concentrations ug/L	ug/m(3)	ppbv
SVB-07-05	5	Silty Sand (Af)	11	11,000	1,623
SVB-08-05	5	Silty Sand (Af)	2.7	2,700	398
SVB-08-10	10	Silty Sand	7.1	7,100	1,047
SVB-08-910(2)	10	Silty Sand	15	15,000	2,213
SVB-09-05	5	Silty Sand (Af)	9.0	9,000	1,328
SVB-09-10	10	Gravelly Sand	23	23,000	3,393
SVB-10-05	5	Sand	42	42,000	6,196
SVB-10-10	10	Sand	27	27,000	3,983
SVB-11-10	10	Sandy Silt	0.5	500	74
SVB-11-910(2)	10	Sandy Silt	0.4	400	59
SVB-11-15	15	Sandy Silt	ND	ND	ND
SVB-12-05	5	Gravelly Sand (Af)	ND	ND	ND
SVB-12-10	10	Gravelly Sand	3.0	3,000	433
SVB-13-05	5	Gravelly Sand (Af)	24	24,000	3,541
SVB-13-10.5	10.5	Gravelly Sand (Af)	37	37,000	5,458
SVB-13-910.5(2)	10.5	Gravelly Sand (Af)	45	45,000	6,639
SVB-13-20	20	Sandy Silt	35	35,000	5,163
SVB-14-10	10	Silt	87	87,000	12,835
SVB-14-20	20	Silty Sand	170	170,000	25,079
SVB-15-15	15	Silt	ND	ND	ND
SVB-15-20	20	Silt	0.2	200	30
SVB-16-05	5	Gravelly Sand (Af)	ND	ND	ND
SVB-16-10	10	Gravelly Sand	ND	ND	ND
SVB-16.20.5	20.5	Silt	0.6	600	89

Legend

- Approximate Location of Monitoring Well Installed by Converse Showing Concentration (ug/L) of PCE in Groundwater. ND is Non-detect, NS is Not Sampled. Analytical Data from December 2006.
- Approximate Location of Monitoring Well Installed by URS Showing Concentration (ug/L) of PCE in Groundwater. Analytical Data from October and December 2006.
- Approximate Location of Soil Vapor Sampling Borehole Showing Concentration (ug/m3 and ppbv) of PCE in Soil Vapor Collected from Shallow and Deeper Soil Above Groundwater.
- Approximate Concentration Contour of PCE in Groundwater

PCE tetrachloroethene

ND Analyte not detected at or above the reporting limit

ug/L Micrograms per liter

ug/m3) Micrograms per cubic meter

ppbv Parts per billion by volume

(1) Depth in feet (ft) below ground surface

(2) Soil Samples SVB-08-910, SVB-11-910, and SVB-13-910.5 are duplicates for samples SVB-08-10, SVB-11-10, and SVB-13-10.5 respectively

N
W E
S

0 50 100 Feet

Approximate Scale in Feet

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FIGURE 14
SOIL VAPOR PCE CONCENTRATIONS ALONG OTTAWA DRIVE AND THE BOULEVARD MALL

TETRA TECH

Sources: Clark County Assessors Web Site, URS 2007

S:\Projects Directory\Private Sector - Other Offices\Maryland Square\Groundwater Cap\Figure 3.mxd troy.fegter

APPENDIX A

Boring Logs and Well Construction Diagrams

Log No. MW-1

Date of Drilling: 08/09/00
Driller: Converse
Logged By: ALM

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT				
		SILTY SAND; dry, tan				
2						
4						
6						
8						
10						
12						
14						
16						
18						
20						

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Log No. MW-1

Date of Drilling: 08/09/00
Driller: Converse
Logged By: ALM

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
22		SANDY CLAY; very moist, light brown				
24						
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 30.0'

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Log No. MW-2

Date of Drilling: 10/02/00
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT				
		CLAYEY SILT; white				
2						
4		SILTY CLAY; moist, brown				
6		...slightly moist				
8		...light brown				
10						
12						
14						
		CLAY w/Silt; dark brown				
16						
18		...moist				
20		...very wet				

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Log No. MW-2

Date of Drilling: 10/02/00
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		CLAY; very wet, dark brown				
22		...wet				
24						
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 32.0'

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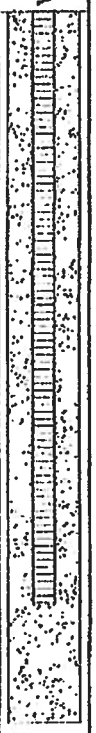
Log No. MW-3

Date of Drilling: 10/02/00
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		CLAY w/Silt; moist, dark brown				
22						
24						
26						
28						
30						
32						
34						
36						
38						
40						



End of Exploration at 32.0'

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Log No. MW-3

Date of Drilling: 10/02/00
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT				
		SILTY CLAY; dry, light brown				
2						
4						
		CLAY w/Silt; slightly moist, medium brown				
6						
8						
		SILTY CLAY; slightly moist, light brown				
10						
12						
		... medium brown				
14						
16						
18		...moist, dark brown				
20						

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Log No. MW-4

Date of Drilling: 10/02/01
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT Type II Fill				
2		SILTY CLAY; dry, light brown				
4						
6						
8						
10						
12						
14		CLAY w/Silt; slightly moist, medium brown				
16						
18						
20						

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Log No. MW-4

Date of Drilling: 10/02/00
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		CLAY w/Silt; slightly moist, medium brown				
22						
24						
		...very moist				
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 32.0'

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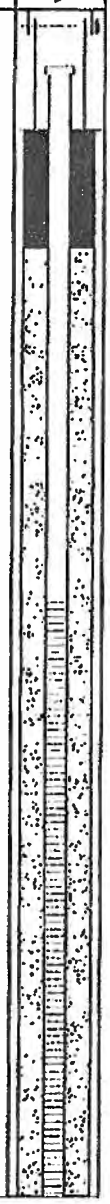
Log No. MW-5

Date of Drilling: 10/03/00
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT Type II Fill				
2						
		SILTY CLAY; dry, light brown				
4						
6						
8						
10		CLAY w/Silt; slightly moist, light brown				
12						
14						
16						
		CLAY w/Silt; slightly moist, medium brown				
18						
20						



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Log No. MW-5

Date of Drilling: 10/03/00
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
22						
24						
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 32.0'

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Log No. MW-6

Date of Drilling: 10/03/00
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT Type II Fill				
2		CLAY w/Silt; dry, medium brown				
4						
6						
8						
		slightly moist, light brown				
10						
		CLAY w/Silt; slightly moist, white/brown				
12						
14		CLAY w/Silt; hard, light brown				
16						
18		CALICHE; hard				
20						

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Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication
In Engineering and
Environmental Sciences

Log No. MW-6

Date of Drilling: 10/03/00
Driller: Converse
Logged By: JMW

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		CLAY w/Silt; slightly moist, light brown				
22						
24		....wet				
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 32.0'

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Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-7

Date of Drilling: 09/19/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT				
		SAND; dry, grey and brown				
2						
4						
6						
8						
10						
		CALICHE; dry, white				
12						
		SAND; dry, light brown				
14						
		CALICHE; dry, white				
16		SAND; dry, white				
18						
20						

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Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication
in Engineering and
Environmental Sciences

Log No. MW-7

Date of Drilling: 09/19/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		SILTY CLAY; wet, brown				
22		CLAY; wet, brown				
24						
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 30.0'

APPROVED BY OX

Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-8

Date of Drilling: 09/19/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT				
2		SAND; dry, white				
4						
6		SAND; dry, light brown				
8		CALICHE; dry, white				
10						
12		CALICHE; dry, white				
14		SAND w/Silt; dry, light brown				
16		SAND w/Silt; dry, white and grey				
18						
20						

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Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-8

Date of Drilling: 09/19/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
22		CALICHE; dry, white				
		CLAY w/Silt; wet, brown				
24						
		CLAY; wet, brown				
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 30.0'

APPROVED BY: ON

Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication
in Engineering and
Environmental Sciences

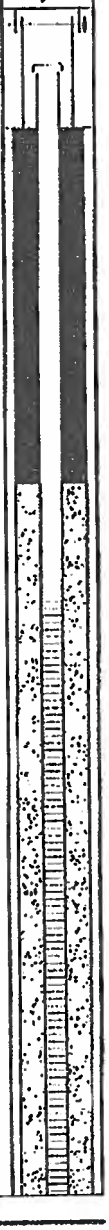
Log No. MW-9

Date of Drilling: 09/19/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT				
2		SAND; dry, brown				
4						
6		CALICHE; dry, white				
8		SAND w/Silt; dry, white				
10		CALICHE; hard				
12		SAND w/Silt; dry, white				
14						
16						
18						
20		CALICHE; dry, white				



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Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

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In Engineering and
Environmental Sciences

Log No. MW-9

Date of Drilling: 09/19/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		SANDY SILT; dry, brown				
22						
24		CLAY; wet, brown				
26						
28						
30						
32						
34						
36						
38						
40						

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Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-9

Date of Drilling: 09/19/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.				
42						
44						
46						
48						
50						
52						
54						
56						
58						
60						

End of Exploration at 50.0'

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Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-10

Date of Drilling: 09/20/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT				
		SAND; dry, grey				
2						
4		CALICHE; dry, white				
		SAND; dry, brownish grey				
6						
8						
10						
12						
14						
16						
18						
20						

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Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-10

Date of Drilling: 09/20/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		SILTY CLAY; wet, brown				
22						
24						
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 30.0'

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Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-11

Date of Drilling: 09/20/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT				
		SAND; dry, brown				
2						
4						
6						
8		SAND; dry, brownish grey				
10						
		SAND; dry, light brown				
12						
14		FINE SAND; dry, white				
16						
18						
20						

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3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

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Environmental Sciences

Log No. MW-11

Date of Drilling: 09/20/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
22						
24		SAND; dry, brown				
		SILTY CLAY; wet, brown				
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 33.5'

APPROVED BY ON

Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication
In Engineering and
Environmental Sciences

Log No. MW-12

Date of Drilling: 09/20/02
Driller: Converse
Logged By: AMK

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT				
2		SAND; dry, brown				
4						
6		FINE SAND; dry, brown				
8						
10						
12						
14		CALICHE; dry, white				
16						
18						
20						

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3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-12

Date of Drilling: 09/20/02
Driller: Converse
Logged By: AMK

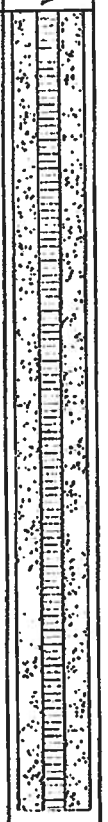
Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
22						
24		SANDY SILT; dry, brown				
		SAND; dry, brown				
26						
28						
30						
32						
34						
36						
38						
40						



End of Exploration at 33.5'

APPROVED BY OK

Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication in Engineering and Environmental Sciences

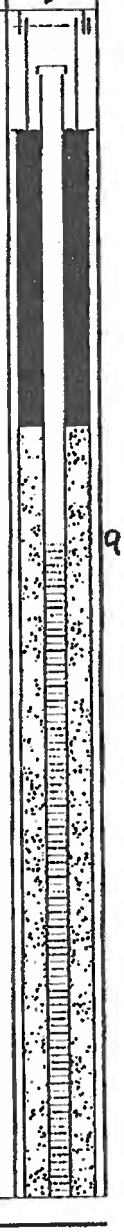
Log No. MW-13

Date of Drilling: 05/06/03
Driller: Converse
Logged By: ALM

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		ASPHALT Type II Fill				
2						
4		CALICHE				
6		SANDY SILT w/gravel; moist,tan				
8						
10						
12						
14						
16						
18		CLAYEY SAND; moist, tan				
20		SANDY CLAY; very moist, red				



9'

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3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication
In Engineering and
Environmental Sciences

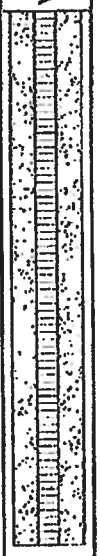
Log No. MW-13

Date of Drilling: 05/06/03
Driller: Converse
Logged By: AL.M

Location:
Borehole Diameter:
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Air Rotary
Driving Wt. and Drop:

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.				
22						
24						
26						
28						
30						
32						
34						
36						
38						
40						



End of Exploration at 29.0'

APPROVED BY: O.N.

Maryland Square
3661 South Maryland Parkway
Las Vegas, NV

Project No.
00-43367-05

Drawing No.

Converse Consultants

Over 60 Years of Dedication
In Engineering and
Environmental Sciences

Log No. MW-14

Date of Drilling: 11/14/03
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

DRAFTED BY ESB

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		Asphalt/Aggregate base				
2		Clayey sand; tan, slightly moist				
4						
6						
8						
10						
12						
14		Sandy lean clay; few caliche, gravel, white, moist	50/6			
16						
18						
20			13/20			

APPROVED BY ON

Kishnor/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

Drawing No.

Log No. MW-14

14

Date of Drilling: 11/14/03
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		Sandy lean clay; few caliche, gravel, white, moist				
22						
		Sandy lean clay; brown, moist				
24		Silty sand with gravel				
26						
28						
		Silty sand with gravel				
30						
32						
34						
36						
38						
40						

End of Exploration at 40.0'

TRANSFERRED BY: [illegible]

APPROVED BY: [illegible]

Kishnor/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

Over 50 Years of Dedication
In Engineering and
Environmental Sciences

Log No. MW-15

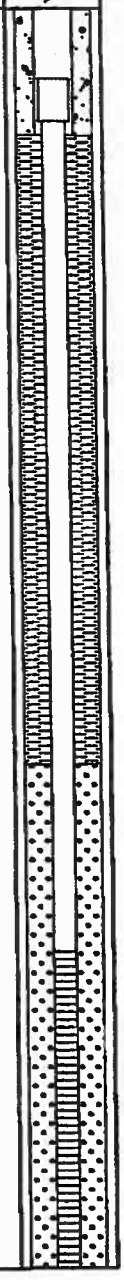
Date of Drilling:
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mogile B-57
Driving Wt. and Drop:

DRAFTED BY ESB

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		Asphalt				
2		Type II fill				
		Sand				
4						
6						
8						
		Silty Sand				
10						
12						
14						
16						
18						
20						



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Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-15

15

Date of Drilling:
Driller: Elite
Logged By: JI

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mogile B-57
Driving Wt. and Drop:

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
22		Caliche				
24		Sandy Clay				
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 30.5'

Klahnor/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Converse Consultants

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In Engineering and
Environmental Sciences

Drawing No.

LOG NO. MW-10

16

Date of Drilling:
Driller: Hilti
Logged By: U

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Description	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		Asphalt				
		Sand and Gravel Type II, loose:				
2		Sand with gravel; light brown				
4						
6						
		Gravel with sand and clay				
8		...little gravel				
10		Sandy clay; light brown				
12						
14		Clayey sand; light brown, slightly moist				
16		Gravel; loose				
		Clayey sand; light brown, slightly moist				
18						
20		Caliche				

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

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In Engineering and
Environmental Sciences

Log No. MW-16 16

Date of Drilling:
Driller: Elite
Logged By: JI

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment Mobile B-57
Driving Wt. and Drop:

DRAFTED BY 11/11/05

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		Sandy lean clay; reddish, slightly moist				
22						
24						
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 35.0'

APPROVED BY ON

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

Drawing No.

Log No. B-17

Date of Drilling: 11/12/03
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

DRAFTED BY ESB

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		Asphalt/ Aggerate base				
		Clayey sand; light brown, slightly moist				
2						
4						
		Caliche				
6		...few gravel				
8						
		Clayey sand; light brown, slightly moist				
10						
12						
14						
16						
18						
20						

APPROVED BY ON

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

Log No. B-17

Date of Drilling: 11/12/03
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

DRAFTED BY ESB

Depth (ft)	Graphic Log	SUMMARY OF SUBSURFACE CONDITIONS This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
22		Sandy lean clay; reddish brown, moist				
24						
26						
28						
30						
32						
34						
36						
38						
40						

APPROVED BY ON

End of Exploration at 35.0'

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

URS

BOREHOLE LOG
MW-17

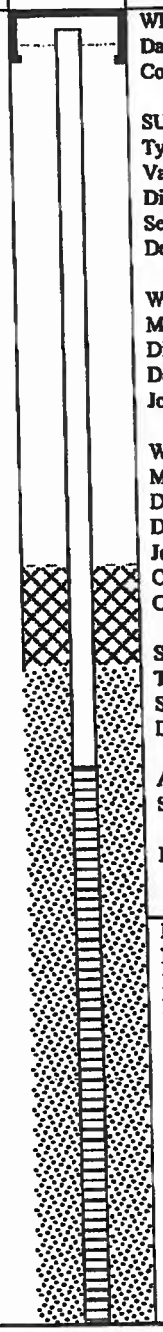
Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/14/05
Date Completed:	3/14/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	0930							Asphalt
1								
2								
3						ML		0'-7' Gravely SILT: lt cream, sl. moist
4								
5								
6								
7								
8						SP		7'-11' SAND: lt. Tan, poorly sorted, fine grained, moist
9								
10								
11								
12								
13								
14								
15								
16								
17								
18						ML		11' –37' Sandy SILT: lt. tan to creamy, sl. moist to v. moist
19								
20								
21								
22								
23								
24								
25								

Well: MW-17
Elev.: 1,990.92



Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 3/14/05
Comp. Rep: S. Ball

SURFACE COMPLETION
Type: Flush mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-15'
Joints: flush

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 15'-30'
Joints: flush
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type : Montgomery
Size: 3
Depth: 13'-37'

ANNULUS SEAL
Sand Pack: bentonite
Depth: 11'-13'
Borehole: concrete
Depth: 0'-11'

REMARKS
No sampling was performed
Borehole was drilled an a
Monitor well was installed.

URS

BOREHOLE LOG
MW-17

Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/14/05
Date Completed:	3/14/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-17 Elev.: 1,990.92	Remarks/Well Information
26										
27										
28										
29										
30										
31						ML		Same as above.		
32										
33										
34										
35										
36	1125									
37								Bottom of borehole @ 37' bgs. Groundwater encountered at approximately 20' bgs.		
38										
39										
40										
41										
42										
43										
44										REMARKS
45										
46										
47										
48										
49										
50										
51										

Log No. B-18

Date of Drilling: 11/12/03
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

DRAFTED BY ESB

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		Asphalt/Agregate Type II				
2		Clayey sand; light brown, slightly moist				
4						
6						
8						
10		Silty sand; few gravels, dark brown, slightly moist				
12		Poorly graded sand with silt; light brown, slightly moist				
14						
16						
18						
20						

APPROVED BY ON

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

Log No. B-16

Date of Drilling: 11/12/03
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

DRAFTED BY ESB

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
22						
24						
26						
		Sandy lean clay; light brown, moist				
28						
30						
32						
34						
36						
38						
40						

APPROVED BY ON

End of Exploration at 35.0'

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

URS

BOREHOLE LOG
MW-18

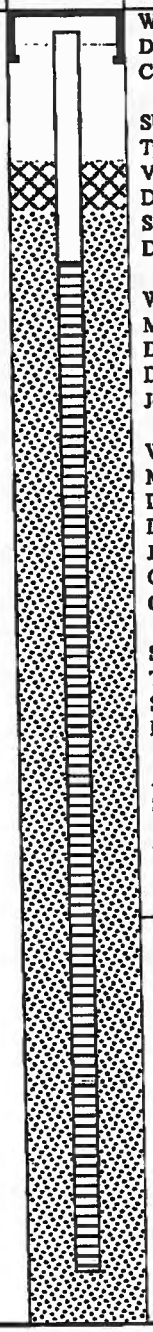
Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/10/05
Date Completed:	3/10/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	0834							Asphalt
1								0'-3' Gravely SILT: lt. tan
2								3'-7' color change to lt. brn
3						ML		
4								
5								
6								
7								
8								
9								
10						ML		7'-15' Sandy SILT: lt. tan, sl. moist to v. moist
11								
12								
13								
14								
15						Cali che		15'-16' CALICHE: wht, tan, v. hard, v. moist
16								
17								
18								
19								
20								
21						ML		16'-27' SILT: brn, v. moist
22								
23								
24								
25								

Well: MW-18
Elev.: 1,962.87



Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 3/14/05
Comp. Rep: S. Ball

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-5'
Joints: flush

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 5'-25'
Joints: flush
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type : Montgomery
Size: 3
Depth: 4'-27'

ANNULUS SEAL
Sand Pack: bentonite
Depth: 3'-4'
Borehole: concrete
Depth: 0'-3'

REMARKS
No sampling was performed
Borehole was drilled an a
Monitor well was installed.

URS

BOREHOLE LOG
MW-18

Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/10/05
Date Completed:	3/10/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-18 Elev.: 1,962.87	Remarks/Well Information
26	118					ML		same as above		
27								Bottom of borehole @ 27' bgs. Groundwater encountered at Approximately 9' bgs.		
28										
29										
30										
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										REMARKS
45										
46										
47										
48										
49										
50										
51										

Log No. MW-19

Date of Drilling: 11/13/03
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

DRAFTED BY ESB

SUMMARY OF SUBSURFACE CONDITIONS

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Depth (ft)	Graphic Log	Description	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		Asphalt/Aggregate				
2		Clayey sand; light brown, slightly moist				
4						
6		Silty sand with gravel; dark brown, slightly moist				
8						
10		...tan				
12						
14		...brown				
16						
18						
20						

APPROVED BY ON

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

Log No. MW-19 14

Date of Drilling: 11/13/03
Driller: Hile
Logged By: H

Location:
Borehole Diameter: 8.25
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

SUMMARY OF SUBSURFACE CONDITIONS

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Depth (ft)	Graphic Log	Description	Blow Count	PID/OVA Readings (ppm)	Hydrocarbon Odor Smelled	Well Detail
22		Sandy lean clay; reddish brown, very moist				
24						
26						
28						
30						
32						
34		Caliche				
36						
38						
40						

End of Exploration at 35.0'

PREPARED BY: OK
APPROVED BY:

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Converse Consultants

Over 50 Years of Dedication
In Engineering and
Environmental Sciences

Drawing No.

Log No. MW-20

Date of Drilling: 11/13/03 | Location: | Ground Surface Elevation (ft):
Driller: Elite | Borehole Diameter: 8.25" | Equipment: Mobile B-57
Logged By: JJ | Groundwater Depth (ft): | Driving Wt. and Drop:

DRAFTED BY ESB

SUMMARY OF SUBSURFACE CONDITIONS

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Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		Asphalt/Aggregate				
2		Silty sand with gravel; dark brown, slightly moist				
4						
6		Clayey sand; tan, slightly moist				
		Poorly graded sand with silt; light brown, slightly moist				
8		Clayey sand few gravels; tan, slightly moist				
10		Caliche				
12		Clayey sand with gravel; tan, slightly moist				
14						
16						
18						
20		Poorly graded sand with silt; light brown, slightly moist				

APPROVED BY ON

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

Drawing No.

Log No. MW-20 70

Date of Drilling: 11/13/03
Driller: Ellis
Logged By: JD

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

SUMMARY OF SUBSURFACE CONDITIONS

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Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Stability	Well Design
22						
24						
26						
28						
30						
32						
34						
36						
38						
40						

End of Exploration at 35.0'

DRAWN BY: JB
APPROVED BY: JC

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

Over 50 Years of Dedication
In Engineering and
Environmental Sciences

Log No. MW-21

Date of Drilling: 11/1/03
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

DRAFTED BY: ESB

APPROVED BY: DC

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Description	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
0		Asphalt/Aggregate				
2		Clayey sand with gravel; tan, slightly moist				
4		Sandy lean clay with gravel; tan, slightly moist				
6						
8						
10						
12						
14						
16						
18		...tan				
20						

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

Drawing No.

Converse Consultants

Over 50 Years of Dedication
In Engineering and
Environmental Sciences

Log No. MW-21

21

Date of Drilling: 11/13/03
Driller: Elite
Logged By: JJ

Location:
Borehole Diameter: 8.25"
Groundwater Depth (ft):

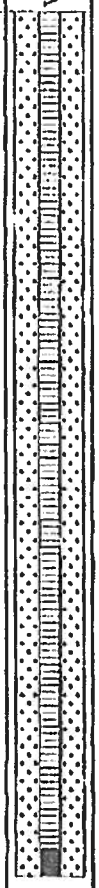
Ground Surface Elevation (ft):
Equipment: Mobile B-57
Driving Wt. and Drop:

DRAFTED BY ESB

SUMMARY OF SUBSURFACE CONDITIONS

This log is part of the report prepared by Converse for this project and should be read with the report. This summary applies only at the location and time of the exploration. Subsurface conditions may differ at other locations and may change at this location with the passage of time. The data presented is a simplified model of the actual conditions encountered.

Depth (ft)	Graphic Log	Summary of Subsurface Conditions	Blow Count	PID/OVA Reading (ppm)	Hydrocarbon Odor/Staining	Well Design
		Sandy lean clay; light brown, slightly moist				
22		Clayey sand; light brown, slightly moist				
24		Sandy lean clay; tan, slightly moist				
26						
28						
30						
32						
34						
36						
38						
40						



End of Exploration at 35.0'

APPROVED BY ON

Kishner/Maryland Square
3661 So. Maryland Parkway
Las Vegas, Nevada

Project No.
00-43367-06

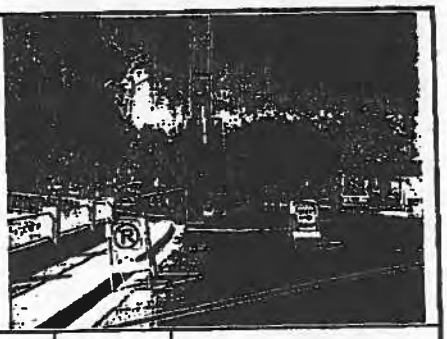
Drawing No.

Converse Consultants

Over 50 Years of Dedication in Engineering and Environmental Sciences

URS

BOREHOLE LOG
MW-22



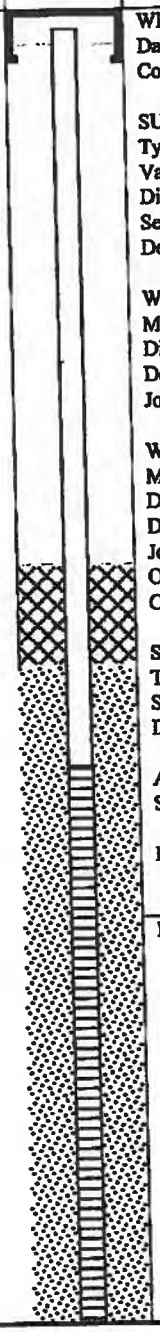
Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/10/05
Date Completed:	3/10/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	1310							Asphalt
1								
2						ML		0'-5' SILT: lt tan, dry, hard
3								
4								
5						Cali che		5'-7' CALICHE: wht., v. hard, moist
6								
7								
8								
9								
10								
11								
12								
13								
14								
15						ML		7'-37' Gravely SILT: lt. tan to lt. brn, sl. moist to moist
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

Well: MW-22
Elev.: 1,974.76



Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 3/10/05
Comp. Rep: S. Ball

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-15'
Joints: flush

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 15'-35'
Joints: flush
Opening: 0.02" slotted
Cap: expanding

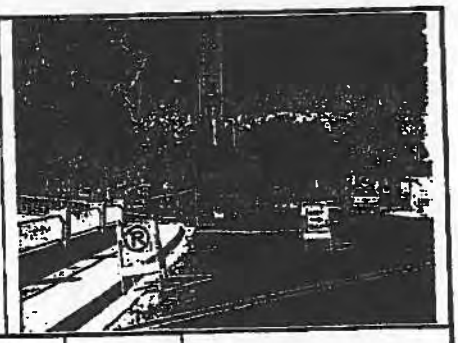
SAND FILTER PACK
Type : Montgomery
Size: 3
Depth: 13'-37'

ANNULUS SEAL
Sand Pack: bentonite
Depth: 11'-13'
Borehole: concrete
Depth: 0'-11'

REMARKS

URS

BOREHOLE LOG
MW-22



Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

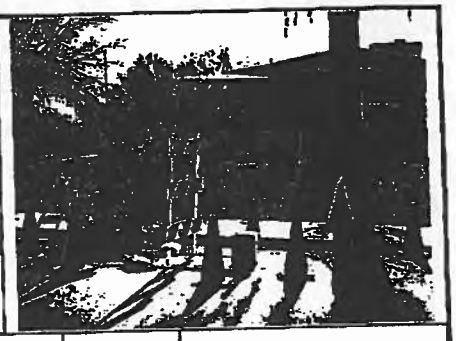
Project No. 2698724.00005

Date Started:	3/10/05
Date Completed:	3/10/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-22 Elev.: 1,974.76	Remarks/Well Information
26										
27										
28										
29										
30										
31						ML		same as above.		
32										
33										
34										
35										
36	1600									
37								Bottom of borehole @ 37' bgs Groundwater encountered at approximately 22' bgs.		
38										
39										
40										
41										
42										
43										
44										REMARKS
45										
46										
47										
48										
49										
50										
51										

URS

BOREHOLE LOG
MW-23



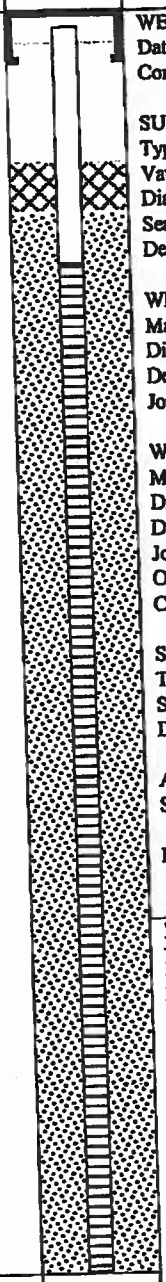
Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/9/05
Date Completed:	3/9/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	1310							Asphalt
1						SM		0'-2' Gravely silty SAND: dry
2								
3						ML		2'-5' SILT: brn, some gravel, moist
4								
5								
6								
7								
8								
9								
10								
11								
12								
13						ML		5'-25' Sandy SILT: lt. brn, dry to v. moist
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								Bottom of borehole @ 25 ft. bgs Groundwater encountered approx. 9' bgs

Well: MW-23
Elev.: 1,962.32



Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 3/9/05
Comp. Rep: S. Ball

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-5'
Joints: flush

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 5'-25'
Joints: flush
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type: Montgomery
Size: 3
Depth: 4'-25'

ANNULUS SEAL
Sand Pack: bentonite
Depth: 3'-4'
Borehole: concrete
Depth: 0'-3'

REMARKS
No sampling was performed
Borehole was drilled an a
Monitor well was installed.

URS

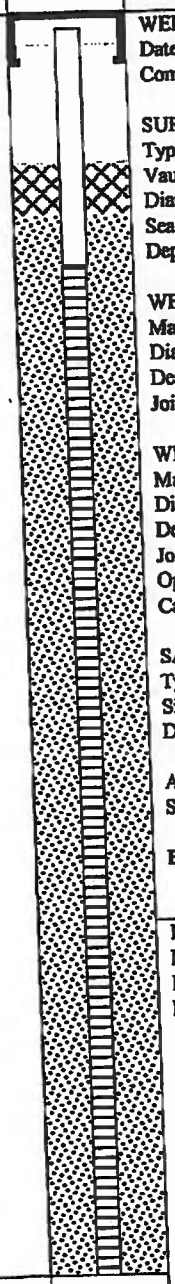
BOREHOLE LOG
MW-24

Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/9/05
Date Completed:	3/9/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	1222							Asphalt
1								
2								
3								
4								
5								
6								
7								
8						SM		0'-16' Fine SAND: lt. brn, dry to v. moist, find grained sand
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20						ML		16'-25'Sandy SILT: brn to lt. brn, v. moist, fine grained sand
21								
22								
23								
24		1350						
25								Bottom of borehole @ 25 ft. bgs Groundwater encountered approx. 9' bgs



Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 3/9/05
Comp. Rep: S. Ball

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-5'
Joints: flush

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 5'-25'
Joints: flush
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type : Montgomery
Size: 3
Depth: 4'-25'

ANNULUS SEAL
Sand Pack: bentonite
Depth: 3'-4'
Borehole: concrete
Depth: 0'-3'

REMARKS
No sampling was performed
Borehole was drilled an a
Monitor well was installed.

P:\AlPhillips\Maryland Square\MS June 2005 Report\MS B Log MW-24.doc

URS

BOREHOLE LOG
MW-25

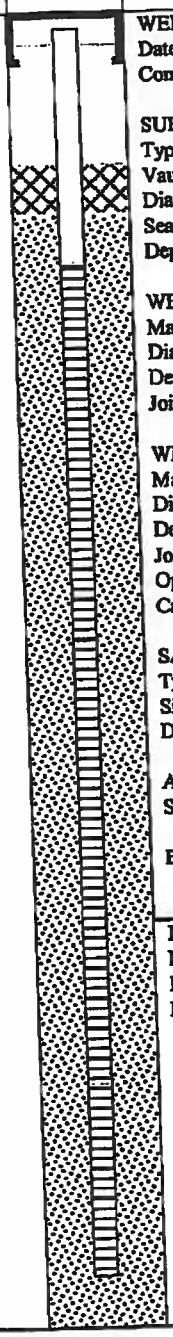
Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/11/05
Date Completed:	3/11/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	1028							Asphalt
1								
2								
3								
4						ML		0'-10' Sandy SILT: brn, dry to sl. moist
5								
6								
7								
8								
9								
10						GW		10'-13' Silty Gravel
11								
12								
13								
14								
15								
16								
17								
18						ML		13'-27' Sandy SILT: brn, v. moist, coarse sand
19								
20								
21								
22								
23								
24								
25								

Well: MW-25
Elev.: 1,960.74



Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 3/11/05
Comp. Rep: S. Ball

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-5'
Joints: flush

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 5'-25'
Joints: flush
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type : Montgomery
Size: 3
Depth: 4'-30'

ANNULUS SEAL
Sand Pack: bentonite
Depth: 3'-4'
Borehole: concrete
Depth: 0'-3'

REMARKS
No sampling was performed
Borehole was drilled an a
Monitor well was installed.

URS

BOREHOLE LOG
MW-25

Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

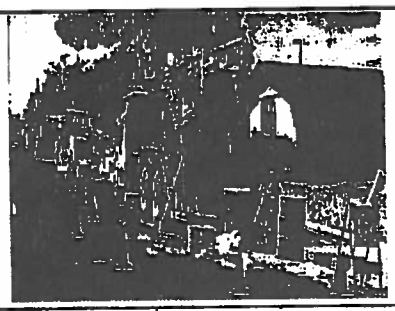
Project No. 2698724.00005

Date Started:	3/11/05
Date Completed:	3/11/05
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Scott Ball

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-25 Elev.: 1,960.74	Remarks/Well Information
26						ML		Same as above.		
27						Cali che		27'-28' CALICHE		
28						ML		28'-30' SILT		
29										
30								Bottom of borehole @ 30 ft. bgs Groundwater encountered at Approximately 10' bgs.		
31										
32										
33										
34										
35										
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
51										

URS

BOREHOLE LOG
MW-26



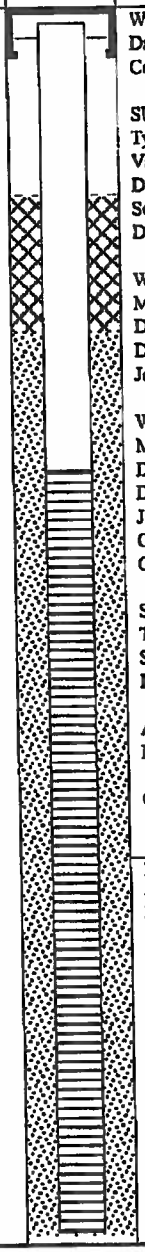
Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/22/06
Date Completed:	3/22/06
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	Cuttings Inspection
Logged By:	Randy S. Kyes

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	1030							Asphalt
1						GW		0'-5' Sandy GRAVEL, poor sort, (road base), dry
2								
3								
4								
5	1115					SM		5'-13' Silty SAND, brn, dry, some small gravel.
6								
7								
8								
9								
10								
11								
12								
13						CL		13'-24' Silty CLAY, brn, moist, some pea gravel.
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24						CL		24'-40' Silty CLAY, brn, v. wet
25								

Well: MW-27
Elev.:



Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 3/22/05
Comp. Rep: R.S. Kyes

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-10'
Joints: flush

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 10'-35'
Joints: flush
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type : Montgomery
Size: 3
Depth: 7'-40'

ANNULUS SEAL
Bentonite
Depth: 4'-7'
Concrete
Depth: 0'-4'

REMARKS
No sampling performed. borehole was drilled and a monitor well was installed.

Soil profile characterized by inspection of drill cuttings.

URS

BOREHOLE LOG
MW-26

Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/22/06
Date Completed:	3/22/06
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	Cuttings Inspection
Logged By:	Randy S. Kyes

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-25 Elev.: 1,960.74	Remarks/Well Information
26										
27						CL		24'-40' Silty CLAY, brn, v. wet		
28										
29										
30										
31										
32										
33						CL		24'-40' Silty CLAY, brn, v. wet		
34										
35										
36										
37										
38										
39	1150									
40								Bottom of borehole @ 40 ft. bgs Groundwater encountered at Approximately 15' bgs.		
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
51										

URS

BOREHOLE LOG
MW-27

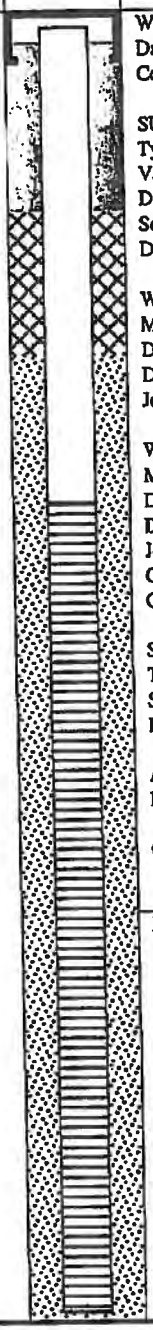
Al Phillips The Cleaner
Maryland Square Shopping Center
Subsurface Investigation
Las Vegas, Nevada

Project No. 2698724.00005

Date Started:	3/22/06
Date Completed:	3/23/06
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	Cuttings Inspection
Logged By:	Randy S. Kyes

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	1520							Asphalt
1						SW		0'-5' Gravely SAND, well sorted, (road base), dry
2								
3								
4								
5						GM		5'-12' GRAVEL, w/ silty sand, dry, well sorted.
6								
7								
8								
9								
10								
11								
12						CL		12'-21' Silty CLAY, brn, moist,
13								
14								
15	1545 0714							
16								
17								
18								
19								
20								
21								21'-22' CALICHE, soft, whitish
22								
23								
24						CL		22'-26' Silty CLAY, brn, v. wet
25								

Well: MW-27
Elev.:



Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 3/23/05
Comp. Rep: R.S. Kyes

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-10'
Joints: flush

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 10'-35'
Joints: flush
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type : Montgomery
Size: 3
Depth: 7'-40'

ANNULUS SEAL
Bentonite
Depth: 4'-7'
Concrete
Depth: 0'-4'

REMARKS
No sampling performed. borehole was drilled and a monitor well was installed.

Soil profile characterized by inspection of drill cuttings.

Restart @ 0714 on 03/23

URS

BOREHOLE LOG
MW-27

Al Phillips The Cleaner Maryland Square Shopping Center Subsurface Investigation Las Vegas, Nevada Project No. 2698724.00005	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	3/22/06 3/23/06 WDC Exploration Hollow Stem Auger Cuttings Inspection Scott Ball	

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-25 Elev.: 1,960.74	Remarks/Well Information
26										
27						CL		26'-40' Silty CLAY, brn, v. wet		
28										
29										
30										
31										
32										
33										
34						CL		34'-40' same as above		
35										
36										
37										
38										
39	0727									03/23/06.
40								Bottom of borehole @ 40 ft. bgs Groundwater encountered at Approximately 15' bgs.		
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
51										

BOREHOLE LOG
MW-28

Al Phillips The Cleaner
Maryland Square Shopping Center
Groundwater Monitoring Well Installation
Las Vegas, Nevada
Project No. 2698724

Date Started:	10/25/2007
Date Completed:	10/25/2007
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Holly Woodward

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	0915							ASPHALT
						GW		6"-1' GRAVEL
1								
2								
3						Af		1'-6' Silty SAND: fine-grain, lt. brown, sl. moist, med. dense., poorly graded w. sl. plasticity, Artificial fill
4								
5								
6								
7								
8						SM		6'-12' silty SAND: brown, sl. moist
9								
10								
11								
12								
13						SM		12'-15' silty SAND: brown, sl. moist, some pea gravel and gravel
14								
15								15'-35' silty SAND: brown
16								
17	1020							17'-17.5' encountered some gravel
18								
19								
20						SM		
21								
22								
23								
24								
25								

Well: MW-28
Elev.:

Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 10/25/2007
Comp. Rep: H. Woodward

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-15'
Joints: 5', 25'

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 15'-35'
Joints: 15', 25'
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type : Monterey
Size: 3
Depth: 12'-35'

ANNULUS SEAL
Sand Pack: bentonite
Depth: 9'-12'
Borehole: concrete
Depth: 0'-9'

REMARKS
No sampling was performed
Borehole was drilled and a Monitor well was installed.

BOREHOLE LOG
MW-28

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 2698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	10/25/2007 10/25/2007 WDC Exploration Hollow Stem Auger None Holly Woodward	

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-28 Elev.:	Remarks/Well Information
26										
27										
28										
29										
30						SM		Same as above		
31										
32										
33										
34										
35								Bottom of borehole @ 35 ft. bgs Groundwater encountered at Approximately 15'-16' bgs		
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
51										

BOREHOLE LOG
MW-29

Al Phillips The Cleaner
Maryland Square Shopping Center
Groundwater Monitoring Well Installation
Las Vegas, Nevada
Project No. 2698724

Date Started:	10/24/2007
Date Completed:	10/25/2007
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Holly Woodward

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	1255							ASPHALT
1						Af		6"-1.5' silty SAND: brown, sl. moist, Med. dense, some gravel, Artificial fill
2						ML		1.5'-4' sandy SILT: lt. brown, roots in soil
3								
4								
5								
6								
7								
8								
9								
10								
11						SM		4'-19' silty SAND: brown, sl. moist, some gravel
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22						CL		19'-35' CLAY: brown, wet, some pea gravel and sand
23								
24								
25								

Well: MW-29
Elev.:

Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 10/25/2007
Comp. Rep: H. Woodward

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-15'
Joints: 5', 15'

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 15'-35'
Joints: 15', 25'
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type : Monterey
Size: 3
Depth: 12'-35'

ANNULUS SEAL
Sand Pack: bentonite
Depth: 9'-12'
Borehole: concrete
Depth: 0'-9'

REMARKS
No sampling was performed
Borehole was drilled and a Monitor well was installed.

BOREHOLE LOG
MW-29

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 2698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	10/24/2007 10/25/2007 WDC Exploration Hollow Stem Auger None Holly Woodward

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-29 Elev.:	Remarks/Well Information
26										
27										
28										
29										
30						CL		Same as above		
31										
32										
33										
34										
35								Bottom of borehole @ 35 ft bgs Groundwater encountered at Approximately 18.5' bgs		
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
51										

BOREHOLE LOG
MW-30

Al Phillips The Cleaner
Maryland Square Shopping Center
Groundwater Monitoring Well Installation
Las Vegas, Nevada
Project No. 2698724

Date Started:	10/26/2007
Date Completed:	10/26/2007
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Holly Woodward

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION
0	0900							Asphalt
1						Af		6"-2' Silty SAND: brown, sl. moist, Med. dense, some gravel, Artificial fill
2								
3						ML		2'-5' Sandy SILT: brown, some pea gravel and gravel
4								
5								
6								
7								
8						ML		5'-13' sandy SILT: brown, some pea gravel, gravel, and clay
9								
10								
11								
12								
13						SM		13'-14' Silty SAND: brown with some pea gravel
14								
15								
16								
17								
18								
19						GC		14'-28' Sandy, silty GRAVEL: poorly graded
20								
21								
22								
23								
24	0945							
25								

Well: MW-30
Elev.:

Remarks/Well Information

WELL CONSTRUCTION
Date Compl.: 10/26/2007
Comp. Rep: H. Woodward

SURFACE COMPLETION
Type: Flush Mount
Vault: Traffic
Diameter: 12"
Seal: Concrete
Depth: 0'-1'

WELL CASING
Material: PVC
Diameter: 4"
Depth: 0'-20'
Joints: 10', 20'

WELL SCREEN
Material: PVC
Diameter: 4"
Depth: 20'-40'
Joints: 20', 30'
Opening: 0.02" slotted
Cap: expanding

SAND FILTER PACK
Type : Monterey
Size: 3
Depth: 17'-40'

ANNULUS SEAL
Sand Pack: bentonite
Depth: 14'-17'
Borehole: concrete
Depth: 0'-14'

REMARKS
No sampling was performed
Borehole was drilled and a Monitor well was installed.

BOREHOLE LOG
MW-30

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 2698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	10/26/2007 10/26/2007 WDC Exploration Hollow Stem Auger None Holly Woodward	

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-30 Elev.:	Remarks/Well Information
26						GC		Same as above		
27										
28						SM		28'-33' Silty SAND: brown, wet, some pea gravel		
29										
30										
31										
32										
33						CL		33'-40' Sandy, silty CLAY: hard, wet		
34										
35										
36										
37										
38										
39										
40	1020							Bottom of borehole @ 40 ft bgs Groundwater encountered at Approximately 24' bgs		
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
51										

BOREHOLE LOG
MW-31

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 2698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	3/5/2008 3/6/2008 WDC Exploration Hollow Stem Auger None Lisa Lowe	

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-31 Elev.: 1937.93	Remarks/Well Information
26						SW		22'-30' gravelly SAND: lt. brown, wet, poorly sorted with some silt and pea gravel		
27										
28										
29										
30						ML		30-'-35' sandy SILT: lt. brown, wet, stiff with some pea gravel		
31										
32										
33										
34										
35						CL		35'-45' gravelly CLAY: lt. brown, wet, stiff with some sand and silt		
36										
37										
38										
39										
40										
41										
42										
43										
44										
45								Bottom of borehole @ 45 ft. bgs Groundwater encountered at Approximately 17 ft bgs. *Borehole drilled to 45 ft bgs due to gravelly SAND (22'-30') collapsing into borehole		
46										
47										
48										
49										
50										
51										

URS

BOREHOLE LOG
MW-31

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 26698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	3/4/2008 3/5/2008 WDC Exploration Hollow Stem Auger None Lisa Lowe	

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-31 Elev.: 1937.93	Remarks/Well Information
0								0-4" ASPHALT		WELL CONSTRUCTION Date Compl.: 3/5/2008 Comp. Rep: L. Lowe
1						Af		4"-1.5' gravelly SAND: brown, sl. moist with up to 1.5" diameter angular rocks		
2								1.5'-9' silty SAND: tan, sl. moist, well sorted, fine grained, some plasticity with some pea gravel		SURFACE COMPLETION Type: Flush Mount Vault: Traffic Diameter: 12" Seal: Concrete Depth: 0'-2'
3								3'-4' same except lt. brown		
4								4'-9' silty SAND: tan, sl. moist, well sorted, fine grained, no plasticity		
5										WELL CASING Material: PVC Diameter: 4" Depth: 0'-13.5' Joints: 3.5', 13.5'
6								6'-6.5' some caliche nodules		
7										
8										WELL SCREEN Material: PVC Diameter: 4" Depth: 13.5'-33.5' Joints: 13.5', 23.5' Opening: 0.02" slotted Cap: expanding
9						SM		9'-13' silty SAND: lt. brown, sl. moist, well sorted, sl. plasticity with some pea gravel		
10										
11										
12										SAND FILTER PACK Type : Colorado Size: 812 Depth: 11'-45'
13								13'-22' silty SAND, lt. brown, moist, sl. plasticity, poorly sorted, fine grain with some pea gravel		
14										
15										ANNULUS SEAL Bentonite Depth: 2'-11'
16								@16' same except sand more coarse		
17										
18										REMARKS No sampling was performed Borehole was drilled and a Monitor well was installed.
19								@19' same except wet		
20										
21										
22								22'-30' gravelly SAND: lt. brown, wet, poorly sorted with some silt and pea gravel		
23						SW				
24										
25										

BOREHOLE LOG
MW-32

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 26698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	3/4/2008 3/4/2008 WDC Exploration Hollow Stem Auger None Holly Woodward/Lisa Lowe	

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-32 Elev.: 1952.82	Remarks/Well Information
0								0-4.5" ASPHALT		WELL CONSTRUCTION Date Compl.: 3/4/2008 Comp. Rep: L. Lowe
1						Af		@ 4.5" to 3' silty SAND: fine-grained, lt. brown, sl. moist, med. dense, poorly graded w. sl. plasticity, some pea gravel, artificial fill		
2										SURFACE COMPLETION Type: Flush Mount Vault: Traffic Diameter: 12" Seal: Concrete Depth: 0'-2'
3						ML		3'-6' sandy SILT: lt. brown, sl. moist		
4										
5										WELL CASING Material: PVC Diameter: 4" Depth: 0' to 13.5' Joints: 3.5', 13.5'
6						SM		6'-15' silty SAND: brown, sl. moist, poorly graded, some gravel		
7										
8										WELL SCREEN Material: PVC Diameter: 4" Depth: 13.5' to 33.5' Joints: 13.5', 23.5' Opening: 0.02" slotted Cap: expanding
9										
10										
11										
12										SAND FILTER PACK Type : Colorado Size: 812 Depth: 11'-35'
13										
14										
15						CL		15'-25' CLAY: brown, sl. moist, med. dense, poorly graded, some sand and gravel		ANNULUS SEAL Bentonite Depth: 2'-11'
16										
17								@17.5' same as above but very moist		
18										REMARKS No sampling was performed Borehole was drilled and a Monitor well was installed. *0' to 25' was logged during The drilling of B-T on 10/24/2007 by Holly Woodward
19										
20										
21										
22										
23										
24										
25						ML		25'-31' clayey SILT, lt. brown, wet, stiff		

BOREHOLE LOG
MW-32

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 2698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	3/4/2008 3/4/2008 WDC Exploration Hollow Stem Auger None Holly Woodward/Lisa Lowe	

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-32 Elev.: 1952.82	Remarks/Well Information
26								25'-31' clayey SILT, lt. brown, wet, stiff		
27										
28										
29										
30						ML				
31								31'-35' same with pea gravel		
32										
33										
34										
35								Bottom of borehole @ 35 ft. bgs Groundwater encountered at Approximately 17.5 feet bgs.		
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
51										

BOREHOLE LOG
MW-33

Al Phillips The Cleaner
Maryland Square Shopping Center
Groundwater Monitoring Well Installation
Las Vegas, Nevada
Project No. 26698724

Date Started:	3/5/2008
Date Completed:	3/6/2008
Drilling Company:	WDC Exploration
Drilling Method:	Hollow Stem Auger
Sampling Method:	None
Logged By:	Lisa Lowe

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-33 Elev.: 1950.92	Remarks/Well Information
0								0-4" ASPHALT		WELL CONSTRUCTION Date Compl.: 3/6/2008 Comp. Rep: L. Lowe
1						Af		4"-2' SAND, lt. brown, st. moist, poorly sorted with up to 1" diameter angular Rocks, Artificial Fill		
2						SM		2'-5' silty SAND: lt. brown, sl. moist, well sorted with up to 1.5" long gypsum crystals		SURFACE COMPLETION Type: Flush Mount Vault: Traffic Diameter: 12" Seal: Concrete Depth: 0'-2'
3										
4										
5								5'-9' sandy SILT: brown, sl moist, stiff with some pea gravel		WELL CASING Material: PVC Diameter: 4" Depth: 0'-13.5' Joints: 3.5', 13.5'
6										
7										
8										WELL SCREEN Material: PVC Diameter: 4" Depth: 13.5' to 33.5' Joints: 13.5', 23.5' Opening: 0.02" slotted Cap: expanding
9								9'-16' gravelly SILT: brown sl. moist, stiff with some fine grain sand		
10										
11										
12										SAND FILTER PACK Type : Colorado Size: 812 Depth: 11'-35'
13										
14						ML				
15										ANNULUS SEAL Bentonite Depth: 2'-11'
16								16'-25' sandy SILT, brown, moist, stiff with some pea gravel		
17										
18										REMARKS No sampling was performed Borehole was drilled and a Monitor well was installed.
19										
20										
21										
22										
23										
24										
25								25'-34' clayey SILT, lt. brown, wet, stiff		

BOREHOLE LOG
MW-33

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 2698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	3/5/2008 3/6/2008 WDC Exploration Hollow Stem Auger None Lisa Lowe

Depth In Feet	Time (0100 hrs)	Sample	Well Material Log	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: MW-33 Elev.: 1950.92	Remarks/Well Information
26								25'-34' clayey SILT, lt. brown, wet, stiff		
27										
28										
29										
30						ML				
31										
32										
33										
34								34'-35' silty CLAY: white, moist, stiff		
35								Bottom of borehole @ 35 ft. bgs Groundwater encountered at Approximately 16.5' bgs.		
36										
37										
38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
51										

BOREHOLE LOG
MW-T2

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 26698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	3/4/2008 3/5/2008 WDC Explorations Hollow-Stem Auger Grab/Dedicated Bailer Lisa Lowe	

Depth In Feet	Time (0100 hrs)	Sample	Blow Count (ft)	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: B-T2 Elev.:	Remarks/Well Information
0								0-4" ASPHALT		WELL CONSTRUCTION Date Compl.: Comp. Rep:
						Af		4" to 1' silty SAND: lt. brown, sl. moist, poorly sorted with 1-2" diameter angular and rounded rocks		
1						SM		1'-7.5' silty SAND: tan, sl. moist, fine grained, well sorted, no plasticity, with some pea gravel and gypsum		SURFACE COMPLETION Type: Vault: Diameter: Seal: Depth:
2										
3										
4										
5										WELL CASING Material: Diameter: Depth: Joints:
6										
7										
8								7.5'-13' sandy SILT: brown, moist, sl. plasticity		WELL SCREEN Material: Diameter: Depth: Joints: Opening: Cap:
9						ML				
10										
11										
12										SAND FILTER PACK Type : Size: Depth:
13								13'-17' same except stiff		
14										
15										ANNULUS SEAL Sand Pack: Depth: Borehole: Depth:
16										
17								17'-20' same with some pea gravel		
18						CL				REMARKS
19	1210	W			B-T2					
20								Bottom of borehole @ 20'bgs Encountered Groundwater at approx. 18'		
21										
22										
23										
24										
25										

BOREHOLE LOG
B-T

Al Phillips The Cleaner Maryland Square Shopping Center Groundwater Monitoring Well Installation Las Vegas, Nevada Project No. 26698724	Date Started: Date Completed: Drilling Company: Drilling Method: Sampling Method: Logged By:	10/24/2007 10/25/2007 WDC Explorations Hollow-Stem Auger Grab/Temporary PVC casing Holly Woodward	

Depth In Feet	Time (0100 hrs)	Sample	Blow Count (ft)	PID/FID (ppm)	Sample Number	USCS/Other	Graphic Log	SOIL DESCRIPTION	Well: B-T Elev.:	Remarks/Well Information
0								0-4.5" ASPHALT		WELL CONSTRUCTION Date Compl.: 10/24/2007 Comp. Rep: H. Woodward
1						Af		@ 4.5" to 3' silty SAND: fine-grained, lt. brown, sl. moist, med. dense, poorly graded w. sl. plasticity, some pea gravel, artificial fill		
2										SURFACE COMPLETION Type: NA Vault: NA
3										Diameter: NA Seal: NA Depth: NA
4						ML		3'-6' sandy SILT: lt. brown, sl. moist		
5										WELL CASING Material: PVC Diameter: 1.25" Depth: 0-22' Joints: flush
6										
7										
8										WELL SCREEN Material: PVC Diameter: 1.25" Depth: 22-25' Joints: flush Opening: 0.02" Slotted Cap: Expanding
9						SM		6'-15' silty SAND: brown, sl. moist, poorly graded, some gravel		
10										
11										
12										SAND FILTER PACK Type : Monterey Size: 3 Depth: 19-25'
13										
14										
15								15'-17.5' CLAY: brown, sl. moist, med. dense, poorly graded, some sand and gravel		ANNULUS SEAL Sand Pack: NA Depth: NA Borehole: NA Depth: NA
16										
17								@17.5' same as above but very moist		
18						CL				REMARKS
19										
20										
21										
22										
23										
24										
25								Bottom of borehole @ 25'bgs Encountered Groundwater at approx. 22'		

APPENDIX B

Summary of Remedial Action Alternatives Costs for Groundwater

Appendix B

Draft Corrective Action Plan for Groundwater - Maryland Square PCE Site

Summary of Corrective Action Alternatives Costs

TABLE B-1

Alternative 1: No Action

Capital Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment**
None					
			Subtotal	***$0***	
			Total capital Costs	***$0***	
Operation, Maintenance and Monitoring Costs – SSD					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment**
Sub-slab and Residential Monitoring	1	annual	$118,000	$118,000	Previous MD Sq
			Annual Cost (Subtotal)	***$120,000***	
			30-Year Present Worth Factor at 5.0% discount factor	*15.37*	
			Net Present Worth of 30 Years of Operation, Maintenance and Monitoring Costs	***$1,840,000***	
Operation, Maintenance and Monitoring Costs – GW Monitoring					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment**
Quarterly GW Monitoring	4	quarters/year	$31,250	$125,000	Previous MD Sq
			Annual Cost (Subtotal)	***$130,000***	
			30-Year Present Worth Factor at 5.0% discount factor	*15.37*	
			Net Present Worth of 30 Years of Operation, Maintenance and Monitoring Costs	***$2,000,000***	
			Alternative 1 Total Cost	***$3,840,000***	***Rounded***

Assumptions

All dollar amounts in Subtotals and Totals to nearest ten-thousand dollars
All values are in 2010 Dollars
Net present worth discount rate is 5.0%

Abbreviation and Acronyms

AS/SVE	Air Sparge/ Soil Vapor Extraction	MNA	Monitored Natural Attenuation
BCY	Bulk Cubic yards	Mobe	Mobilization
bgs	Below ground surface	PCE	Tetrachloroethene
China Lake FS	2005 Cost estimate for similar site (China Lake) using RACER	PRB	Permeable Reactive Barrier
cfm	Cubic feet per minute	Previous MD Sq	Previous cost estimates for Maryland Square Shopping Center Remediation
CY	Cubic yard		
Decon	Decontamination		
Demobe	Demobilization	RACER	Remedial Action Cost Engineering and Requirements System, designed for Remediation Projects
EOV	Emulsified vegetable oil		
GW	Groundwater		
gpm	Gallons per minute	SF	Square Foot
IC	Institutional Controls	Site Prep	Site Preparation
kwh	Kilowatt hour		
LF	Linear foot	SSD	Sub-slab depressurization
LS	Lump Sum	µg/L	Micrograms per liter of PCE
MG	Million gallon		

Appendix B

Draft Corrective Action Plan for Groundwater - Maryland Square PCE Site

Summary of Corrective Action Alternatives Costs

TABLE B-2

Alternative 2A: In Situ Chemical Treatment of Hotspots and Residential Area, Institutional Controls (IC), Sub-Slab Depressurization (SSD) Systems, and Monitored Natural Attenuation (MNA)

Cost Item	Quantity	Unit	Cost/Unit	Item Cost	Comment/Source
Capital Costs					
Site Prep for Equipment Laydown	1	LS	$10,000	$10,000	Engineer's Estimate
Injection Wells (76 at 40')	3040	LF	$160	$486,400	China Lake FS
Bench Scale Test	1	LS	$7,000	$7,000	Vendor Quote
Pilot Study	1	LS	$25,000	$25,000	Vendor Quote
Additional SSD systems	10	Homes	$5,000	$50,000	Previous MD Sq
Implementation of ICs	1	LS	$50,000	$50,000	China Lake FS
			Subtotal	***$628,400***	
			Mobe/ Demobe/ Well Abandonment (15%)	*$94,260*	
			Design (10% or $10,000 minimum)	*$62,840*	
			Construction management (15% or $10,000 minimum)	*$94,260*	
			Administrative/Legal (5% or $10,000 minimum)	*$31,420*	
			Contingency (25%)	*$157,100*	
			Total capital Costs	***$1,070,000***	
Operation, Maintenance and Monitoring Costs − Hotspot Reagent					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Reagent injection in Hotspot	25	tons	$3,552	$88,792	Vendor Quote
Reagent Injection Labor	240	hrs	$50	$12,000	Vendor Quote
Reagent Injection Equipment	5%	Reagent	$88,792	$4,440	Engineer's Estimate
			Annual Cost (Subtotal)	***$110,000***	
			Contingency (20%)	*$22,000*	
			Annual Cost + Contingency	*$132,000*	
			4-Year Present Worth Factor at 5.0% discount factor	*3.55*	
			Net Present Worth of 4 Years of Hotspot Injection Costs	***$470,000***	
Operation, Maintenance and Monitoring Costs − Upgradient Reagent					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Reagent Injection Upgradient of Residences	17	tons	$3,552	$59,194	Vendor Quote
Reagent Injection Labor	240	hrs	$50	$12,000	Vendor Quote
Reagent Injection Equipment	5%	Reagent	$59,194	$2,960	Engineer's Estimate
			Annual Cost (Subtotal)	***$80,000***	
			Contingency (20%)	*$16,000*	
			Annual Cost + Contingency	*$96,000*	
			10-Year Present Worth Factor at 5.0% discount factor	*7.72*	
			Net Present Worth of 10 Years of Upgradient Area Injection Costs	***$740,000***	
Operation, Maintenance and Monitoring Costs − GW Monitoring and IC					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Quarterly GW Monitoring	4	quarters/year	$31,250	$125,000	Previous MD Sq
Annual reporting and IC Implementation	1	annual	$67,000	$67,000	Engineer's Estimate
			Annual Cost (Subtotal)	***$200,000***	
			Contingency (20%)	*$40,000*	
			Annual Cost + Contingency	*$240,000*	
			30-Year Present Worth Factor at 5.0% discount factor	*15.37*	
			Net Present Worth of 30 Years of GW and IC Monitoring Costs	***$3,690,000***	
Operation, Maintenance and Monitoring Costs − SSD Monitoring					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Sub-slab and Residential Monitoring	1	annual	$118,000	$118,000	Previous MD Sq
			Annual Cost (Subtotal)	***$120,000***	
			Contingency (20%)	*$24,000*	
			Annual Cost + Contingency	*$144,000*	
			10-Year Present Worth Factor at 5.0% discount factor	*7.72*	
			Net Present Worth of 10 Years of SSD Monitoring Costs	***$1,110,000***	
Closeout Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Closeout Report	1	LS	$67,000	$67,000	China Lake FS
			(Subtotal)	***$70,000***	
			30-Year Present Worth Factor at 5.0% discount factor	*0.23*	
			Net Present Worth of Close-out Costs	***$20,000***	
			Alternative 2A Total Cost	***$7,100,000***	***Rounded***

TABLE B-2 (Continued)

Alternative 2A: In Situ Chemical Treatment of Hotspots and Residential Area, Institutional Controls (IC), Sub-Slab Depressurization (SSD) Systems, and Monitored Natural Attenuation (MNA)

Assumptions

All dollar amounts in Subtotals and Totals to nearest ten-thousand dollars
All values are in 2010 Dollars See Table B-1 for abbreviations and acronyms
Net present worth discount rate is 5.0%
76 new wells will need to be installed, making a total of 80 injection wells
Injection points or wells will be at about 17-40 bgs in Years 1 through 10 GW velocity will be between 0.5-4 foot per day
Initially treating a concentration of approximately 1,000 ug/L, decreasing to 500 after Year 5
SSD systems would operate for 2 years and GW monitoring would be for 10 years
Injection will be directly in roadways or right-of-ways
Oxidant demand based on high sulfates at site

Injection well abandonment part of demobilization costs
Implementation of ICs cost based on length of time required

Appendix B

Draft Corrective Action Plan for Groundwater - Maryland Square PCE Site

Summary of Corrective Action Alternatives Costs

TABLE B-3

Alternative 2B: In Situ Chemical Treatment, ICs, SSD Systems, and MNA

Capital Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Site Prep for Equipment Laydown	1	LS	$10,000	$10,000	Engineer's Estimate
Site Prep for Injection Wells	121	Wells	$3,000	$363,000	Engineer's Estimate.
New Injection Wells (349 at 40')	13960	LF	$160	$2,233,600	China Lake FS
Bench Scale Test	1	LS	$7,000	$7,000	Vendor Quote
Pilot Study	1	LS	$25,000	$25,000	Vendor Quote
Additional SSD systems	10	Homes	$5,000	$50,000	Previous MD Sq
Implementation of ICs	1	LS	$50,000	$50,000	China Lake FS
			Subtotal	***$2,738,600***	
			Mobe/ Demobe/ Well Abandonment (15%)	*$410,790*	
			Design (10% or $10,000 minimum)	*$273,860*	
			Construction management (15% or $10,000 minimum)	*$410,790*	
			Aministrative/Legal (5% or $10,000 minimum)	*$136,930*	
			Contingency (25%)	*$684,650*	
			Total capital Costs	***$4,660,000***	
Operation, Maintenance and Monitoring Costs − Reagent and SSD					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Reagent	1383	tons	$3,552	$4,913,065	Vendor Quote
Reagent Injection Labor	1089	hrs	$50	$54,450	Vendor quote
Reagent Injection Equipment	5%	Reagent	$4,913,065	$245,653	Engineer's Estimate
Sub-slab and Residential Monitoring	1	annual	$118,000	$118,000	Previous MD Sq
			Annual Cost (Subtotal)	***$5,340,000***	
			Contingency (20%)	*$1,068,000*	
			Annual Cost + Contingency	*$6,408,000*	
			3-Year Present Worth Factor at 5.0% discount factor	*2.72*	
			Net Present Worth of 3 Years of Operation and Maintenance Costs	***$17,450,000***	
Operation, Maintenance and Monitoring Costs − GW Monitoring and IC					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Annual reporting and IC Implementation	1	annual	$67,000	$67,000	
Quarterly GW Monitoring	4	quarters/year	$31,250	$125,000	Previous MD Sq
			Annual Cost (Subtotal)	***$200,000***	
			Contingency (20%)	*$40,000*	
			Annual Cost + Contingency	*$240,000*	
			5-Year Present Worth Factor at 5.0% discount factor	*4.33*	
			Net Present Worth of 5 Years of Operation, Maintenance and Monitoring Costs	***$1,040,000***	
Closeout Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Closeout Report	1	LS	$67,000	$67,000	Previous MD Sq
			(Subtotal)	***$70,000***	
			5-Year Present Worth Factor at 5.0% discount factor	*0.78*	
			Net Present Worth of Close-out Costs	***$60,000***	
			Alternative 2B Total Cost	***$23,210,000***	***Rounded***

Assumptions

- All dollar amounts in Subtotals and Totals to nearest ten-thousand dollars
- All values are in 2010 Dollars — See Table B-1 for abbreviations and acronyms
- Net present worth discount rate is 5.0%
- 14 existing wells in the vicinity are available for injection
- 349 new wells will need to be installed, making a total of 363 injection wells
- Will inject equal amounts of reagent over 2 years
- Injection points or wells will be at about 17-37 bgs. GW velocity will be between 0.5-4 foot per day
- Initially treating a concentration of approximately 1,000 ug/L, decreasing to 500 after year 1
- SSD systems would operate for 2 years and GW monitoring would be for 4 years
- One-third of the wells will require some site prep. Other sites will be directly in roadways or right-of-ways
- Oxidant demand based on high sulfates at site
- Implementation of ICs cost based on length of time required

Appendix B

Draft Corrective Action Plan for Groundwater - Maryland Square PCE Site

Summary of Corrective Action Alternatives Costs

TABLE B-4

Alternative 3: Permeable Reactive Barrier (PRB), ICs, SSD Systems, and MNA

Capital Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Site Prep	1	LS	$10,000	$10,000	Engineer's Estimate
Decon Facilities	1	LS	$71,820	$71,820	China Lake FS
Waste Management	1	LS	$7,140	$7,140	China Lake FS
Stockpile	1	LS	$14,760	$14,760	China Lake FS
Pilot Study and Bench-Scale Tests	1	LS	$75,000	$75,000	Vendor Quote
Excavation	400	BCY	$50	$20,000	China Lake FS
Spoil Disposal	200	BCY	$200	$40,000	China Lake FS
Zero-valent Iron for 18-38' BGS	844	tons	$800	$675,200	Vendor Quote
PRB Installation	844	tons	$592	$500,000	Vendor Quote
Borrow	107	CY	$10	$1,070	Engineer's Estimate
Fill in Lifts	360	CY	$10	$3,600	Engineer's Estimate
Street Repair	900	SY	$120	$108,000	Engineer's Estimate
Wells (9 at 40 ft)	36	LF	$450	$16,200	Engineer's Estimate
Additional SSD systems	10	Homes	$5,000	$50,000	Engineer's Estimate
Implementation of ICs	1	LS	$50,000	$50,000	Engineer's Estimate
			Subtotal	***$1,642,790***	
			Mobe/ Demobe/ Well Abandonment (15%)	*$246,419*	
			Design (10% or $10,000 minimum)	*$164,279*	
			Construction management (15% or $10,000 minimum)	*$246,419*	
			Administrative/Legal (5% or $10,000 minimum)	*$82,140*	
			Contingency (25%)	*$410,698*	
			Total capital Costs	***$2,800,000***	
Operation, Maintenance and Monitoring Costs – SSD Monitoring					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Sub-slab and Residential Monitoring	1	annual	$118,000	$118,000	Previous MD Sq
			Annual Cost (Subtotal)	***$120,000***	
			Contingency (20%)	*$24,000*	
			Annual Cost + Contingency	*$144,000*	
			10-Year Present Worth Factor at 5.0% discount factor	*7.72*	
			Net Present Worth of 10 Years of SSD Monitoring Costs	***$1,110,000***	
Operation, Maintenance, and Monitoring Costs – GW Monitoring and ICs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Quarterly GW Monitoring	4	quarters/year	$31,250	$125,000	Previous MD Sq
Annual Reporting and IC Implementation	1	annual	$67,000	$67,000	Engineer's Estimate
			Annual Cost (Subtotal)	***$200,000***	
			Contingency (20%)	*$40,000*	
			Annual Cost + Contingency	*$240,000*	
			30-Year Present Worth Factor at 5.0% discount factor	*15.37*	
			Net Present Worth of 30 Years of Operation, Maintenance and Monitoring Costs	***$3,690,000***	
Maintain PRB					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Replace barrier	1	LS	$1,369,770	$1,369,770	China Lake FS
			(Subtotal)	***$1,370,000***	
			20-Year Present Worth Factor at 5.0% discount factor	*0.38*	
			Net Present Worth of PRB Replacement Costs	***$520,000***	
Closeout Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Closeout Report	1	LS	$67,000	$67,000	China Lake FS
			(Subtotal)	***$70,000***	
			30-Year Present Worth Factor at 5.0% discount factor	*0.23*	
			Net Present Worth of Close-out Costs	***$20,000***	
			Alternative 3 Total Cost	***$8,140,000***	***Rounded***

Assumptions

All dollar amounts in Subtotals and Totals to nearest ten-thousand dollars
All values are in 2010 Dollars — See Table B-1 for abbreviations and acronyms
Net present worth discount rate is 5.0%
The wall will be 375' long, 3' wide and extend to the bottom of the treatment zone
7 new monitoring wells will need to be installed
New wells: 1 additional upgradient monitoring well, 2 downgradient, and 6 in the wall (3 upgradient edge and 3 downgradient edge)
The treatment zone would be at about 18-38 bgs. GW velocity will be between 0.5-4 feet per day
Initially treating a concentration of approximately 1,000 ug/L, decreasing to 500 after Year 10 . The treatment would last for 20 years.
SSD systems would operate for 3 years and GW monitoring would be for 20 years
Implementation of ICs cost based on length of time required

Appendix B

Draft Corrective Action Plan for Groundwater - Maryland Square PCE Site

Summary of Corrective Action Alternatives Costs

TABLE B-5

Alternative 4: Air Sparge/ Soil Vapor Extraction (AS/SVE), ICs, SSD Systems, and MNA

Capital Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Site Characterization	1	LS	$30,000	$30,000	Previous MD Sq
Site Prep	1	LS	$20,000	$20,000	Previous MD Sq
AS/SVE Installation and startup	1	LS	$163,000	$163,000	Previous MD Sq
Air permitting	1	LS	$11,000	$11,000	Previous MD Sq
AS Wells (11 at 40')	440	LF	$160	$70,400	China Lake FS
SVE Wells (12 at 17')	204	LF	$160	$32,640	China Lake FS
Pilot Study	1	LS	$25,000	$25,000	Vendor Quote
Additional SSD systems	10	Homes	$5,000	$50,000	Engineer's Estimate
Implementation of ICs	1	LS	$50,000	$50,000	China Lake FS
			Subtotal	***$452,040***	
			Mobe/ Demobe/ Well Abandonment (15%)	*$67,806*	
			Design (10% or $10,000 minimum)	*$45,204*	
			Construction management (15% or $10,000 minimum)	*$67,806*	
			Aministrative/Legal (5% or $10,000 minimum)	*$22,602*	
			Contingency (25%)	*$113,010*	
			Total capital Costs	***$770,000***	
Operation, Maintenance and Monitoring Costs – AS/SVE and SSD					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
AS/SVE O&M	1	annual	$82,000	$82,000	Previous MD Sq
Annual Air Monitoring	1	annual	$43,000	$43,000	Previous MD Sq
Sub-slab and Residential Monitoring	1	annual	$118,000	$118,000	Previous MD Sq
			Annual Cost (Subtotal)	***$250,000***	
			Contingency (20%)	*$50,000*	
			Annual Cost + Contingency	*$300,000*	
			10-Year Present Worth Factor at 5.0% discount factor	*7.72*	
			Net Present Worth of 10 Years of AS/SVE and SSD Monitoring Costs	***$2,320,000***	
Operation, Maintenance, and Monitoring Costs - GW Monitoring and ICs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Quarterly GW Monitoring	4	quarters/year	$31,250	$125,000	Previous MD Sq
Annual Reporting and IC Implementation	1	annual	$67,000	$67,000	China Lake FS
			Annual Cost (Subtotal)	***$200,000***	
			Contingency (20%)	*$40,000*	
			Annual Cost + Contingency	*$240,000*	
			30-Year Present Worth Factor at 5.0% discount factor	*15.37*	
			Net Present Worth of 30 Years of Operation, Maintenance and Monitoring Costs	***$3,690,000***	
Closeout Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Closeout Report	1	LS	$67,000	$67,000	China Lake FS
			(Subtotal)	***$70,000***	
			30-Year Present Worth Factor at 5.0% discount factor	*0.23*	
			Net Present Worth of Close-out Costs	***$20,000***	
			Alternative 4 Total Cost	***$6,800,000***	***Rounded***

Assumptions

All dollar amounts in Subtotals and Totals to nearest ten-thousand dollars
All values are in 2010 Dollars See Table B-1 for abbreviations and acronyms
Net present worth discount rate is 5.0%
23 new wells will need to be installed, 12 for the SVE and 11 for the AS
Each SVE well will have an air flow rate of 40 cubic feet per second
Injection points or wells will be at about 20-40 bgs with a radius of influence (ROI) of 10'. GW velocity will be between 0.5-4 feet per day
Initially treating a concentration of approximately 1,000 ug/L, decreasing to 500 ug/L after Year 10 .
SSD systems would operate for 3 years and GW monitoring would be for 20 years
Wells will be located in mall parking lot.
Implementation of ICs cost based on length of time required

Appendix B

Draft Corrective Action Plan for Groundwater - Maryland Square PCE Site

Summary of Corrective Action Alternatives Costs

TABLE B-6

Alternative 5: Groundwater Extraction and Treatment, ICs, SSD Systems, and MNA

Capital Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment**
Site Characterization	1	LS	$30,000	$30,000	Previous MD Sq
Site Prep and Slab work	1	LS	$100,000	$100,000	Engineer's Estimate
Air permitting	1	LS	$11,000	$11,000	Previous MD Sq
New GW Wells (29 at 40')	560	LF	$200	$112,000	China Lake FS
Submersible Pumps	14	EA	$5,000	$70,000	Engineer's Estimate
Well Electrical Connections	29	EA	$7,500	$217,500	Engineer's Estimate
Pump Test	1	LS	$25,000	$25,000	Vendor Quote
Additional SSD systems	10	Homes	$5,000	$50,000	Engineer's Estimate
Underground Injection Control Permit	1	LS	$15,000	$15,000	Engineer's Estimate
Equipment Installation (2 WWTPs)	1	LS	$75,000	$75,000	Vendor Quote
Site Electrical	1	LS	$50,000	$50,000	Engineer's Estimate
Trenching and Backfilling (2' wide, 4' deep, medium soil)	14,300	LF	$3.58	$51,123	Engineer's Estimate
Yard Piping (2" PVC)	19800	LF	$3.59	$71,033	Engineer's Estimate
Replace Pavement (6" thick, concrete)	28600	SF	$3.23	$92,235	Engineer's Estimate
Implementation of ICs	1	LS	$50,000	$50,000	China Lake FS
			Subtotal	***$1,019,890***	
			Mobe/ Demobe/ Well Abandonment (15%)	*$152,984*	
			Design (10% or $10,000 minimum)	*$101,989*	
			Construction management (15% or $10,000 minimum)	*$152,984*	
			Aministrative/Legal (5% or $10,000 minimum)	*$50,995*	
			Contingency (25%)	*$254,973*	
			Total capital Costs	***$1,740,000***	
Operation, Maintenance and Monitoring Costs – SSD Monitoring					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Sub-slab and Residential Monitoring	1	annual	$118,000	$118,000	Previous MD Sq
			Annual Cost (Subtotal)	***$120,000***	
			Contingency (20%)	*$24,000*	
			Annual Cost + Contingency	*$144,000*	
			10-Year Present Worth Factor at 5.0% discount factor	*7.72*	
			Net Present Worth of 10 Years of SSD Monitoring Costs	***$1,110,000***	
Operation, Maintenance, and Monitoring Costs – System O&M, GW Monitoring and ICs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Quarterly GW Monitoring	4	quarters/year	$31,250	$125,000	Previous MD Sq
GW Treatment System Rental (2 WWTPs)	13.0	28-day Cycles	$6,396	$83,148	Vendor Quote
Rent Space for WWTP on Golf Course (50' x 25')	12.0	month	$1,250	$15,000	Engineer's Estimate
Electrical Power	12.0	Horsepower	$1,005	$12,057	See Below
Activated Carbon Replacement	4.0	per year	$11,975	$47,900	Vendor Quote
Inspection of Operations	52 weeks	14 hrs per week	$50	$36,400	Engineer's Estimate
Electrical, well and pump O&M	1%	Capital Cost	$1,740,000	$17,400	Engineer's Estimate
Annual reporting and IC Implementation	1	annual	$67,000	$67,000	Previous MD Sq
			Annual Cost (Subtotal)	***$410,000***	
			Contingency (20%)	*$82,000*	
			Annual Cost + Contingency	*$492,000*	
			30-Year Present Worth Factor at 5.0% discount factor	*15.37*	
			Net Present Worth of 30 Years of Operation, Maintenance and Monitoring Costs	***$7,560,000***	
Closeout Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Closeout Report	1	LS	$67,000	$67,000	China Lake FS
Equipment Removal	1	LS	$7,806	$7,806	Vendor Quote
Site Restoration	1	LS	$50,000	$50,000	Engineer's Estimate
			(Subtotal)	***$130,000***	
			30-Year Present Worth Factor at 5.0% discount factor	*0.23*	
			Net Present Worth of Close-out Costs	***$40,000***	
			Alternative 5 Total Cost	***$10,450,000***	***Rounded***

TABLE B-6 (Continued)
Alternative 5: Groundwater Extraction and Treatment, ICs, SSD Systems, and MNA
Assumptions
All dollar amounts in Subtotals and Totals to nearest ten-thousand dollars. See Table B-1 for abbreviations and acronyms
All values are in 2010 Dollars Net present worth discount rate is 5.0%
Peak flow is 55 gpm (3.9 gpm/well from 14 extraction wells)
Treated water will be re-injected.
14 new wells will be installed.
Assume $0.10 per KWH and 65% wire-to-water efficiency for motors
Wells will be screened from about 20-40 bgs.
Initially treating a concentration of approximately 1,000 ug/L, decreasing to 500 ug/L after Year 7.
SSD systems would operate for 10 years and GW monitoring would be for 20 years
Wells will be directly in roadways or right-of-ways. No land acquisition or purchase costs are included
One wastewater treatment system will be on the golf course property. Rental rate for open space assumed at $1/sf/month.
Electrical power connection points are near site and each extraction well. Carbon filters will be changed out every 6 months
No hardness control will be required in the treatment system, wells, and yard piping
Implementation of ICs cost based on length of time required

Appendix B

Draft Corrective Action Plan for Groundwater - Maryland Square PCE Site

Summary of Corrective Action Alternatives Costs

TABLE B-7

Alternative 6: In-situ Enhanced Bioremediation, ICs, SSD Systems, and MNA

Capital Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment**
Site Prep for Equipment Laydown	1	LS	$20,000	$20,000	Engineer's Estimate
New Injection Wells(80 at 40')	3200	LF	$180	$576,000	China Lake FS
Bench Scale Test	1	LS	$7,000	$7,000	Previous MD Sq
Pilot Study	1	LS	$25,000	$25,000	Vendor Quote
Additional SSD systems	10	Homes	$5,000	$50,000	Previous MD Sq
Implementation of ICs	1	LS	$50,000	$50,000	China Lake FS
			Subtotal	***$728,000***	
			Mobe/ Demobe/ Well Abandonment (15%)	*$109,200*	
			Design (10% or $10,000 minimum)	*$72,800*	
			Construction management (15% or $10,000 minimum)	*$109,200*	
			Administrative/Legal (5% or $10,000 minimum)	*$36,400*	
			Contingency (25%)	*$182,000*	
			Total capital Costs	***$1,240,000***	
Operation, Maintenance, and Monitoring Costs − Hotspot Reagent					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Vegetable Oil Reagent	48	Wells Annually	$18,945	$909,378	Vendor Quote
Reagent Injection	1	LS	$182,000	$182,000	Vendor quote
			Annual Cost (Subtotal)	***$1,100,000***	
			Contingency (20%)	*$220,000*	
			Annual Cost + Contingency	*$1,320,000*	
			3-Event Present Worth Factor at 5.0% discount factor	*2.72*	
			Net Present Worth of 3 Years of Operation and Maintenance Costs	***$3,590,000***	
Operation, Maintenance, and Monitoring Costs − Upgradient Reagent, GW Monitoring, SSD and ICs (Year 1 - 10)					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Vegetable Oil Reagent	32	Wells Annually	$18,945	$606,252	Vendor Quote
Reagent Injection	1	LS	$121,000	$121,000	Vendor Quote
Quarterly GW Monitoring	4	quarters/year	$31,250	$125,000	Previous MD Sq
Sub-slab and residential Monitoring	1	annual	$118,000	$118,000	Previous MD Sq
Annual reporting and IC Implementation	1	annual	$67,000	$67,000	China Lake FS
			Annual Cost (Subtotal)	***$1,040,000***	
			Contingency (20%)	*$208,000*	
			Annual Cost + Contingency	*$1,248,000*	
			10-Year Present Worth Factor at 5.0% discount factor	*7.72*	
			Net Present Worth of 10 Years of Operation, Maintenance and Monitoring Costs	***$9,640,000***	
Operation, Maintenance, and Monitoring Costs − GW Monitoring and ICs (Year 11 - 30)					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Quarterly GW Monitoring	4	quarters/year	$31,250	$125,000	Previous MD Sq
Annual reporting and IC Implementation	1	annual	$67,000	$67,000	China Lake FS
			Annual Cost (Subtotal)	***$200,000***	
			Contingency (20%)	*$40,000*	
			Annual Cost + Contingency	*$240,000*	
			Year-10 to Year-30 Present Worth Factor at 5.0% discount factor	*7.65*	
			Net Present Worth of 20 Years of Operation, Maintenance and Monitoring Costs	***$1,840,000***	
Closeout Costs					
Cost Item	**Quantity**	**Unit**	**Cost/Unit**	**Item Cost**	**Comment/Source**
Closeout Report	1	LS	$67,000	$67,000	China Lake FS
			(Subtotal)	***$70,000***	
			30-Year Present Worth Factor at 5.0% discount factor	*0.23*	
			Net Present Worth of Close-out Costs	***$20,000***	
			Alternative 6 Total Cost	***$16,330,000***	***Rounded***

Assumptions

All dollar amounts in Subtotals and Totals to nearest ten-thousand dollars
All values are in 2010 Dollars — See Table B-1 for abbreviations and acronyms
Net present worth discount rate is 5.0%
76 new wells will need to be installed, making a total of 80 injection wells
10 year lifespan, injection of EVO in hotspot over 3 years and upgradient of residences for 10 years.
Injection points or wells will be at about 17-37 bgs with a ROI of 10'. GW velocity will be between 2-4 feet per day
Initially treating a concentration of approximately 1,000 ug/L, decreasing to 500 ug/L after Year 5.
SSD systems would operate for 3 years and GW monitoring would be for 10 years
Sites will be directly in roadways or right-of-ways
Reagent costs based on high sulfates concentrations.
Implementation of ICs cost based on length of time required

Appendix B
Draft Corrective Action Plan for Groundwater - Maryland Square PCE Site
Summary of Corrective Action Alternatives Costs

TABLE B-8				
Summary				
Alternative	***Capital Costs***	***Future Costs***	***Total Cost***	**Total Cost Rank (0=Lowest)**
	$0	*$3,840,000*	*$3,840,000*	**0**
Alternative 2A: Alternative 2A: In Situ Chemical Treatment of Hotspots and Residential Area, Institutional Controls (IC), Sub-Slab Depressurization (SSD) Systems, and Monitored Natural	*$1,070,000*	*$6,030,000*	*$7,100,000*	**1**
Alternative 2B: Alternative 2B: In Situ Chemical Treatment, ICs, SSD Systems, and MNA	*$4,660,000*	*$18,550,000*	*$23,210,000*	6
Alternative 3: Alternative 3: Permeable Reactive Barrier (PRB), ICs, SSD Systems, and MNA	*$2,800,000*	*$5,340,000*	*$8,140,000*	3
Alternative 4: Alternative 4: Air Sparge/ Soil Vapor Extraction (AS/SVE), ICs, SSD Systems, and MNA	*$770,000*	*$6,030,000*	*$6,800,000*	**2**
Alternative 5: Alternative 5: Groundwater Extraction and Treatment, ICs, SSD Systems, and MNA	*$1,740,000*	*$8,710,000*	*$10,450,000*	5
Alternative 6: Alternative 6: In-situ Enhanced Bioremediation, ICs, SSD Systems, and MNA	*$1,240,000*	*$15,090,000*	*$16,330,000*	4
Minimum (except for No Action)	*$770,000*	*$5,340,000*	*$6,800,000*	
Median (except for No Action)	*$1,490,000*	*$7,370,000*	*$9,295,000*	
Average (except for No Action)	*$2,046,667*	*$9,958,333*	*$12,010,000*	
Maximum	*$4,660,000*	*$18,550,000*	*$23,210,000*	

Assumptions
All dollar amounts in Subtotals and Totals to nearest ten-thousand dollars
All values are in present worth 2010 Dollars

See Table B-1 for abbreviations and acronyms