Prepared for

Arizona Department of Environmental Quality
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Phoenix, Arizona 85007

FINAL FEASIBILITY STUDY

CENTRAL AND CAMELBACK
WATER QUALITY ASSURANCE REVOLVING FUND SITE
PHOENIX, ARIZONA

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I certify that this document and all attachments presented in this report are accurate and complete. This report was prepared by the staff of Geosyntec Consultants under my supervision to ensure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who are directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete.

Expires 3/31/18

Kirk Craig, P.E.
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6/4/15
Date

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LIST OF ACRONYMS AND ABBREVIATIONS

1,2-DCA	1,2-dichloroethane
AAC	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
ARS	Arizona Revised Statutes
AWQS	Arizona Aquifer Water Quality Standard
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
cDCE	cis-1,2- dichloroethene
COC	contaminant of concern
COP	City of Phoenix
DHC	*Dehalococcoides spp.*
DSD	Development Services Department
EAB	enhanced anaerobic bioremediation
E_h	redox potential
EPA	United States Environmental Protection Agency
ERA	Early Response Action
ERH	electrical resistive heating
EVO	emulsified vegetable oil
FS	Feasibility Study
ft	feet
GAC	granular activated carbon
gpm	gallons per minute
HGC	Hydro Geo Chem, Inc.
ISCO	*in situ* chemical oxidation
ISCR	*in situ* chemical reduction
ISTR	*in situ* thermal remediation
ITRC	Interstate Technology & Research Council
LGAC	liquid-phase granular activated carbon
LUST	leaking underground storage tank
µg/L	micrograms per liter
mV	millivolt
MNA	monitored natural attenuation
MTBE	methyl tert-butyl ether
OEC	One East Camelback (property)
ppmv	parts per million by volume
PCE	tetrachloroethene
PQGWP	Poor Quality Groundwater Withdrawal Permit

PRAP	Proposed Remedial Action Plan
PRB	permeable reactive barrier
RO	Remedial Objective
RSL	Regional Screening Level
SCSA	Southwest Corner Source Area
Site	Central and Camelback Water Quality Assurance Revolving Fund Site
SRL	Soil Remediation Level
SRP	Salt River Project
SVE	soil vapor extraction
TCE	trichloroethene
VGAC	vapor-phase granular activated carbon
VOC	volatile organic compound
WQARF	Water Quality Assurance Revolving Fund
ZVI	zero valent iron

1. INTRODUCTION

1.1 Purpose and Scope of the Feasibility Study Report

The Central and Camelback Water Quality Assurance Revolving Fund (WQARF) Site (the "Site") is located in Phoenix, Arizona (Figure 1-1). The Site consists of on-Site soil impact and a plume of impacted groundwater originating from the former dry cleaning facility Maroney's Cleaners and Laundry (Maroney's). This Feasibility Study (FS) Report was prepared by Geosyntec Consultants (Geosyntec) for the Arizona Department of Environmental Quality (ADEQ).

This FS Report was prepared in accordance with Arizona Administrative Code (AAC) Title 18, Environmental Quality, Chapter 16, Department of Environmental Quality WQARF Program, Article 4, Remedy Selection (R18-16), and is based on the data and findings of previous investigations, including the Remedial Investigation (RI) Report, prepared by Hydro Geo Chem, Inc. (HGC) [2014]. The objectives of this FS are as follows:

1. Identify remedial options and alternatives that will achieve the Remedial Objectives (ROs) as outlined in the Remedial Objectives Report [ADEQ, 2014a]; and

2. Evaluate the identified remedies, recommend alternatives, and comply with the requirements of Arizona Revised Statutes (ARS) §49-282.06.

Identified remedies were also compared to the groundwater pump and treat and soil vapor extraction (SVE) technologies currently being implemented as early response actions (ERAs) at the Site.

Based on the objectives stated above, this FS presents recommendations for the preferred remedy, that:

1. Assure the protection of public health, welfare, and the environment;
2. To the extent practicable, provide for the control, management, or cleanup of hazardous substances so as to allow for the maximum beneficial use of waters of the state;
3. Is reasonable, necessary, cost-effective, and technically feasible; and
4. Address any well (used for municipal, domestic, industrial, irrigation or agricultural purposes) that could produce water that would not be fit for its current or reasonably foreseeable end use without treatment.

The FS was conducted in accordance with the ADEQ WQARF Remedy Selection Rule, as presented in AAC Rl8-16-407, Feasibility Study.

1.2 Report Organization

The remainder of this FS Report is organized as follows:

- Section 2, "Site Background", presents a summary of the Site, including physiographic setting, the nature and extent of contamination, and a risk evaluation;
- Section 3, "Feasibility Study Scoping", presents the regulatory requirements of pertinent statutes and rules, delineates the remediation areas, and presents the ROs identified by ADEQ;
- Section 4, " Early Response Actions", summarizes the ERAs that have been undertaken at the Site;
- Section 5, "Identification and Screening of Remediation Technologies", presents an evaluation and screening of various remedial technologies related to contamination in groundwater, and lists the technologies that have been retained for inclusion into the reference and alternative remedies;
- Section 6, "Development of Reference Remedy and Alternative Remedies", presents the evaluation process and selection of a reference remedy, a more aggressive remedy, and a less aggressive remedy;
- Section 7, " Evaluation of Remedies", presents a summary of the three selected remedies compared to each other based on practicability, permitting, source control, cost, risk, and benefit, and includes a discussion of uncertainties associated with each remedy;
- Section 8, "Proposed Remedy", presents the recommended remedy, discusses how the remedy will meet the requirements of ARS §49-282.06 and AAC R18-16-407; and
- Section 9, "References", provides a list of references cited in this report.

2. SITE BACKGROUND

This section presents a summary of the Site background, physiographic setting, the nature and extent of contamination, and a risk evaluation. Additional background details are presented in the RI Report [HGC, 2014].

2.1 Site Description

The Site is located in the northern area of Phoenix, Arizona (Figure 1-1). The Site is bounded by Missouri Avenue to the north, Pierson Street to the south, 2^{nd} Street to the east, and 3^{rd} Avenue to the west. A former Maroney's dry cleaning facility was operated at 4902 North Central Avenue near the southwest corner of the Central Avenue and Camelback Road intersection. The RI Report refers to this area as the southwest corner source area (SCSA). The Site boundary is generally defined by the historical extents of the groundwater plume originating from SCSA (Figure 2-1).

2.2 Site Registry

In 1993, groundwater investigations associated with multiple nearby leaking underground storage tank (LUST) sites indicated the presence of tetrachloroethylene (PCE) the primary contaminant of concern (COC) and other volatile organic compounds (VOCs) above their respective Arizona Aquifer Water Quality Standards (AWQSs). The results of groundwater samples collected in the vicinity of the Site indicated the presence of PCE at concentrations as high as 20,000 micrograms per liter (μg/L). In 1999, after further studies confirmed the presence of contamination, the area was placed on the WQARF Registry as the Central and Camelback Site. The following year, the SCSA was listed as part of the same Site (ADEQ, 2015).

2.3 Site History

The following Site historical information is summarized from the RI Report [HGC, 2014]):

Prior to 1940, the Site was generally used for agricultural purposes. Starting in the late 1930s, residential developments, primarily single-family homes, were constructed along the main roads. Larger multi-family buildings were constructed starting in the 1950s. With the increase in residents in the area, commercial development began to occur along Central Avenue and Camelback Road. These included retail and service activities, such as automotive repair and service stations, and dry cleaning and laundry services.

Several dry cleaners have operated in the area, with two currently operating, Uptowne Cleaners at 5104 North Central Avenue and Society Cleaners at 16 East Camelback Road. As the former Maroney's facility is the primary source area, only that property's history is summarized herein. Information about additional dry cleaners in the vicinity of the Site is available in the RI Report.

Maroney's began operation in 1950 and was owned by Edwin K. and Margaret Maroney. Over the next 55 years, the dry cleaner was operated by twelve different owners. The facility ceased operations in 2006. The building was originally constructed between 1949 and 1951. Two additions occurred, the first before or during 1954 and the second before or during 1958. The building was demolished between October 2006 and February 2007. The building concrete slab-on-grade remains at the Site. A hazardous waste inspection conducted in 1993 indicated minor spillage at some locations within the dry cleaning operations.

LUST sites in and around the Site area include a former Weiss Guys Car Wash and several automobile fuel and service stations. Releases at these LUST sites were documented generally between the mid-80s and mid-90s. These sites are discussed in greater detail in the RI Report.

2.4 Source Area Definition

Soil, soil gas, and groundwater monitoring results indicated a variety of COCs and potential sources in the area. The contaminants of concern at the Site are PCE, trichloroethylene (TCE), and cis-1,2-dichloroethene (cDCE), with PCE as the primary COC detected at concentrations exceeding the AWQS of 5 µg/L. TCE was also detected at concentrations exceeding its AWQS of 5 µg/L; however, these concentrations may be the result of PCE degradation, rather than a separate TCE source. PCE impacts in groundwater extend north and northeast of the former Maroney's facility, and previous sampling results indicated the potential presence of dense non-aqueous phase liquid in soil and groundwater beneath the former building.

Other contaminants in the vicinity originating from the historical LUST site releases include benzene, toluene, ethylbenzene, and xylenes (BTEX), methyl tert-butyl ether (MTBE), and 1,2-dichloroethane (1,2-DCA). Both benzene and 1,2-DCA have been detected above their respective AWQS [HGC, 2014].

During site characterization, an ERA was determined necessary to prevent migration of the COCs to extraction wells adjacent to the SCSA. Groundwater modeling of the underlying aquifer and step-down testing of the groundwater extraction wells were conducted to design the groundwater extraction ("pump and treat") system. The system was installed and commissioned in 2003 to control the migration of the PCE plume. An additional ERA was initiated at the SCSA to remediate soils to supplement the groundwater ERA. In 2005, an SVE pilot test was performed, that demonstrated the effectiveness of this treatment technology for source area vadose zone remediation. A full-scale SVE system was installed, with operation beginning in 2007. These systems are currently running as ERAs, mitigating both the source area impacts and the plume migration.

Prior to 2000, the groundwater flow direction at the Site was to the north. The northerly flow direction was likely primarily due to groundwater recharge from the unlined Salt River Project (SRP) Grand Canal located approximately 0.3 miles to the south of the Site. Lining of parts of the Grand Canal commenced in 1994. Additional lining of the Grand Canal was performed in

2004. After lining of the Grand Canal, the groundwater flow direction changed to the east, and then to southeast due to removal of the recharge from the Grand Canal and due to operation of a groundwater extraction system for dewatering the aquifer beneath the One East Camelback (OEC) building located on the southeast side of the intersection of Central Avenue and Camelback Road (Figure 2-1). Extraction from the dewatering system commenced in 1994. Based on monitoring performed in December 2014, the groundwater flow direction was generally to the southeast [Geosyntec, 2015].

2.5 Chronology of Primary Site Activities

The following outlines many of the primary events and investigative milestones for the project, as largely described on the WQARF Central and Camelback website [ADEQ, 2015]:

1993: PCE impacts first detected on the Site during LUST site investigations.

1999-2000: The plume area and SCSA were placed on the WQARF Registry due to detections of high PCE concentrations in the groundwater.

2001: Four monitoring wells, CC-1 through CC_4, were installed in early 2001. CC-1 through CC-3 were installed near the north end of the Maroney's structure and CC-4 was installed near the northeast corner. Monitoring well CC-5 was installed later that year. ADEQ installed and initiated four groundwater extraction wells, EW-1 through EW-4, as the first ERA at the Site to remediate the groundwater source area impacts while also controlling VOC migration.

2003: The groundwater remediation system began operation. Extracted water was treated by passing the groundwater through liquid-phase granular activated carbon (LGAC) and discharging the treated water to a lateral of the SRP Grand Canal. The City of Phoenix (COP) sanitary sewer system was used as a secondary effluent discharge point when the SRP canal system was closed for maintenance. Eleven additional groundwater monitor wells were installed to further delineate the extent of PCE impacts in groundwater.

2004: Monitoring well CC-6 was installed in the SCSA to further evaluate the central plume and to monitor the treatment system's effects.

2005: Three monitoring wells were installed in 2005 to further delineate the contamination. CC-7 and CC-8 were installed north of the SCSA, and CC-9 was installed to the northwest. Based on the results of continued Site investigations and ERA evaluation, an SVE pilot test was conducted at the former Maroney's facility. The results of the pilot test indicated that SVE was an effective technology for vadose zone remediation in the SCSA.

2006: Two additional groundwater monitor wells, CC-10 and CC-11, were installed at the northern end of the plume on Medlock Drive and Orange Street, respectively.

2007: The remedial investigation was initiated to determine the nature and extent of the Site impacts. Twelve potentially interested parties were notified. Three additional groundwater monitor wells were installed; two on Pierson Street (CC-12 and CC-13) and one near the former Weiss Guys car wash location west of the Maroney's building (CC-14). The full-scale SVE system was commissioned in November.

2008: Two additional groundwater monitor wells, CC-16 and CC-18, were installed to further delineate the plume. CC-16 was installed on Georgia Avenue, and CC-18 was installed to the north of OEC.

2009: Starting in June, the SVE system was adjusted to a two-week on/two-week off pulse operation schedule to assess rebound and the potential for more efficient extraction of COCs.

2010: The groundwater pump and treat system was shut down from early January until early March. The initial shutdown was due to the drying and cleaning of the SRP Grand Canal. Budgetary constraints resulted in system downtime until early March. Once the system was restarted, it remained operational for the remainder of the year, with two of the four extraction wells operating. The SVE system was shut down from July to early September due to contracting and funding.

2011: The pump and treat system was shut down again in January for SRP Grand Canal cleanout. The system remained shut down until March for minor repairs and upgrades. Two of the four extraction wells were online for the remainder of the year. The SVE system continued to operate on a two-week on/two-week off pulse schedule until December, after which time the system was operated continuously. A new SVE well was constructed (SVE-2s/2d).

2012: The new SVE well was connected to the existing SVE system after a pilot test determined its feasibility.

2013: One of the groundwater extraction wells, EW-1, was compromised due to sand infiltration. The pumping equipment was moved from this well to monitor well CC-5, which has remained operational since commissioning. Two additional groundwater monitor wells, CC-15 and CC-17, were installed north of Camelback Road and east of Central Avenue. CC-15 was installed on Colter Street and CC-17 on Medlock Drive. A passive soil gas survey was conducted to investigate potential alternate source locations.

2014: HGC completed the RI Report. Geosyntec began performing operation, maintenance, and monitoring (OMM) for the ERAs. The groundwater treatment system was shut down in December due to an SRP Grand Canal dry cleanout.

2015: The groundwater pump and treat system was restarted in February following the SRP Grand Canal cleanout.

2.6 <u>Risk Evaluation from RI Report</u>

The risk evaluation conducted by HGC assessed the COCs and potential exposure pathways present at the Site. The soil, soil vapor, and groundwater monitoring results below the former Maroney's facility, as well as the downgradient groundwater impacts to the north and northeast of the Site, were included in the evaluation. Four components of exposure pathways were evaluated, including source of release, retention of transport media, exposure point, and exposure route.

Exposure via the groundwater pathway could occur due to the potential future conversion of SRP irrigation wells located in the vicinity of the Site to drinking water supply wells. Residents could be exposed by ingestion, inhalation, or dermal contact with impacted water. Cancer and non-cancer health hazards were calculated using the United States Environmental Protection Agency (EPA) Regional Screening Level (RSL) calculator. Cancer risk calculated for impacted groundwater exposure ranged from $1.3x10^{-5}$ to $2.3x10^{-4}$, with a cumulative risk of $4.1x10^{-4}$, which exceeds the upper end of the generally acceptable risk management range of $1x10^{-4}$ to $1x10^{-6}$. The non-cancer health hazard quotient was determined to be 1.91 to 19.8 for children and 1.76 to 15.5 for adults, both of which exceeded the target level of 1.0.

The air pathway includes exposure from vapor-phase COCs through inhalation. Soil vapor concentrations were used to assess this risk. Both cancer and non-cancer risks were estimated to be below the acceptable levels.

The soil contact pathway was determined to be incomplete at the time of the RI Report. The soil samples that have been analyzed from the Site have not shown COC concentrations above reporting limits.

Though there are no natural surface water features in the vicinity of the Site, the canal systems in the area were included for evaluation. The canals contain pumped and treated groundwater that is utilized largely for irrigation purposes. Residents may be exposed by dermal contact with the water. The *in situ* COCs in the extraction wells used to supply water to the canals have been consistently detected at lower concentrations than the RSL for dermal contact with PCE (56 µg/L).

3. FEASIBILITY STUDY SCOPING

The following subsections present the regulatory requirements of pertinent statutes and rules, delineation of the remediation areas, and the ROs identified by ADEQ.

3.1 Regulatory Requirements

According to ARS §49-282.06, the following factors must be considered for selecting remedial actions:

- Population, environmental, and welfare concerns at risk;
- Routes of exposure;
- Amount, concentration, hazardous properties, environmental fate, such as the ability to bio-accumulate, persistence and probability of reaching the waters of the state, and the form of the substance present;
- Physical factors affecting environmental exposure, such as hydrogeology, climate, and the extent of previous and expected migration;
- The extent to which the amount of water available for beneficial use will be preserved by a particular type of remedial action;
- The technical practicability and cost-effectiveness of alternative remedial actions applicable to a site; and
- The availability of other appropriate federal or state remedial action and enforcement mechanisms, including, to the extent consistent with this article, funding sources established under the Comprehensive Environmental Response, Compensation, and Liability Act, to respond to the release.

The Remedy Selection Rule AAC R18-16-407, Feasibility Study, states that an FS is a process by which to identify a reference remedy and alternative remedies that appear to be capable of achieving ROs and to evaluate the remedies based on the comparison criteria to select a remedy that complies with ARS §49-282.06.

3.2 Conceptual Site Model Summary

A detailed history and description of the Site is available in the RI Report. The following is a summary of the information presented therein [HGC, 2014].

3.2.1 Site History

The former Maroney's facility, located at the southwest corner of Central Avenue and Camelback Road operated at the Site from approximately 1950 until 2006. Contamination was first detected at the Site in 1993, with PCE being detected during independent LUST site investigations. PCE is the primary COC at the Site. Additional COCs include TCE and cDCE.

Both PCE and TCE have been detected at concentrations exceeding their respective AWQS of 5 µg/L (for both compounds). Other contaminants from historical LUST sites in the vicinity have also been identified, including BTEX, MTBE, and 1,2-DCA.

The released PCE transferred from the soil to groundwater, and migrated with historic groundwater flows to the north and northeast of the Site, leading to a plume nearly 0.5 miles long. Lining of parts of the SRP Grand Canal and operation of the groundwater dewatering extraction system on the OEC property resulted in reversal of the flow direction from northerly to the southeasterly (Section 2.4). PCE has also been detected in soil gas at the Site. A groundwater pump and treat system and an SVE system were implemented as ERAs to mitigate and control the source area and plume extent.

3.2.2 Site Hydrogeology

The regional groundwater is located within the West Salt River Valley Sub-Basin within the Phoenix Basin. This sub-basin is a broad alluvial valley with unconsolidated sand, gravel, silt, and clay. Beneath the Site is the Upper Alluvial Unit (UAU), which is comprised of silt and sand with some gravel and thin clay lenses. Though regionally the UAU is considered to be an unconfined aquifer, available information indicates that the local aquifer is semi-confined to the top 200 feet due to the presence of clay layers at depth. Under the UAU are the Middle Alluvial Unit (MAU) and the Lower Alluvial Unit (LAU). However, due to the semi-confined nature of the UAU and based on groundwater data collected at groundwater monitor wells CC-1 and CC-2, the lower units are not impacted. Figure 3-1 shows the lithology at the Site, created from boring log information collected during monitor well installation. This cross section shows the presence of confining silts and clays that have created the semi-confined nature of the UAU beneath the Site.

3.2.3 Groundwater Flow and Contaminant Transport

As mentioned previously, the lining of the SRP Grand Canal has impacted the depth to groundwater and the groundwater flow direction. The canal to the west of Central Avenue was lined in 1995, and the canal to the east was lined in 2004. Prior to the canal lining, leakage from the canal served to recharge the underlying aquifer, with groundwater mounding occurring directly beneath the canal. The Grand Canal is located south of the Site, and the groundwater mounding created a northerly flow in the Site's groundwater. Figure 3-2 shows the local groundwater contours and flow directions as observed in December 1994, before the canal was lined. Additionally, the groundwater mounding artificially elevated the groundwater table in the area to approximately 40 feet (ft) below ground surface (bgs). The lining of the canal removed the recharge source, and as a result, the mound dissipated and the groundwater table lowered. As the mounded groundwater dissipated, the flow direction changed from north through northeast, east, and southeast. Currently, groundwater at the Site flows to the south-southeast with the water table at approximately 65 ft bgs. Figure 3-3 shows the groundwater contours and flow direction as of December 2014. Figure 3-3 also demonstrates how the groundwater extraction and treatment system and the OEC extraction system impact local groundwater elevation contours.

3.2.4 Baseline Human Health Risk Assessment

As discussed in Section 2.6, HGC performed a risk evaluation for the Site. In summary, the groundwater pathway has the only complete exposure route that exceeds acceptable risk levels. The air and surface water both have risk levels below the acceptable risk target levels. The soil exposure pathway is deemed to be incomplete; however, this is partially due to the lack of VOCs detected in soil samples shallower than 30 ft bgs.

3.3 Delineation of Remediation Areas

The following subsections discuss the delineation of impacts to the vadose zone and groundwater at the Site, as well as the uncertainties associated with the delineations.

3.3.1 Vadose Zone

The analytical results of soil gas samples collected at the Site indicate the presence of elevated VOCs, particularly PCE and TCE, with the primary impacted area being the SCSA in the footprint of the former Maroney's facility. In 2007, soil sampling in the unsaturated zone on the SCSA showed detectable concentrations in 45 of 65 samples, with one sample having a concentration of 210 milligrams per kilogram (mg/kg), which is above the non-residential Arizona Soil Remediation Level (SRL) of 13 mg/kg. A passive soil gas survey in 2011 further delineated the impacts within the vadose zone beneath the former Maroney's facility. The analytical results from the passive gas samplers demonstrated the presence of several VOCs in the soil gas, with PCE detected in 24 of 26 samplers and TCE detected in 18 of 26 samplers [HGC, 2014]. Figure 3-4 presents the results of the 2011 on-Site passive soil gas sampling. The highest semi-quantitative detections were detected in the southwest corner of the Site, at sampling locations PSG-21 and PSG-22. The higher VOC concentrations are unevenly distributed, indicating potential preferential pathways for the soil gas migration at the Site.

Two additional areas were investigated using passive soil gas surveys and collection of soil vapor concentrations profiles for PCE with depth in 2011. Boring SB-01 was advanced near Uptown Cleaners and boring SB-02 was advanced near Society Cleaners (Figure 3-5). At SB-01, the soil vapor concentration increases with depth, while SB-02 shows a heterogeneous distribution. Since relatively low levels of PCE were detected in these areas, it is not conclusive that either of these sources contributed to the groundwater impacts that are being addressed by this FS. Therefore, the vadose zone remediation areas do not include either of these locations.

3.3.2 Groundwater

Initial hydraulic permeability estimates for the Site range from 15 to 75 feet/day, which is higher than expected given the clay and silt documented in the Site borings. Most wells in the area have a total depth of 100 to 120 ft bgs. Depth to water is currently 65 ft bgs, though historically it has been as high as 40 ft bgs due to mounding from the unlined SRP Grand Canal recharge.

The groundwater plume has been affected by the changes in the groundwater flow. Impacted groundwater had previously been transported from the former Maroney's facility to the north, with a plume length of nearly one half mile. Figure 3-6 demonstrates the northerly transport of contaminants from the Site and outlines the plume extent and concentrations as of 1995 to 1998, including the high concentrations present in the SCSA. The once primarily northerly transport was replaced by movement to the northeast, east, southeast, and then south-southeast near the dewatering and extraction wells. Figures 2-1 and 3-7 show the PCE plume extent from 2005 compared to the plume in 2014. The plume outlines the estimated extent of groundwater containing PCE at concentrations greater than the AWQS of 5 µg/L. Between 2005 and 2014, the impacted area was greatly decreased, demonstrating the effectiveness of the ERA groundwater extraction and treatment system. Figure 3-7 shows the latest concentration gradient measurements as of December 2014 [Geosyntec, 2015].

The largest area of residually impacted groundwater is located near monitor well CC-17 (Figure 3-7). This well was installed in June 2013 to delineate the eastern portion of the plume. However, sampling results have demonstrated the presence of elevated PCE concentrations in the well, with detected concentrations ranging from 120 and 140 µg/L. Sampling results also indicate that the VOC impacts in the vicinity of CC-17 may have been transported to the north historically, as shown by elevated concentrations detected in CC-11. More recent sampling results indicate that the impacts appear to be migrating to the south-southeast, with increasing concentrations recorded in CC-18.

3.3.3 Areas of Uncertainty

Previously identified data gaps include the delineation of the western edge of the plume and the estimated mass of VOCs contained in the plume. This information is critical to understanding mass removal and remaining impacts. Additionally, limited information is available regarding the potential for natural attenuation at the Site, with minimal and dated monitored natural attenuation (MNA) parameter information available. Updated MNA information would help document the extent of degradation within the plume.

Due to the more recent discovery of impacts near CC-17, the extent of impacts in this vicinity is unknown. Specifically, there are no monitor wells between CC-18 and the OEC extraction wells. With the apparent southerly migration of contaminants from the CC-17 area and the increasing concentrations at CC-18, VOCs may be transported to the OEC wells, but no monitor wells are in place to detect this potential migration.

One final area of uncertainty relates to the OEC wells. Limited information is available about this extraction system and associated permits. As this extraction system plays an important role in the local groundwater flow, understanding its design and operational parameters would provide a more complete understanding of the behavior of the groundwater in the vicinity of the Site.

3.4 Remedial Objectives

The ROs for the Site were developed by ADEQ pursuant to AAC R18-16-406 of the Remedy Selection Rule. ROs are established for the current and reasonably foreseeable uses of land and waters of the state that have been or are threatened to be affected by a release of a hazardous substance. Pursuant to AAC R18-16-406(D), it is specified that reasonably foreseeable uses of land are those likely to occur at the Site and the reasonably foreseeable uses of water are those likely to occur within one hundred years, unless Site-specific information suggests a longer time period is more appropriate.

Reasonably foreseeable uses are those likely to occur, based on information provided by water providers, well owners, land owners, government agencies, and others. ADEQ prepared a Land and Water Use Report (Use Report) [2014b] based on information gathered during the public involvement process. Not every use identified in the requisite Use Report will have a corresponding RO, based on whether or not the use is reasonably foreseeable.

The ROs must be stated in the following terms: (1) protecting against the loss or impairment of each use; (2) restoring, replacing, or otherwise providing for each use; (3) when action is needed to protect or provide for the use; and (4) how long action is needed to protect or provide for the use.

3.4.1 ROs for Land Use

Generally, the Site is located in a mixed urban, commercial, and residential area. Based on the current zoning maps provided by COP, the Site is zoned as residential (single and multiple family) and commercial (restricted, retail, intermediate, and high density). Based on future land use plans provided by COP, there are no immediate plans to change the land use or zoning for the areas of COP within and adjacent to the Site.

Although the former drycleaner property is currently zoned for commercial use, reasonably foreseeable use may be residential, as has been indicated by the current property owner. Therefore, residential SRLs apply and ROs for land use at the former drycleaner property were established. The ROs state that soil conditions are to be restored to the remediation standards for PCE in residential areas as specified in AAC R18-7-203. As long as soil concentrations exceed the remediation standard, actions must be taken to prevent exposure to contaminants. Identified exposure routes include direct contact with soil resulting from construction or industrial activities or inhalation of contaminants from vapor intrusion into occupied structures. This action is needed for the present time and for as long as the level of contamination in the soil threatens its use as a residential property.

3.4.2 ROs for Groundwater Use

The Site lies within the Phoenix Active Management Area (AMA). The Phoenix AMA was created by the Arizona Groundwater Management Code passed in 1980 and covers approximately 5,646 square miles in central Arizona. All groundwater withdrawn from any AMA must occur under a groundwater right or permit, unless groundwater is being withdrawn from an exempt well.

According to Arizona Department of Water Resources (ADWR) records, there are 11 non-exempt withdrawal wells in the Site; one irrigation well, and ten dewatering wells. ADWR records indicate that there are no exempt withdrawal wells at the Site and there are no grandfathered rights at the Site. COP and SRP have service area rights in the Site; however, of these two entities, only SRP currently has a groundwater extraction well at the Site.

Questionnaires were mailed to COP, SRP, and land owners to obtain information regarding current and future uses of groundwater within the Site. The following paragraphs identify current and foreseeable reported groundwater uses within the Site and proposed ROs.

The Site is in the Phoenix AMA, an area where groundwater use is controlled and regulated. COP does not have groundwater wells within the Site but has indicated that it may install wells in the future. Currently, a portion of the groundwater within the Site is impacted with COCs that would restrict use of the groundwater by COP if the city wanted to use the groundwater for municipal purposes.

SRP currently owns one well (13.5E-9.4N) within the Site boundaries. PCE has consistently been detected above the AWQS of 5.0 µg/L in the well; however, concentration trends have been declining to near the AWQS in recent years. The SRP well is intermittently operated to provide water for irrigation; however, SRP anticipates that the well may transition to drinking water supply in the reasonably foreseeable future, either by directly connecting the well to municipal water distribution systems or by piping to municipal water treatment plants located on the SRP canal system. Currently, the SRP well is not pumped on a regular basis and according to SRP; there are no anticipated changes in the pumping schedule.

One Camelback Inc., the property owner of the OEC property on the southeast corner of Central Avenue and Camelback Road, currently has ten dewatering wells surrounding their building at the property. The dewatering wells are used to pump groundwater from the aquifer to lower the depth of groundwater and to prevent groundwater from entering the building's underground parking garage. The extracted groundwater is treated due to the presence of petroleum hydrocarbons from a LUST release in this area. Groundwater treatment includes passing the water through an air stripper to remove VOCs prior to discharge into the COP storm water sewer.

The remedial objective for regional groundwater at the Site is to protect for the use as a groundwater supply by COP and SRP. This action will be needed if/when groundwater use changes to municipal/drinking water. This action will be needed for as long as the level of impacts in the groundwater threaten the use of the regional groundwater for municipal/drinking water uses.

3.4.3 ROs for Surface Water Use

The surface water use portion of the Use Report indicates that surface water usage within the Site is for residential irrigation. The surface water source comes from groundwater wells outside the Site. Surface water for use in the Site is provided/distributed by the Medlock Homeowners Association canal system, which is supplied by the SRP from sources outside the Site.

Since current surface water use in the Site is for irrigation and comes from groundwater sources outside the Site; no surface water RO is necessary at this time.

4. EARLY RESPONSE ACTIONS

The following information is summarized from the *Remedial Investigation Report* [HGC, 2014]. For the purposes of remediating the source area and to mitigate further aquifer impacts, two ERA activities were implemented at the Site. The first ERA was a groundwater extraction and treatment system and the second was an SVE system. The following is a description of these activities, which forms the basis of the FS for the vadose zone and groundwater remediation.

4.1 Groundwater Extraction and Treatment System

The groundwater extraction system was constructed to contain and control the movement of impacted groundwater in the SCSA, with particular emphasis on mitigating migration from the SCSA to the OEC groundwater extraction system. After modelling the groundwater and Site conditions, five extraction wells were installed between October and December 2001 (EW-1, EW-2, EW-3, and EW-4, and CC-5, which originally used as a monitor well). Step-drawdown tests were conducted after the wells were installed. These tests determined that the wells could pump up to 40 gallons per minute (gpm) each. Based on these results, the treatment system was designed to treat up to 180 gpm with chlorinated VOC concentrations up to 5,600 µg/L.

The treatment system has two LGAC vessels arranged in series, each holding up to 10,000 pounds of activated carbon. The system is monitored by a ROCLINK™ software control system that will shut down the extraction system through automation if an alarm situation is detected. System construction was completed in January 2003, with startup testing for three to four weeks. The official start date was February 6, 2003.

Treated groundwater was initially discharged to the COP sewer and later to the SRP Grand Canal. The COP discharge permit was no longer necessary and was terminated in 2012. The carbon in the LGAC vessels has been changed eight times between April 2003 and May 2015.

On January 20, 2009, the pump at EW-4 was shut down due to continuously low detected PCE concentrations. Both EW-2 and EW-3 were shut down in mid-2009 due to low concentrations; however, EW-2 was restarted in October 2009. In March 2013, the pumping system from EW-1 was moved to CC-5 due to diminished pumping capacity at EW-1 caused by sand infiltration. The system is currently extracting groundwater from EW-2 and CC-5 at about 28 and 17 gpm, respectively. Monitor wells in the area have shown significant decreases in VOC concentrations since the extraction system began operating. The influent concentrations to the system were recently detected at 14 µg/L for PCE, 2.0 µg/L for TCE, and non-detect for cDCE. Effluent concentrations for the treatment system are continually not detected above reporting limits. In 2014, approximately 61 acre-feet of water were pumped, removing an estimated 3.4 pounds of PCE. Since the system was started in 2003, an estimated 313 pounds of VOCs have been removed, approximately 291 pounds of which were PCE.

4.2 SVE System Installation, Start-Up, and Operation

The following subsections provide information pertinent to the installation, startup and testing of the Site's SVE system.

4.2.1 SVE System Testing

The SVE system was designed to remove and treat VOCs (primarily PCE and TCE) from the SCSA vadose zone, which had been identified as a source area for the groundwater impacts. Two SVE wells, SVE-1 and SVE/MP-1D, were installed in June 2004 with pilot testing conducted in 2005.

The pilot test was conducted using SVE-1 and SVE/MP-1D and a portable SVE system including a positive displacement blower, flow measurement and control instrumentation, and an off-gas carbon treatment system with two 2,000-pound vapor-phase granular activated carbon (VGAC) vessels in series. The system was operated for 22 hours, during which time detected concentrations ranged from 310 to 660 parts per million by volume (ppmv) of PCE and 5.9 to 12 ppmv of TCE. The tests and additional modeling demonstrated that SVE was an effective remediation technology at the Site.

4.2.2 SVE System Installation and Operation

SVE system construction was completed in October 2007 with an air permit issued by the Maricopa County Air Quality District for SVE operation. The components for the system are located in a fenced area northwest of the former dry cleaning building (Figure 4-1). Two 5,000-pound capacity VGAC vessels are connected in series to treat the extracted vapors. The system was officially started on November 20, 2007, with extraction from SVE-1 and SVE/MP-1D. An additional well, SVE-FC, was added to the system in February 2008.

The system operated continuously, with the exception of minor shutdowns for maintenance purposes, until June 2009. Because VOC concentrations in extracted soil gas had become asymptotic, the system was generally operated on a two weeks on, two weeks off schedule starting in June 2009 until December 2011. In February 2011, the moisture removal system was modified, which resulted in an increase in air flow and VOC concentrations. The system was changed to run continuously in December 2011, a change that has generally continued to present day with increased mass removal benefit.

As of November 2012, an estimated 4,174 pounds of PCE and TCE had been removed, with estimated removal rates declining from 5 pounds per day at the start to 2 pounds per day at the end of 2012. At this point, the SVE system was tested and additional boreholes were installed, including SVE-2, which was approximately 30 feet southwest of SVE-1 and SVE-FC (Figure 4-1). Relatively high PCE concentrations were initially observed at this location. SVE-2 was added to the SVE system on December 12, 2012, which significantly increased PCE/TCE recoveries to ten pounds per day. By September 2014, the recovery rate had decreased to less than one pound per day, with a total mass recovery estimated at 6,180 pounds since the system began operating [HGC, 2014]. Currently, the system removes approximately 0.7 pounds per day, with an estimated total mass recovery of over 6,350 pounds since the system began through April 2015.

5. IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

This section provides a detailed discussion of the identification and screening of remediation technologies for potential implementation at the Site. Technologies are identified and screened separately for remediation of the vadose zone and groundwater. Remediation areas are defined in Section 3.3.

5.1 Technology Screening

This section defines and describes remediation technology screening assumptions, as well as treatment technologies, for the Site considered to be acceptable by ADEQ for achieving the ROs and to comply with the requirements of AAC Rl8-16-407. The following assumptions and system requirements were used during the identification and screening of remedial technologies. Conservative COC concentrations were assumed as follows:

- PCE at a concentration of 100 µg/L in groundwater near CC-17;
- PCE at a concentration of 25 µg/L in groundwater at the SCSA; and
- PCE is still present in the vadose zone at the SCSA: soil concentrations are unknown, but sufficient mass is still present in the subsurface to lead to contaminant removal rates of a fraction of a pound per day.

The appropriate remediation technologies were identified and screened according to the following criteria:

- Contaminant treatment effectiveness;
- Constructability;
- Flexibility/expandability;
- O&M requirements;
- Operational hazards; and
- Cost-effectiveness

The remediation technologies that pass the technology screening are retained for use in development of the reference remedy and alternative remedies later in this report.

5.2 Flow Rates and Dosage Rates

The flow rates or dosage rates for active remedies will depend on the remedial strategy (Section 6). Flow rates for SVE and groundwater extraction are based on operation of the current ERA systems, and are estimated based on: 1) vadose and saturated zone soil types at the Site, 2) conceptual remediation system designs, and 3) project engineering experience.

For the vadose zone, the current ERA system operates at approximately 190 cubic feet per minute. Because SVE is not needed in any other areas of the Site, the expected flow rate for an SVE remedy would be similar to this, although it could be slightly higher if the system is expanded. In any case, the current treatment system is sufficient to treat these extraction rates, and additional capacity will not be needed.

For groundwater extraction, the current ERA system, which pumps from the SCSA, operates at approximately 45 to 50 gpm. Additional groundwater extraction could be performed from the detached plume area near well CC-17 (Figure 3-7). Depending on the number of wells required, this could add an additional 25 to 50 gpm of flow. Also, converting wells from the OEC dewatering system could provide an additional 25 to 50 gpm of flow to the system. Even if flow is increased to a total of 150 gpm, the current treatment system has sufficient capacity for these flows.

In situ groundwater technologies have been evaluated herein for this Site. For any injection-based technologies, the actual flowrates that can be achieved will depend on lithologies in the areas to be injected. Based on the remediation areas discussed in Section 3.3 above, the area most likely to be considered for injections would be the detached plume near CC-17. Based on extraction rates from the current groundwater extraction wells, amendment injection rates using permanent injection wells should be in the range of 1 to 5 gpm per well or more; in addition, it is expected that multiple wells could be connected via manifolds and injected at the same time, thus increasing the overall amendment injection flowrates.

5.2.1 Mass Removal

VOC mass removal estimates are based on the performance of the current ERA systems. The SVE system currently removes a fraction of a pound per day of VOC mass. If the system is expanded, this could increase for a period of time, but then would be expected to decrease as more mass is removed from the subsurface and the system reaches asymptotic conditions.

For groundwater, approximately 3.4 pounds of VOCs were removed in 2014. This is consistent with essentially full time operation of the system at 50 gpm, with influent concentrations of approximately 15 μg/l. If extraction is performed from other areas where concentrations are higher, it is expected that mass removal would increase. For example, pumping from the CC-17 detached plume could result in removal of an additional 20 pounds/year of PCE (assuming a 50 gpm extraction rate and an influent concentration of 100 μg/l from this area). In reality, if pumping was performed in the CC-17 area, groundwater with lower VOC concentrations would also be extracted, which would result in a lower actual influent concentration. In addition, concentrations would be anticipated to decrease with time after startup.

5.2.2 End Use

The end use of the treated groundwater will be based on the remedial system discharge alternative. For this use, the selected technology and system design(s) must comply with all applicable Federal, state and local requirements. Further discussion of end use options is included in Sections 5.4.

5.3 Screening of Treatment Technologies

Technologies are described below that are commonly used for treating the concentration levels of VOCs at the Site. The basic treatment mechanisms and the suitability and limitations of the technologies are discussed. Rather than perform a detailed and quantitative screening of each technology according to the criteria listed above, technologies are screened against these technologies in a general sense. Technologies that are retained are then used to develop remedies for the Site (Section 6). The reasons a particular technology is retained for further evaluation or eliminated from consideration are also discussed. The results of the technology screening are summarized in Table 5-1.

5.3.1 Soil Vapor Extraction

SVE is an established and proven removal technology for the COCs in the vadose zone, particularly in situations where excavation and off-site disposal of impacted soil is impractical. SVE involves the installation of a series of extraction wells in the impacted soil above the water table and applying vacuum to pull soil vapors containing COCs from the vadose zone. The SVE wells are typically connected via a header system to collect the soil vapor for discharge to the atmosphere, with or without first being treated to remove the PCE (and other volatiles), depending on the quantity emitted and local regulations.

SVE has been operating at the Site as an ERA since 2007 and has been effective at removing VOC mass from the subsurface. SVE is retained as a treatment technology for soil at the Site.

5.3.2 Groundwater Extraction and Treatment using LGAC

Extraction and treatment is a removal technology for groundwater that can be effective for sites impacted with VOCs for hydraulic containment and/or migration control. A groundwater extraction and treatment system has been operating at this Site as an ERA since 2003 and has been reasonably effective at controlling additional VOC migration in groundwater from the SCSA. The hydraulic conditions at the Site are favorable for groundwater extraction, and additional areas could be targeted. The LGAC vessels have been successful at removing VOCs from the extracted water, so no additional treatment technology evaluation is required. Extraction and treatment using LGAC is retained as a treatment technology for groundwater at the Site.

5.3.3 *In Situ* Chemical/Biological Reduction

In situ reduction can be accomplished using either biological or chemical mechanisms. *In situ* biological reduction, also known as enhanced anaerobic bioremediation (EAB), is an *in situ* remediation approach that uses microorganisms in the subsurface to degrade chloroethenes, such as PCE to ethene and ethane. During EAB, PCE is completely transformed to innocuous byproducts via the following reductive dechlorination pathway:

PCE → TCE → cDCE → vinyl chloride → ethene

EAB generally occurs through the addition of fermentable carbon compounds that serve as electron donors for bacteria that use the chloroethenes as electron acceptors, once competing electron acceptors have been removed from groundwater (e.g. dissolved oxygen). The hydrogen produced during fermentation reactions is the primary electron donor for dechlorinating bacteria and drives EAB. This electron transfer process may either occur metabolically (providing the bacteria with energy for population growth and maintenance) or cometabolically (without energy benefit to the bacteria).

The two primary requirements for successful implementation of EAB are: 1) adequate spatial distribution of the electron donor to achieve strongly reducing conditions, and 2) a microbial community capable of complete reductive dechlorination of the chloroethenes.

Electron Donors

Multiple carbon substrates are available as electron donors for EAB. However, based on experience with the available substrates, the generally most effective (in performance, handling requirements, and cost) substrates in the type of subsurface environment that is present at this Site would be sodium lactate or emulsified vegetable oil (EVO).

Sodium lactate is readily biodegraded by fermenting bacteria into electron donors usable by dechlorinating bacteria, and therefore dechlorination can be enhanced almost immediately after injection. However, because it is a "fast-release" substrate, it is often exhausted within 3 to 6 months following injection. EVO is considered a "slow-release" substrate. It is primarily comprised of edible oils that will slowly dissolve into the groundwater. Because of this, dechlorination is not typically stimulated as quickly by slow-release substrates as fast-release substrates, but the substrate will continue to promote dechlorination for a longer period (i.e., 18 to 24 months). Commercial EVO products often have a small proportion of a fast-release substrate, such as lactate, to provide both initial and longer term stimulation of EAB.

Bioaugmentation

Bioaugmentation is the addition of bacteria that have the ability to promote complete degradation of PCE to ethene. At many sites, the lack of the necessary bacteria, *Dehalococcoides spp*. (DHC), causes degradation to "stall out" at cDCE or vinyl chloride. DHC is the only known bacteria to completely degrade PCE to ethene. Although DHC is commonly found throughout the contiguous United States, it is not present at all sites. In addition, there may be circumstances where DHC is present at a site but either the populations are too low to support significant dechlorination or the type of DHC present does not degrade PCE efficiently. In fact, recent EPA guidance has concluded that bioaugmentation often reduces the remediation timeframe and costs of EAB [EPA, 2013].

In situ chemical reduction (ISCR) can also accomplish VOC degradation. It can also overcome biological limitations that may occur with EAB because it does not rely on the presence of specific microbes. Zero valent iron (ZVI) is a common chemical reductant that can treat VOC-impacted groundwater (Section 5.3.5).

A practical and often cost effective approach is to use amendments that combine both chemical and biological degradation mechanisms. One class of such amendments are carbon-iron combinations. These products combine physical, chemical, and biological treatment methods into an injectable material composed of ZVI and organic carbon. The amendments can yield redox potential (E_h) in the -500 to -650 millivolt (mV) range. This E_h is significantly lower (more favorable) than that achieved when using either organic materials (lactate, molasses, and sugars) or reduced metal alone. E_h in this range facilitates the timely and effective removal of normally recalcitrant chlorinated organics, including PCE, TCE, and cDCE, without the formation of potentially problematic intermediates, such as dichloroethene or vinyl chloride from the anaerobic degradation of PCE.

Following injection, these amendments slowly ferment to release fatty acids and nutrients. This process supports reductive dechlorination of chlorinated ethenes without accumulation of metabolites and is less disrupting of natural habitats; minimizes production of fermentation end-products, such as methane.

Because of the similarities and common advantages of chemical and biological reduction, all of these amendments/technologies are retained as a treatment technology for groundwater at this Site.

5.3.4 *In Situ* Thermal Treatment

In situ thermal remediation (ISTR) is an aggressive technology that is best suited for removal of VOCs from high concentration source areas. It is included in this evaluation of alternatives to allow comparison of slower, less aggressive technologies (EAB and ISCR), with a more aggressive (and more expensive) approach. The most common thermal remediation technologies are electrical resistance heating (ERH), thermal conduction heating, and steam injection. Each of these has advantages and disadvantages, but all would be applicable for VOC remediation. For the purposes of this evaluation, it is assumed that ERH would be the option selected for ISTR, if implemented. ERH applies electricity into the ground through electrodes. ERH passes electrical current through impacted soil and groundwater; the aquifer provides resistance to the flow of the electrical current, and as a result heat is generated *in situ*, with temperatures of up to the boiling point of water being possible. This heating volatilizes VOCs *in situ* and steam strips them from the subsurface. Vapors and steam are then extracted, cooled, and treated using standard methods. The technology has been demonstrated as an effective method for the removal of

VOCs from both vadose and saturated zones, especially in low permeability soils where other standard remedial technologies are less efficient.

ISTR is not retained as a treatment technology for the Site, primarily because it is not cost effective for the low VOC concentrations that remain, even in the CC-17 area detached plume. ISTR is most effective in source areas that contain non-aqueous phase liquids. It is not appropriate for the <100 μg/L of PCE concentrations remaining at this Site.

5.3.5 Permeable Reactive Barrier using ZVI

ZVI can be trenched or injected into the ground perpendicular to groundwater flow as a permeable reactive barrier (PRB). The ZVI would then intercept and treat the VOC-impacted groundwater via chemical reduction as it flows through the PRB. While ZVI can be effective for remediation of VOCs, it is less aggressive than other *in situ* technologies because it relies on advective flow of groundwater to transport COCs to the barrier; thus, it is passive. At sites where construction is straightforward, PRBs can be cost-effective and can perform well in treating VOC-impacted groundwater. However, the depth of installation at this Site would preclude simple trenching as a means of emplacement, which would make construction costs prohibitively expensive. In addition, the commercial/industrial area where a PRB would be installed would make construction very difficult. Therefore, a PRB using ZVI is not retained as a treatment technology for this Site.

5.3.6 *In Situ* Chemical Oxidation

In situ chemical oxidation (ISCO) relies on injection of a powerful oxidizing agent to destroy the organic compounds. Several oxidants are available and have been proven effective for chlorinated ethenes, including persulfate, permanganate, and modified Fenton's reagent. All of these oxidants are considered effective for oxidizing PCE and its biological degradation products, TCE, DCE, and vinyl chloride [ITRC, 2005]. The oxidant is generally delivered to the site in concentrated formulations or as solids, mixed in the field, and then injected through semi-permanent injection wells or temporary injection points (if site geology allows for use of direct push technology).

Groundwater in the CC-17 area is already moderately reducing (as evidenced by low dissolved oxygen, reduced E_h, and the presence of PCE reductive dechlorination daughter products). In addition, ISCO is generally not cost effective for low concentrations of VOCs, such as those that are currently present at the Site. Therefore, ISCO is not retained as a treatment technology for this Site.

5.3.7 Monitored Natural Attenuation

MNA uses natural processes occurring in groundwater to reduce contaminant concentrations over time. Dilution, adsorption, volatilization, precipitation, complexation, and biological degradation of the contaminants occur in the groundwater. Of these processes, reductive dechlorination (using biological and/or abiotic degradation processes) is usually the most significant degradation process for chlorinated solvents such as PCE and TCE. MNA would allow these processes to continue as they have in the past, without disturbances potentially caused by implementation of active remedial technologies. For this Site, MNA as a stand-alone remedy would include shutting down the groundwater extraction and treatment ERA, which may not meet groundwater standards. Because of this, MNA may be relied upon in combination with other active remedies, but may not be sufficient to remediate the Site by itself.

5.4 Treated Water Discharge

If continued groundwater extraction is implemented as a part of the preferred remedy for the Site, significant quantities of water would need to be extracted and treated. The treated groundwater was initially discharged to the COP sewer system and later to the SRP canal system, which is where it is currently discharged. The COP discharge permit was no longer necessary and was terminated in 2012. It is assumed that if additional extraction locations are added as a part of the remedy, treated water discharge to the SRP canal will continue.

6. DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES

Using the retained remedial technologies, selection of remedial measures, prescribed remedial strategies, and discharge considerations, a Reference Remedy has been developed along with two alternative remedies for comparison. The Reference Remedy and each alternative remedy consist of a remedial strategy and measures to achieve ROs for the Site.

The remedial strategies to be developed are discussed below. Note that a strategy may incorporate more than one remediation technology or methodology. As provided in AAC R18-16-407(F), remedial strategies for consideration may include:

- Plume remediation to achieve water-quality standards for COCs in waters of the state throughout the Site;
- Physical containment to contain contaminants within definite boundaries;
- Controlled migration to control the direction or rate of migration, but not necessarily to contain migration of contaminants;
- Source control to eliminate or mitigate a continuing source of contamination;
- Monitoring to observe and evaluate the contamination at the Site through the collection of data; and
- No action.

Remedial measures necessary for each alternative remedy have been identified with consideration of the needs of the water providers (COP and SRP) and their customers, including the quantity and quality of water, water rights, other legal constraints, reliability of water suppliers, and any operational implications. Such remedial measures may include, but are not limited to, well replacement, well modification, water treatment, provision of replacement water supplies, and engineering controls. Where remedial measures are necessary to achieve ROs, such remedial measures will remain in effect as long as required to ensure the continued achievement of those objectives.

The combination of the remedial strategy and remedial measures for each alternative remedy are designed to achieve the ROs. The Reference Remedy and each alternative remedy also may include contingent remedial strategies or remedial measures to address reasonable uncertainties regarding the achievement of ROs, or uncertain timeframes in which ROs will be achieved. The Reference Remedy and the alternative remedies are described below.

6.1 Reference Remedy - Strategy and Measures

The following subsections present the remedial strategies and control measures for the vadose and groundwater Reference Remedies, as well as the associated permits and agreements.

6.1.1 Vadose Zone Remedial Strategies and Measures

The remedial strategies for the vadose zone Reference Remedy are:

- Physical containment to capture contaminants within definite boundaries;
- Source control to eliminate or mitigate a continuing source of contamination; and
- Monitoring to observe and evaluate the contamination at the Site through the collection of data.

The vadose zone remediation area is essentially limited to the footprint of the former Maroney's facility at the SCSA. Because of this, the remedial strategies center on controlling any sources of COCs and continued removal of VOC mass, as well as monitoring of the extraction system.

The remedial measures for the vadose zone Reference Remedy are centered on continued operation of the current ERA SVE system as follows:

1. Continued operation of the existing SVE system, using VGAC to treat the extracted soil vapor. The SVE system currently removes VOCs at approximately 0.7 pounds per day, and has removed over 6,300 pounds to date.
2. The current operational monitoring will be continued to assess remedy progress.
3. A soil gas survey will be performed in the SCSA, similar to what was performed in 2011. Based on the results of this survey, the SVE remedy may change. If results suggest that the current extraction network cannot address all areas of residual impacts, then the system will be expanded (the More Aggressive Remedy as described in Section 6.2.); if the soil gas survey results suggest that relatively low VOC mass remains, then the SVE system will be shut down temporarily to assess rebound (the Less Aggressive Remedy, described in Section 6.3.)

6.1.2 Groundwater Remedial Strategies and Measures

The remedial strategies for the groundwater Reference Remedy are:

- Physical containment to capture contaminants within definite boundaries;
- Source control to eliminate or mitigate a continuing source of contamination; and
- Monitoring to observe and evaluate the contamination at the Site through the collection of data.

The remedial measures for the groundwater Reference Remedy are centered on continued operation of the current ERA groundwater extraction and treatment system, along with expansion to include treatment of other areas of the plume to accelerate remediation:

1. Continued operation of the existing groundwater extraction and treatment system, which pumps from wells within the SCSA. In 2014, the system removed approximately 3.4 pounds of VOCs. It has removed approximately 313 pounds of VOCs to date.
2. Installation of a sentinel monitor well south of CC-18 and north of the OEC dewatering wells (Figure 6-1). This well would then be sampled for VOCs monthly for 3 months. Depending on the results of this sampling, the Reference Remedy would include one of the following options:
    a. If the CC-18 sentinel well shows VOCs greater than an AWQS, this would imply that the VOCs extend further south than previously thought, and that they may have already reached the OEC dewatering wells. In this scenario, the Reference Remedy could then include expanded extraction by incorporating OEC wells into the current treatment system. This option would require significant coordination between ADEQ and the OEC property owners. The resulting extraction flowrate would still be within the range that the current treatment system can accept.
    b. If the CC-18 sentinel well shows VOCs less than AWQS, then this would imply that the southern extent of the CC-17 detached plume is still north of the CC-18 sentinel well. In this scenario, CC-18 would be converted to a groundwater extraction well. Further, an additional extraction well may be installed to the west of CC-18. The well(s) would then be connected to the existing treatment system, and extraction would be performed from the current SCSA well network. In this manner, the remaining detached plume would be captured and treated before it could migrate to the OEC dewatering wells. The resulting extraction flowrate would still be within the range that the current treatment system can accept.
3. Expanded operational monitoring would be performed to assess progress of the Reference Remedy.

6.1.3 Reference Remedy Permits and Agreements

Multiple permits and/or agreements would be necessary to authorize installation and operation of the Reference Remedy:

- Pre-construction notifications (Notice of Intent forms) and post-construction reporting (Driller's Reports) would need to be prepared for any new groundwater extraction/monitor wells that are installed.
- Well construction and/or modification work must be conducted by an ADWR-licensed driller. New wells must also comply with the ADWR's well construction standards,

which are found in ARS §45-594, -595, -596 and -600 of the Groundwater Code. The potential change in use of CC-18 from a monitor well to an extraction well will also require a permit change.

- A construction permit from the COP Development Services Department (DSD) may be required for the installation of conveyance piping from the new extraction wells to the existing groundwater extraction and treatment system. This will require preparation and submittal of design plans and specifications (i.e., civil, plumbing, mechanical, electrical) to COP.
- The permit that allows for discharge to the SRP canal may need to be modified to account for increased flow, if the groundwater extraction system is expanded.
- Operation of OEC dewatering wells would require a new COP sewer discharge permit. As these wells serve to dewater an underground structure, they cannot be shut down when the SRP canal is closed for maintenance. As such, the treatment system would need to be able to continuously discharge water, and the COP sewer system would serve as an alternate discharge point when discharge to the SRP canal is not allowed.
- The existing Poor Quality Groundwater Withdrawal Permit (PQGWP) may need to be updated.
- Based upon an understanding of its historic policies, ADEQ will need to negotiate/obtain access agreements with the current land owner(s) for well installations and for assuming operation of the OEC dewatering wells.

6.1.4 Source Control

Source control must be considered as an element of the Reference Remedy and all alternative remedies. As described above, source control is included for both the vadose zone and groundwater Reference Remedy.

6.2 More Aggressive Alternative Remedy - Strategy and Measures

The following subsections present the remedial strategies and control measures for the vadose and groundwater More Aggressive Alternative Remedies, as well as the associated permits and agreements.

6.2.1 Vadose Zone Remedial Strategies and Measures

The remedial strategies for the vadose zone More Aggressive Remedy are:

- Physical containment to capture contaminants within definite boundaries;
- Source control to eliminate or mitigate a continuing source of contamination; and
- Monitoring to observe and evaluate the contamination at the Site through the collection of data.

The vadose zone remediation area is essentially limited to the footprint of the former Maroney's facility at the SCSA. Because of this, the remedial strategies center on controlling any sources of contamination and continued removal of mass, as well as monitoring of the system.

The remedial measures for the vadose zone More Aggressive Remedy are centered on expansion of the current ERA SVE system. As described for the Reference Remedy, a soil gas survey will be performed in the SCSA, similar to what was done in 2011. If results suggest that the current extraction network cannot address all areas of remaining contamination, the system will be expanded to include additional extraction locations. The more aggressive remedy is assumed to include one additional extraction location. The current treatment system, which includes two 5,000-pound VGAC treatment vessels will have sufficient capacity to treat the additional vapor, and no additional equipment is required.

6.2.2 Groundwater Remedial Strategies and Measures

The remedial strategies for the groundwater More Aggressive Remedy are:

- Plume remediation to achieve water-quality standards for COCs in waters of the state throughout the Site;
- Physical containment to contain contaminants within definite boundaries;
- Source control to eliminate or mitigate a continuing source of contamination; and
- Monitoring to observe and evaluate the contamination at the Site through the collection of data.

The remedial measures for the groundwater More Aggressive Remedy include all aspects of the groundwater Reference Remedy. This includes operation of the current ERA groundwater extraction and treatment system, and additional extraction either from the OEC dewatering wells, and/or extraction from the area south of CC-17.

In addition to the expanded extraction, the More Aggressive Remedy also includes *in situ* treatment to target the remaining contaminant detached plume centered around monitor well CC-17. The injections will be performed in two "barrier" configurations oriented from west to east, one along the north side of East Medlock Road just upgradient (if possible) of well CC-17, and another in the parking lot just south of East Medlock Road, downgradient of CC-17 (Figure 6-1). Each barrier will be approximately 250 ft in length and will be approximately 100 ft apart. These barriers will treat contaminated groundwater as it flows through them toward the extraction wells located to the south. The recommended amendment for this application is a combined chemical/biological amendment These types of amendments overcome limitations associated with biological amendments such as emulsified vegetable oil (EVO) because the iron component eliminates the need for bioaugmentation. Also, concentrations currently present at the Site are potentially too low to support rapid growth of Dehalococcoides.

A pre-design investigation is needed in order to further refine the understanding of contaminant distribution with depth in this area. Well CC-17 has a relatively long screen (40 ft), and the sample results from this well likely represent significant dilution/averaging across this screen length. It is possible that higher concentrations are present in discrete lithologies within the 40 ft screened interval. While an injection program could be designed to deliver amendment across this entire interval, that approach would likely be overly conservative and result in excessive costs.

In addition to the pre-design investigation, pilot testing is recommended to determine optimum delivery methods and injection point spacing. Pilot testing for treatment effectiveness of the amendment is not needed, but it can be very useful for gaining design parameters to be used in full scale injection. For purposes of this FS, the following assumptions are made:

- Target injection depths are from 70-80 ft bgs;
- Permanent injection wells are required in order to reach target depths; and
- Well spacing of 20 ft (and, therefore, radius of influence of 10 ft from each well) will allow for a complete barrier.

Using this approach, it is anticipated that ten injection wells would be required in each barrier.

6.2.3 More Aggressive Remedy Permits and Agreements

Multiple permits and/or agreements as follows, would be necessary to authorize installation and operation of the more aggressive groundwater remedy:

- Pre-construction notifications (Notice of Intent forms) and post-construction reporting (Driller's Reports) would need to be prepared for any new extraction wells that are installed (additional SVE wells or the new groundwater extraction well).
- Well construction and/or modification work must be conducted by an ADWR-licensed driller. New wells must also comply with the ADWR's well construction standards, which are found in ARS §45-594, -595, -596 and -600 of the Groundwater Code. The potential change in use of CC-18 from a monitor well to an extraction well will also require a permit change. Additional permits may be required for the injection wells.
- A construction permit from the COP DSD may be required for the installation of conveyance piping from the new extraction wells to the existing groundwater extraction and treatment system. This will require preparation and submittal of design plans and specifications (i.e., civil, plumbing, mechanical, electrical) to the City.
- The permit that allows for discharge to the SRP canal may need to be modified to account for increased flow, if the groundwater extraction system is expanded.

- Based upon an understanding of its historic policies, ADEQ will need to negotiate/obtain access agreements with the current land owner(s) for well installations and for assuming operation of the OEC dewatering wells.

6.2.4 Source Control

Source control must be considered as an element of the Reference Remedy and all alternative remedies. As described above, source control is included for both the vadose zone and groundwater More Aggressive Remedies.

6.3 Less Aggressive Alternative Remedy -Strategy And Measures

The following subsections present the remedial strategies and control measures for the vadose and groundwater Less Aggressive Alternative Remedies, as well as the associated permits and agreements.

6.3.1 Vadose Zone Remedial Strategies and Measures

The remedial strategy for the vadose zone Less Aggressive Remedy is:

- Monitoring to observe and evaluate the contamination at the Site through the collection of data

The vadose zone remediation area is essentially limited to the footprint of the former Maroney's facility at the SCSA. As described for the Reference Remedy, a soil gas survey will be performed in the SCSA, similar to what was done in 2011. If the soil gas survey results suggest that relatively low VOC mass remains, then the SVE system will be shut down temporarily to assess rebound. The details of the rebound monitoring would be developed in a subsequent Proposed Remedial Action Plan (PRAP), which would also include criteria for restarting the system. If the system did require restarting, then this would essentially change back to the Reference Remedy, which is continued operation of the current ERA SVE system.

6.3.2 Groundwater Remedial Strategies and Measures

The remedial strategies for the groundwater Less Aggressive Remedy are:

- Physical containment to capture contaminants within definite boundaries;
- Source control to eliminate or mitigate a continuing source of contamination; and
- Monitoring to observe and evaluate the contamination at the Site through the collection of data.

The remedial measures for the groundwater Less Aggressive Remedy are continued operation of the current ERA groundwater extraction and treatment system. The current groundwater monitoring network would be used to assess progress of the remedy.

6.3.3 Reference Remedy Permits and Agreements

Since no additional systems or components would be installed, no additional permits and/or agreements would be necessary. However, periodic renewal of existing permits may be required.

6.3.4 Source Control

Source control must be considered as an element of the Reference Remedy and all alternative remedies. As described above, source control is included for both the vadose zone and groundwater Less Aggressive Remedies. Even though the SVE system would be shut down, source control is still achieved, because it would be restarted if COC concentrations rebounded to unacceptable levels.

7. COMPARISON OF REMEDIAL ALTERNATIVES

The following subsections present a comparison of the remedial alternatives and provide detailed evaluations of the associated remedies.

7.1 Comparison Criteria: Practicability, Cost, Risk, and Benefit

In accordance with the Remedy Selection Rule (R18-16-407, Feasibility Study), this FS has been completed to identify a Reference Remedy and alternative remedies that appear to be capable of achieving ROs, and to evaluate the remedies based on the comparison criteria in order to select a remedy that complies with ARS §49-282.06. The Remedy Selection Rule specifies that practicability, costs, risks, and benefits are the primary remedy evaluation criteria.

7.2 Detailed Evaluation of Remedies

Tables 7-1 and 7-2 present the detailed evaluation of the remedies for soil and groundwater, respectively, in regards to the comparison criteria. The text below summarizes how each remedy performs against these criteria.

7.2.1 Reference Remedy

The practicability, protectiveness, cost, and benefits for both the soil and groundwater Reference Remedies is discussed in the following subsections.

7.2.1.1 Practicability

The Reference Remedy for both soil and groundwater involve technologies that are already operating at the Site (pump and treat and SVE). For the soil Reference Remedy, the SVE system will continue operating as it is currently constructed, and therefore is highly practicable. SVE is a known effective remedy for VOC impacts in the vadose zone, and it is reliable.

For the groundwater Reference Remedy, groundwater extraction and treatment is a well-established technology that can be highly effective in the short-term and moderately effective in the long-term. While this technology in general is highly feasible, the fact that the Reference Remedy includes expansion to include either the OEC dewatering wells or additional extraction wells northeast of the SCSA does present some challenges for construction, primarily due to existing infrastructure and utilities that need to be avoided. However, the groundwater Reference Remedy is still considered to be highly practicable.

7.2.1.2 Protectiveness

The Reference Remedy for both soil and groundwater is protective, as each removes the COCs from the subsurface. The remedies mitigate exposure pathways and are consistent with current and future land use. Both remedies offer source control, as extraction occurs directly in the source area.

7.2.1.3 Cost

Costs for the Reference Remedies are presented in Table 7-3; detailed costs are presented in Appendix A. These costs are considered practical given the limited current and foreseeable funding available by the ADEQ WQARF program, which will be responsible for implementing the remedy. From Table 7-3, capital costs for the soil Reference Remedy are approximately $52,800, and annual O&M costs are approximately $115,500. The SVE system is assumed to operate for an additional five years, although the actual duration will depend on data collected during operations.

For groundwater, costs for the reference remedy are presented for both options of extraction from the CC-18 area and from the OEC area. For the CC-18 extraction option, capital costs are approximately $516,000, and for the OEC option capital costs are approximately $422,000. Annual O&M costs are assumed to be the same for both options and are approximately $211,000. The groundwater extraction and treatment system is assumed to operate for five years, although the actual duration will depend on data collected during operations.

7.2.1.4 Benefits

The Reference Remedy for soil is continued operation of the successful ERA SVE system, and the Reference Remedy for groundwater provides prompt hydraulic containment for the CC-17 detached plume. This will mitigate the continued migration of VOC mass, which will reduce the time to complete remediation. Continued monitoring of the systems during operations will provide a means for evaluating the effectiveness of remediation.

7.2.2 More Aggressive Remedy

The practicability, protectiveness, cost, and benefits for both the soil and groundwater More Aggressive Remedies is discussed in the following subsections.

7.2.2.1 Practicability

The More Aggressive Remedy for both soil and groundwater involves expansion of technologies that are already operating at the Site (pump and treat and SVE). For soil, the SVE system will add extraction points and continue operating in the SCSA, and therefore is highly practicable. SVE is a known effective remedy for VOC impacts in the vadose zone, and it is reliable.

For the groundwater, extraction and treatment is a well-established technology that can be highly effective in the short-term and moderately effective in the long-term. While this technology in general is highly feasible, the fact that the Reference Remedy includes expansion to include either the OEC dewatering wells or additional extraction wells northeast of the SCSA does present some challenges for construction, primarily due to the infrastructure that needs to be avoided.

The More Aggressive Remedy for groundwater also includes *in situ* treatment using chemical/biological reduction. This remedy component is more aggressive and will have higher short- and long-term effectiveness; however, installation of multiple injection wells on commercial and/or private property could be difficult. All of these factors combine to make the More Aggressive Remedy for groundwater moderately practicable.

7.2.2.2 Protectiveness

The More Aggressive Remedy for both soil and groundwater is highly protective, as each removes VOC mass from the subsurface. The remedies mitigate exposure pathways and are consistent with current and future land use. Both remedies offer source control, as extraction occurs directly in the source area, and the groundwater remedy adds aggressive *in situ* treatment of the remaining VOC detached plume.

7.2.2.3 Cost

Costs for the More Aggressive Remedy for soil and groundwater are presented in Table 7-3; detailed costs are presented in Appendix A. The costs for the More Aggressive Remedy for soil are considered practical given the limited current and foreseeable funding available by the ADEQ WQARF program. However, costs for the More Aggressive Remedy for groundwater are relatively high, due to the installation of a network of amendment injection wells.

From Table 7-3, capital costs for the More Aggressive Remedy for soil are approximately $105,000, and annual O&M costs are approximately $127,000. The SVE system is assumed to operate for five years, although the actual duration will depend on data collected during operations.

For groundwater, costs for the More Aggressive Remedy are presented assuming that the CC-18 extraction option is selected. The capital costs are estimated to be $1,410,000, and annual O&M costs are $333,000. The groundwater extraction and treatment system is assumed to operate for three years, although the actual duration will depend on data collected during operations.

7.2.2.4 Benefits

The More Aggressive Remedy for soil expands the successful ERA SVE system. The More Aggressive Remedy for groundwater provides hydraulic containment of the VOC plume and *in situ* treatment of the CC-17 detached plume. This will mitigate the continued migration of VOC mass, which will reduce the time to complete remediation. It is assumed that the *in situ* treatment component will reduce the operational timeframe of the groundwater extraction and treatment system by at least two years. Continued monitoring of the groundwater system during operations will provide a means for evaluating the effectiveness of remediation.

7.2.3 Less Aggressive Remedy

The practicability, protectiveness, cost, and benefits for both the soil and groundwater Less Aggressive Remedies is discussed in the following subsections.

7.2.3.1 Practicability

The Less Aggressive remedy for soil involves shutdown of the ERA SVE system, which would have very high feasibility and reliability. However, effectiveness may be low if significant residual VOC mass remains.

The Less Aggressive Remedy for groundwater entails operation of the current groundwater extraction and treatment system; this technology is well-established and can be highly effective in the short-term and moderately effective in the long-term. Since no expansion is included, the Less Aggressive Remedy for groundwater is still considered to be highly practicable.

7.2.3.2 Protectiveness

The Less Aggressive Remedy for soil may not be protective if significant residual VOC mass remains in the vadose zone, because no further treatment would be performed. If rebound was to occur, then the contingency would be to default back to the Reference Remedy (operation of the ERA SVE system).

The Less Aggressive Remedy for groundwater is protective, as it mitigates exposure pathways and is consistent with current and future land use. It offers source control, as extraction occurs directly in the source area.

7.2.3.3 Cost

Costs for the Less Aggressive Remedies are presented in Table 7-3; detailed costs are presented in Appendix A. These costs are considered practical given the limited current and foreseeable funding available by the ADEQ WQARF program.

For soil, capital costs for the Less Aggressive Remedy are approximately $40,000, and annual O&M costs are approximately $24,000. This remedy consists of quarterly rebound sampling for two years following shutdown of the SVE system.

For groundwater, capital costs for the Less Aggressive Remedy are approximately $16,500, and annual O&M costs are approximately $164,000. The groundwater extraction and treatment system is assumed to operate for ten years, because additional time is needed for the CC-17 detached plume to attenuate. The actual duration will depend on data collected during operations.

7.2.3.4 Benefits

The Less Aggressive Remedy for soil doesn't provide benefit, since remediation activities cease (natural attenuation mechanisms for chlorinated VOCs in the vadose zone are very slow). The Less Aggressive Remedy for groundwater is continued operation of the successful ERA system. This will mitigate the continued migration of VOC mass from the SCSA, but it may not adequately address the detached plume near CC-17.

7.3 Comparison of Remedies

Comparison of the remedies is required under the Remedy Selection Rule (R18-16-407, Feasibility Study). A comparison of the remedies for soil is provided in Table 7-4, and a comparison of the remedies for groundwater is provided in Table 7-5.

7.3.1 Practicability

Each of the remedies is considered to be technically and operationally practicable. The Reference Remedy and More Aggressive Remedy for soil have equally high practicability, as both remedies rely primarily on the existing SVE system, with low-risk modifications for the More Aggressive Remedy. The Reference Remedy for groundwater has the highest practicability, as it utilizes the groundwater system as it currently is, without the challenges associated with the required modifications for the More Aggressive Remedy.

7.3.2 Protectiveness

The More Aggressive Remedy for both soil and groundwater is the most protective, while the Less Aggressive Remedy is the least protective.

7.3.3 Cost

The More Aggressive Remedy for both soil and groundwater is the most costly, while the Less Aggressive Remedy is the least costly.

7.3.4 Benefit

The three remedies each benefit the environment through remediation of VOC impacts at the Site over time. Although it is clearly the lowest cost, the Less Aggressive Remedy does not contain/remediate soil at the source if significant residual VOC mass remains in the subsurface. The Less Aggressive Remedy for groundwater may not adequately address the detached plume near CC-17, and thus, provides less benefit that will likely result in a longer time period to achieve remediation.

The Reference Remedies for soil and groundwater provide source control, and they address the CC-17 detached plume at costs considered practical between the Less and More Aggressive Remedies. While the More Aggressive remedy for groundwater provides the most protectiveness and the shortest remediation timeframe, the incremental benefit compared to the Reference Remedy is not considered to be worth the significant additional cost.

8. PROPOSED REMEDY

The following subsections present the proposed remedy for both soil and groundwater as well as the basis for selecting the proposed remedy.

8.1 Process and Reason for Selection

The Reference Remedies for both soil and groundwater are recommended as the proposed remedies at the Site. This recommendation is based on what is considered to be the best combination of remedial effectiveness, practicability, cost, and benefit for restoration and use of the groundwater resource.

8.2 Achievement of Remedial Objectives

The Reference Remedies for soil and groundwater achieve the ROs for the Site, as described in Section 3.5. Continued operation of the ERA SVE system will provide source control for soil and will prevent migration to groundwater. Expansion of the currently operating groundwater extraction and treatment system will enhance removal of COCs from the subsurface and will address the remaining detached plume near CC-17.

8.3 Achievement of Remedial Action Criteria Pursuant To ARS §49-282.06

It is recommended that the Reference Remedies be selected as the Final Remedies for soil and groundwater at the Site. Based on a comparison with the More Aggressive and Less Aggressive Remedies, the Reference Remedies:

- Provide for adequate protection of public health and welfare and the environment;
- Provide a thorough and timely means for continued monitoring of the existing groundwater impacts, including assessment of plume capture by extraction wells, and evaluation of the progress of remediation over time;
- To the extent practicable, provide for the control, management, and cleanup of the COCs in the groundwater;
- Provide for the beneficial use of the groundwater resource by COP and SRP; and
- Are reasonable, cost-effective, and technically feasible.

8.4 Consistency with Water Management and Land Use Plans

The Reference Remedies for soil and groundwater are consistent with water management plans and general land use plans.

8.5 Contingencies

A monitoring program will be developed to evaluate operational efficiency and to assess effectiveness of each remedial system. For the soil Reference Remedy (SVE), operational monitoring will be conducted to assess the effectiveness of contaminant removal. Current operations suggest that mass removals are decreasing; if this continues, operation of the SVE system in a pulsed manner may be considered (e.g. cycle the SVE system off and on every one to two weeks). This approach will allow for temporary VOC rebound while the system is shut down, and subsequent removal of the VOC's when the system is restarted.

For the groundwater Reference Remedy, operational and performance monitoring will be conducted to assess plume capture as well as the effect of extraction on nearby monitor wells. Should monitoring results indicate inadequate capture of the VOC plume or incomplete treatment of extracted water, contingency actions could be implemented. These actions may include: 1) increasing the pumping rate from one or more wells/extraction points to expand capture; 2) installing additional extraction locations to enhance capture; and 3) installing supplemental monitor wells or piezometer wells, as necessary, for use in evaluating the adequacy of plume capture.

If performance monitoring suggests that the extraction system is reaching diminishing returns (e.g. asymptotic concentrations in nearby monitor wells), then additional contingencies could be considered. As with the SVE system, a pulsed pumping strategy could be implemented, or the system could be temporarily shut down and a rebound study could be conducted to assess the extent of VOC's remaining in the groundwater.

For both the soil and groundwater Reference Remedies, contingencies will be presented in detail in the PRAP and subsequent remedial design documents.

9. REFERENCES

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TABLES

Table 5-1
Summary of Technology Screening
Central and Camelback WQARF Site
Phoenix, Arizona

Technology	Retained?	Reason for Elimination
SVE	Yes	
Groundwater Extraction and Treatment Using LGAC	Yes	
In situ chemical reduction	Yes	
In situ biological reduction	Yes	
In situ thermal treatment	No	Not cost effective for low concentrations
Permeable Reactive Barrier	No	Not cost effective at Site depths; Low constructability
In situ chemical oxidation	No	Not cost effective for low concentrations; groundwater is already reducing
Monitored Natural Attenuation	No	Not likely to meet standards as stand-alone remedy

Abbreviations and Acronyms:
WQARF - Water Quality Assurance Revolving Fund
SVE – soil vapor extraction
LGAC – liquid-phase granular activated carbon

Table 7-1

Remedy Evaluation for Soil
Central and Camelback WQARF Site
Phoenix, Arizona

Remedial Alternative	Will Alternative Meet Remedial Objectives?	*Practicability*				*Costs*	Benefit of Remediation	Regulatory/Public Acceptance
		Feasibility	Short/Long Term Effectiveness	Reliability	Protectiveness	Discussion		
Reference Remedy - Current SVE System (Early Response Action)	Yes	Very feasible, system is already constructed and operational	SVE is a known effective remedy for VOC contamination in the vadose zone; the current system has removed significant mass but may be beginning to reach asymptotic removals.	SVE is a known and reliable remediation technology.	The reference remedy is protective, as it removes contaminants from the source and prevents further migration. It mitigates exposure pathways and is consistent with current and future land use. Remediation will be continued until contaminant levels are below standards.	No capital costs would be incurred, and O&M costs would be the same as the current ERA system.	The reference remedy would provide continued reduction of contaminant concentrations and mass in the vadose zone, which would result in lower risk.	Highly likely
More Aggressive Remedy - Expanded SVE System	Yes	Addition of SVE extraction points on the SCSA is very feasible.	SVE is a known effective remedy for VOC contamination in the vadose zone; adding extraction point(s) to the current system would help mitigate the asymptotic removals that are beginning to become apparent at the site if significant additional mass remains. Adding additional extraction system(s) at offsite locations would increase short and long term effecetiveness.	SVE is a known and reliable remediation technology.	The more aggressive remedy is protective, as it removes contamiants from the source and prevents further migration. It mitigates exposure pathways and is consistent with current and future land use. Remediation will be continued until contaminant levels are below standards.	Capital costs would include a small amount for installation of additional extraction location(s) in the SCSA.	The more aggressive remedy would provide continued reduction of contaminant concentrations and mass in the vadose zone, which would result in lower risk.	Highly likely
Less Aggressive Remedy - Shutdown of Current System	Uncertain	Very feasible, current system would need to be shut down	This remedy has low effectivness in the short term and long term; however, it is possible that residual contamination at the site is low.	Since nothing is operating under this remedy, reliability is very high.	No further active remediation would be performed, therefore the protectiveness of this remedy is unknown. It is possible that confirmation sampling would show that no further risks are posed by the residual VOCs due to the existing ERA.	The only additional costs for this remedy would be for decommissioning/ demobilizing the current system and post-remediation monitoring	No additional remediation would be performed, so no benefits would occur.	Moderately unlikely

ERA - Early Response Action
O&M - Operation and Maintenance
SCSA - Southwest Corner Source Area
SVE - Soil Vapor Extraction
VOC - Volatile Organic Compound

Table 7-2

Remedy Evaluation for Groundwater
Central and Camelback WQARF Site
Phoenix, Arizona

Remedial Alternative	Will Alternative Meet Remedial Objectives?	*Practicability*				*Costs*	Benefit of Remediation	Regulatory/Public Acceptance
		Feasibility	Short/Long Term Effectiveness	Reliability	Protectiveness	Discussion		
Reference Remedy - Expanded Pumping	Yes	The reference remedy is moderately to highly feasible; constructing piping across Central Ave would be a potential challenge. The treatment system is already constructed and operational.	Groundwater extraction and treatment is a well established technology; addition of the OEC or new pumping wells will have high short-term effectiveness and moderate long-term effectiveness. Groundwater extraction generally reaches a point of dimishing returns due to back diffusion from low permeability areas, but it appears to have been effective at this site.	Groundwater extraction is a known and reliable remediation technology.	The reference remedy is protective, as it removes contaminants from the subsurface and controls migration. It eliminates exposure pathways and is consistent with current and future land use. Remediation will be continued until contaminant levels are below standards. Since no hotspot treatment is included, the timeframe could be longer than the more aggressive remedy.	Capital costs include connecting the new wells to the current well network and treatment system; O&M costs will be similar to the current ERA system.	The reference remedy would provide continued reduction of contaminant concentrations and mass in the aquifer, which would result in lower risk. The addition of new extraction wells may accelerate the remediation timeframe.	
More Aggressive Remedy - Expanded Pumping plus In Situ Reduction	Yes	The more aggressive remedy is moderately feasible; as with the reference remedy, constructing piping across Central Ave would be a potential challenge. The treatment system is already constructed and operational. Installation of injection wells is another potential challenge, as it would involve gaining access to public right of way and potentially private property.	This remedy would have very high short and long-term effectiveness, as in situ treatment would be performed in addition to the expanded groundwater extraction. Chemical/biological reduction is demonstrated to be effective as long as adequate amendment delivery is acheived.	Groundwater extraction is a known and reliable remediation technology; in situ chemical and biological reduction has been well established as a remediation technology for VOCs over the past decade.	The more aggressive remedy is protective, as it removes contaminants from the subsurface source and controls migration. In addition, it provides destruction of the highest concentration areas in situ. It eliminates exposure pathways and is consistent with current and future land use. Remediation will be continued until contaminant levels are below standards.	Capital costs include connecting OEC wells to the current well network and treatment system, as well as installation of injection wells and injection of amendment; O&M costs for the groundwater extraction component will be similar to the current ERA system; the in situ treatment is assumed to require an additional injection in Year 2.	The more aggressive remedy would provide continued reduction of contaminant concentrations and mass in the aquifer, which would result in lower risk. Additional risk reduction would occur through the aggressive treatment of the hotspot upgradient of the extraction wells.	
Less Aggressive Remedy - Current System (Early Response Action)	Yes	This remedy is very feasible, as the system is already running.	Groundwater extraction and treatment is a well established technology; it generally reaches a point of dimishing returns due to back diffusion from low permeability areas, but it appears to have been effective at this site.	Groundwater extraction is a known and reliable remediation technology.	The less aggressive remedy is protective, as it removes contaminants from the subsurface and controls migration. It eliminates exposure pathways and is consistent with current and future land use. Remediation will be continued until contaminant levels are below standards. Since no hotspot treatment is included, the timeframe could be longer.	No additional capital costs would be incurred; O&M costs will be similar to the current ERA system.	This remedy would provide continued reduction of contaminant concentrations and mass in the aquifer, which would result in lower risk.	

ERA - Early Response Action
OEC - One East Camelback
O&M - Operation and Maintenance
SCSA - Southwest Corner Source Area
VOC - Volatile Organic Compound

Table 7-3
Cost Summary
Central and Camelback WQARF Site
Phoenix, Arizona

Soil and Groundwater Remedies	Capital Costs	O&M Costs (annual)	NPV	Potential Range	
				(-50%)	(+100%)
Soil Less Aggressive Remedy	$40,000	$24,400	$84,000	$42,000	$168,000
Soil Reference Remedy	$52,800	$115,500	$526,400	$263,200	$1,052,800
Soil More Aggressive Remedy	$105,000	$127,000	$625,600	$312,800	$1,251,200
Groundwater Less Aggressive Remedy	$16,500	$163,900	$1,167,900	$584,000	$2,335,800
Groundwater Reference Remedy (CC-18)	$515,600	$211,400	$1,382,400	$691,200	$2,764,800
Groundwater Reference Remedy (OEC)	$421,900	$211,400	$1,288,700	$644,400	$2,577,400
Groundwater More Aggressive Remedy(1)	$1,410,700	$333,500	$2,597,900	$1,299,000	$5,195,800

Notes: (1) Assumes the CC-18 option for expanded pumping.

Abbreviations:
NPV - net present value
O&M - operation and maintenance
OEC - One East Camelback (property)

Table 7-4. Soil Remedy Scoring

Soil Remedial Alternative Scoring
Central and Camelback WQARF Site
Phoenix, Arizona

Remedial Alternative	Will Alternative Meet Remedial Objectives?	*Practicability*				*Cost*	Benefit of Remediation	Total
		Feasibility	Short/Long Term Effectiveness	Reliability	Protectiveness	Estimated Costs		
Reference Remedy - Current SVE System (Early Response Action)	5	5	5	5	5	5	4	34
More Aggressive Remedy - Expanded SVE System	5	4	5	5	5	4	5	33
Less Aggressive Remedy - Shutdown of Current System	2	5	2	3	1	3	0	16

SVE - soil vapor extraction

Scoring	
5	Best (Criterion completely satisfied)
4	Above Average
3	Average (Criterion partially satisfied)
2	Below Average
1	Poor
0	No benefit

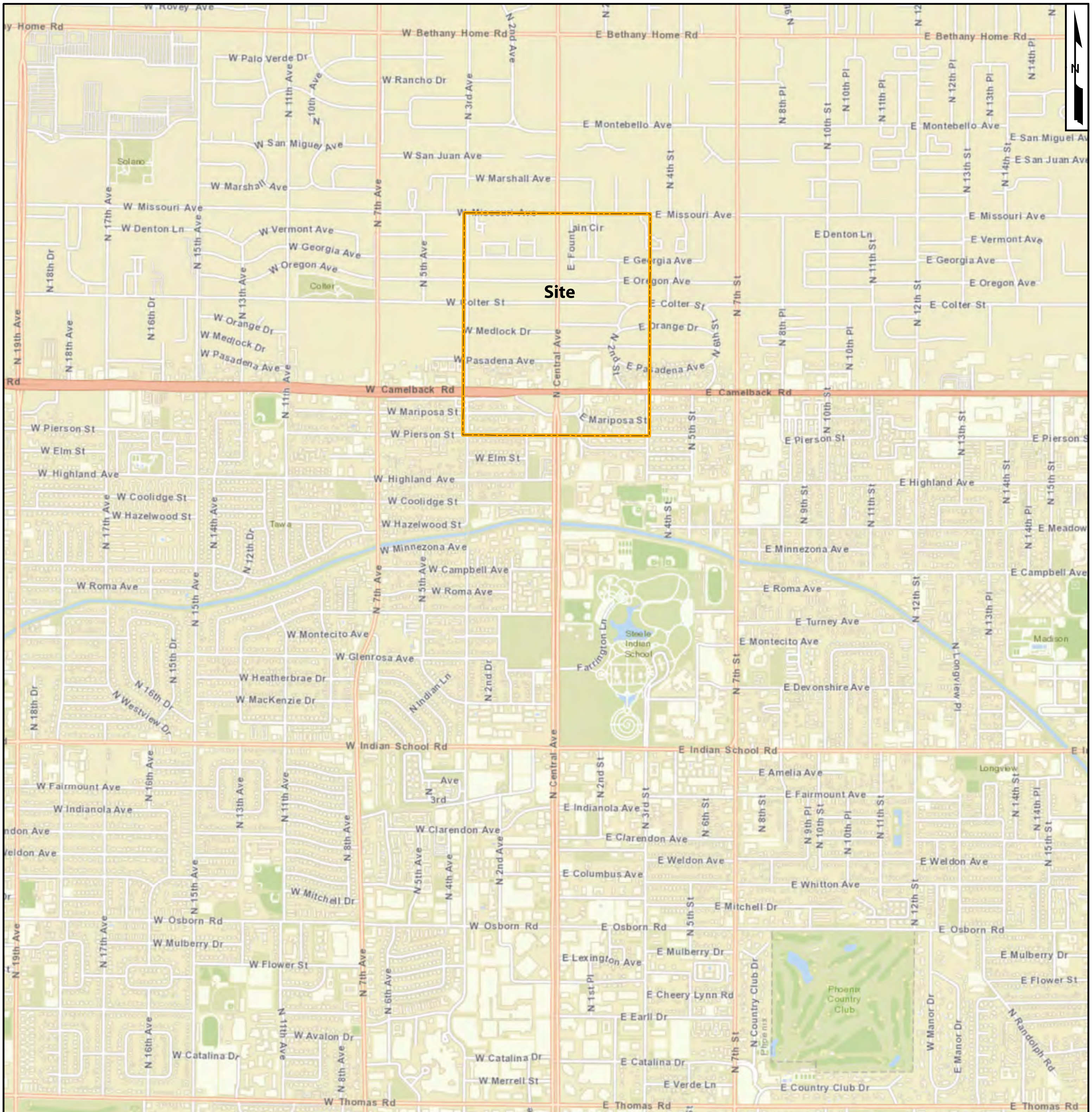
Table 7-5. Groundwater Remedy Scoring

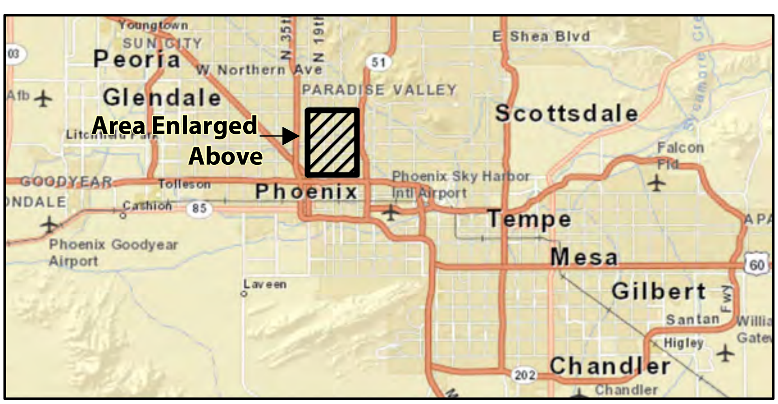
Groundwater Remedial Alternative Scoring
Central and Camelback WQARF Site
Phoenix, Arizona

Remedial Alternative	Will Alternative Meet Remedial Objectives?	*Practicability*				*Cost*	Benefit of Remediation	Total
		Feasibility	Short/Long Term Effectiveness	Reliability	Protectiveness	Estimated Costs		
Reference Remedy - Expanded Pumping	5	4	4	5	5	4	4	31
More Aggressive Remedy - Expanded Pumping plus In Situ Reduction	5	3	5	4	5	2	5	29
Less Aggressive Remedy - Current System (Early Response Action)	3	5	3	5	3	5	3	27

Scoring	
5	Best (Criterion completely satisfied)
4	Above Average
3	Average (Criterion partially satisfied)
2	Below Average
1	Poor
0	No benefit

FIGURES





2,000 1,000 0 2,000 Feet

Site Location

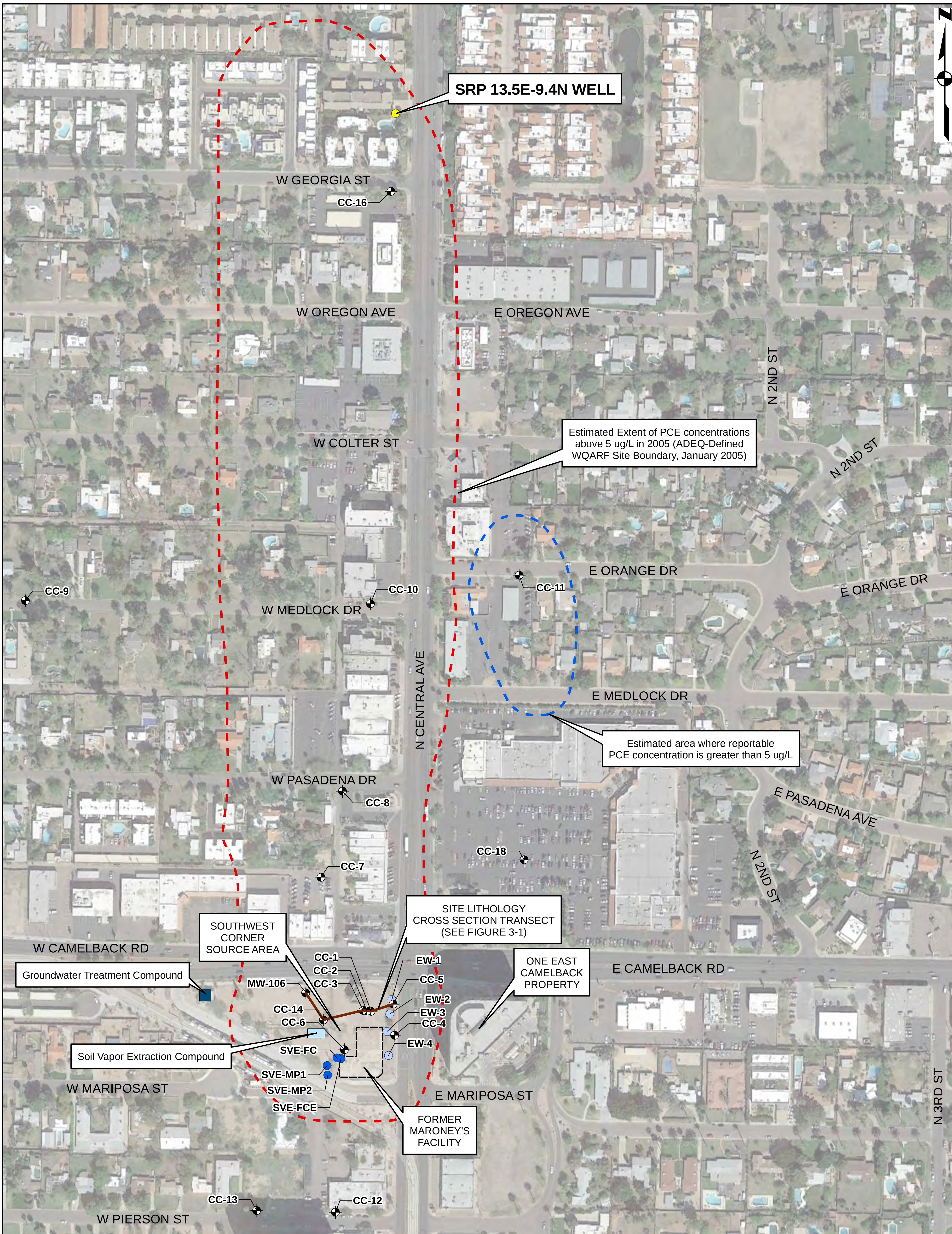
Central and Camelback WQARF Site
Phoenix, AZ

Geosyntec consultants

Figure 1-1

Phoenix, AZ | January 2015

P:\GIS\SP0143_ASRAC_Central\Camelback\Camelback\SiteLocationMap.mxd\JGordon



Legend

- SVE WELL
- EXTRACTION WELL
- GROUNDWATER MONITORING WELL
- ESTIMATED EXTENT OF PCE CONCENTRATIONS ABOVE 5 ug/L IN 2005
- ESTIMATED AREA WHERE REPORTABLE PCE CONCENTRATION IS GREATER THAN 5 ug/L
- SITE LITHOLOGY CROSS SECTION TRANSECT (SEE FIGURE 3-1)

Note: Figure source - HGC, 2014

200 100 0 200 Feet

PCE Plume Delineation from Remedial Investigation

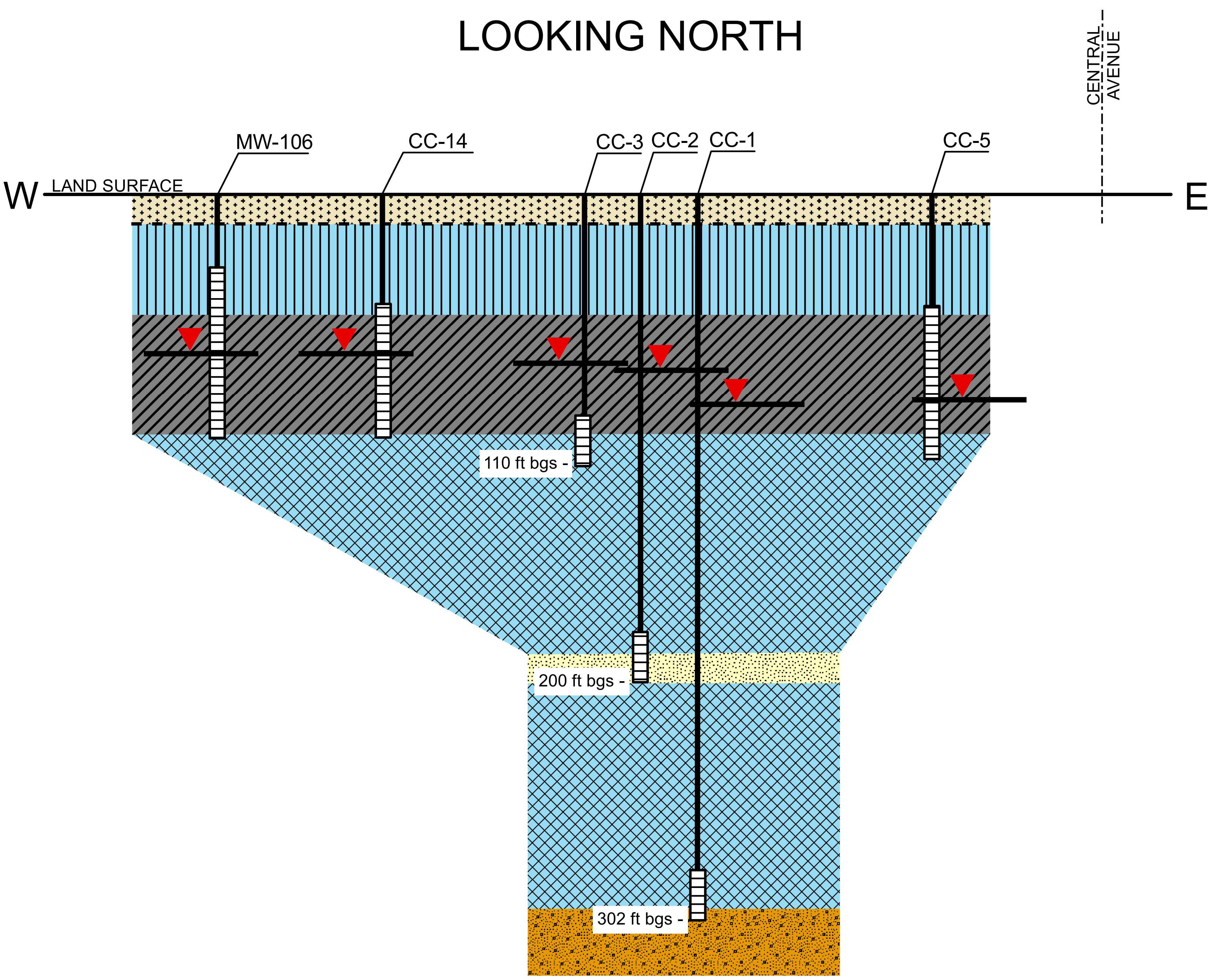
Central and Camelback WQARF Site
Phoenix, AZ

Geosyntec consultants

Phoenix, AZ | May 2015

Figure 2-1

Document Name: figure2-1_RI_plume



Legend

- 180 ft / - 200 ft — MONITOR WELL SCREEN INTERVAL

CC-5 — MONITOR WELL IDENTIFICATION NUMBER

- 200 ft — SCREEN DEPTH

DEPTH TO GROUNDWATER

Note:
Figure source - HGC, 2014

LITHOLOGY

SM
SM/ML
CL
ML/CL
SP
GP
Inferred Lithologic Contact

Approximate Horizontal Scale in Feet
0 15 30

Site Lithology

Central and Camelback WQARF Site
Phoenix, AZ

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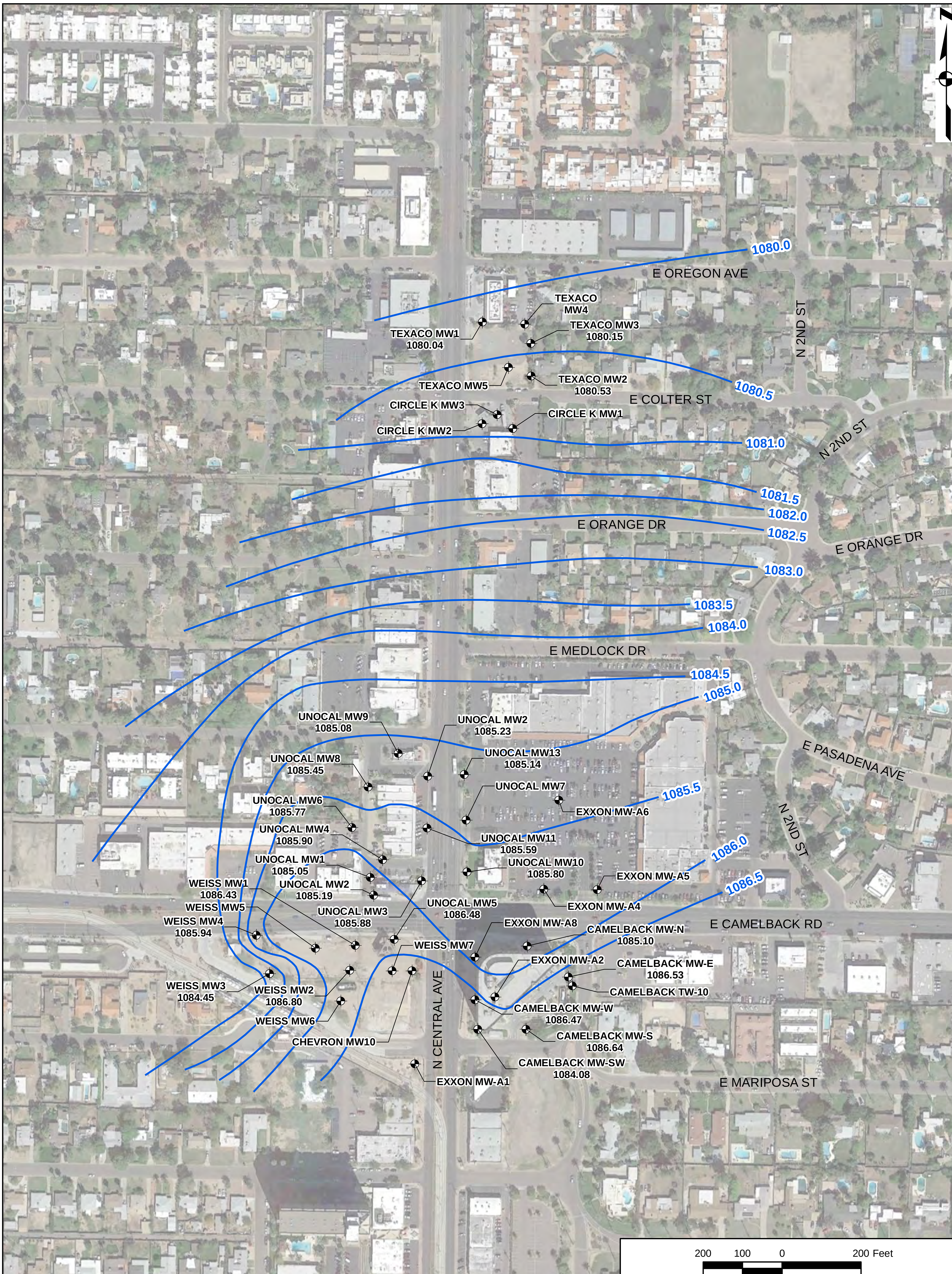
Phoenix, AZ | May 2015

Figure 3-1

Document Name: figure3-1_site_lith



Legend

WEISS MW1
1086.43

MONITOR WELL WITH IDENTIFICATION NUMBER AND MEASURED GROUNDWATER ELEVATION IN FEET (WHERE AVAILABLE)

GROUNDWATER ELEVATION CONTOUR IN FEET AMSL DECEMBER 1994

Note:
Figure source - ADEQ, 2014b (Land Use Report)

GW Potentiometric Surface Elevation Contours December 1994

Central and Camelback WQARF Site
Phoenix, AZ

Geosyntec consultants

Phoenix, AZ | May 2015

Figure 3-2

Document Name: figure3-2_gw_cons_dec1994

Legend

CC-10 1070.35 — MONITOR WELL WITH IDENTIFICATION NUMBER AND MEASURED GROUNDWATER ELEVATION IN FEET (WHERE AVAILABLE)

SVE-2 — SOIL VAPOR EXTRACTION WELL WITH IDENTIFICATION NUMBER

GROUNDWATER ELEVATION CONTOUR IN FEET AMSL DECEMBER 2014 (DASHED WHERE INFERRED)

Notes:
1. CC-1, CC-2, CC-5, EW-1, EW-2, and EW-4 were not used for contouring.
2. Well measurements taken February 22, 2014.
3. NM = not measured.
4. Figure source - Geosyntec, 2015

200 100 0 200 Feet

GW Potentiometric Surface Elevation Contours December 2014

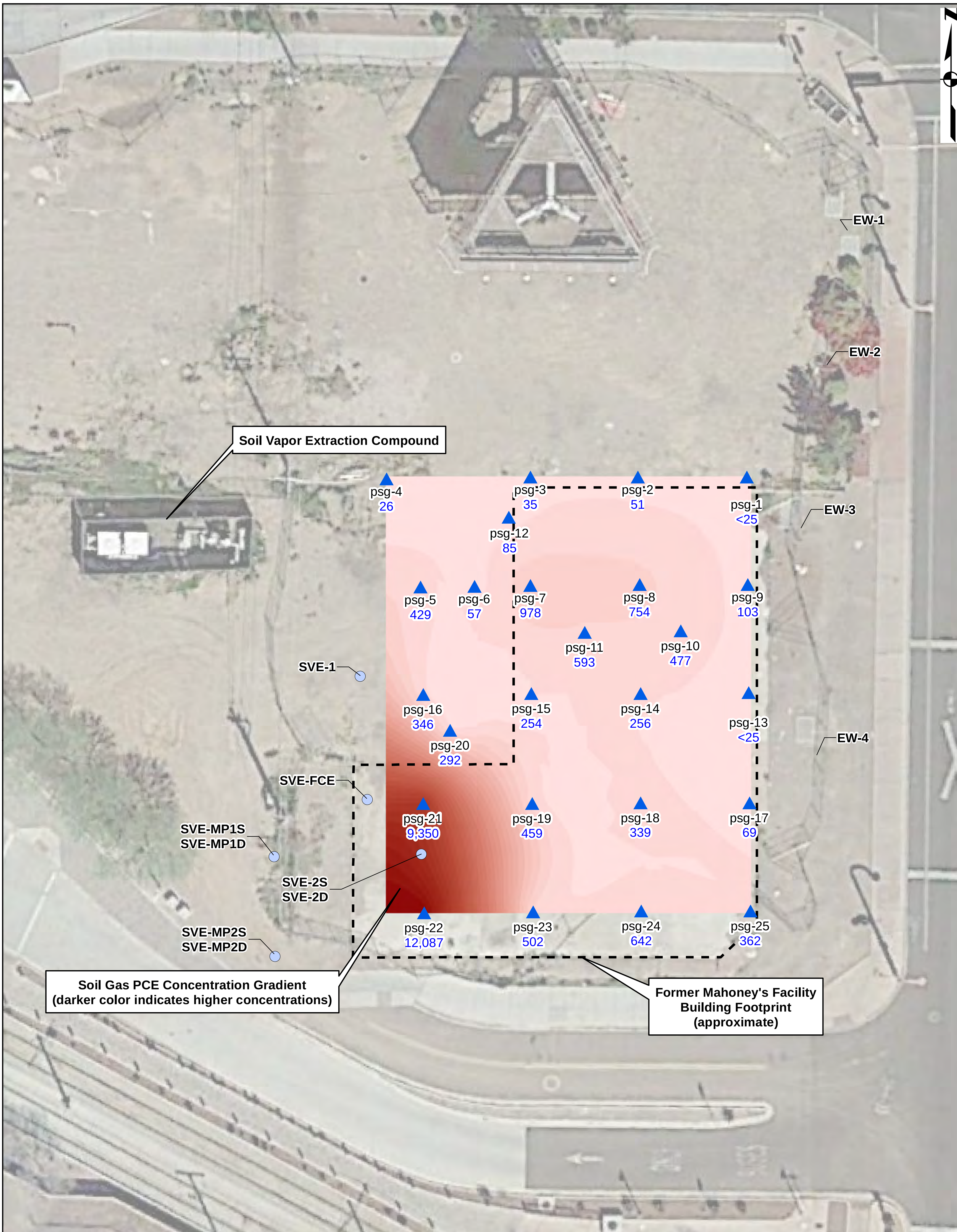
Central and Camelback WQARF Site
Phoenix, AZ

Geosyntec consultants

Phoenix, AZ | May 2015

Figure 3-3

Document Name: figure3-3_gw_cons_dec2014



20 10 0 20 Feet

2011 PCE - Soil Gas Source Area Interpretation

Central and Camelback WQARF Site
Phoenix, AZ

Geosyntec consultants

Phoenix, AZ | May 2015

Figure 3-4

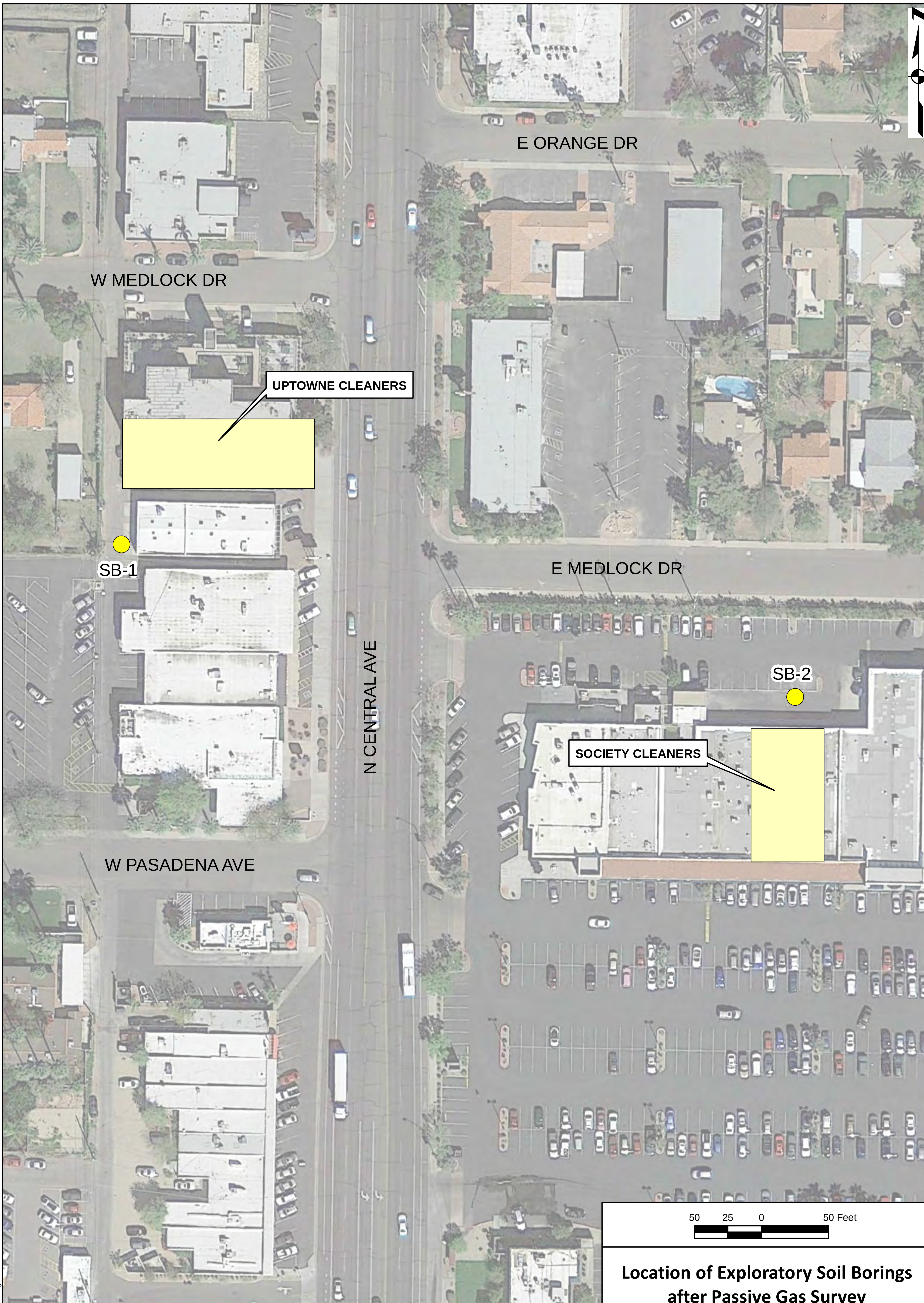
Legend

psg-16 346 — APPROXIMATE PASSIVE SOIL GAS SAMPLING LOCATION WITH IDENTIFICATION NUMBER AND PCE CONCENTRATION (nanograms)

SVE-MP1S SVE-MP1D — SOIL VAPOR EXTRACTION WELL LOCATION WITH IDENTIFICATION NUMBER

Note:
Figure source - Beacon Environmental Services, Inc., 2011

Document Name: figure3-4_2011_sg_pce



Legend

SB-1

EXPLORATORY SOIL BORING AFTER PASSIVE GAS SURVEY

Location of Exploratory Soil Borings after Passive Gas Survey

Central and Camelback WQARF Site
Phoenix, AZ

Geosyntec consultants

Phoenix, AZ | May 2015

Figure 3-5

Document Name: figure3-5_explore_borings

Legend

WEISS MW3
6.8 (9/98)

MONITOR WELL WITH IDENTIFICATION NUMBER AND MAXIMUM PCE CONCENTRATION (ug/L) BETWEEN 1995 AND 1998 ALONG WITH THE SPECIFIC SAMPLING EVENT MONTH (IN PARENTHESES)

PCE ISOCONTOUR (ug/L) - DASHED WHERE INFERRED OR UNKNOWN

Note:
Figure source - HGC, 2014

Document Name: figure3-6_pce_95_to_86

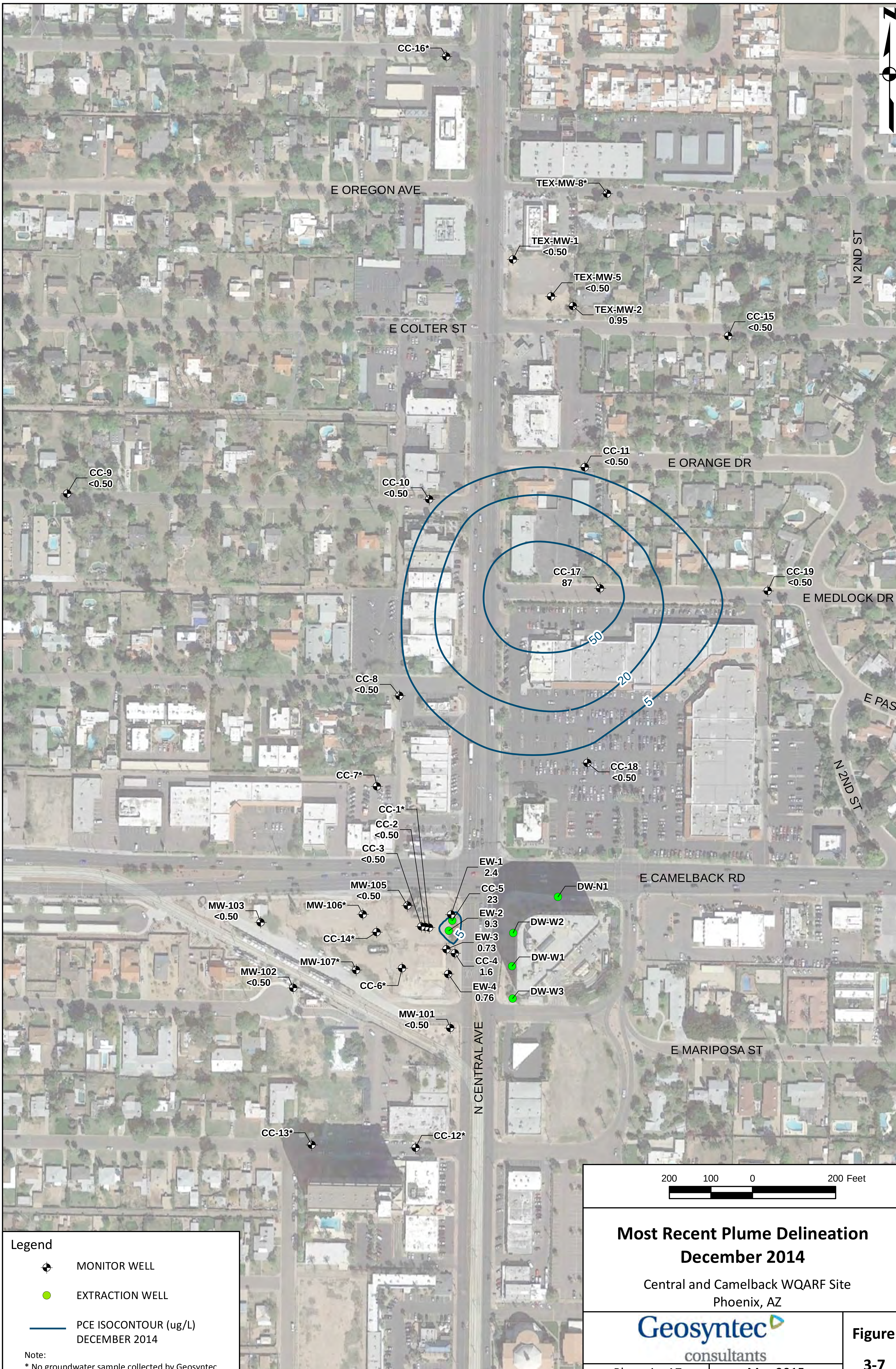
PCE Isoconcentrations 1995 to 1998

Central and Camelback WQARF Site
Phoenix, AZ

Geosyntec consultants

Phoenix, AZ | May 2015

Figure 3-6



Most Recent Plume Delineation
December 2014

Central and Camelback WQARF Site
Phoenix, AZ

Geosyntec consultants

Phoenix, AZ | May 2015

Figure 3-7

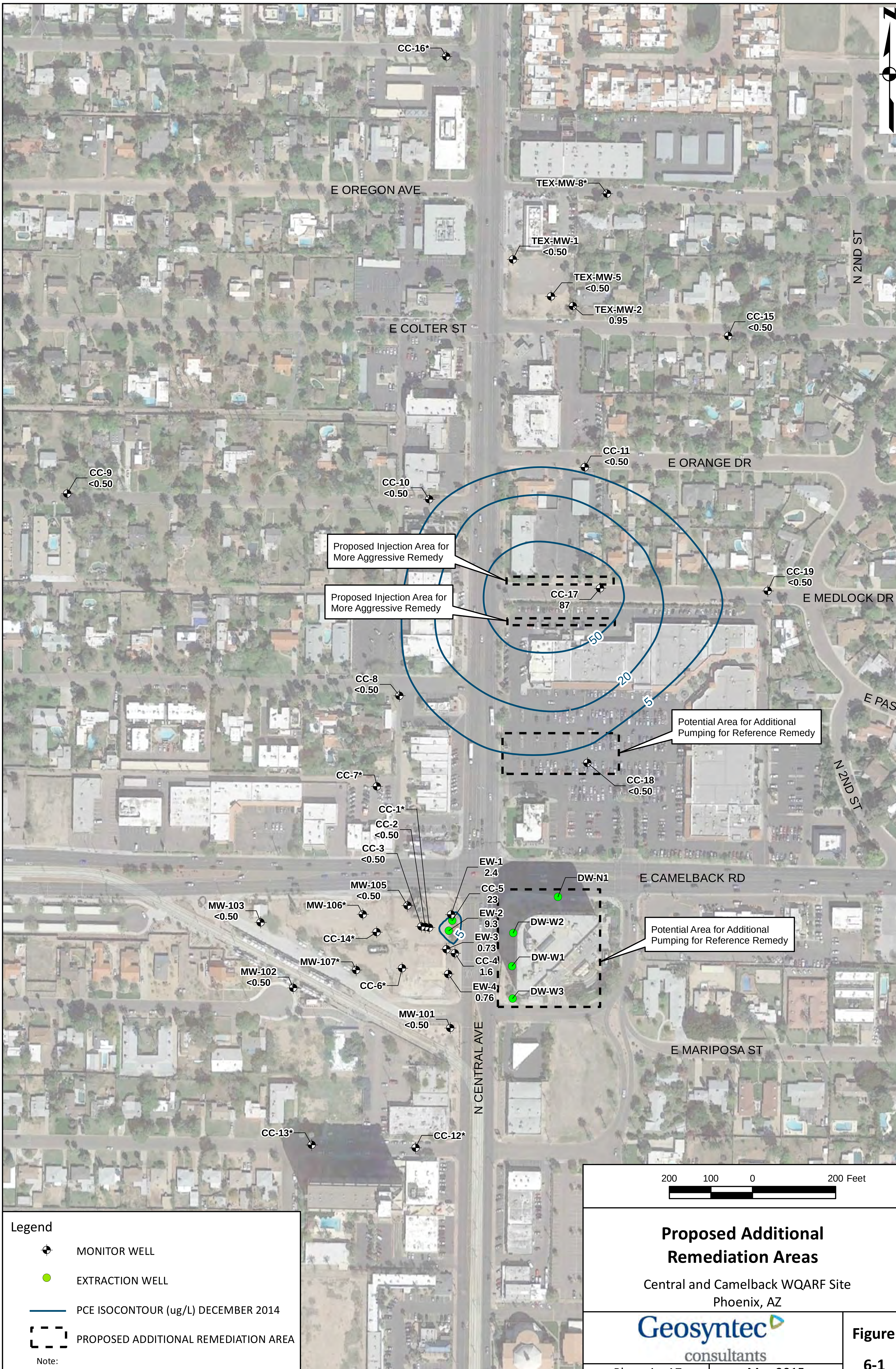
SVE System Layout

Central and Camelback WQARF Site
Phoenix, AZ

Geosyntec consultants

Figure 4-1

Phoenix, AZ | April 2015



Proposed Additional Remediation Areas

Central and Camelback WQARF Site
Phoenix, AZ

Phoenix, AZ | May 2015

Figure 6-1

Document Name: figure6-1_prop_addl_remed_areas

APPENDIX A

Soil Less Aggressive Remedy
SVE

Function		Units	Quantity	Cost Per Unit	Total Cost	Total Cost (- 50%)	Total Cost (+ 100%)
Capital Costs							
	Work Plan	each	1	$10,000.00	$10,000		
	Soil Gas survey	each	1	$15,000.00	$15,000		
	Reporting	each	1	$10,000.00	$10,000		
	Transportation and misc. costs	estimate	1	$5,000	$5,000		
Capital Costs Subtotal					**$40,000**	**$20,000**	**$80,000**
Contingency (Bid)		%	1	0%	$0		
Contingency (Scope)		%	1	0%	$0		
Subtotal					**$40,000**	**$20,000**	**$80,000**
Project Management		%	1	0%	$0		
Remedial Design		%	1	0%	$0		
Construction Management		%	1	0%	$0		
					$0		
Capital Costs Total					**$40,000**	**$20,000**	**$80,000**
OM&M		**annual**					
	OM&M labor	hours	64	$100	$6,400		
	Oversight and Reporting	hours	40	$150	$6,000		
	utilities	annual	0	$7,500	$0		
	LGAC Changeout	annual	0	$10,000	$0		
	Misc (includes analytical costs)	LS	1	$5,000	$5,000		
OM&M subtotal					**$17,400**		
Contingency (Bid & Scope)		%	1	20%	$3,480.00		
Project Management		%	1	10%	$1,740		
Technical Support		%	1	10%	$1,740		
OM&M Annual Costs Years 1-2					**$24,360**	**$12,180**	**$48,720**
Present Value Analysis							
Total Capital Costs					**$40,000**	**$20,000**	**$80,000**
Annual O&M Costs Years 1-2 (Present Worth)					**$44,043**	**$22,022**	**$88,087**
Total Present Worth Cost					**$84,043**	**$42,022**	**$168,087**

Soil Reference Remedy
SVE

Function		Units	Quantity	Cost Per Unit	Total Cost	Total Cost (- 50%)	Total Cost (+ 100%)
Capital Costs							
	Work Plan	estimate	1	$10,000.00	$10,000		
	Soil Gas survey	estimate	1	$15,000.00	$15,000		
	Reporting	estimate	1	$10,000.00	$10,000		
	Transportation and misc. costs	estimate	1	$5,000	$5,000		
Capital Costs Subtotal					**$40,000**	**$20,000**	**$80,000**
Contingency (Bid)		%	1	10%	$4,000		
Contingency (Scope)		%	1	10%	$4,000		
Subtotal					**$48,000**	**$24,000**	**$96,000**
Project Management		%	1	10%	$4,800		
Remedial Design		%	1	0%	$0		
Construction Management		%	1	0%	$0		
					$0		
Capital Costs Total					**$52,800**	**$26,400**	**$105,600**
OM&M							
	OM&M labor	hours	300	$100	$30,000		
	Oversight and Reporting	hours	100	$150	$15,000		
	utilities	annual	1	$7,500	$7,500		
	Repair and maintenance	annual	1	$10,000	$10,000		
	VGAC Changeout	annual	1	$10,000	$10,000		
	Misc (includes analytical costs)	LS	1	$10,000	$10,000		
OM&M subtotal					**$82,500**		
Contingency (Bid & Scope)		%	1	20%	$16,500.00		
Project Management		%	1	10%	$8,250		
Technical Support		%	1	10%	$8,250		
OM&M Annual Costs Years 1-5					**$115,500**	**$57,750**	**$231,000**
Present Value Analysis							
Total Capital Costs					**$52,800**	**$26,400**	**$105,600**
Annual O&M Costs Years 1-5 (Present Worth)					**$473,573**	**$236,786**	**$947,146**
Total Present Worth Cost					**$526,373**	**$263,186**	**$1,052,746**

Soil More Aggressive Remedy
Expanded SVE

Function		Units	Quantity	Cost Per Unit	Total Cost	Total Cost (- 50%)	Total Cost (+ 100%)
Capital Costs							
	Work Plan/Design	estimate	1	$15,000.00	$15,000		
	Mob/Demob	each	1	$5,000.00	$5,000		
	Soil Gas survey	estimate	1	$15,000.00	$15,000		
	Install additional SVE borings (assume 2)	estimate	2	$5,000.00	$10,000		
	connect SVE wells to system	estimate	1	$10,000.00	$10,000		
	Reporting	estimate	1	$10,000.00	$10,000		
	Transportation and misc. costs	estimate	1	$5,000	$5,000		
					$0		
Capital Costs Subtotal					**$70,000**	**$35,000**	**$140,000**
Contingency (Bid)		%	1	10%	$7,000		
Contingency (Scope)		%	1	10%	$7,000		
Subtotal					**$84,000**	**$42,000**	**$168,000**
Project Management		%	1	10%	$8,400		
Remedial Design		%	1	10%	$8,400		
Construction Management		%	1	5%	$4,200		
Capital Costs Total					**$105,000**	**$52,500**	**$210,000**
OM&M							
	OM&M labor	hours	352	$100	$35,200		
	Oversight and Reporting	hours	120	$150	$18,000		
	utilities	annual	1	$7,500	$7,500		
	LGAC Changeout	annual	1	$10,000	$10,000		
	Repair and maintenance	annual	1	$10,000	$10,000		
	Misc (includes analytical costs)	LS	1	$10,000	$10,000		
OM&M subtotal					**$90,700**		
Contingency (Bid & Scope)		%	1	20%	$18,140.00		
Project Management		%	1	10%	$9,070		
Technical Support		%	1	10%	$9,070		
OM&M Annual Costs Years 1-5					**$126,980**	**$63,490**	**$253,960**
Present Value Analysis							
Total Capital Costs					**$105,000**	**$52,500**	**$210,000**
Annual O&M Costs Years 1-5 (Present Worth)					**$520,643**	**$260,322**	**$1,041,286**
Total Present Worth Cost					**$625,643**	**$312,822**	**$1,251,286**

Groundwater Less Aggressive Remedy
Pump and Treat

Function		Units	Quantity	Cost Per Unit	Total Cost	Total Cost (- 50%)	Total Cost (+ 100%)
Capital Costs							
	Work Plan/Design	each	1	$15,000.00	$15,000		
					$0		
					$0		
Capital Costs Subtotal					**$15,000**	**$7,500**	**$30,000**
Contingency (Bid)		%	1	0%	$0		
Contingency (Scope)		%	1	0%	$0		
Subtotal					**$15,000**	**$7,500**	**$30,000**
Project Management		%	1	10%	$1,500		
Remedial Design		%	1	0%	$0		
Construction Management		%	1	0%	$0		
					$0		
Capital Costs Total					**$16,500**	**$8,250**	**$33,000**
OM&M		**annual**					
	OM&M labor	hours	496	$100	$49,600		
	Oversight and Reporting	hours	200	$150	$30,000		
	utilities	annual	1	$7,500	$7,500		
	Repair and maintenance	annual	1	$15,000	$10,000		
	LGAC Changeout	annual	1	$10,000	$10,000		
	Misc (includes analytical costs)	LS	1	$10,000	$10,000		
OM&M subtotal					**$117,100**		
Contingency (Bid & Scope)		%	1	20%	$23,420.00		
Project Management		%	1	10%	$11,710		
Technical Support		%	1	10%	$11,710		
OM&M Annual Costs Years 1-10					**$163,940**	**$81,970**	**$327,880**
Present Value Analysis							
Total Capital Costs					**$16,500**	**$8,250**	**$33,000**
Annual O&M Costs Years 1-10 (Present Worth)					**$1,151,446**	**$575,723**	**$2,302,892**
Total Present Worth Cost					**$1,167,946**	**$583,973**	**$2,335,892**

Groundwater Reference Remedy
Expanded Pump and Treat - CC-18 Option

Function		Units	Quantity	Cost Per Unit	Total Cost	Total Cost (- 50%)	Total Cost (+ 100%)
Capital Costs							
	Work Plan/Design	each	1	$50,000.00	$50,000		
	Permitting	each	1	$15,000.00	$15,000		
	Mob/Demob	each	1	$10,000.00	$10,000		
	Install 1 new extraction well	estimate	1	$20,000.00	$20,000		
	convert CC-18 to extraction well	estimate	1	$10,000.00	$10,000		
	contruct pipeline and connect wells to treatment system	estimate	1	$200,000.00	$200,000		
	Reporting	each	1	$20,000.00	$20,000		
	Transportation and misc. costs	estimate	1	$5,000	$5,000		
Capital Costs Subtotal					**$330,000**	**$165,000**	**$660,000**
Contingency (Bid)		%	1	15%	$49,500		
Contingency (Scope)		%	1	10%	$33,000		
Subtotal					**$412,500**	**$206,250**	**$825,000**
Project Management		%	1	10%	$41,250		
Remedial Design		%	1	10%	$41,250		
Construction Management		%	1	5%	$20,625		
					$0		
Capital Costs Total					**$515,625**	**$257,813**	**$1,031,250**
OM&M		**annual**					
	OM&M labor	hours	600	$100	$60,000		
	Oversight and Reporting	hours	240	$150	$36,000		
	utilities	annual	1	$15,000	$15,000		
	Repair and maintenance	annual	1	$15,000	$15,000		
	LGAC Changeout	annual	1	$10,000	$10,000		
	Misc (includes analytical costs)	LS	1	$15,000	$15,000		
OM&M subtotal					**$151,000**		
Contingency (Bid & Scope)		%	1	20%	$30,200.00		
Project Management		%	1	10%	$15,100		
Technical Support		%	1	10%	$15,100		
OM&M Annual Costs Years 1-5					**$211,400**	**$105,700**	**$422,800**
Present Value Analysis							
Total Capital Costs					**$515,625**	**$257,813**	**$1,031,250**
Annual O&M Costs Years 1-5 (Present Worth)					**$866,782**	**$433,391**	**$1,733,563**
Total Present Worth Cost					**$1,382,407**	**$691,203**	**$2,764,813**

Groundwater Reference Remedy
Expanded Pump and Treat - OEC Option

Function		Units	Quantity	Cost Per Unit	Total Cost	Total Cost (- 50%)	Total Cost (+ 100%)
Capital Costs							
	Work Plan/Design	each	1	$50,000.00	$50,000		
	Permitting	each	1	$15,000.00	$15,000		
	Mob/Demob	each	1	$10,000.00	$10,000		
	contruct pipeline and connect wells to treatment system	estimate	1	$170,000.00	$170,000		
	Reporting	each	1	$20,000.00	$20,000		
	Transportation and misc. costs	estimate	1	$5,000	$5,000		
Capital Costs Subtotal					**$270,000**	**$135,000**	**$540,000**
Contingency (Bid)		%	1	15%	$40,500		
Contingency (Scope)		%	1	10%	$27,000		
Subtotal					**$337,500**	**$168,750**	**$675,000**
Project Management		%	1	10%	$33,750		
Remedial Design		%	1	10%	$33,750		
Construction Management		%	1	5%	$16,875		
					$0		
Capital Costs Total					**$421,875**	**$210,938**	**$843,750**
OM&M		**annual**					
	OM&M labor	hours	600	$100	$60,000		
	Oversight and Reporting	hours	240	$150	$36,000		
	utilities	annual	1	$15,000	$15,000		
	Repair and maintenance	annual	1	$15,000	$15,000		
	LGAC Changeout	annual	1	$10,000	$10,000		
	Misc (includes analytical costs)	LS	1	$15,000	$15,000		
OM&M subtotal					**$151,000**		
Contingency (Bid & Scope)		%	1	20%	$30,200.00		
Project Management		%	1	10%	$15,100		
Technical Support		%	1	10%	$15,100		
OM&M Annual Costs Years 1-5					**$211,400**	**$105,700**	**$422,800**
Present Value Analysis							
Total Capital Costs					**$421,875**	**$210,938**	**$843,750**
Annual O&M Costs Years 1-5 (Present Worth)					**$866,782**	**$433,391**	**$1,733,563**
Total Present Worth Cost					**$1,288,657**	**$644,328**	**$2,577,313**

Groundwater More Aggressive Remedy
Expanded Pump and Treat and In Situ Treatment
Costs are in Addition to Reference Remedy Costs

Function		Units	Quantity	Cost Per Unit	Total Cost	Total Cost (- 50%)	Total Cost (+ 100%)
Capital Costs							
	Bench-Scale Testing/Pilot Study						
	Work Plan	ea	1	$10,000.00	$10,000		
	Pre-injection characterization (discrete sampling)	estimate	6	$10,000.00	$60,000		
	Injection testing	estimate	1	$10,000.00	$10,000		
	Reporting and updated Design	estimate	1	$10,000.00	$10,000		
	Well Installation and amendment injection						
	Mob/Demob	each	1	$10,000.00	$10,000		
	Permitting	estimate	1	$10,000.00	$10,000		
	EHC-L Chemical	lb	12,500	$1.75	$21,875		
	Chemical delivery	lb	12,500	$0.60	$7,500		
	Injection Well Installation	well	20	$15,000.00	$300,000		
	Injection trailer with manifold	estimate	1	$20,000.00	$20,000		
	Injections	day	15	$2,500.00	$37,500		
	Soil Disposal	cy	20	$50.00	$1,000		
	Installation of monitoring wells	well	4	$15,000.00	$60,000		
	Installation Reporting	estimate	1	$15,000.00	$15,000		
					$0		
					$0		
Capital Costs Subtotal					**$572,875**	**$286,438**	**$1,145,750**
Contingency (Bid)		%	1	15%	$85,931		
Contingency (Scope)		%	1	10%	$57,288		
Subtotal					**$716,094**	**$358,047**	**$1,432,188**
Project Management		%	1	10%	$71,609		
Remedial Design		%	1	10%	$71,609		
Construction Management		%	1	5%	$35,805		
					$0		
Capital Costs Total					**$895,117**	**$447,559**	**$1,790,234**
Quarterly sampling							
	Site inspection/maintenance	hours	20	$100	$2,000		
	Quarterly Groundwater monitoring (10 wells)	well	4	$1,200	$4,800		
	Groundwater analytical costs (15 wells for VOCs and MNA parameters)	sample	12	$500	$6,000		
	Reporting	hours	40	$100	$4,000		
	Transportation and misc. costs	estimate	1	$5,000	$5,000		
	Total Per Quarter				$21,800		
OM&M subtotal					**$87,200**		
Contingency (Bid & Scope)		%	1	20%	$17,440.00		
Project Management		%	1	10%	$8,720		
Technical Support		%	1	10%	$8,720		
OM&M Annual Costs Years 1-3					**$122,080**	**$61,040**	**$244,160**
Present Value Analysis							
Total Capital Costs					**$895,117**	**$447,559**	**$1,790,234**
Annual O&M Costs Years 1-3 (Present Worth)					**$320,377**	**$160,188**	**$640,753**
Total Present Worth Cost					**$1,215,494**	**$607,747**	**$2,430,987**