Prepared for

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FEASIBILITY STUDY

WEST CENTRAL PHOENIX NORTH CANAL PLUME WATER QUALITY ASSURANCE REVOLVING FUND SITE PHOENIX, ARIZONA

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WEST CENTRAL PHOENIX NORTH CANAL PLUME
WATER QUALITY ASSURANCE REVOLVING FUND SITE
PHOENIX, ARIZONA

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.

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Principal Engineer

1/28/2020
Date

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LIST OF ACRONYMS AND ABBREVIATIONS

1,1-DCE	1,1-dichloroethene
AAC	Arizona Administrative Code
acfm	actual cubic feet per minute
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
ARS	Arizona Revised Statutes
AS	air sparge
AWQS	Aquifer Water Quality Standard
AZPDES	Arizona Pollution Discharge Elimination System
CAB	Community Advisory Board
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COCs	contaminants of concern
COP	City of Phoenix
DEUR	Declaration of Environmental Use Restriction
EISB	enhanced *in situ* bioremediation
ERA	Early Response Action
ERD	enhanced reductive dechlorination
ERH	electrical resistive heating
EVO	emulsified vegetable oil
FS	Feasibility Study
ft bgs	feet below ground surface
ft	feet
Geosyntec	Geosyntec Consultants, Inc.
Giltspur	Giltspur Exhibits
GPLs	groundwater protection levels
gpm	gallons per minute
HGC	Hydro Geo Chem, Inc.
HCZ	HCZ Custom Homes
in WC	inches of water column
ISCO	*in situ* chemical oxidation
ISCR	*in situ* chemical reduction
ISGR	*in situ* gaseous reduction
ISTR	*in situ* thermal remediation
IX	ion exchange
J&E	Johnson and Ettinger
LAU	Lower Alluvial Unit
Locus	Locus Technologies, Inc.
LGAC	liquid-phase granular activated carbon

LSGS	Lower Sand and Gravel Unit
MAU	Middle Alluvial Unit
MFGS	Middle Fine-Grained Subunit
µg/L	micrograms per liter
MNA	monitored natural attenuation
NAPL	non-aqueous phase liquid
NCP	North Canal Plume
NPV	net present value
O&M	operations and maintenance
P&T	pump and treat
PCE	tetrachloroethene
PQGWP	Poor Quality Groundwater Permit
Precise/Paraflex	Precise Metals Products Company/Paraflex Machine and Tool Company
PRB	permeable reactive barrier
RI	Remedial Investigation
ROI	radius of influence
ROs	Remedial Objectives
RSLs	Regional Screening Levels
scfm	standard cubic feet per minute
SGWS	Shallow Groundwater System
SM	Standard method
SRL	Soil Remediation Level
SRP	Salt River Project Agricultural Improvement and Power District
Stevens	Stevens Engineering, Inc.
SVE	soil vapor extraction
SVSL	soil vapor screening level
TCE	trichloroethene
Triad	Triad Trucking Company
UAU	Upper Alluvial Unit
UIC	Underground Injection Control
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VGAC	vapor-phase granular activated carbon
VISL	vapor intrusion screening level
VOC	volatile organic compound
WCP	West Central Phoenix
WOC	West Osborn Complex
WQARF	Water Quality Assurance Revolving Fund
ZVI	zero valent iron

1. INTRODUCTION

1.1 Purpose and Scope of the Feasibility Study Report

The North Canal Plume (NCP) Water Quality Assurance Revolving Fund (WQARF) Site (the "Site"), located in Phoenix, Arizona and is one of five WQARF sites collectively included in the West Central Phoenix (WCP) area. The Site is bounded approximately by Indian School Road to the north, Grand Avenue to the east, West Flower Street to the south, and 40th Avenue to the west (Figure 1).

This Feasibility Study (FS) Report was prepared by Geosyntec Consultants, Inc. (Geosyntec) for the Arizona Department of Environmental Quality (ADEQ) 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) [2017]. This FS Report was prepared in accordance with the FS Work Plan prepared by ADEQ [2016].

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 Revised Remedial Objectives Report [ADEQ, 2020]; and

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

Based on the objectives stated above, the 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 to allow for the maximum beneficial use of waters of the state;
3. Are reasonable, necessary, cost-effective, and technically feasible; and
4. Address groundwater wells 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.

1.2 Report Organization

The remainder of this FS Report is organized as follows:

- Section 2, "Site Background," presents a summary of the site description, physiographic setting, nature and extent of impacts, and a risk evaluation summary;
- Section 3, "Feasibility Study Scoping," presents the regulatory requirements presented in statute and rule, delineates the remedial areas, and presents the ROs identified in the RI;
- Section 4, "Identification and Screening of Remediation Technologies," presents the evaluation and screening of various remedial measures and strategies related to the impacts in soil and groundwater and lists the technologies that have been retained for evaluation as part of the reference and alternative remedies pursuant to AAC R18-16-407 (E) and (F);
- Section 5, "Development of Reference Remedy and Alternative Remedies," presents the selected reference remedy, a more aggressive remedy, a less aggressive remedy, and discussions of the associated remedial measures and remedial strategies pursuant to AAC R18-16-407 (E);
- Section 6, "Comparison of Remedies," compares the remedies to each other based on the comparison criteria of practicability, cost, risk, and benefit. Uncertainties associated with the remedies and comparison criteria are discussed pursuant to AAC R18-16-407 (H);
- Section 7, "Proposed Remedy," presents the proposed remedy as required in AAC R18-16-407 (I), and discusses how it will achieve the ROs, how the comparison criteria were considered, and how the proposed remedy will meet the requirements of ARS §49-282.06;
- Section 8, "Community Involvement," documents the community involvement activities conducted in association with the FS; and
- Section 9, "References," provides a list of references cited in this FS.

2. SITE BACKGROUND

This section presents a summary of the Site background, physiographic setting, the nature and extent of impacts, and a risk evaluation. A detailed background and chronology are included in the RI Report [HGC, 2017].

2.1 Site Description

The Site is located in west central Phoenix, Arizona (Figure 1), and is bounded approximately by Indian School Road to the north, Grand Avenue to the east, West Flower Street to the south, and 40th Avenue to the west. The Site has been occupied by a variety of industrial facilities since development began in the mid-1950s. Historical industrial activities included metal plating and casting, machine and tool manufacturing, aerospace parts manufacturing, furniture manufacturing, and automobile salvage and repair.

2.2 Site Physiography

A detailed description of the Site physiography is provided in the RI Report [HGC, 2017]. Briefly, the Site is located in the West Salt River Valley of the Phoenix Basin, which is a broad alluvial valley filled with layers of unconsolidated sand, gravel, silt, and clay. Total depth to bedrock is unknown, but is estimated to be at least 1,500 feet below ground surface (ft bgs). The Site hydrogeology is typical for the West Salt River Valley, consisting of three alluvial units:

- Upper Alluvial Unit (UAU) - composed of silty to gravely sand, sandy silt, and gravel with interbedded clay lenses, extending 300 to 400 ft bgs;
- Middle Alluvial Unit (MAU) - composed of silt and clay interbedded with silty sand and gravel, extending to a depth of more than 800 ft bgs; and
- Lower Alluvial Unit (LAU) - which includes evaporate deposits and overlies the crystalline and volcanic bedrock.

Two distinct aquifers are present in the UAU underlying the Site. The Shallow Groundwater System (SGWS) is located in the upper UAU. The groundwater table coincides with the top of the SGWS and is currently present at an approximate average depth of 130 ft bgs. Below approximately 240 ft bgs, a course-grained zone commonly referred to as the Lower Sand and Gravel Subunit (LSGS) of the UAU extends to the top of the MAU. The two aquifers are separated by a semi-confining fine-grained unit, the Middle Fine-Grained Subunit (MFGS). The LSGS is regarded as the primary regional water bearing unit for production.

Depth to groundwater has declined considerably since 1998. This is attributed primarily to the lining of the Salt River Project Agricultural Improvement and Power District (SRP) Grand Canal, and resulting reduction in recharge. Prior to lining the canal, the flow direction in the SGWS varied from northeast to northwest beneath the Site. After lining the canal, groundwater flow transitioned toward the south. There were no apparent changes in the gradient in the LSGS associated with the

canal lining. Results from groundwater elevation monitoring in October 2016 indicate that groundwater flows in the SGWS in a south-southwesterly direction (Figure 2).

Large vertical hydraulic gradients exist between the different hydrostratigraphic units underlying the site, and downward vertical gradients from the SGWS to the LSGS subunit potentially exist.

2.3 Nature and Extent of Impacts

The results of the RI indicate the occurrence of three plumes of impacted groundwater within the SGWS underlying the Site. These plumes have been termed the West Plume, the Central Plume, and the East Plume, respectively (Figure 3). The Site boundaries are generally defined by the extent of the groundwater impacts.

Limited pump data indicate a downward hydraulic gradient and potential limited connectivity between the SGWS and LSGS, which could provide the potential for vertical flow or leakage between the aquifer units; however, the low concentrations of contaminants of concern (COCs) detected in the LSGS suggest minimal downward migration has occurred.

The RI Report concluded that several current and former facilities described in the following subsections are likely sources of vadose zone and groundwater impacts at the Site.

2.3.1 West Plume

The West Plume is centered near the intersection of 39th Avenue and Clarendon Avenue and comprises trichloroethene (TCE) and 1,1-dichloroethene (1,1-DCE)-impacted groundwater (Figure 4). Primary likely residual source areas for the West Plume are located at the following facilities:

- The former Precise Metals Products Company/Paraflex Machine and Tool Company (Precise/Paraflex) facility, located at 3856 West Clarendon Avenue and 3820-3839 North 39th Avenue; and
- The former Giltspur Exhibits (Giltspur) facility, located at 3840-3846 West Clarendon Avenue.

Secondary likely residual source areas for the West Plume are located at the following facilities:

- The former facilities, located at 4001 West Indian School Road; and
- The Stevens Engineering, Inc. (Stevens) facility, located at 3946 West Clarendon Avenue.

2.3.2 Central Plume

The Central Plume is centered near the intersection of 36th Avenue and Clarendon Avenue, and comprised of TCE, 1,1-DCE, tetrachloroethene (PCE), and hexavalent chromium-impacted

groundwater (Figures 4 and 6, respectively). Likely residual source areas for the Central Plume are located at the following facilities:

- The former Southwest Metals facility, located at 3615-3711 West Clarendon Avenue;
- The former Osborn Products facility, located at 3632-3702 West Clarendon Avenue;
- The former Magic Metals facility, located at 3632 West Whitton Avenue;
- The former Triad Trucking Company (Triad) facility, located at 3883 North 36th Avenue; and
- The former Pyramid Industries facility, located at 3648-3700 North 36th Avenue.

2.3.3 East Plume

The East Plume is centered near the intersection of 34th Avenue and Clarendon Avenue, and comprises PCE-impacted groundwater (Figure 5). The primary likely residual source area for the East Plume is at the HCZ Custom Homes (HCZ) property at 3422 West Clarendon Avenue and the area in the vicinity thereof.

2.4 Site History

The following Site chronology is summarized from the RI Report [HGC, 2017].

1982 – 1989: TCE was detected in four City of Phoenix (COP) municipal supplies wells (COP-70, COP-71, COP-151, and COP-152) above the Arizona Aquifer Water Quality Standard (AWQS) of 5 micrograms per liter (µg/L). Production wells COP-70 and COP-71 were removed from service in 1983 and COP-151 and COP-152 were shut down in 1989.

1984: Initial field investigation activities commenced.

1987 – 2001: In 1987, ADEQ established the WCP area as a WQARF Priority List site. Subsequently in 1998, the WCP WQARF Priority List site was divided into five WQARF Registry sites, and the Site was placed on the WQARF Registry List with a score of 22 out of a possible 120. The Site score was re-evaluated in 2000, with a revised score of 27.

2005: An Interim RI Report summarizing activities to date was prepared and issued by Locus Technologies (Locus) for ADEQ [Locus, 2005]. The Interim RI Report included descriptions of an initial Early Response Action (ERA) investigation, and other activities and evaluations.

2006: A second ERA Evaluation and Technical Report was prepared summarizing investigation activities, including passive soil gas surveys at several suspected residual source areas within the Site. Focused soil, soil gas, and groundwater

sampling was performed in areas where elevated volatile organic compound (VOC) concentrations were observed during the passive soil gas surveys. Select borings were converted to groundwater monitoring wells.

2007: A soil vapor extraction (SVE) well and two SVE observation points were installed, and one-day SVE pilot test was performed at the former Osborn Products facility. An aquifer test (pumping test) was performed at the former Southwest Metals facility to assess the hydraulic properties of the shallow aquifer and to assess potential groundwater treatment options for the regional groundwater plume.

2013: The existing monitor well network was redeveloped for groundwater monitoring and sampling. Results from groundwater monitoring indicated that the plume may be moving in a southerly direction. The ADEQ Underground Storage Tank (UST) Program State Lead Unit installed 26 wells and an SVE/air sparge (AS) remediation system at the former Triad facility.

2014 - 2016: Continued groundwater monitoring performed. Soil vapor partition testing and a limited passive soil vapor survey were conducted in the East Plume to evaluate the area for local sources of impacts. An ERA Evaluation was prepared focusing on the Central Plume. Slug tests were performed on several monitor wells across the Site to estimate hydraulic conductivity. Additional groundwater monitoring wells were installed, and an industrial survey was conducted in the West Plume to identify additional sources of groundwater impacts.

2017: The RI Report prepared by HGC for ADEQ [HGC, 2017] was issued summarizing activities to the date of the report, describing the nature and extent of impacts at the Site, risk analyses, and proposed ROs. In the RI report HCZ was identified as a VI concern. Geosyntec conducted an SVE pilot study that indicated sufficient mass of PCE remained to warrant continuation of the ERA using an SVE system with additional blower and VGAC capacity [Geosyntec, 2017].

2018: Associated with site characterization a Geosyntec installed a triple-nested SVE well [Geosyntec, 2018a] and conducted indoor air sampling at HCZ. The results of the indoor air sampling did not indicate a need for a response action [Geosyntec, 2018b] to address VI. Geosyntec also prepared a VI assessment [Geosyntec, 2018c] and conducted a VI evaluation to address the VI data gaps identified in the RI Report. Results indicated that observable PCE or TCE VI does not appear to be present at the former facilities located at 4001 West Indian School Road, Stevens facility, the former Pyramid Industries facility, Giltspur facility, the former Osborn Products facility, and the former Triad facility. Concentrations of TCE in sub-slab samples collected from the former Southwest Metals facility and Precise/Paraflex facility exceed the vapor intrusion screening levels (VISLs) and additional indoor

air samples may be warranted at the Precise/Paraflex and former Southwest Metals facilities to further evaluate the potential for TCE vapor intrusion at these sites [Geosyntec, 2018d].

2019: A full-scale SVE system was connected to the onsite SVE wells at HCZ and began operations. VOC concentrations at the combined influent, the GAC effluent, and four of the five individual extraction wells displayed decreasing trends over the 5-day startup period [Geosyntec, 2019].

2.5 Risk Evaluation Summary

The risk evaluation provided in the RI Report provided the following:

- An assessment of the COCs and relevant human receptors and exposure scenarios;
- An evaluation of potential exposures and pathways present at the Site; and
- A Characterization of human health concerns associated with the Site-related COCs through a comparison to the relevant Arizona standards for groundwater and soil impacts and risk-based screening levels for soil vapor.

The soil, soil vapor, and groundwater monitoring results from the Site were included in the evaluation. This section provides a summary of the relevant sections of the RI Report.

COCs identified for the Site include PCE, TCE, 1,1-DCE, and chromium, based on their presence in groundwater at concentrations greater than their respective AWQSs. PCE and TCE have been detected in soil and/or soil vapor at various locations. Total chromium and hexavalent chromium were detected in soil overlying the Central Plume.

An evaluation of current land and water use was performed for the Site. Land use includes commercial, industrial, and residential occupancy. Potential receptors therefore include residents and commercial/industrial workers. Impacted media at the Site include groundwater, soil, and soil vapor. Because no natural points of discharge of groundwater to surface water exist in the vicinity of the Site, the RI Report concluded that no risk characterization for surface water was necessary.

The identification of potentially complete exposure pathways is based on four components, which include:

- A source and mechanism of release;
- Retention or transport media;
- An exposure point (i.e., a setting where contact with impacted media occurs); and
- A route of exposure (e.g., ingestion).

2.5.1 Soil

Investigative activities described in the RI include extensive soil borings, including exploratory borings and installation of monitoring wells. Results of analyses conducted during ERAs and RI activities indicate that COCs, including PCE, TCE, and chromium are present in soils underlying the Central Plume; however, the RI Report noted that relatively few soil samples have been collected at shallow depths (less than 5 ft bgs), and that the reported detections of COCs in soil occurred at depths that are not relevant to the soil contact exposure pathway at the Site. Based on current and foreseeable future land use, and the lack of detections in shallow soil, the RI Report concluded that the soil contact pathway is incomplete. However, concentrations of PCE and TCE were detected in soil at concentrations that are greater than Soil Remediation Levels (SRLs).

2.5.2 Soil Vapor

The RI Report concluded that transport of vapor-phase COCs to outdoor and indoor air with subsequent inhalation exposure is a potentially complete exposure pathway. The RI Report stated that while inhalation exposure from outdoor air would be negligible due to the effects of atmospheric mixing, vapor intrusion into buildings and subsequent inhalation exposure is of potential concern.

The RI Report screened soil vapor analytical data and compared the concentrations of COCs to soil vapor screening levels (SVSLs) that were developed from two methodologies:

- The United States Environmental Protection Agency (USEPA) Regional Screening Levels (RSLs) for air in an industrial setting, using an empirical attenuation factor of 0.03; and
- The USEPA implementation of the Johnson and Ettinger (J&E) vapor intrusion model, configured for slab-on-grade construction over sandy loam.

The methodologies and specific screening levels used are described in detail in the RI Report, and the results summarized below.

2.5.2.1 West Plume

Applying the RSLs, the RI Report concluded that concentrations of the COCs exceeded their respective SVSLs at the following current or former facilities in the West Plume:

- Precise/Paraflex, for PCE and TCE;
- Giltspur Exhibits, for TCE;
- 4001 West Indian School Road, for TCE; and
- Stevens, for TCE.

The RI Report stated that while the SVSLs derived from the J&E model were less conservative, they were consistent in indicating that concentrations of TCE in soil vapor exceed risk-based

screening levels for the four facilities stated above. However, the concentration of PCE at the former Precise/Paraflex facility was below the SVSL for PCE derived from the J&E model.

2.5.2.2 Central Plume

Applying the RSLs, the RI Report concluded that concentrations of the COCs exceeded their respective SVSLs at the following current or former facilities in the Central Plume:

- Osborn Products, for PCE and TCE;
- Pyramid Industries, for PCE and TCE;
- Southwest Metal, for PCE and TCE; and
- Triad, for PCE and TCE.

The RI Report stated that while the SVSLs derived from the J&E model were less conservative, they were consistent in indicating that concentrations of TCE in soil vapor exceed risk-based screening levels for the four facilities stated above. The concentration of PCE at the former Osborn Products, Pyramid Industries, and Southwest Metal facilities was below the SVSL for PCE derived from the J&E model. The concentration of PCE at the former Triad facility exceeded the SVSLs from both models.

2.5.2.3 East Plume

Applying the RSLs, the RI Report concluded that concentrations of PCE and TCE exceeded their respective SVSLs at the HCZ property. The RI Report stated that while the SVSLs derived from the J&E model were less conservative, they were consistent indicting that concentrations of PCE and TCE exceed risk-based screening levels at HCZ.

2.5.3 Groundwater

The Site boundaries are largely defined by the extent of groundwater impacts, with groundwater providing both a retention and transport medium for the COCs. The RI Report states that consumptive use of groundwater provides a potentially complete exposure pathway of concern via direct ingestion, inhalation, or dermal contact with impacted groundwater. Vertical migration of the impacted groundwater from the SGWS has the potential to impact water supply wells that produce from the deeper aquifers, and the SGWS itself may be developed for future groundwater production. The RI Report evaluated groundwater analytical data for monitoring wells in the three plumes and compared the concentrations of the COCs detected to their respective AWQS; the methodology used is described in the RI Report and the results are summarized below.

2.5.3.1 West Plume

The RI Report concluded that concentrations of the following COCs exceed their respective AWQS in the West Plume:

- 1,1-DCE, which has an AWQS of 7 µg/L, was detected at 67 µg/L in well WCP-230 on 26 October 2016; and
- TCE, which has an AWQS of 5 µg/L, was detected at 120 µg/L in well WCP-230 on 26 October 2016.

Updated data from the May 2019 sampling report is presented in Section 3.2.2

2.5.3.2 Central Plume

The RI Report concluded that concentrations of the following COCs exceed their respective AWQS in the Central Plume:

- Total chromium, which has an AWQS of 100 µg/L, was detected at 170 µg/L in well WCP-214 on 01 November 2016;
- 1,1-DCE, which has an AWQS of 7 µg/L, was detected at 29 µg/L in well WCP-214 on 1 November 2016;
- PCE, which has an AWQS of 5 µg/L, was detected at 8.3 µg/L in well WCP-210 on 1 November 2016; and
- TCE, which has an AWQS of 5 µg/L, was detected at 110 µg/L in well WCP-214 on 1 November 2016.

Updated data from the May 2019 sampling report is presented in Section 3.2.2

2.5.3.3 East Plume

The RI Report concluded that concentrations of the following COCs exceed their respective AWQS in the East Plume:

- PCE, which has an AWQS of 5 µg/L, was detected at 430 µg/L in Well WCP-208S on 27 October 2016.

Furthermore, the RI Report stated that soil vapor concentrations of PCE at the HCZ property exceed the relevant groundwater protection level (GPL), which suggests that groundwater may continue to be impacted by overlying soil vapor impacts.

Updated data from the May 2019 sampling report is presented in Section 3.2.2.

3. FEASIBILITY STUDY SCOPING

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

3.1 Regulatory Requirements

Per 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 human and 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 practicality 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 ARS §49-282.06, funding sources established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to respond to the release.

The Remedy Selection Rule, AAC R18-16-407, 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 an approach that complies with ARS §49-282.06.

3.2 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.

3.2.1 Vadose Zone

Analytical results reported in the RI Report indicate the presence of VOCs in soil gas and soil, and of chromium in soil, at various properties associated with the site. These properties were likely residual source areas, identified in the RI as having the potential for VOC VI or data gaps. In 2018 Geosyntec reviewed the shallow soil vapor data and the screening levels developed in the RI. The review identified potentially over-conservative assumptions in the RI that are not aligned with current USEPA guidance documents. Geosyntec derived revised SVSLs for PCE and TCE using

the most recent USEPA-provided J&E vapor intrusion model for specific soil vapor depths of 5, 10, and 15 ft bgs [2018a, Geosyntec]. However, the conservative default screening criteria provided in the RI indicated that a potential VI risk may be present at these sites, and the extent of previous investigations were relatively limited. Therefore, a soil vapor evaluation at the site identified as data gaps was conducted by Geosyntec in 2018 to address these data gaps.

3.2.1.1 West Plume

The West Plume is centered near the intersection of 39th Avenue and Clarendon Avenue and is delineated in area by the extent of TCE and 1,1-DCE-impacted groundwater. The RI Report stated that the available soil and soil vapor data suggest that releases have occurred at or in the vicinity of the former Precise/Paraflex facility, former Giltspur facility, former Stevens facility, and at the former facility located at 4001 West Indian School Road. During the 2018 VI evaluation indoor air samples were collected from the former Giltspur facility, former Stevens facility, and the former facilities located at 4001 West Indian School Road. No samples were detected above the RSL of 3.0 µg/m^3 for commercial indoor air screening other than one sample collected at the former Stevens facility detected at concentration of 3.49 µg/m^3. Additionally, sub-slab vapor probes were installed in the former Stevens facility and former Precise/Paraflex facility. Temporary shallow soil vapor probes were also installed in the former Precise/Paraflex facility. TCE was detected in one of the two sub-slab vapor sample in the three shallow soil vapor samples collected from Precise/Paraflex at concentrations greater than the TCE VISL [2018d, Geosyntec].

3.2.1.2 Central Plume

The Central Plume is centered near the intersection of 36th Avenue and Clarendon Avenue, and is delineated in area by the extent of PCE, TCE, 1,1-DCE, and hexavalent chromium-impacted groundwater. The primary likely COC residual source areas for the Central Plume have been identified in the vicinities of the former Southwest Metal facility, the former Osborn Products facility, the former Magic Metals facility, the former Triad facility, and the former Pyramid Industries facility.

The RI Report stated that the available soil data suggest that releases have occurred at or in the vicinity of these facilities. Concentrations of PCE and TCE in soil were observed to exceed the relevant SRLs and GPLs at the former Osborn Products facility, and hexavalent chromium was detected in soil at the former Magic Metals facility. During the 2018 VI evaluation indoor air samples were collected from the former Pyramid Industries facilities and former Triad facility with no detectable concentrations of VOCs reported. Sub-slab vapor samples collected from the former Southwest Metals facility and the former Osborn Products facility. TCE was detected in two of the four samples collected from Southwest Metals facility at concentrations greater than the TCE VISL. Shallow soil vapor samples were also collected from Triad Trucking and VOCs and were not detected at concentrations greater than VISLs [2018b, Geosyntec].

3.2.1.3 East Plume

The East Plume is centered near the intersection of 34th Avenue and Clarendon Avenue, and comprises PCE-impacted groundwater. The primary likely residual source area for the East Plume is at the HCZ property and in the vicinity thereof. The RI Report stated that the available soil and soil vapor data suggest that releases have occurred at or in the vicinity of this facility. Concentrations of PCE in soil vapor were observed to exceed the relevant GPL at the HCZ property. In 2017, Geosyntec conducted two SVE pilot studies and established that SVE could be an effective remedial technology at the HCZ property [2017, Geosyntec]. Indoor air samples were also collected from the HCZ facility and did not indicate a need for a response action [Geosyntec, 2018b] Further in 2018, Geosyntec performed a supplemental investigation of the deep vadose zone and installed triple-nested vapor extraction well was installed. Results of site characterization and the pilot studies suggested that a full-scale SVE implementation as an ERA was warranted. Geosyntec commissioned a full-scale SVE system in March 2019. Samples collected at the combined influent, the GAC effluent, and the five individual extraction wells on the first day after the system fully operated for an hour. Detected PCE concentrations ranged from 973,000 micrograms per cubic meter (µg/m^3) at SVE-2 to approximately 11,000,000 µg/m^3 at SVE-3D [2018c, Geosyntec].

3.2.2 Groundwater

Analytical results reported in the RI indicate the presence of the COCs in groundwater, and the footprints of the three groundwater plumes are used to approximately delineate the Site. Groundwater elevations in the SGWS aquifer have decreased considerably since the initial investigations at the site, and the ambient flow direction has approximately reversed in direction from primarily northerly to southerly. The RI Report describes a decrease in groundwater elevation of approximately 60 feet (ft) across the Site since the lining of the Grand Canal in 1998, with groundwater elevations typically observed between 130 and 140 ft bgs as of 2016. The RI Report also states that while a minimal hydraulic connection may exist between the SGWS and the deeper LSGS aquifer, the two aquifers are separated by a semi-confining layer and impacts exceeding the relevant AWQS are confined to the SGWS at present.

The approximate lateral extent of the plumes is described below.

3.2.2.1 West Plume

The West Plume is centered near the intersection of 39th Avenue and Clarendon Avenue and comprises TCE and 1,1-DCE-impacted groundwater. The RI Report states that the West Plume is believed to have originated near the former Precise/Paraflex and former Giltspur facilities, extends to the west of those facilities to approximately West 40th Avenue, to the east by North 39th Ave., and is approximately bounded to the north and south by Indian School Road and the Grand Canal, respectively. In 2019, the highest concentration of the COCs in groundwater (110 µg/L of TCE and 78 µg/L of 1,1-DCE) were in well WCP-230, located near the intersection of Indian School

Road and 40th Avenue, which may suggest an additional source in the vicinity of the former facilities at 4001 West Indian School Road.

The RI Report estimated that groundwater velocities in the West Plume vary between 1.1 and 17 ft per year, and suggests that the plume is stable and that low groundwater velocities likely limit the rate of COC migration.

3.2.2.2 Central Plume

The Central Plume is centered near the intersection of 36th Avenue and Clarendon Avenue, and comprises commingled PCE, TCE, 1,1-DCE, and hexavalent chromium-impacted groundwater plumes. The RI Report states that the Central Plume is believed to have originated near the former Pyramid Industries facility (for VOCs) and the former Magic Metals facility (for hexavalent chromium). The Central Plume is largely bounded to the east and west by 35th Avenue and 39th Avenue, respectively, and to the north by Indian School Road. The toe of the plume extends south past the grand canal and commingles with the VOC plumes that are part of the West Osborn Complex (WOC) WQARF Site, adjoining to the south. The highest concentrations of COCs in groundwater reported in 2019 were 94 µg/L of TCE in well WCP-MW-214 at the former Pyramid Industries facility, 5.2 µg/L of PCE in well WCP-210, and 180 µg/L of hexavalent chromium in well WCP-227 at the former Pyramid Industries facility.

Groundwater flow velocities in the Central Plume were estimated in the RI Report to vary from 19 ft/year in the southern part of the plume to 115 ft/year in the northern part. The RI Report stated that the plume is stable and that low groundwater velocities in the southern portion of the plume likely limit the rate of COC migration.

3.2.2.3 East Plume

The East Plume is centered near the intersection of 34th Avenue and Clarendon Avenue, and comprises PCE-impacted groundwater. The RI Report states that the East Plume is believed to have originated near the HCZ facility. The East Plume is approximately bounded by Grand Avenue to the north and east, the Grand Canal to the south, and 35th Avenue to the west, but is not well-delineated in the direction of Grand Avenue. The presence of a fault running parallel to Grand Avenue may provide a hydraulic barrier between the east and west sides of the fault. The highest concentration of PCE observed in 2019 was 290 µg/L in well WCP-MW-213 near the HCZ facility.

The RI Report estimated an average groundwater velocity in the East Plume of approximately 35 ft/year, and stated that the East Plume may continue migrating southward, possibly commingling with the WOC WQARF Site plume.

3.2.3 Areas of Uncertainty

Data gaps identified by the RI Report include the following:

- Elevated TCE concentrations in groundwater samples collected from monitoring well WCP-230 suggest that one or more additional local sources may be contributing to the West Plume. Soil vapor data from the former facilities at 4001 West Indian School Road and Stevens facility suggest that an additional contributing source or sources in their vicinities may not have been adequately defined;

- Results from the 2018 VI evaluation addressed data gaps identified in the 2017 RI; the evaluation results indicate that PCE or TCE are not resulting in unacceptable risk to site occupants associated with vapor intrusion at the facility at 4001 West Indian School Road, former Stevens facility, Pyramid Industries facility, Giltspur facility, Osborn facility, or Triad facility;

- The VI evaluation identified soil vapor concentrations of TCE above the VISLs at both the Precise/Paraflex and the Southwest Metals facilities; however, subsequent indoor air monitoring at these facilities demonstrated that no unacceptable risk was occurring associated with vapor intrusion, addressing this data gap identified in the RI; and

- The available data are insufficient to determine the background concentrations of chromium in the shallow and LSGS aquifers.

3.3 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. HGC prepared a Land and Water Use Evaluation as part of the RI Report [HGC, 2017], based on information gathered during the public involvement process. Results of land and water use questionnaires are described in the Land and Water Use Survey and are included in Appendix P of the RI Report [HGC, 2017]. Not every use identified in the land and water use questionnaires 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) time frames 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.

The following sections summarize the ROs established for the Site in the Revised RO Report [ADEQ, 2020].

3.3.1 Remedial Objectives for Land Use

Per the Revised RO Report, ROs for land use are established for those properties known to be contaminated with hazardous substances above an SRL or a risk-based screening level. Soil data collected at the various facilities associated with the Site indicate that vadose zone impacts exceed regulatory standards for COCs for land use.

The RO for soil at the Site is:

> *Protect against the loss or impairment of land threatened by the contaminants of concern, PCE and TCE, at the WCP NCP WQARF Site and restore land that has been impaired by the contaminants of concern at the WCP NCP WQARF Site to below applicable remediation levels. Action is needed for the present time and for as long as necessary to ensure that the level of contamination in the soil associated with the Site no longer exceeds applicable remediation levels.*

3.3.2 Remedial Objectives for Groundwater Use

The Site lies entirely within the Phoenix Active Management Area (AMA). Groundwater extraction within the Phoenix AMA must occur under a groundwater right or permit. Arizona Department of Water Resources (ADWR) records indicate that there is one irrigation well, no AMA-exempt wells, and no grandfathered rights within the Site. COP and SRP both have groundwater rights within the Site.

COP does not presently have production wells within the Site, but has stated that it may install wells in the future. At present, impacts to the groundwater at the Site would restrict the use of untreated groundwater withdrawn by the COP. SRP currently owns one production well within the Site area, designated 9.5E-7.7N. TCE has been detected above the AWQS of 5.0 µg/L in this well. Historically, this well has provided water for irrigation, but SRP has stated that it plans to transition the well to drinking water production in the reasonably foreseeable future. In 1999, SRP agreed to temporarily discontinue regular pumping of this well at the request of ADEQ. SRP is currently pumping the well intermittently and there may be anticipated changes in the pumping schedule.

Per the Revised RO Report, the ROs for groundwater at the Site is to protect the groundwater for use by COP and SRP, stated as follows:

Irrigation Use

Protect against the loss or impairment of irrigation water threatened by the contaminants of concern at the WCP NCP WQARF Site. Where protection cannot be achieved in a reasonable, necessary, or cost-effective manner; restore, replace, or otherwise provide for irrigation water that is lost or impaired by the contaminants of concern at the WCP NCP WQARF Site. Action is needed for as long as necessary to ensure that, while the water exists and the resource remains available, the contamination associated with the WCP NCP WQARF Site does not prohibit or limit the designated use of groundwater.

Potable Use

Protect against the loss or impairment of potable water threatened by the contaminants of concern at the WCP NCP WQARF Site. Where protection cannot be achieved in a reasonable, necessary, or cost-effective manner; restore, replace, or otherwise provide for potable water that is lost or impaired by the contaminants of concern at the WCP NCP WQARF Site. Action is needed for as long as necessary to ensure that, while the water exists and the resource remains available, the contamination associated with the WCP NCP WQARF Site does not prohibit or limit the designated use of groundwater

As such, groundwater protection is currently needed. This action will be needed as long as the levels of residual impacts threaten the use of the regional groundwater for municipal/drinking water purposes.

3.3.3 Remedial Objectives for Surface Water Use

Surface water at the Site is present only in engineered canals for irrigation use. Water from SRP irrigation wells outside of the Site is discharged to the concrete-lined Grand Canal, which serves downstream agricultural and urban irrigation customers. Because the primary source of this surface water is from outside of the Site, no ROs for surface water are specified.

4. IDENTIFICATION AND SCREENING OF REMEDIATION TECHNOLOGIES

This section presents the evaluation and screening of various remedial strategies and measures related to the impacts in soil and groundwater and lists the technologies that have been retained for evaluation as part of the reference and alternative remedies. A detailed discussion of the remediation technologies evaluated for potential implementation at the Site is provided.

4.1 Remedial Strategies

The Remedy Selection Rule, AAC R18-16-407 (Feasibility Study), prescribes six remedial strategies to be developed, incorporating one or more remediation technologies or methodologies. These strategies are:

1. Plume remediation, a strategy to achieve water quality standards for COCs in waters of the state throughout the Site;

2. Physical containment, a strategy to contain impacts within definite boundaries;

3. Controlled migration, a strategy to control the direction or rate of migration but not necessarily to contain migration of the impacts;

4. Source control, a strategy to eliminate or mitigate a continuing source of impacts;

5. Monitoring, a strategy to observe and evaluate the impacts at the Site through the collection of data; and

6. No action, a strategy that consists of no action at the Site.

4.2 Remedial Measures and Technologies Screening Assumptions

This section defines and describes the general assumptions about the Site that were used during the identification and screening of remedial technologies.

4.2.1 Concentrations of COCs in Vadose Zone and Groundwater

COC concentrations were assumed as follows:

- Presumed to treat within an average 100 µg/L total VOC concentration plume. Maximum chlorinated VOC concentrations of 300 µg/L in groundwater, based on most recent groundwater sampling results and concentration trends; and
- Maximum hexavalent chromium concentrations of 250 µg/L in groundwater, based on most recent groundwater sampling results and concentration trends.

4.2.2 Groundwater Chemistry and Natural Attenuation Conditions

As mentioned above, groundwater velocities were calculated to be approximately 20 ft/year to the south in the West Plume, 20 ft/year to the south in the southern portion of the Central Plume, and 35 ft/year to the south in the East Plume. Vertical interaction between shallow and deep groundwater is expected to have been locally enhanced by historical pumping of SRP wells 9.5E-7.7N and 10.5E-7.5N (HGC, 2017). However, at the time of the RI completion (HGC, 2017), these wells were not active. Non-remedial pumping of SRP wells may reoccur in the future to sustain future municipal water needs. Aquifer conditions are assumed to be generally aerobic, with insignificant organic carbon availability for biotic attenuation of the COCs by native biota. In the absence of an engineered intervention, attenuation of the COCs is expected to be driven primarily by dilution, dispersion, and phase separation.

4.2.3 Flow Rates and Dosage Rates

Flow rates and dosage rates for active remedies depend on the remedial strategy. For injection-based technologies, the actual flow rates that can be achieved will depend on the lithology in the areas to be extracted from or injected into. Results from the RI and ERA activities were used to generate estimates of flow rates and radii of influence (ROI) for groundwater and soil vapor extraction.

4.2.3.1 Soil Vapor Extraction

Flow rates for SVE are based on the reported operation of a pilot ERA SVE system [Locus, 2008a] conducted in the vicinity of the former Osborn Products facility. Methodology and results of the test are described in detail in the test report and in the RI Report. This study, which utilized an extraction well screened from 35 to 65 ft bgs under a vacuum of 18 inches of water column (in WC), developed a flow rate of 119 actual cubic feet per minute (acfm) and an observed ROI of 18 ft. Based on these results and for the purpose of soil vapor extraction, it is assumed that a 15-ft radius of influence could be established with the withdrawal of approximately 100 standard cubic feet per minute (scfm).

4.2.3.2 Groundwater Extraction

An aquifer test was performed by Locus in the vicinity of the former Southwest Metal facility as part of the RI [Locus, 2008b]. Methodology and results of the test are described in detail in the test report and in the RI Report. The well pumped was WCP-227, a 4-inch diameter monitoring well screened from 120 to 165 ft bgs in a formation described as silty sand with clay. Static depth to water was 135 ft bgs, and the calculated capture zone width at the well was 136 ft at a withdrawal rate of 8.5 gallons per minute (gpm). Based on these results, it is assumed that a 100-ft wide capture zone could be established for the purpose of hydraulic containment with an extraction rate of approximately 10 gpm.

4.3 Screening of Remedial Measure

Remediation technologies were identified and screened according to the following criteria:

- Treatment effectiveness;
- Constructability;
- Flexibility and expandability;
- Operations and maintenance (O&M) requirements;
- Operational hazards; and
- Cost-effectiveness

Table 1 provides a summary of the remedial measures that were screened and their general viability according to the criteria above. 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.

Technologies that were evaluated for treating the media and concentration levels of the COCs observed at the Site are described below. The basic treatment mechanisms and the suitability and limitations of the technologies are discussed. Technologies that are retained are then used to develop reference and alternative remedies for the Site. Justification for retaining or dismissing particular technologies from consideration is also discussed.

4.3.1 Groundwater Extraction and Treatment

Extraction and treatment (i.e., "pump-and-treat," [P&T]) is a technology for groundwater that can be effective for hydraulic containment and/or migration control for sites impacted by VOCs and soluble metals such as hexavalent chromium. P&T systems typically utilize submersible pumps in extraction wells to extract groundwater and transfer it via conveyance piping into an aboveground treatment system. The post-treatment water is subsequently discharged to a municipal sewer, a canal or other surface water conveyance, an infiltration basin, or re-injected into the subsurface with an injection well. These systems can control the subsurface flow of impacted groundwater, mitigating migration and/or reducing the footprint of the impacts. Liquid-phase granular activated carbon (LGAC) is typically employed for VOC removal via adsorption onto the media surface, while ion exchange (IX) resin is commonly employed for the removal of soluble metals.

The primary limitation for P&T is typically long cleanup times when used as the primary remedial measure in heterogeneous formations where diffusion from fine-grained layers provides a secondary source. Additionally, the ineffectiveness of LGAC for hexavalent chromium, and of IX for VOCs, reduces the cost effectiveness of implementation of P&T in commingled plumes, such as the Central Plume. Still, P&T is widely used and is proven as a component for groundwater impact treatment. This measure is highly implementable with respect to both the design and operation of a treatment system, and is amenable to the hydrostratigraphy of the site. Therefore, P&T is retained as a remedial measure for additional evaluation.

4.3.2 In Situ Chemical Oxidation

In situ chemical oxidation (ISCO) is a frequently used technology that includes the injection of chemical oxidants into the subsurface to treat soil and groundwater impacts. Common amendments used for ISCO include permanganate, persulfate, hydrogen peroxide, and ozone. These highly reactive amendments oxidize the COCs to produce innocuous byproducts. Chemical oxidizers are typically injected through wells or temporary injection points using gravity or pressurized injection methods to achieve horizontal distribution. Catalysts may be included or required to promote reactions for some amendments, such as sodium persulfate. ISCO, as with other *in situ* methods, typically includes higher capital costs than *ex situ* methods such as P&T, but may provide significant savings through long-term O&M cost reductions and reduced time to closure.

The utility of ISCO for groundwater treatment is limited due to the large and dilute VOC plumes, coupled with the suspected presence of significant quantities of chromium (specifically, trivalent chromium) in the geological formations. Because of the large and dilute plumes, the volume of injectate required to achieve the treatment objectives over the full footprint of the plumes would be cost prohibitive. Furthermore, ISCO can convert insoluble, non-hazardous trivalent chromium to the more soluble, hazardous hexavalent chromium. Total chromium has been observed at concentrations of up to 3,990 µg/L (WCP-63M, February 2015) in the Central Plume and has been observed in double-digit µg/L across the Site. However, sodium permanganate as an ISCO remedy has a relatively long half-life, and it typically readily distributes via dispersion in groundwater; therefore, ISCO using permanganate may be effective in treating a limited portion of the plume (near a source area). Because of the potential for oxidation of total chromium to dissolved (hexavalent) chromium, a pilot study should be performed to understand specific Site conditions, and the implementability of this remedy.

ISCO is retained as a feasible remedial measure for additional evaluation.

4.3.3 *In Situ* Chemical Reduction

In situ chemical reduction (ISCR) is generally similar to ISCO in execution, but uses strong chemical reductants to convert the COCs to innocuous byproducts. Chemical reducing agents include zero valent iron (ZVI), ferrous iron, sodium dithionite, and calcium polysulfide. Because groundwater at the Site is typically aerobic or moderately chemically oxidizing, a large quantity of the injectate would be consumed in reactions associated with ambient groundwater general chemistry as opposed to reduction of target COCs. However, in addition to treating chlorinated VOCs, ISCR can convert soluble hexavalent chromium to insoluble trivalent chromium. As such, this technology is compatible with the chromium impacts present in the Central Plume and the background chromium concentrations Site-wide. While ISCR may be impractical for treating the entirety of broad, low-concentration, dissolved-phase plumes, it may be cost-effective for residual source area treatment.

ISCR is retained as a feasible remedial measure for additional evaluation for residual source area treatment.

4.3.4 *In Situ* Gaseous Reduction

In situ gaseous reduction (ISGR) is a special application of ISCR in which the chemical reductant is introduced in the gas phase, rather than as a liquid or suspended in a liquid (e.g., ZVI). Gas phase applications have distinct advantages in vadose zone treatments, including better distribution (including by diffusion) into fine-grained materials. ISGR typically uses hydrogen sulfide gas, an aggressive chemical reductant, and has been demonstrated to be effective in reducing hexavalent chromium to trivalent chromium.

Unlike other amendments that may persist in the subsurface for months or years post-treatment (e.g., permanganate), hydrogen sulfide is completely converted to innocuous compounds through reactions with common soil minerals within days or weeks. While ISGR requires additional logistical measures due to the use of a gaseous reagent, it can provide very short time-to-closure for well-defined vadose zone residual source areas. Thus, ISGR is retained as a feasible remedial measure for additional evaluation for residual source area treatment.

4.3.5 Enhanced *In Situ* Bioremediation

Enhanced *in situ* bioremediation (EISB) treats groundwater impacts by stimulating microbial growth, which converts COCs to innocuous byproducts. EISB may take advantage of either aerobic or anaerobic microbial growth, which are biological methods comparable to ISCO and ISCR, respectively. Frequently, EISB includes the addition of a prepared microbial culture to provide the appropriate microorganisms for the desired reactions. Because aerobic EISB methods are typically considered ineffective for treatment of chlorinated VOCs, and may (like ISCO) convert trivalent chromium to hexavalent chromium, for the purpose of this FS, EISB for the remainder of this FS will include only anaerobic (reductive) methods.

At the Site, a reductive EISB implementation would require introduction of amendments to the groundwater that would supply organic carbon, an electron donor, a microbial culture, and other nutrients and/or substrates to stimulate microbial growth. This growth would take place in two phases; the first would drive the aquifer from aerobic (oxidizing) conditions to anaerobic (reducing) conditions, and the second would convert the COCs to innocuous byproducts (i.e., chlorinated VOCs to ethene and hexavalent chromium to trivalent chromium). A pilot-scale study would be required to evaluate the best implementation approach for the remedy before moving to a full-scale implementation.

Challenges for implementing EISB are similar to ISCR, and include low COC concentrations, a large plume footprint area, and the generally aerobic groundwater conditions. An EISB system would also require the installation of new wells specifically designed for EISB injection. As with other *in situ* methods, EISB is anticipated to have significantly higher capital costs than ex-situ

pump and treat systems, However, these costs may be offset by reduced or no O&M costs and reduced time to closure. EISB is, and is generally perceived to be, a "green" or environmentally friendly technology when compared to alternatives, and is typically well-received by community stakeholders. EISB is not practical for treatment of entire dissolved-phase plumes at the Site, though it may be cost-effective for residual source area treatment and is therefore retained as a feasible remedial measure for additional evaluation.

4.3.6 Soil Vapor Extraction

SVE is an established and proven removal technology for the VOCs in the vadose zone, particularly in conditions where excavation and off-site disposal of impacted soil is impractical. SVE involves the installation of a series of extraction wells in the impacted vadose zone and applying vacuum to extract soil vapors containing VOCs. The SVE wells are typically connected via conveyance piping to an extraction system, followed by discharge to the atmosphere, with or without first being treated to remove the VOCs, depending on the quantity emitted and local regulations. The treatment method used for the VOCs is typically based on the concentration and chemical properties of the COCs. For the Site, vapor-phase granular activated carbon (VGAC) would likely be the most cost-effective treatment.

SVE is only effective for VOCs, and cannot address the hexavalent chromium present at the Central Plume. SVE is effective in providing source control and preventing vadose zone contamination from migrating to groundwater, but does not provide treatment for the dissolved plume and is therefore typically used in conjunction with other remedial measures when groundwater impacts are present. SVE has been widely and effectively implemented in conditions similar to those at the Site, and is considered highly technically implementable. SVE is therefore retained as a feasible remedial measure for additional evaluation.

4.3.7 Air Sparge

AS systems introduce compressed gasses below the water table through injection wells, where the gasses expand and travel upward through the saturated zone to the unsaturated zone. VOCs partition from impacted groundwater into the introduced bubbles or air channels and are removed by advection to the vadose zone. AS systems are complimentary to SVE systems, typically providing groundwater treatment while the SVE system provides overlying soil vapor mitigation. AS is only effective for VOCs, and cannot address the hexavalent chromium present at the Central Plume. While AS may promote aerobic biological activity for aerobically degraded compounds, it is unlikely to have any such effects for COCs at the Site.

The limited effective ROI of an AS well makes treatment of large, dilute plumes impractical, but AS may be cost-effective for residual source area treatment. For locations where SVE is viable, AS as a complimentary measure may be beneficial. Thus, AS is retained as a feasible remedial measure for additional evaluation.

4.3.8 *In Situ* Thermal Remediation

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, less aggressive technologies (EISB 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 being achieved that exceed the boiling point of the COCs. This heating volatilizes VOCs *in situ* and an SVE system removes them from the subsurface. Vapors are then 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 most effective in source areas that contain non-aqueous phase liquids (NAPLs) and cannot be economically implemented for diffuse/low concentration impacts. ISTR is not retained as a treatment technology for additional evaluation for the Site, primarily because it is not cost effective for the low VOC concentrations that remain.

4.3.9 Permeable Reactive Barrier

A permeable reactive barrier (PRB) is typically a special application of ISCO, ISCR, or EISB, whereby the amendments are introduced such that they form a wall of reactive materials through which impacted groundwater passively flows. PRBs are constructed either by trenching and backfilling with amended materials, or by injecting the amendments in a series of locations determined by the effective radius achievable for the Site-specific hydrostratigraphy. Within the PRB, chemical and biological reactions occur that convert the COCs to innocuous byproducts; as a result, an effective PRB will mitigate further downgradient migration of COCs.

For relatively shallow, well-characterized plumes with predictable directions of travel and relatively high groundwater velocities, PRBs can be a cost-effective way to clean up groundwater due to the reliance on natural groundwater flow with no ongoing energy/electrical costs associated with groundwater pumping. Once in operation, no aboveground equipment is required, allowing for normal and continued above ground property use post-installation.

Groundwater velocities at the Site are relatively slow. The time required for a substantial portion of the dissolved plumes to interact with a PRB would likely be much longer than the expected lifespan of the amendments in the PRB. This would be exacerbated at the Site, where aerobic

groundwater is present. Further, the depth of a PRB installation required at this Site would preclude simple trenching as a means of emplacement. While a PRB can be installed through subsurface injection, the slow groundwater velocities present at the Site make such an approach unlikely to be more advantageous than ISCR or EISB for source areas. PRBs are therefore not retained as feasible remedial measures for additional evaluation for the Site.

4.3.10 Monitored Natural Attenuation

Monitored natural attenuation (MNA) is a widely-applied remedial measure when natural processes are expected to reduce COC concentrations over time. Such natural processes include dilution, dispersion, sorption, volatilization, and chemical or biological stabilization or transformation. For chlorinated VOCs, such as PCE, TCE, and 1,1-DCE, natural reductive dechlorination (via biological and/or abiotic degradation processes) is usually the most significant degradation process when conditions are favorable (i.e., anaerobic environment with available organic carbon). Application of MNA requires the identification of the most likely attenuation processes and an estimation of the time required for these processes to meet the remedial objectives. MNA also includes implementation of a plan to observe the progress of the remedy to monitor that natural attenuation proceeds and that unexpected migration of impacts does not occur.

For very dilute plumes, such as the Site plumes, MNA is often the only technically feasible solution. MNA is frequently included as a component in a larger remedial strategy, sometimes coupled with more active remediation at source areas. MNA is retained as a feasible remedial measure for additional evaluation.

5. DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES

This section presents the selected Reference Remedy, a More Aggressive Remedy, and a Less Aggressive Remedy for each of the three plumes associated with the Site. Evaluations of the alternatives include a discussion of the associated remedial measures and remedial strategies pursuant to AAC R18-16-407 (E). The reference and alternative remedies for the three plumes are summarized in Table 2. The conceptual locations of alternative remedy features are shown on Figure 7.

The Reference Remedy and alternative remedies consist of combinations of remedial strategies and their associated remedial measures, selected to achieve the ROs for the Site. The remedies also include contingent remedial strategies (contingencies) to address reasonable uncertainties regarding the achievement of ROs, or uncertain timeframes in which ROs will be achieved. Where remedial measures are necessary to achieve ROs, such remedial measures will remain in effect as long as required for continued achievement of those objectives.

5.1 Reference Remedies

The following subsections present the remedial strategies and measures for the Reference Remedies associated with the plume, as well as the associated permits and agreements that would be anticipated to be required.

5.1.1 West and Central Plumes

The remedial strategies for the Reference Remedy for the West and Central Plumes are:

- Vadose zone source control to mitigate a continuing source of contamination;
- Plume remediation to achieve water quality standards for COCs in waters of the state throughout the Site;
- Physical containment, a strategy to contain COCs within definite boundaries;
- Controlled migration, a strategy to control the direction or rate of migration but not necessarily to contain migration of the COCs; and
- Monitoring to observe and evaluate the COCs at the Site through the collection of data.

These remedial strategies would be performed using the measures described in the following subsections.

5.1.1.1 Reference Remedy SVE

Implementation of SVE for the West and Central Plumes Reference Remedy will comprise the following:

- Installation of one SVE system per plume consisting of an estimated 250 cubic foot per minute (cfm) blower;

- Installation of eight SVE wells per plume (100-ft deep assumed for cost estimating purposes); and
- Operational monitoring to assess remedial progress and system performance (assumed 5 years per plume for cost estimating purposes).

The operation of the SVE system will provide source control through the removal of VOC mass in the vadose zone, which will mitigate the potential for vapor intrusion and ongoing groundwater impacts from the residual VOCs. SVE performance and capacity will be evaluated, and upgrades will be recommended as part of the PRAP, if warranted. However, for the purpose of this FS, it is assumed that the SVE system for the Reference Remedy will be a blower with a 250-cfm capacity, that eight SVE wells will be installed, and the SVE system in each plume will continue to be operated for up to five years, or until asymptotic decreases in soil vapor VOC concentrations are observed. SVE system optimization will be conducted throughout the five-year period, which includes a contingency for expansion of the system (Subsection 5.1.2.4). Operational schedules may be adjusted to enhance VOC removal. After SVE system shut-down, VOCs will be monitored for rebound for a period of three months, after which confirmation soil vapor samples will be collected to support demonstration of achieving the ROs and discontinued SVE operations.

5.1.1.2 Plume Remediation, Physical Containment, and Controlled Migration

P&T systems would be installed at the West Plume and the Central Plume to intercept the plumes migrating toward the south across an east-west transect in the vicinity of WCP-234 and WCP-27, respectively. Based on the results of the prior aquifer test, three extraction wells withdrawing approximately 10 gpm/well would be estimated to provide a capture zone up to 300 ft wide at the transect. The extracted groundwater would be treated by a 50-gpm capacity system (the additional capacity included for contingency) comprised of submersible extraction pumps, conveyance piping to a treatment compound, pretreatment with bag filtration to remove particulates, LGAC to remove VOCs, and discharge to the Grand Canal. The P&T for the Central Plume will also include IX for treatment of chromium and hexavalent chromium. This remedy assumes up to 30-years of operation per plume.

This extraction well configuration would intercept the normal movement of the plume along the ambient gradient. Hydraulic containment would be provided for the highest concentration portion of the plume, as well as treatment of majority of the plume. The migration of the plume along a north/south axis toward the treatment system would be enhanced.

5.1.1.3 Monitoring

MNA would consist of semiannual groundwater level measurements and sampling for the relevant COCs and MNA parameters for a period of five years. Sampling frequency may be dependent on concentration trends. If COC concentrations trends are declining over five years groundwater level measurements and sampling may be adjusted to occur annually. The existing monitoring well

network would be used to collect data to monitor and evaluate the nature and extent of impacts to the Site during groundwater remediation. Only the wells required to delineate the West and Central Plumes would be sampled to support the West and Central Plume remedies

Due to the large area covered by the two dilute plumes, the application of MNA is appropriate for the peripheral portions of the plumes where the COCs may be reasonably anticipated to be attenuated by natural processes (e.g., dilution and dispersion) before they reach the vicinity of the P&T systems. As a result, the P&T systems do not need to be designed to capture the entire footprint of the plumes as it presently exists.

5.1.1.4 Contingencies

The following contingency remedial measures have been identified to address potential uncertainty in the achievement of the ROs:

- Additional groundwater monitoring wells may be required to replace wells that may become unusable due to changing groundwater elevation, fouling, or other conditions;
- Higher pumping rates and/or additional groundwater extraction wells may be required for hydraulic containment or control of the plume if Site hydrostratigraphy provides smaller-than-expected capture zones, or if natural attenuation proceeds more slowly than anticipated;
- P&T implementation may be modified from a stand-alone system to a component in a larger, regional system (e.g., in combination with the Central Plume) if cost analysis for such a system suggests better economy;
- SVE systems may be expanded if soil vapor concentrations do not decrease sufficiently over time, and if groundwater concentrations suggest continued vadose zone source impacts and contribution to the plume are present. This contingency may necessitate up to six additional SVE extraction wells, for a total of 10 SVE wells per plume;
- ISCO may be implemented at each plume if Site conditions (e.g., plume concentration, plume footprint, and local hydrostratigraphy) and a cost analysis indicate that implementation would provide better economy over the life of the remedy; and
- If SRP resumes pumping of well 9.5E-7.7N and/or 10.5E-7.5N or future water supply demands call for the installation of new production wells by COP or SRP, the well(s) would be monitored for VOC and hexavalent chromium concentrations in withdrawn groundwater. If concentrations exceeded applicable AWQS for the municipal well or applicable surface water standards for an irrigation well, contingencies would then be implemented. If the VOC concentrations exceed an applicable AWQS or surface water standards, then wellhead treatment would be implemented. Wellhead treatment would consist of a LGAC and/or IX treatment system located adjacent to the well. Treated groundwater would then be pumped into the COP piping system or SRP canal.

5.1.1.5 Permits and Agreements

Multiple permits and/or agreements would be necessary to authorize installation and operation of the Reference Remedy for the West Plume, including:

- Pre-construction notifications (i.e., ADWR Notice of Intent to Drill) and post-construction reporting (Driller's Reports) would 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 comply with ADWR standards found in ARS §45-594, -595, -596 and -600 of the Groundwater Code;
- A Poor Quality Groundwater Withdrawal Permit (PQGWP) must be obtained from ADWR;
- General construction permits and right-of-way construction permits would be required from the COP for the installation of a new P&T system and associated conveyance piping. This would require preparation and submittal of design plans and specifications (i.e., civil, plumbing, mechanical, electrical) to COP;
- Access agreements with private land owners or purchase of land would be required if the P&T system components and/or associated conveyance piping needs to be located on private property; and
- A discharge agreement with SRP and an Authorization to Discharge under the Arizona Pollutant Discharge Elimination System (AZPDES Permit) would be required for discharge to the SRP Grand Canal.

5.1.2 East Plume

The remedial strategies for the Reference Remedy for the East Plume are:

- Operation of the existing source control to mitigate a continuing source of contamination;
- Plume remediation to achieve water quality standards for COCs in waters of the state throughout the Site;
- Physical containment, a strategy to contain COCs within definite boundaries;
- Controlled migration, a strategy to control the direction or rate of migration but not necessarily to contain migration of the COCs;
- Source control, a strategy to eliminate or mitigate a continuing source of COCs; and
- Monitoring to observe and evaluate the COCs at the Site through the collection of data.

These remedial strategies would be carried out using the measures described in the following subsections.

5.1.2.1 Reference Remedy SVE

Implementation of SVE for the East Plume Reference Remedy will comprise the following:

- Continued system O&M to assess remedial progress and system performance; and
- Installation of up to six additional SVE wells.

The SVE system will provide source control through the removal of VOC mass in the vadose zone, which will mitigate the potential for vapor intrusion and ongoing groundwater impacts from the residual VOCs. SVE performance and capacity will be evaluated, and upgrades will be recommended as part of the PRAP, if warranted. It is assumed that the SVE system for the Reference Remedy will continue to operate at its current capacity, that the existing five SVE wells will continue to comprise the extraction well field, and the system will continue to be operated for up to five years, or until asymptotic decreases in soil vapor VOC concentrations are observed. SVE system optimization will be conducted for up to five years, which will include a contingency for expansion of the system (Subsection 5.1.2.4). Operational schedules may be adjusted to enhance VOC removal. After SVE system shut-down, VOCs will be monitored for rebound for a period of three months, after which confirmation soil vapor samples will be collected to support demonstration of achieving the ROs and discontinued SVE operations.

5.1.2.2 Plume Remediation, Physical Containment, and Controlled Migration

A P&T system would be installed to intercept the plume across an east-west transect in the vicinity of WCP-205. Based on the results of the prior aquifer test, three extraction wells withdrawing approximately 10 gpm per well are estimated to provide a capture zone up to 300 ft wide at the transect. The extracted groundwater would be treated by a 50-gpm capacity system comprised of submersible extraction pumps, conveyance piping to a treatment pad, pretreatment with bag filtration to remove fines, LGAC to remove VOCs, and discharge to the Grand Canal. This remedy assumes up to 30-years of operation per plume.

This extraction well configuration would intercept the normal movement of the plume along the ambient gradient. Hydraulic containment would be provided for the highest concentration portion of the plume, as well as treatment of majority of the remainder of the plume. The migration of the plume along a north/south axis toward the treatment system would be enhanced.

5.1.2.3 Monitoring

MNA would consist of semiannual groundwater level measurements and sampling for the relevant COCs and MNA parameters. Sampling frequency may be dependent on concentration trends. If COC concentrations trends are declining over five years groundwater level measurements and sampling may be adjusted to occur annually. The existing monitoring well network would be used to collect data to monitor and evaluate the nature and extent of impacts to the Site during

groundwater remediation. Only the wells required to delineate the East Plume would be sampled to support the East Plume remedy.

Due to the large area covered by the dilute plume, the application of MNA is appropriate for the peripheral portions of the plume where the COCs may be reasonably anticipated to be attenuated by natural processes (e.g., dilution and dispersion) before they reach the vicinity of the P&T system. As a result, the P&T system does not need to be designed to capture the entire footprint of the plume as it presently exists.

For the vadose zone remedy, soil vapor sampling in the vicinity of the SVE system and a post-SVE soil vapor sampling event would be required to monitor and evaluate remedial effectiveness.

5.1.2.4 Contingencies

The same contingency requirements as those specified in for the West and Central Plume Reference Remedy (Subsection 5.1.1.4) would be required for the East Plume Reference Remedy.

5.1.2.5 Permits and Agreements

The same permit requirements as those specified in for the West Plume Reference Remedy (Subsection 5.1.1.5) would be required for the East Plume Reference Remedy.

5.2 More Aggressive Remedies

The following subsections present the More Aggressive Remedies that have been developed for the three plumes. The remedial strategies for the More Aggressive Remedies include measure listed in the Reference Remedy plus additional plume-specific remedial strategies, measures, and contingencies.

5.2.1 West and Central Plumes

The More Aggressive Remedy for the West and Central Plume includes additional measures for the Plume Remediation, Physical Containment, and Controlled Migration strategies. The large volume and dilute concentration of impacts in the West and Central Plumes suggest that aggressive chemical or biological (e.g., ISCR, EISB) remediation measures would be impractical for implementation outside of targeted source area remediation. However, a targeted ISCO implementation within the source area using sodium permanganate, would expedite the remediation of the plume and speed up achieving the ROs for the Site.

5.2.1.1 More Aggressive Remedy SVE

The West and Central Plume More Aggressive Remedies include the measures listed in the Reference Remedy, plus installation of four additional SVE wells per plume (12 SVE wells per plume total).

5.2.1.2 Plume Remediation, Physical Containment, and Controlled Migration

The More Aggressive remedy assumes that the proposed P&T system would be installed as proposed in the Reference Remedy at both the West and Central Plumes. In addition to the P&T system, ISCO at each plume would be implemented as part of the More Aggressive Remedy. Injection of a liquid oxidant, such as sodium permanganate, would be performed to target VOCs within the lithology of shallow groundwater at the suspected source area, where elevated VOCs are detected. Three injection wells are proposed per plume. The injection wells would be installed within private property or COP right-of-way. Each well is assumed to be screened within the SGWS. A secured compound would be used to house an oxidant tank, pump, and manifold to distribute oxidant to the proposed injection wells. The viability of ISCO should be assessed via a pilot study to determine the potential mobilization of dissolved metals, prior to the PRAP.

Due to the large footprint area covered by the dilute plume, the application of MNA would still be necessary for the peripheral portions of the plume, even with an expanded hydraulic containment system.

5.2.1.3 Contingencies

Previously identified contingencies presented in Section 5.1.1.4 would also be applicable here. If data collected during operation of the P&T system indicate continuing impacts are occurring from a VOC source, additional injection wells, a treatment pad with reagent storage vessels, and associated conveyance piping would be constructed.

5.2.1.4 Permits and Agreements

No additional permits or agreements are required beyond those listed for the Reference Remedy for the West Plume.

5.2.2 East Plume

The More Aggressive Remedy for the East Plume includes additional measures for the Plume Remediation, Physical Containment, and Controlled Migration strategies. The large volume and dilute concentration of impacts in the East Plume suggest that aggressive chemical or biological (e.g., ISCR, EISB) remediation measures would be impractical for implementation outside of targeted source area remediation. A targeted ISCO implementation within the source area using

sodium permanganate, would expedite the remediation of the plume and speed up achieving the ROs for the Site.

5.2.2.1 More Aggressive Remedy SVE

The East Plume More Aggressive Remedy for vadose zone soil includes the measures listed in the Reference Remedy SVE, plus additional remedial strategies. These include continued operation of the existing SVE system and installation of 12 additional SVE wells (17 wells total).

5.2.2.2 Plume Remediation, Physical Containment, and Controlled Migration

The East Plume More Aggressive Remedy includes the measures listed in the Reference Remedy, plus additional remedial ISCO as described in Section 5.2.1.2.

5.2.2.3 Contingencies

The East Plume More Aggressive Remedy contingencies include the same measures listed in the Reference Remedy, plus additional contingencies listed in Section 5.2.1.3.

5.2.2.4 Permits and Agreements

No additional permits or agreements are required beyond those listed for the Reference Remedy for the East Plume.

5.3 Less Aggressive Remedies

The following subsections present the Less Aggressive Remedies that have been developed for the three plumes. The remedial strategies for the Less Aggressive Remedies do not include the activities listed in the Reference Remedy.

5.3.1 West and Central Plumes

The remedial strategy for the Less Aggressive Remedy for the West Plume is to observe and evaluate the COCs through the collection of data. This remedial strategy would be performed using the measures and contingencies described in the following subsections.

5.3.1.1 Less Aggressive Remedy

The West and Central Plume Less Aggressive Remedies include the measures listed in the Reference Remedy, but with only four SVE wells.

5.3.1.2 Monitoring

MNA would consist of annual groundwater level measurement and sampling for the relevant COCs and MNA parameters. Sampling frequency may be dependent on concentration trends. If

COC concentrations trends are declining over five years groundwater level measurements and sampling may be adjusted to occur annually. The existing monitoring well network would be used to collect data to monitor and evaluate the nature and extent of impacts to the Site during groundwater remediation. Only the wells required to delineate the West Plume would be sampled to support the West Plume remedy.

5.3.1.3 Contingencies

Contingency remedial measures to address potential uncertainty in the achievement of the ROs include the addition of monitoring wells, implementation of ISCO, and wellhead treatment as described in Subsection 5.1.1.4.

5.3.1.4 Permits and Agreements

No additional permits or agreements are required beyond those listed for the Reference Remedy for the West and Central Plumes.

5.3.2 East Plume

The remedial strategies for the Less Aggressive Remedy for the East Plume are:

- Source control, a strategy to mitigate a continuing source of COCs; and
- Monitoring to observe and evaluate the COCs at the Site through the collection of data.

These remedial strategies will be implemented using the measures described in the following subsections.

5.3.2.1 Less Aggressive Remedy

The East Plume Less Aggressive Remedy includes the measures listed in the Reference Remedy, but with only the five existing SVE wells.

5.3.2.2 Monitoring

MNA would consist of quarterly to semiannual groundwater level measurement and sampling for the relevant COCs and MNA parameters during SVE operations, and semiannual monitoring for the same afterwards. Sampling frequency may be dependent on concentration trends. If COC concentrations trends are declining over five years groundwater level measurements and sampling may be adjusted to occur annually. The existing monitoring well network would be used to collect data to monitor and evaluate the nature and extent of impacts to the Site during vadose zone remediation. Only the wells required to delineate the East Plume would be sampled to support the East Plume remedy.

For the vadose zone remedy, soil vapor sampling in the vicinity of the SVE system and a post-SVE soil vapor sampling event would be required to monitor and evaluate remedial effectiveness.

5.3.2.3 Contingencies

Contingency remedial measures to address potential uncertainty in the achievement of the ROs include the addition of monitoring wells, implementation of ISCO, and wellhead treatment as described in Subsection 5.1.1.4.

5.3.2.4 Permits and Agreements

No additional permits or agreements are required beyond those listed for the Reference Remedy for the East Plume.

6. COMPARISON OF REMEDIES

This section of the FS compares the remedies to each other based on the comparison criteria of practicability, risk, cost, and benefit. Uncertainties associated with each remedy or comparison criteria are discussed, where identified, pursuant to AAC R18-16-407 (H). Contingencies presented for the remedies are not included in the analysis of practicability, risk, cost, or benefit.

Practicability includes an assessment of feasibility, short- and long-term effectiveness, and the reliability of the remedial alternative. The risk criterion includes assessment of the overall protectiveness of public health and the environment in terms of fate and transport of the COCs, current and future land and water uses, exposure pathways and durations of potential exposure, changes in risk during remediation, and residual risk at the end of remediation. The cost analysis includes capital, operating, maintenance, and life cycle costs. Evaluation of benefits includes the assessment of lowered risk, reduced COC concentration or volume, decrease in liability, and preservation of existing and future uses.

6.1 Detailed Evaluation of Remedies

Table 3 presents a summary of the detailed evaluation of the remedies with respect to the comparison criteria. A remedial alternative of "no action" is also included in Table 3. The following subsections detail how the remedies perform against these criteria.

For cost analyses, the estimates are conceptual and assumed to have similar margins of error: between +50% and -30% (i.e., the actual costs are expected to be between 30% less than and 50% more than the estimated costs). A 30-year remediation period is assumed for the sake of comparison. The SVE remedial measure for the three plumes was assumed to last up to five years. Costs to replace monitoring wells are assumed to be consistent for the remedies, and each plume is assumed to include approximately 20 monitoring wells. Groundwater monitoring costs for the West, Central, and East Plumes are based on laboratory costs for analysis of VOCs in groundwater by USEPA Method 8260B, while those for the Central Plume also include the cost of analysis for hexavalent chromium by Standard Method (SM) 3500. Treatment system performance monitoring analytical costs are based on the same analytical methods, with the addition of analysis of VOCs in soil vapor samples by USEPA Method TO-15 for the SVE system at the East Plume.

6.1.1 Reference Remedy – West Plume

6.1.1.1 Practicability

The Reference Remedy for the West Plume comprises three significant components: an SVE system, including eight SVE wells, a P&T system utilizing LGAC (for plume remediation and containment/control) and MNA. The COCs in the West Plume (TCE and 1,1-DCE) are known to be amenable to LGAC removal. This combination of remedial measures has been successfully applied multiple times in the geological vicinity of the Site, and no significant technological or

hydrogeological barriers to application are anticipated. These measures provide both short- and long-term effectiveness; in the short-term by providing source area control (if identified during additional Site investigations), establishing hydraulic containment or control over the most concentrated portion of the plume, and in the long term by reducing the size of the plume. This Reference Remedy is a feasible and practicable remedial approach for the Site.

While the technologies involved are highly practicable, the construction of new wells and a treatment system in a heavily developed industrial district may present challenges to implementation. For example, if the ideal locations of new wells and the treatment system are on private property, the property owners may be averse to allowing construction of infrastructure on their property and the long-term access that would be required for O&M. If the wells are instead placed in public rights-of-way, street closures would likely be necessary for well installation and monitoring, and siting the treatment compound could be difficult. In addition, both private and public utilities and infrastructure would need to be avoided during siting and installation of the wells and the associated conveyance piping. Nonetheless, these potential impediments to constructing the new infrastructure are not unique to this remedy, and implementation of this remedy is still considered technically feasible.

6.1.1.2 Risk

The vadose zone Reference Remedy is protective, as it will increase source control through removal of VOC mass in the vadose zone. The Reference Remedy will mitigate the risk that residual TCE and 1,1-DCE in the vadose zone could be a long-term source of groundwater contamination. The vadose zone remedy reduces the potential exposure pathways and is consistent with current and future industrial land use.

Because there are low levels of naturally occurring organic material in the SGWS, the COCs are unlikely to be significantly immobilized through sorption or converted to other compounds through biological processes. Advection, dilution, dispersion, and capture by the P&T system are the most probable modes of transport and fate for the impacts under the Reference Remedy.

No aquatic or terrestrial biota are at risk from the impacts at the West Plume. The Reference Remedy for the West Plume is protective of human health and the environment because it mitigates potential exposure via the groundwater consumption pathway by providing capture and remediation of the majority of the plume, and continued monitoring of the remainder of the plume as it naturally attenuates. After remediation, no unacceptable residual risk to public health or aquatic or terrestrial biota will remain.

6.1.1.3 Cost

A summary of costs for the Reference Remedy for the West Plume is presented in Table 4. The cost for the vadose zone Reference Remedy is estimated to range between $550,000 and $1,200,000. The cost for the groundwater Reference Remedy is estimated to range between

$2,600,000 and $12,300,000. The upper ends of these cost ranges conservatively include estimated costs for potential implementation of the listed contingencies.

6.1.1.4 Benefit

The operation of an SVE system in the Reference Remedy is beneficial since it will remove VOC mass in the vadose zone, it will mitigate the potential for residual TCE to pose a vapor intrusion risk to site occupants and as a long-term source of groundwater contamination, and it will reduce the time to complete remediation and ultimately achieve the ROs.

The Reference Remedy for the West Plume would mitigate the continued migration of impacted groundwater, reduce the concentration and volume of the impacted groundwater, and reduces the time to achieve the ROs. The Reference Remedy would protect and enhance the groundwater of the site for future uses.

6.1.2 Reference Remedy – Central Plume

6.1.2.1 Practicability

The Reference Remedy for the Central Plume comprises three significant components: an SVE system including eight SVE wells, a P&T system utilizing LGAC and IX (for plume remediation and containment/control) and monitored natural attenuation. The COCs in the Central Plume (TCE, chromium and hexavalent chromium) are known to be amenable to removal by LGAC and IX. This combination of remedial measures has been successfully applied multiple times in the geological vicinity of the Site, and no significant technological or hydrogeological barriers to application are anticipated. These measures provide both short- and long-term effectiveness; in the short-term by establishing hydraulic containment or control over the most concentrated portion of the plume, and in the long term by reducing the size of the plume. This Reference Remedy is a feasible and practicable remedial approach for the Site.

As with the Reference Remedy for the West Plume, while the technologies involved are highly practicable, the construction of new wells and a treatment system in a heavily developed industrial district may present challenges to implementation. These potential impediments to constructing the new infrastructure are not unique to this remedy, however, and implementation of this remedy is considered technically feasible.

6.1.2.2 Risk

As with the Reference Remedy for the West Plume, SVE will be protective provide source control through removal of VOC mass from the vadose zone. Additionally, there are low levels of naturally occurring organic material in the SGWS, and the COCs are unlikely to be significantly immobilized through sorption or converted to other compounds through biological processes.

Advection, dilution, dispersion, and capture by the P&T system are the most probable modes of transport and fate for the impacts under the Reference Remedy.

No aquatic or terrestrial biota are at risk from the impacts at the Central Plume. The Reference Remedy for the Central Plume is protective of human health and the environment because it mitigates potential exposure via the groundwater consumption pathway by providing capture and remediation of the majority of the plume, and continued monitoring of the remainder of the plume as it naturally attenuates. After remediation, no unacceptable residual risk to public health or aquatic or terrestrial biota will remain.

6.1.2.3 Cost

A summary of costs for the Reference Remedy for the Central Plume is presented in Table 4. The cost for the vadose zone Reference Remedy is estimated to range between $550,000 and $1,200,000. The cost for the groundwater Reference Remedy is estimated to range between $2,600,000 and $12,300,000. The upper ends of these cost ranges conservatively include estimated costs for potential implementation of the listed contingencies.

6.1.2.4 Benefit

The operation of an SVE system in the Reference Remedy is beneficial since it will remove VOC mass in the vadose zone, it will mitigate the potential for residual TCE to pose a vapor intrusion risk to site occupants and as a long-term source of groundwater contamination, and it will reduce the time to complete remediation and ultimately achieve the ROs.

The Reference Remedy for the Central Plume would mitigate the continued migration of impacted groundwater, reduce the concentration and volume of the impacted groundwater, and reduce the time to achieve the ROs versus natural attenuation. The Reference Remedy would protect and enhance the groundwater of the site for future uses.

6.1.3 Reference Remedy – East Plume

6.1.3.1 Practicability

The Reference Remedy for the East Plume comprises three significant components: an SVE system (for vadose zone source remediation of VOCs), a P&T system utilizing LGAC (for plume remediation and containment/control) and MNA. The COC in the East Plume (PCE) is known to be amenable to LGAC and SVE removal. This combination of remedial measures has been successfully applied multiple times in the geological vicinity of the Site, and no significant technological or hydrogeological barriers to application are anticipated. These measures provide both short- and long-term effectiveness. In the short term, this is accomplished by reducing the transport of PCE via the soil vapor pathway to groundwater by SVE and by establishing hydraulic containment or control over the most concentrated portion of the plume by P&T. In the long term,

the Reference Remedy will reduce soil vapor concentrations in the residual source area to levels that are not anticipated to potentially result in groundwater impacts, and will reduce the size of the plume. This Reference Remedy is a feasible and practicable remedial approach for the Site.

While the technologies involved are highly practicable, the construction of new wells and a treatment system in a heavily developed industrial district may present challenges to implementation. These potential impediments to constructing the new infrastructure are not unique to this remedy, however, and implementation of this remedy is considered technically feasible.

6.1.3.2 Risk

There are low levels of naturally occurring organic material in the SGWS, and the COCs are unlikely to be significantly immobilized through sorption or converted to other compounds through biological processes. Advection, dilution, dispersion, and capture by the P&T system are the most probable modes of transport and fate for the groundwater impacts under the Reference Remedy, while transport via soil vapor, extraction, and capture by the SVE system are the most probable modes of transport and fate for the vadose zone impacts.

No aquatic or terrestrial biota are at risk from the impacts at the East Plume. The Reference Remedy for the East Plume is protective of human health and the environment because it mitigates potential exposure via the groundwater consumption pathway by providing capture and remediation of the majority of the plume, and continued monitoring of the remainder of the plume as it naturally attenuates. After remediation, no unacceptable residual risk to public health or aquatic or terrestrial biota will remain.

6.1.3.3 Cost

A summary of costs for the Reference Remedy for the East Plume is presented in Table 4. The cost for the vadose zone Reference Remedy is estimated to range between $560,000 and $1,200,000. The cost for the groundwater Reference Remedy is estimated to range between $2,600,000 and $12,300,000. The upper ends of these cost ranges conservatively include estimated costs for potential implementation of the listed contingencies.

6.1.3.4 Benefit

The Reference Remedy for the East Plume would continue to provide source area control in the vadose zone, mitigate the continued migration of impacted groundwater, reduce the concentration and volume of the impacted groundwater, and reduce the time to achieve the ROs versus natural attenuation. The Reference Remedy would protect and enhance the vadose zone and groundwater of the site for future uses.

6.1.4 More Aggressive Remedy – West Plume

The practicability, risk, cost, and benefit of the More Aggressive Remedy for the West Plume are discussed in the following subsections.

6.1.4.1 Practicability

The More Aggressive Remedy for the West Plume expands the Reference Remedy P&T system to include ISCO, which would provide a source area remedy in addition to hydraulic containment across a majority of the plume. Therefore, the More Aggressive Remedy is also a feasible and practicable remedial approach for the Site. The More Aggressive Remedy also expands on the SVE system with addition of SVE wells, which is also deemed a feasible and practicable approach.

6.1.4.2 Risk

The More Aggressive Remedy for the West Plume is comparably protective of human health and the environment with the Reference Remedy.

6.1.4.3 Cost

Costs for the More Aggressive Remedy for the West Plume are presented in Table 4. The cost for the vadose zone More Aggressive Remedy is estimated to range between $640,000 and $1,400,000. The cost for the groundwater More Aggressive Remedy is estimated to range between $4,100,000 and $14,800,000. The upper ends of these cost ranges conservatively include estimated costs for potential implementation of the listed contingencies.

6.1.4.4 Benefit

The More Aggressive Remedy for the West Plume expands hydraulic control of the plume along with a more aggressive SVE remediation of the vadose zone, and is less reliant upon MNA compared to the Reference Remedy.

6.1.5 More Aggressive Remedy – Central Plume

The practicability, risk, cost, and benefit of the More Aggressive Remedy for the Central Plume are discussed in the following subsections.

6.1.5.1 Practicability

The More Aggressive Remedy for the Central Plume expands the Reference Remedy P&T system to include ISCO, which would provide a source area remedy in addition to hydraulic containment across a majority of the plume. Therefore, the More Aggressive Remedy is also a feasible and practicable remedial approach for the Site. The More Aggressive Remedy also expands on the SVE system with addition of SVE wells, which is also deemed a feasible and practicable approach.

6.1.5.2 Risk

The More Aggressive Remedy for the Central Plume is comparably protective of human health and the environment to the Reference Remedy.

6.1.5.3 Cost

Costs for the More Aggressive Remedy for the Central Plume are presented in Table 4. The cost for the vadose zone More Aggressive Remedy is estimated to range between $640,000 and $1,400,000. The cost for the groundwater More Aggressive Remedy is estimated to range between $4,100,000 and $14,800,000. The upper ends of these cost ranges conservatively include estimated costs for potential implementation of the listed contingencies.

6.1.5.4 Benefit

The More Aggressive Remedy for the Central Plume expands source area remediation by increasing the size of the SVE system and provides ISCO treatment of groundwater near the source area, while continuing to provide hydraulic control of the plume. This remedy is less reliant upon MNA compared to the Reference Remedy.

6.1.6 More Aggressive Remedy – East Plume

The practicability, risk, cost, and benefit of the More Aggressive Remedy for the East Plume are discussed in the following subsections.

6.1.6.1 Practicability

The More Aggressive Remedy for the East Plume expands the Reference Remedy P&T system to include ISCO, which would provide a source area remedy in addition to hydraulic containment across a majority of the plume. Therefore, the More Aggressive Remedy is also a feasible and practicable remedial approach for the Site. The More Aggressive Remedy also expands on the SVE system with addition of SVE wells, which is also deemed a feasible and practicable approach.

6.1.6.2 Risk

The More Aggressive Remedy for the East Plume is comparatively protective of human health and the environment to the Reference Remedy.

6.1.6.3 Cost

Costs for the More Aggressive Remedy for the East Plume are presented in Table 4. The cost for the vadose zone More Aggressive Remedy is estimated to range between $700,000 and $1,500,000. The cost for the groundwater More Aggressive Remedy is estimated to range between

$4,100,000 and $14,800,000. The upper ends of these cost ranges conservatively include estimated costs for potential implementation of the listed contingencies.

6.1.6.4 Benefit

The More Aggressive Remedy for the East Plume expands source area remediation by increasing the size of the SVE system and provides ISCO treatment of groundwater near the source area, while continuing to provide hydraulic control of the plume. This remedy is less reliant upon MNA compared to the Reference Remedy.

6.1.7 Less Aggressive Remedy – West Plume

The practicability, risk, cost, and benefit of the Less Aggressive Remedy for the West Plume are discussed in the following subsections.

6.1.7.1 Practicability

The Less Aggressive Remedy for the West Plume consists of SVE in a source area and MNA, well-established remedial measures that have been demonstrated to have long-term effectiveness. SVE will provide a short and long-term effectiveness by remediating a potentially on-going pathways to groundwater. While MNA does not provide short-term effectiveness, this remedy does enable the implementation of contingencies that would have short-term effectiveness. No significant technological or hydrogeological barriers to application are anticipated. This remedy is considered to be feasible and practicable.

6.1.7.2 Risk

No aquatic or terrestrial biota are at risk from the impacts at the West Plume. The Less Aggressive Remedy for the West Plume is protective of human health because it mitigates the potential for exposure via the groundwater consumption pathway by monitoring potential plume migration towards potential production wells where an exposure pathway could be completed, and including the contingency of applying wellhead treatment for production wells if installed, thereby mitigating exposure.

6.1.7.3 Cost

Costs for the Less Aggressive Remedy for the West Plume are presented in Table 4 The cost for the vadose zone Less Aggressive Remedy is estimated to range between $460,000 and $1,100,000. The cost for the groundwater Less Aggressive Remedy is estimated to range between $570,000 and $14,800,000. The upper ends of these cost ranges conservatively include estimated costs for potential implementation of the listed contingencies.

6.1.7.4 Benefits

The Less Aggressive Remedy for the West Plume provides less benefit than the Reference or More Aggressive Remedies for the West Plume because it can be anticipated to leave the impacted groundwater unavailable for beneficial use for the longest period of time.

6.1.8 Less Aggressive Remedy – Central Plume

The practicability, risk, cost, and benefit of the Less Aggressive Remedy for the Central Plume are discussed in the following subsections.

6.1.8.1 Practicability

The Less Aggressive Remedy for the Central Plume consists of SVE in a source area and MNA. SVE will provide a short- and long-term effectiveness by remediating a potentially on-going pathways to groundwater. While MNA does not provide short-term effectiveness, this remedy does enable the implementation of contingencies that would have short-term effectiveness. No significant technological or hydrogeological barriers to application are anticipated. This remedy is considered to be feasible and practicable.

6.1.8.2 Risk

No aquatic or terrestrial biota are at risk from the impacts at the Central Plume. The Less Aggressive Remedy for the Central Plume is protective of human health because it mitigates the potential for exposure via the groundwater consumption pathway by monitoring potential plume migration towards potential production wells where an exposure pathway could be completed, and including the contingency of applying wellhead treatment for production wells if installed, thereby mitigating exposure.

6.1.8.3 Cost

Costs for the Less Aggressive Remedy for the Central Plume are presented in Table 4. The cost for the vadose zone Less Aggressive Remedy is estimated to range between $460,000 and $1,100,000. The cost for the groundwater Less Aggressive Remedy is estimated to range between $570,000 and $14,800,000. The upper ends of these cost ranges conservatively include estimated costs for potential implementation of the listed contingencies.

6.1.8.4 Benefits

The Less Aggressive Remedy for the Central Plume provides less benefit than the Reference or More Aggressive Remedies for the Central Plume because it can be anticipated to leave the impacted groundwater unavailable for beneficial use for the longest period of time.

6.1.9 Less Aggressive Remedy – East Plume

The practicability, risk, cost, and benefit of the Less Aggressive Remedy for the East Plume are discussed in the following subsections.

6.1.9.1 Practicability

The Less Aggressive Remedy for the East Plume consists of SVE and MNA, both of which are well-established remedial measures that have been demonstrated to have long-term effectiveness. SVE provides both short- and long-term effectiveness for remediation of the vadose zone impacts by mitigating ongoing impacts from the vadose zone to groundwater, if occurring. MNA does not provide short-term effectiveness, but does enable the implementation of contingencies that would have short-term effectiveness. No significant technological or hydrogeological barriers to application are anticipated. This remedy is considered to be feasible and practicable.

6.1.9.2 Risk

No aquatic or terrestrial biota are at risk from the impacts at the East Plume. The Less Aggressive Remedy for the East Plume is protective of human health because it mitigates the potential for exposure via the groundwater consumption pathway by monitoring potential plume migration towards potential production wells where an exposure pathway could be completed, and including the contingency of applying wellhead treatment for production wells if installed, thereby mitigating exposure.

6.1.9.3 Cost

Costs for the Less Aggressive Remedy for the East Plume are presented in Table 4. The cost for the vadose zone Less Aggressive Remedy is estimated to range between $410,000 and $950,000. The cost for the groundwater Less Aggressive Remedy is estimated to range between $570,000 and $14,800,000. The upper ends of these cost ranges conservatively include estimated costs for potential implementation of the listed contingencies.

6.1.9.4 Benefits

While the SVE system included in the Less Aggressive Remedy provides much of the benefit associated with the Reference Remedy (i.e., source control and mitigation of migration of the COCs to groundwater), the Less Aggressive Remedy for the East Plume provides less benefit than the Reference or More Aggressive Remedies for the East Plume because it is more reliant upon MNA and can therefore be anticipated to leave the impacted groundwater unavailable for beneficial use for the longest period of time.

6.2 Discussion of the Comparison Criteria

A discussion of the comparison criteria for the remedies is required under the Remedy Selection Rule, AAC R18-16-407 (H)(3)(e). For discussion, a remedial alternative of "No Action" is included for each of the plumes. Table 5 presents a ranking of the comparison criteria for the remedies. Scores ranged from zero to five, with five indicating the most relative benefit and zero indicating the least relative or no benefit. The following sections describe the practicability, risk, cost, and benefits comparison for remedies.

6.2.1 Practicability

For each of the plumes, the Reference Remedy, Less Aggressive Remedy, and No Action are the most technologically feasible, followed by the More Aggressive Remedy. No technological or hydrogeological barriers are known to exist for the implementation of a P&T system or an SVE system. The More Aggressive Remedies are considered slightly less feasible in general because the installation of an ISCO well network, in addition to that of the P&T system, would require extensive work within developed industrial facilities.

Long-term effectiveness is provided by the Reference, More Aggressive, and Less Aggressive Remedies, but not by No Action. Long-term effectiveness is provided in all cases by the presence of a monitoring program that provides for implementation of contingencies in the future if the groundwater impacts threaten a receptor (e.g., impact an active groundwater production well). Short-term effectiveness is provided by the Reference and More Aggressive Remedies through active remediation (P&T and SVE for all plumes, with additional ISCO for the More aggressive remedy), but not by the Less Aggressive Remedy (except for the East Plume, which retains SVE as a remedial measure) or No Action.

The Reference Remedies and More Aggressive Remedies are considered the most reliable, having been widely applied for similar COCs and hydrogeological conditions within the region. The Less Aggressive Remedy, with no active groundwater remediation and limited abiotic pathways to attenuate the COCs, is the least reliable of the remedial alternatives. Implementation of No Action cannot be considered reliable for reaching the ROs.

Comparing the feasibility, short- and long-term effectiveness, and reliability of the remedies, the remedial alternatives for all three plumes were scored as follows:

Remedy Alternative	Vadose Zone	Groundwater
Reference Remedy	5	4
More Aggressive Remedy	4	2
Less Aggressive Remedy	3	4
No Action	0	0

6.2.2 Risk

With respect to risk, including the overall protectiveness of human health and the environment, the highest protectiveness and most reduced residual risk is provided by the More Aggressive Remedy followed by the Reference Remedy for each plume. The active mitigation provided by these remedies is estimated to provide the shortest times to reach the ROs, which in turn reduces the residual risk. The Less Aggressive Remedy for each plume is expected to require the longest time to meet the ROs, which increases the possibility that potential future groundwater pumping would require the implementation of contingencies (e.g., wellhead treatment). No Action is not protective of human health or the environment.

Comparing the relative risk of the remedies, the remedial alternatives for all three plumes were scored as follows:

Remedy Alternative	Vadose Zone	Groundwater
Reference Remedy	4	4
More Aggressive Remedy	5	4
Less Aggressive Remedy	3	3
No Action	0	0

6.2.3 Cost

Cost comparison for the remedial alternatives was based on the 30-year of each remedy. Although contingency costs were considered in the rankings, extra weight was provided for costs of remedy implementation without contingencies. No Action carries no cost, and was therefore scored highest. Comparing the relative costs of the remedies, the remedial alternatives for all three plumes were scored as follows:

Remedy Alternative	Vadose Zone	Groundwater
Reference Remedy	3	2
More Aggressive Remedy	2	1
Less Aggressive Remedy	4	5
No Action	5	5

6.2.4 Benefits

The value provided by the remedial alternatives includes lowered risk to human health and the environment, reduced concentration and/or volume of impacted groundwater, decreased liability, preservation and enhancement of groundwater for consumption, and acceptance by stakeholders including the public and regulators. Whereas the Reference and More Aggressive Remedy for each plume provide the most benefit by providing the highest potential for significant reduction in the time to achieve the ROs, the costs to achieve these benefits relative to the Less Aggressive Remedy is much higher, resulting in lower overall value relative to the Less Aggressive Remedy. Although it is anticipated that the Less Aggressive Remedy will take much longer to achieve the ROs, the

cost is significantly lower than the Reference and More Aggressive Remedies, providing much higher value. No Action provides no benefit.

Public and regulatory stakeholders are expected to be highly likely to favor the Reference Remedy and the Most Aggressive Remedy, likely to approve of the Less Aggressive Remedy, and unlikely to approve of No Action.

Comparing the relative benefit and value of the remedies, the remedial alternatives for all three plumes were scored as follows:

Remedy Alternative	Vadose Zone	Groundwater
Reference Remedy	4	3
More Aggressive Remedy	5	2
Less Aggressive Remedy	3	4
No Action	0	0

6.2.5 Scoring Results

Results for scoring of the remedial alternatives based on the ranking criteria discussed above are summarized as follows, from highest to lowest score:

Remedy Alternative	Vadose Zone	Groundwater
Reference Remedy	16	13
More Aggressive Remedy	16	9
Less Aggressive Remedy	13	16
No Action	5	5

Full scoring results for the vadose zone and groundwater are presented in Table 5a and 5b, respectively.

7. PROPOSED REMEDY

The following presents the proposed remedy as required in AAC R18-16-407 (I), and discusses how it will achieve the ROs, how the comparison criteria were considered, and how the proposed remedy will meet the requirements of ARS §49-282.06.

7.1 Process and Reason for Selection

The Less Aggressive Remedies are recommended as the proposed remedies for the West Plume, Central Plume, and East Plume groundwater. For the vadose zone, the Reference Remedies were selected for the West and central Plumes, and the More Aggressive Remedy for the East Plume. 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. The Less Aggressive Remedies for groundwater scored the highest when ranking in accordance with the comparison criteria specified in the Remedy Selection Rule, AAC R18-16-407 (H)(3)(e).

7.2 Achievement of Remedial Objectives

The remedial objectives for the site are to restore soil conditions at the site and protect groundwater resources for beneficial use, and each of the three remedies are considered likely to achieve the ROs for the Site. Whereas the Reference and More Aggressive Remedies may potentially achieve the ROs more rapidly, the Less Aggressive Remedies will also achieve the ROs at a much lower cost with no unacceptable risk to public health considering the contingencies that would be in place (e.g., wellhead treatment for groundwater production wells).

7.3 Achievement of Remedial Action Criteria

To meet the remedial action criteria listed in ARS §49-282.06, it is recommended that the Less Aggressive Remedies for groundwater be selected as the Final Remedies for the Site. Based on a comparison with the More Aggressive and Reference Remedies, the Less Aggressive 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.

The selected vadose zone remedies (Reference Remedy for the West and Central Plumes and the

More Aggressive Remedy for the East Plume) will mitigate any potential on-going pathways to groundwater and potential vapor intrusion issues.

7.4 Consistency with Water Management and Land Use Plans

The remedies for the vadose zone and groundwater are consistent with water management plans and general land use plans, considering contingencies that may be implemented if warranted.

8. COMMUNITY INVOLVEMENT

Per the requirements of AAC. R18-16-404, the FS will be made available to the public for review. ADEQ will issue a Notice to the Public announcing the availability of FS on ADEQ's website at http://www.azdeq.gov/node/1075 . The notice may be mailed to the Public Mailing List for the Site, water providers, the Community Advisory Board (CAB), and any other interested parties.

Interested parties can also review the FS and other Site documents at the ADEQ Main Office located at 1110 West Washington Street, Phoenix, Arizona. With 24-hour notice, an appointment to review related documentation is available Monday through Friday from 8:30 a.m. to 4:30 p.m. at the ADEQ Records Management Center. Please contact (602) 771-4380 or (800) 234-5677 to schedule an appointment to review these documents. Other contact information is listed below:

Name/Title	Phone/Fax	E-mail
Eric Mannlein, ADEQ Project Manager	(602) 771-0390	Mannlein.Eric@azdeq.gov
Barbara Boschert, ADEQ Community Involvement Coordinator	(602) 771-8149	Boschert.Barbara@azdeq.gov

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TABLES

Table 1
Screening of Remedial Measures
Feasibility Study
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

	Treatment Effectiveness	Constructability	Flexibility and Expandability	Operations and Maintenance Requirements	Operational Hazards	Cost-Effectiveness	Overall Feasibility for Site
Groundwater Extraction and Treatment (Pump and Treat [P&T])	Effective for hydraulic containment; ineffective for vadose zone source removal	No barriers to constructability forseen; technically feasible	No barriers to expansion	High; length of operation typcally longest of the options presented (years to decades)	No special hazards	Cost-effective for high concentrations; cost-prohibitive for dilute plumes	Retained as feasible
***In Situ* Chemical Oxidation (ISCO)**	Effective for VOCs in groundwater; ineffective for hexavalent chromium in groundwater	No barriers to constructability forseen; technically feasible	No barriers to expansion	No O&M required for single injection designs; O&M required for duration of operation if implemented with P&T	Chemical oxidizers require safe handling precautions; may solubilize chomium	Cost-effective for high concentrations; cost-prohibitive for dilute plumes	Retained as feasible
***In Situ* Chemical Reduction (ISCR)**	Effective for VOCs and hexavalent chromium in groundwater	No barriers to constructability forseen; technically feasible	No barriers to expansion	No O&M required for single injection designs; O&M required for duration of operation if implemented with P&T	Chemical reductants require safe handling precautions	Cost-effective for high concentrations; cost-prohibitive for dilute plumes	Retained as feasible
***In Situ* Gaseous Reduction (ISGR)**	Effective for vadose-zone hexavalent chromium; effectiveness for VOCs not established	No barriers to constructability forseen; technically feasible	No barriers to expansion	Moderate; length of operation typically weeks to months	Gaseous reductants require highest level of safety in handling	Cost-effective for source mitigation of hexavalent chromium	Retained as feasible
Enhanced *In Situ* Bioremediation (EISB)	Effective for VOCs and hexavalent chromium in groundwater	No barriers to constructability forseen; technically feasible	No barriers to expansion	No O&M required for single injection designs; O&M required for duration of operation if implemented with P&T	No special hazards	Cost-effective for high concentrations; cost-prohibitive for dilute plumes	Retained as feasible
Soil Vapor Extraction (SVE)	Effective for VOC source removal; ineffective for hexavalent chromium	No barriers to constructability forseen; technically feasible	No barriers to expansion	Moderate; length of operation typically months to years	No special hazards	Cost-effective for source mitigation of VOCs	Retained as feasible
Air Sparge (AS)	Potentially effective for VOCs in groundwater; ineffective for hexavalent chromium	No barriers to constructability forseen; technically feasible	No barriers to expansion	Moderate; length of operation typically months to years	No special hazards	Cost-effective for high concentrations; cost-prohibitive for dilute plumes	Not retained due to not practicable for large dilute plumes
***In Situ* Thermal Remediation (ISTR)**	Effective for VOC source removal; ineffective for hexavalent chromium	Breadth and depth of impacts may be barriers to constructability; technically feasible but likely challenging	Expansion may be capital intensive but technically feasible	Moderate; length of operation typically weeks to months	High voltage equipment to generate *in situ* heat; fugitive VOCs volatilized/mobilized	Cost-effective for very high-concentration VOCs (e.g., NAPL); cost-prohibitive for dilute VOCs	Not retained due to low concentration of VOCs
Permeable Reactive Barrier (PRB)	Effective for migration control; ineffective for source removal	Trenching is infeasible; injection installation potentially feasible but challenging	Expansion would be capital intensive	None	Hazards associated with injecting under high pressures	Cost-effecitive for high-velocity plumes; otherwise cost-prohibitive	Not retained due to large plume size and low velocity
Monitored Natural Attenuation (MNA)	Natural processes may be effective, but must be demonstrated at site	No barriers to constructability forseen; technically feasible	No barriers to expansion	None	No special hazards	Effective when natural processes demonstrated to be adequate to meet ROs	Retained as feasible

Notes:

VOC is volatile organic compounds.
NAPL is non-aqueous phase liquid.
COC is constituent of concern.
RO is remedial objective.
O&M is operations and maintenance.

Table 2a
Development of Reference Remedy and Alternative Remedies
Vadose Zone Feasibility Study
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

Plume	Reference Remedy	More Aggressive Alternative Remedy	Less Aggressive Alternative Remedy
West Plume	SVE with 8 wells, up to 250 scfm, and VGAC. Monitored natural attenuation for dilute fringe of plume.	SVE with 12 wells, up to 250 scfm, and VGAC. Monitored natural attenuation for dilute fringe of plume.	SVE with 4 wells, up to 250 scfm, and VGAC. Monitored natural attenuation for dilute fringe of plume.
Central Plume	SVE with 8 wells, up to 250 scfm, and VGAC. Monitored natural attenuation for dilute fringe of plume.	SVE with 12 wells, up to 250 scfm, and VGAC. Monitored natural attenuation for dilute fringe of plume.	SVE with 4 wells, up to 250 scfm, and VGAC. Monitored natural attenuation for dilute fringe of plume.
East Plume	SVE with 11 wells, up to 600 scfm, and VGAC. Monitored natural attenuation for dilute fringe of plume.	SVE with 17 wells, up to 600 scfm, and VGAC. Monitored natural attenuation for dilute fringe of plume.	SVE with 5 wells, up to 600 scfm, and VGAC. Monitored natural attenuation for dilute fringe of plume.

Notes:

SVE is soil vapor extraction.

scfm is standard cubic feet per minute.

VGAC is vapor-phase granular activated carbon.

Table 2b
Development of Reference Remedy and Alternative Remedies
Groundwater Feasibility Study
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

Geosyntec consultants

Plume	Reference Remedy	More Aggressive Alternative Remedy	Less Aggressive Alternative Remedy
West Plume	P&T with 3 wells (10 gpm/each) and LGAC. Contingency: P&T with 4 additional wells for a more aggressive remedy. Monitored natural attenuation for dilute fringe of plume. Semiannual groundwater elevation and constituent monitoring.	P&T with 3 wells (10 gpm/each) and LGAC. Addition of ISCO near suspected source areas. Monitored natural attenuation for dilute fringe of plume. Semiannual groundwater elevation and constituent monitoring.	Monitored natural attenuation for dilute fringe of plume.
Central Plume	P&T with 3 wells (10 gpm/each) and LGAC and IX. Contingency: P&T with 4 additional wells for a more aggressive remedy. Monitored natural attenuation for dilute fringe of plume. Semiannual groundwater elevation and constituent monitoring.	P&T with 3 wells (10 gpm/each) and LGAC and IX. Addition of ISCO near suspected source areas. Monitored natural attenuation for dilute fringe of plume. Semiannual groundwater elevation and constituent monitoring.	Monitored natural attenuation for dilute fringe of plume.
East Plume	P&T with 3 wells (10 gpm/each) and LGAC. Contingency: P&T with 4 additional wells for a more aggressive remedy. Monitored natural attenuation for dilute fringe of plume. Semiannual groundwater elevation and constituent monitoring.	P&T with 3 wells (10 gpm/each) and LGAC. Addition of ISCO near suspected source areas. Monitored natural attenuation for dilute fringe of plume. Semiannual groundwater elevation and constituent monitoring.	Monitored natural attenuation for dilute fringe of plume.

Notes:

P&T is pump and treat (i.e., groundwater extraction and treatment).

gpm is gallons per minute.

LGAC is liquid-phase granular activated carbon.

IX is ion exchange.

scfm is standard cubic feet per minute.

ISCO is in situ chemical oxidation.

Table 3a
Evaluation of Remedial Alternatives
Vadose Zone Feasibility Study
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

Remedial Alternative		Will Alternative Meet Remedial Objectives?	Practicability			Risk	Relative Costs	Benefit	
			Feasibility	Short/Long Term Effectiveness	Reliability			Value of Remediation	Public and Regulatory Acceptability
West Plume	**Reference Remedy**	Likely	Technically feasible	Provides short- and long-term effectiveness.	Technically reliable	Protective of human health and the environment. Reduced residual risk after remediation.	Not very high cost considering effectivenes of technology	Reduces time to achieve ROs versus Less Aggressive Remedy. Removes pathways to groundwater and VI	Likely
	More Aggressive Remedy	Likely	Technically feasible	Provides short- and long-term effectiveness.	Technically reliable	Protective of human health and the environment. Reduced residual risk after remediation.	Not very high cost considering effectivenes of technology	Reduces time to achieve ROs versus Reference Remedy. Removes pathways to groundwater and VI	Highly Likely.
	Less Aggressive Remedy	Likely	Technically feasible	Provides long-term effectiveness.	Technically reliable but the timeframe to achieve ROs must be established.	Protective of human health and the environment. Longest time to reach ROs.	Not very high cost considering effectivenes of technology	Removes pathway to groundwater and VI, but takes longest time to achieve Ros comprared to other remedies	Moderately Likely.
Central Plume	**Reference Remedy**	Likely	Technically feasible	Provides long-term effectiveness.	Technically reliable	Protective of human health and the environment. Reduced residual risk after remediation.	Not very high cost considering effectivenes of technology	Reduces time to achieve ROs versus Less Aggressive Remedy. Removes pathways to groundwater and VI	Likely
	More Aggressive Remedy	Likely	*Technically feasible*	Provides short- and long-term effectiveness.	Technically reliable	Protective of human health and the environment. Reduced residual risk after remediation.	Not very high cost considering effectivenes of technology	Reduces time to achieve ROs versus Reference Remedy. Removes pathways to groundwater and VI	Highly Likely.
	Less Aggressive Remedy	Likely	Technically feasible	Provides long-term effectiveness.	Technically reliable but the timeframe to achieve ROs must be established.	Protective of human health and the environment. Longest time to reach ROs.	Not very high cost considering effectivenes of technology	Removes pathway to groundwater and VI, but takes longest time to achieve Ros comprared to other remedies	Moderately Likely.
East Plume	**Reference Remedy**	Likely	Technically feasible.	Provides long-term effectiveness.	Technically reliable	Protective of human health and the environment. Reduced residual risk after remediation.	Not very high cost considering effectivenes of technology	Reduces time to achieve ROs versus Less Aggressive Remedy. Removes pathways to groundwater and VI	Likely
	More Aggressive Remedy	Likely	*Technically feasible*	Provides short- and long-term effectiveness.	Technically reliable	Protective of human health and the environment. Reduced residual risk after remediation.	Not very high cost considering effectivenes of technology	Reduces time to achieve ROs versus Reference Remedy. Removes pathways to groundwater and VI	Highly Likely.
	Less Aggressive Remedy	Likely	Technically feasible	Provides long-term effectiveness.	Technically reliable but the timeframe to achieve ROs must be established.	Protective of human health and the environment. Longest time to reach ROs.	Not very high cost considering effectivenes of technology	Removes pathway to groundwater and VI, but takes longest time to achieve Ros comprared to other remedies	Moderately Likely.

Notes:
RO is remedial objective.
MNA is monitored natural attenuation.
NPV is net present value.

Table 3b
Evaluation of Remedial Alternatives
Groundwater Feasibility Study
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

Remedial Alternative		Will Alternative Meet Remedial Objectives?	Practicability			Risk	Relative Costs	Benefit	
			Feasibility	Short/Long Term Effectiveness	Reliability			Value of Remediation	Public and Regulatory Acceptability
West Plume	**Reference Remedy**	Likely	No technological barriers; comparable implementations successful; considered feasible.	Provides short- and long-term effectiveness.	Measures are widely-utilized in comparable hydrogeological settings and considered reliable.	Protective of human health and the environment. Reduced residual risk after remediation.	High cost relative to effectiveness.	Reduces time to achieve ROs versus MNA. Protects/enhances groundwater resources for beneficial use.	Highly Likely.
	More Aggressive Remedy	Likely	*In situ* treatments require treatability studies before implementation; considered feasible.	Provides short- and long-term effectiveness.	*In situ* treatments require treatability studies before implementation; considered reliable where indicated by treatability studies.	Protective of human health and the environment. Reduced residual risk after remediation.	High cost relative to effectiveness.	Reduces time to achieve ROs versus Reference Remedy. Protects/enhances groundwater resources for beneficial use.	Highly Likely.
	Less Aggressive Remedy	Likely	No technological barriers; comparable implementations successful; considered feasible.	Provides long-term effectiveness.	Natural abiotic processes are reliable but the timeframe to achieve ROs must be established.	Protective of human health and the environment. Longest time to reach ROs.	Low cost relative to effectiveness.	Protects/enhances groundwater resources for beneficial use.	Moderately Likely.
	No Action	No	Technically feasible	Ineffective.	Not reliable.	May not be protective of human health and the environment.	No cost.	No benefit.	Not Likely.
Central Plume	**Reference Remedy**	Likely	No technological barriers; comparable implementations successful; considered feasible.	Provides short- and long-term effectiveness.	Measures are widely-utilized in comparable hydrogeological settings and considered reliable.	Protective of human health and the environment. Reduced residual risk after remediation.	High cost relative to effectiveness.	Reduces time to achieve ROs versus MNA. Protects/enhances groundwater resources for beneficial use.	Highly Likely.
	More Aggressive Remedy	Likely	*In situ* treatments require treatability studies before implementation; considered feasible.	Provides short- and long-term effectiveness.	*In situ* treatments require treatability studies before implementation; considered reliable where indicated by treatability studies.	Protective of human health and the environment. Reduced residual risk after remediation.	High cost relative to effectiveness.	Reduces time to achieve ROs versus Reference Remedy. Protects/enhances groundwater resources for beneficial use.	Highly Likely.
	Less Aggressive Remedy	Likely	No technological barriers; comparable implementations successful; considered feasible.	Provides long-term effectiveness.	Natural abiotic processes are reliable but the timeframe to achieve ROs must be established.	Protective of human health and the environment. Longest time to reach ROs.	Low cost relative to effectiveness.	Protects/enhances groundwater resources for beneficial use.	Moderately Likely.
	No Action	No	Technically feasible	Ineffective.	Not reliable.	May not be protective of human health and the environment.	No cost.	No benefit.	Not Likely.

Table 3b
Evaluation of Remedial Alternatives
Groundwater Feasibility Study
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

Remedial Alternative		Will Alternative Meet Remedial Objectives?	Practicability			Risk	Relative Costs	Benefit	
			Feasibility	Short/Long Term Effectiveness	Reliability			Value of Remediation	Public and Regulatory Acceptability
East Plume	**Reference Remedy**	Likely	No technological barriers; comparable implementations successful; considered feasible.	Provides short- and long-term effectiveness.	Measures are widely-utilized in comparable hydrogeological settings and considered reliable.	Protective of human health and the environment. Reduced residual risk after remediation.	High cost relative to effectiveness.	Reduces time to achieve ROs versus MNA. Protects/enhances groundwater resources for beneficial use.	Highly Likely.
	More Aggressive Remedy	Likely	*In situ* treatments require treatability studies before implementation; considered feasible.	Provides short- and long-term effectiveness.	*In situ* treatments require treatability studies before implementation; considered reliable where indicated by treatability studies.	Protective of human health and the environment. Reduced residual risk after remediation.	High cost relative to effectiveness.	Reduces time to achieve ROs versus Reference Remedy. Protects/enhances groundwater resources for beneficial use.	Highly Likely.
	Less Aggressive Remedy	Likely	No technological barriers; comparable implementations successful; considered feasible.	Provides short-term effectiveness for soil vapor and long-term effectiveness for groundwater.	Natural abiotic processes are reliable but the timeframe to achieve ROs must be established.	Protective of human health and the environment. Longest time to reach ROs.	Low cost relative to effectiveness.	Protects/enhances groundwater resources for beneficial use.	Moderately Likely.
	No Action	No	Technically feasible.	Ineffective.	Not reliable.	May not be protective of human health and the environment.	No cost.	No benefit.	Not Likely.

Notes:
RO is remedial objective.
MNA is monitored natural attenuation.
NPV is net present value.

Table 4a
Cost Estimate Summary -
Vadose Zone Remedy
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

Remedial Alternative		Estimated Costs - Low	Estimated Costs - High
West Plume	Reference Remedy	$550,000	$1,200,000
	More Aggressive Remedy	$640,000	$1,400,000
	Less Aggressive Remedy	$460,000	$1,100,000
Central Plume	Reference Remedy	$550,000	$1,200,000
	More Aggressive Remedy	$640,000	$1,400,000
	Less Aggressive Remedy	$460,000	$1,100,000
East Plume	Reference Remedy	$560,000	$1,200,000
	More Aggressive Remedy	$700,000	$1,500,000
	Less Aggressive Remedy	$410,000	$950,000

Notes:
Estimated costs are assumed to be within a -30% to +50% plus estimated contingency costs margin of error
A 5-year remediation period is assumed for estimation

Table 4b
Cost Estimate Summary -
Groundwater Remedy
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

Geosyntec consultants

Remedial Alternative		Estimated Costs - Low	Estimated Costs - High
West Plume	Reference Remedy	$2,600,000	$12,300,000
	More Aggressive Remedy	$4,100,000	$14,800,000
	Less Aggressive Remedy	$570,000	$14,800,000
Central Plume	Reference Remedy	$2,600,000	$12,300,000
	More Aggressive Remedy	$4,100,000	$14,800,000
	Less Aggressive Remedy	$570,000	$14,800,000
East Plume	Reference Remedy	$2,600,000	$12,300,000
	More Aggressive Remedy	$4,100,000	$14,800,000
	Less Aggressive Remedy	$570,000	$14,800,000

Notes:

Estimated costs are assumed to be within a -30% to +50% plus estimated contingency costs margin of error

A 30-year remediation period is assumed for estimation

Groundwter sampling frequency assumed to be semiannual for the first five years, then annual for the next 25 years

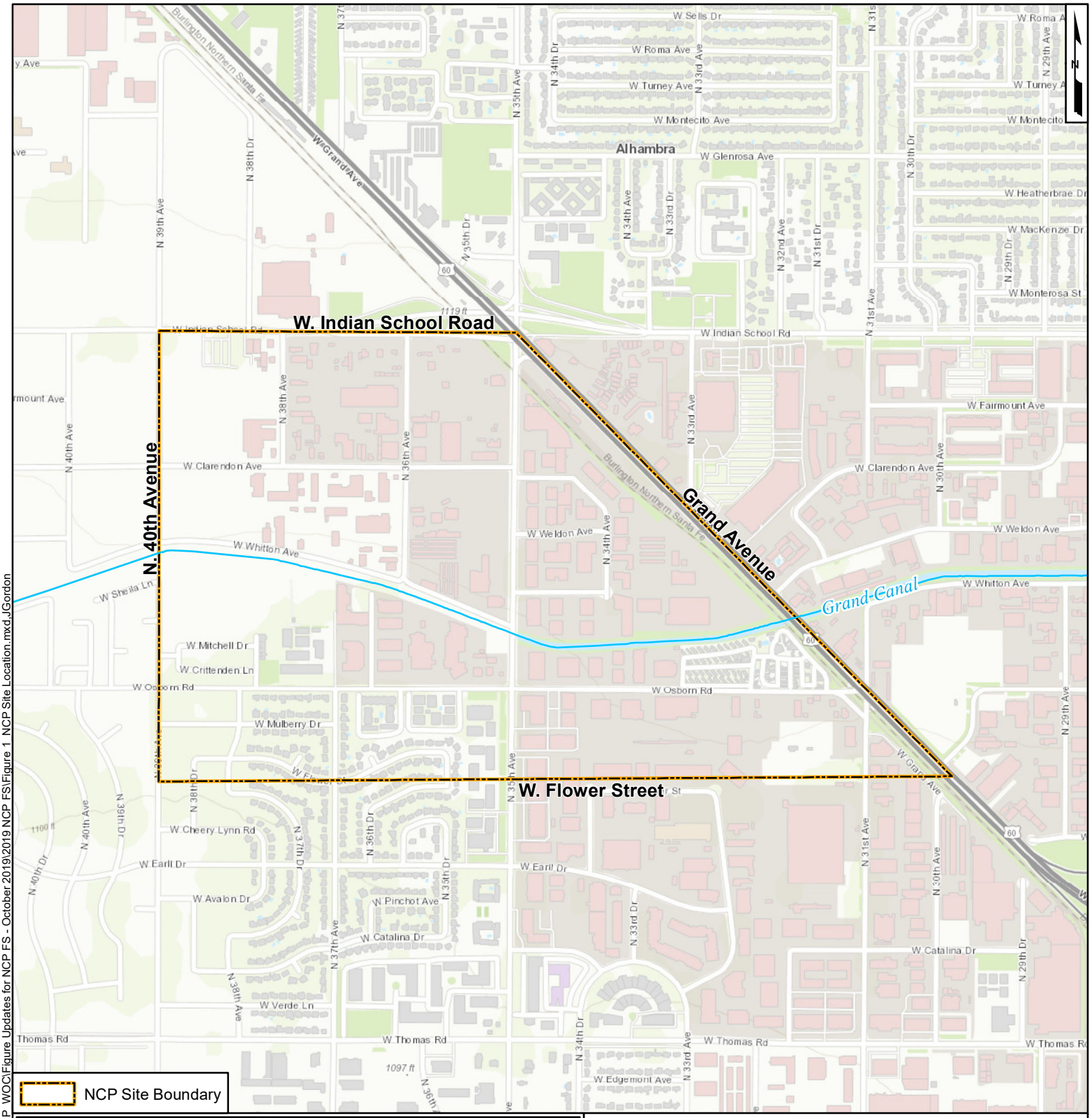
Table 5a
Scoring of Remedial Alternatives
Vadose Zone Feasibility Study
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

Remedial Measure		Practicability	Risk	Cost	Benefit	Total Score
West Plume	**Reference Remedy**	5	4	3	4	16
	More Aggressive Remedy	4	5	2	5	16
	Less Aggressive Remedy	3	3	4	3	13
	No Action	0	0	5	0	5
Central Plume	**Reference Remedy**	5	4	3	4	16
	More Aggressive Remedy	4	5	2	5	16
	Less Aggressive Remedy	3	3	4	3	13
	No Action	0	0	5	0	5
East Plume	**Reference Remedy**	5	4	3	4	16
	More Aggressive Remedy	4	5	2	5	16
	Less Aggressive Remedy	3	3	4	3	13
	No Action	0	0	5	0	5

Table 5b
Scoring of Remedial Alternatives
Groundwater Feasibility Study
North Canal Plume WQARF Site
Phoenix, Arizona
December 2019

Remedial Measure		Practicability	Risk	Cost	Benefit	Total Score
West Plume	**Reference Remedy**	4	4	2	3	13
	More Aggressive Remedy	2	4	1	2	9
	Less Aggressive Remedy	4	3	5	4	16
	No Action	0	0	5	0	5
Central Plume	**Reference Remedy**	4	4	2	3	13
	More Aggressive Remedy	2	4	1	2	9
	Less Aggressive Remedy	4	3	5	4	16
	No Action	0	0	5	0	5
East Plume	**Reference Remedy**	4	4	2	3	13
	More Aggressive Remedy	2	4	1	2	9
	Less Aggressive Remedy	4	3	5	4	16
	No Action	0	0	5	0	5

FIGURES



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Site Vicinity Map

North Canal Plume WQARF Site
Phoenix, Arizona

Geosyntec consultants

Phoenix, AZ | December 2019

Figure 1

WCP-68S (NM)
WCP-34S (NM)
WCP-230 (971.64)
WCP-231 (977.16)
WCP-232 (NM)
TRIAD MW-13 (975.62)
WCP-MW-212 (NM)
WCP-61 (972.25)
WCP-225 (967.59)
WCP-228 (967.39)
TRIAD MW-15 (974.09)
TRIAD MW-10 (NM)
WCP-59 (971.06)
WCP-MW-215 (NM)
TRIAD MW-14 (972.50)
WCP-MW-216 (969.24)
WCP-25 (970.28)
WCP-206 (971.83)
WCP-233 (977.37)
WCP-229 (964.38)
WCP-209 (965.23)
WCP-26 (968.26)
WCP-MW-213 (971.85)
WCP-MW-218 (972.55)
WCP-MW-219 (NM)
WCP-227 (963.02)
WCP-234 (961.19)
WCP-MW-214 (966.18)
WCP-210 (964.90)
WCP-208S (965.88)
WCP-241 (959.70)
WCP-60 (965.92)
DJM MW-13 (NM)
SRP Well 9.5E-7.7N
WCP-62 (964.66)
WCP-27 (NM)
MW-3SR (957.39)
WCP-64 (NM)
WCP-211 (959.41)
WCP-205 (957.54)
WCP-MW-217 (NM)
WCP-207 (944.16)
WCP-226 (946.40)
WCP-242 (937.77)
MW-102SR (NM)
MW-202S (944.36)

965
975
970
960
955
950
945

W Indian School Rd
W Monterosa St
W Fairmount Ave
W Clarendon Ave
W Whitton Ave
W Sheila Ln
W Mitchell Dr
W Crittenden Ln
W Osborn Rd
W Mulberry Dr
W Flower St
W Monterey Way
W Cheery Lynn Rd
W Earll Dr
W Avalon Dr
W Pinchot Ave
W Weldon Ave
N 38th Dr
N 35th Ave
N 32nd Ave
N 31st Dr
N 31st Ave
N 33rd Ave
N 40th Ave
N 39th Ave
N 38th Ave
N 36th Dr
N 36th Ave
N 35th Dr
N 34th Dr
N 42nd Ave
Grand Ave
Burlington Northern Santa Fe
Wilgrand Ave
1124 ft
1119 ft
1116 ft
1113 ft
1107 ft

Shallow Unit Well (Groundwater Elevation)

SRP Well

Groundwater 5 ft Contour Interval

WOC Source Area

0.002 Approximate Groundwater Flow Direction and Hydraulic Gradient (ft/ft)

Groundwater Elevations in Feet Above Mean Sea Level
SGWS = Shallow Groundwater System
NM = Not Measured

Note: Some contours are based on additional monitoring data from the adjoining West Osborn Complex WQARF project. Not all wells for contouring are shown.

400 200 0 400 Feet

SGWS Groundwater Elevation Contours April/May 2019

North Canal Plume WQARF Site
Phoenix, Arizona

Geosyntec consultants

Phoenix, AZ | December 2019

Figure 2

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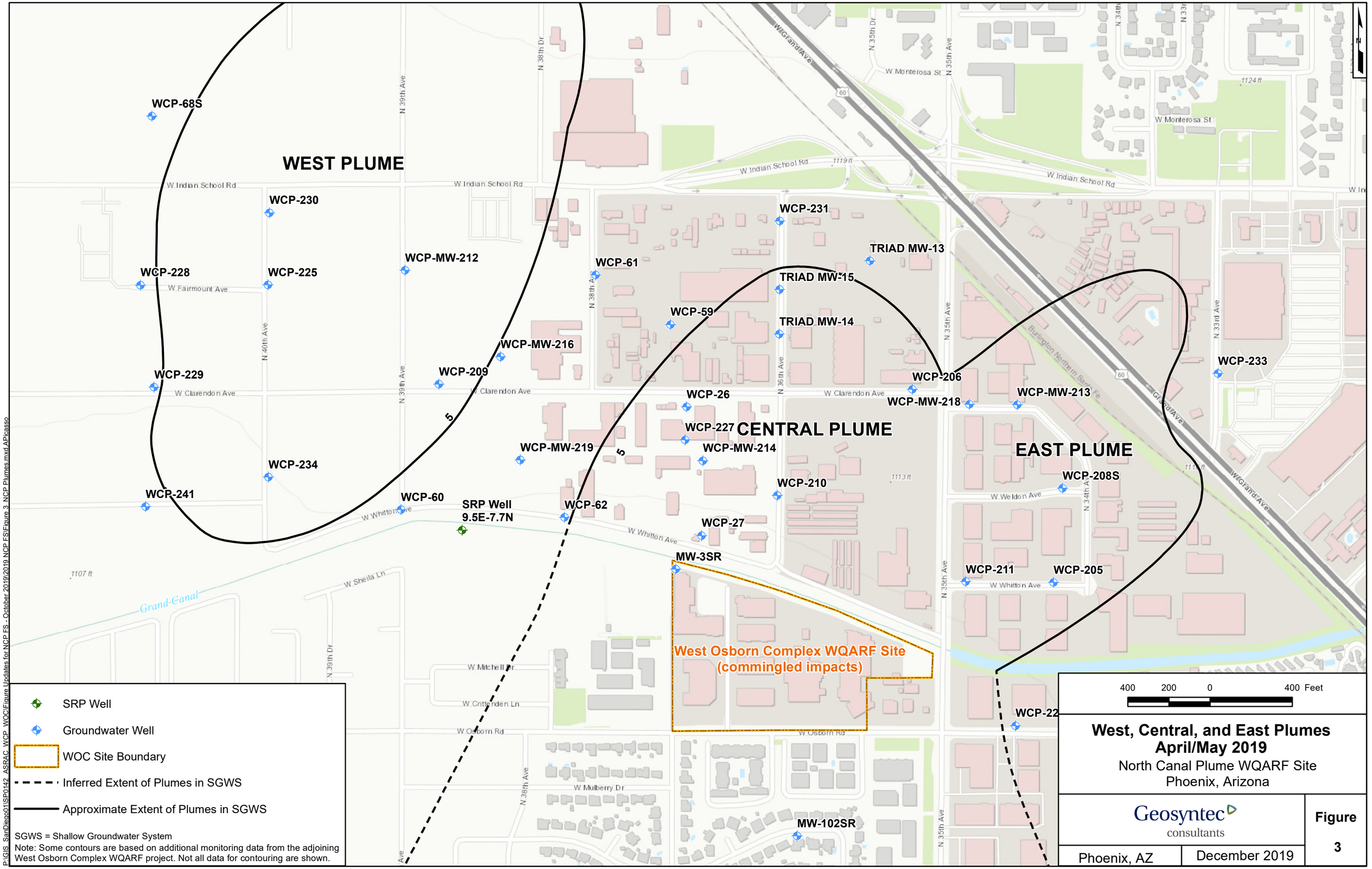
WEST PLUME
CENTRAL PLUME
EAST PLUME
WCP-68S
WCP-230
WCP-228
WCP-225
WCP-MW-212
WCP-61
WCP-231
TRIAD MW-13
TRIAD MW-15
WCP-59
TRIAD MW-14
WCP-MW-216
WCP-209
WCP-229
WCP-206
WCP-233
WCP-26
WCP-MW-218
WCP-MW-213
WCP-227
WCP-MW-219
WCP-MW-214
WCP-210
WCP-208S
WCP-234
WCP-241
WCP-60
SRP Well 9.5E-7.7N
WCP-62
WCP-27
MW-3SR
WCP-211
WCP-205
West Osborn Complex WQARF Site (commingled impacts)
MW-102SR
W Indian School Rd
W Fairmount Ave
W Clarendon Ave
W Whitton Ave
W Monterosa St
W Weldon Ave
W Sheila Ln
W Mitchell Dr
W Crittenden Ln
W Osborn Rd
W Mulberry Dr
N 39th Ave
N 40th Ave
N 38th Dr
N 38th Ave
N 36th Ave
N 35th Dr
N 35th Ave
N 34th Ave
N 33rd Ave
W Grand Ave
Burlington Northern Santa Fe
Grand Canal
1124 ft
1119 ft
1113 ft
1107 ft
60
5
SRP Well
Groundwater Well
WOC Site Boundary
Inferred Extent of Plumes in SGWS
Approximate Extent of Plumes in SGWS
SGWS = Shallow Groundwater System
Note: Some contours are based on additional monitoring data from the adjoining West Osborn Complex WQARF project. Not all data for contouring are shown.
400 200 0 400 Feet
West, Central, and East Plumes
April/May 2019
North Canal Plume WQARF Site
Phoenix, Arizona
Geosyntec consultants
Phoenix, AZ
December 2019
Figure 3
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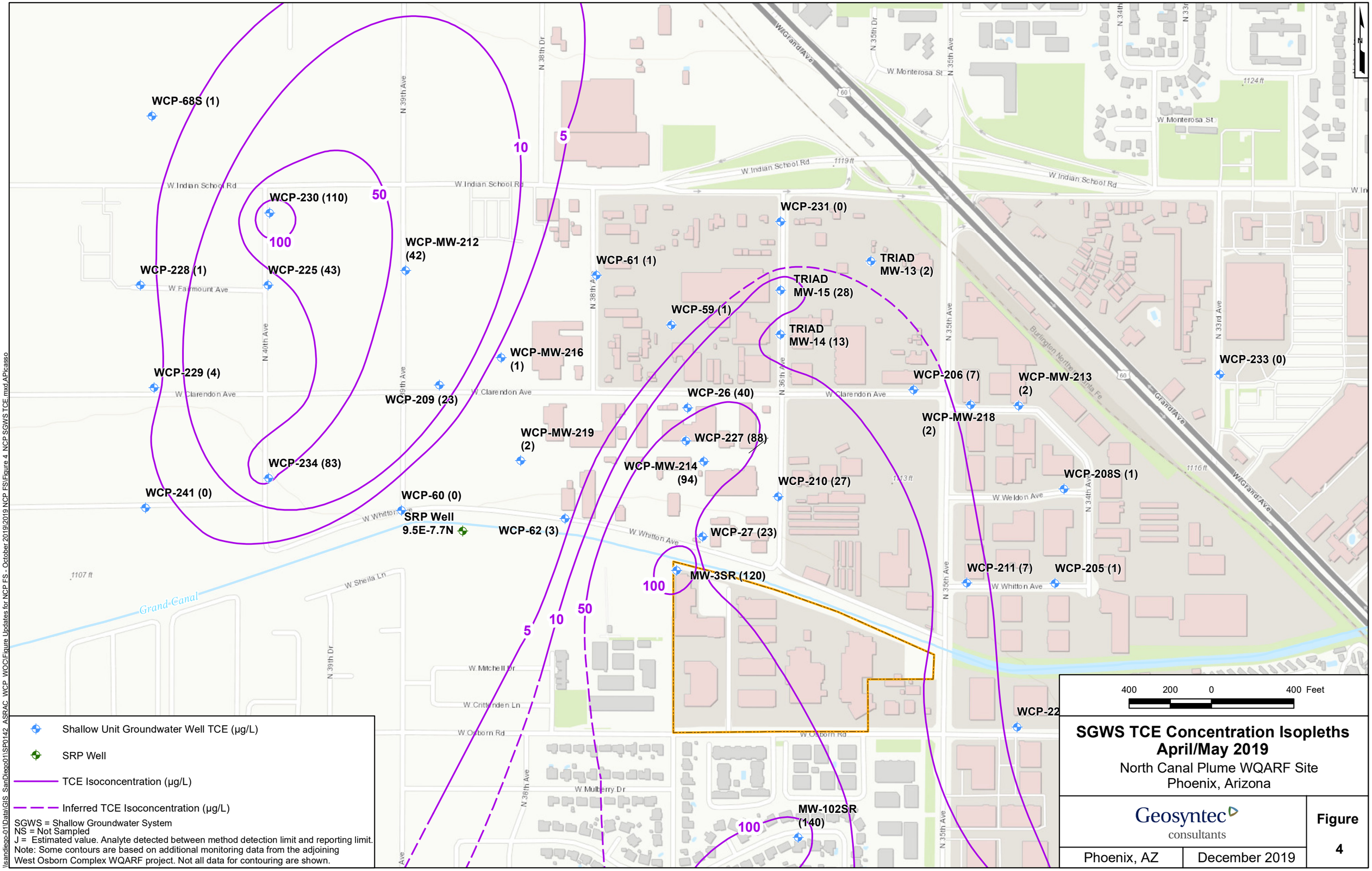

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WCP-68S (<0.5)

WCP-230 (0.84)

WCP-MW-212 (3.1)

WCP-228 (<0.5)

WCP-225 (<0.5)

WCP-61 (<0.5)

TRIAD MW-15 (<0.5)

WCP-231 (<0.5)

TRIAD MW-13 (1.8)

WCP-59 (<0.5)

TRIAD MW-14 (0.52)

WCP-MW-216 (1.9)

WCP-229 (2.5)

WCP-209 (4.9)

WCP-26 (2.1)

WCP-206 (3.5)

WCP-MW-213 (290)

WCP-233 (<0.5)

WCP-227 (3.6)

WCP-MW-218 (8.9)

WCP-MW-219 (<0.5)

WCP-234 (<0.5)

WCP-MW-214 (2.9)

WCP-208S (270)

WCP-241 (<0.5)

WCP-210 (5.2)

WCP-60 (<0.5)

SRP Well 9.5E-7.7N

WCP-62 (<0.5)

WCP-27 (4.9)

MW-3SR (3.5)

WCP-211 (1.7)

WCP-205 (200)

WCP-226 (<0.5)

MW-102SR (3)

5

10

50

100

100

W Indian School Rd

W Monterosa St

W Fairmount Ave

W Clarendon Ave

W Whitton Ave

W Weldon Ave

W Sheila Ln

W Mitchell Dr

W Crittenden Ln

W Osborn Rd

W Mulberry Dr

N 39th Ave

N 40th Ave

N 38th Ave

N 36th Ave

N 35th Ave

N 34th Ave

N 33rd Ave

N 39th Dr

N 35th Dr

W Grand Ave

Burlington Northern Santa Fe

1124 ft

1119 ft

1113 ft

1107 ft

Shallow Unit Groundwater Well PCE (ug/L)

SRP Well

PCE Isoconcentration (µg/L)

Inferred PCE Isoconcentration (µg/L)

WOC Source Area

SGWS = Shallow Groundwater System
NS = Not Sampled
J = Estimated value. Analyte detected between method detection limit and reporting limit.
Note: Some contours are based on additional monitoring data from the adjoining West Osborn Complex WQARF project. Not all data for contouring are shown.

400 200 0 400 Feet

SGWS PCE Concentration Isopleths April/May 2019

North Canal Plume WQARF Site
Phoenix, Arizona

Geosyntec consultants

Phoenix, AZ | December 2019

Figure 5

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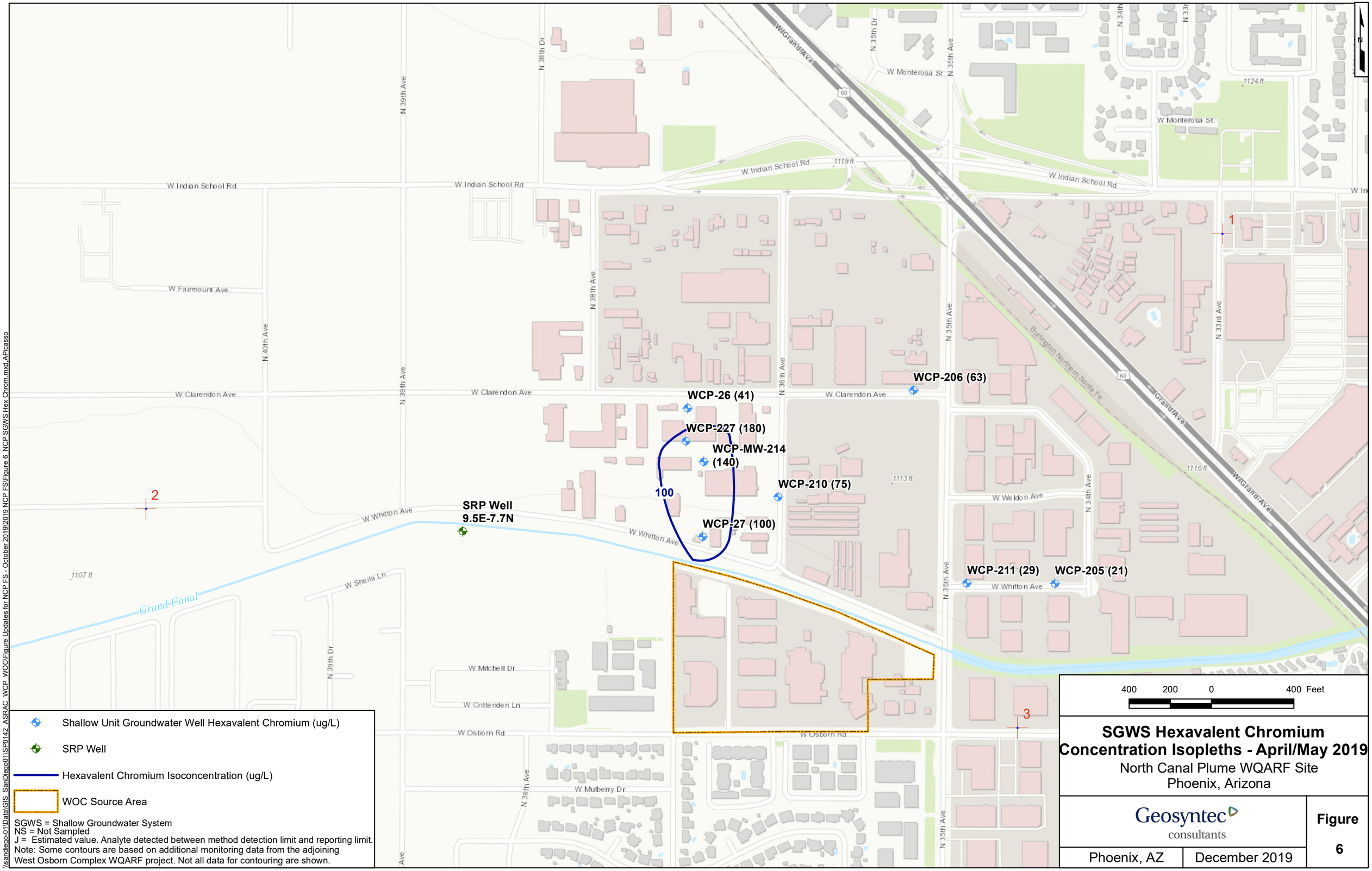

Shallow Unit Groundwater Well Hexavalent Chromium (ug/L)

SRP Well

Hexavalent Chromium Isoconcentration (ug/L)

WOC Source Area

SGWS = Shallow Groundwater System
NS = Not Sampled
J = Estimated value. Analyte detected between method detection limit and reporting limit.
Note: Some contours are based on additional monitoring data from the adjoining West Osborn Complex WQARF project. Not all data for contouring are shown.

SGWS Hexavalent Chromium Concentration Isopleths - April/May 2019

North Canal Plume WQARF Site
Phoenix, Arizona

Geosyntec consultants

Phoenix, AZ | December 2019

Figure 6

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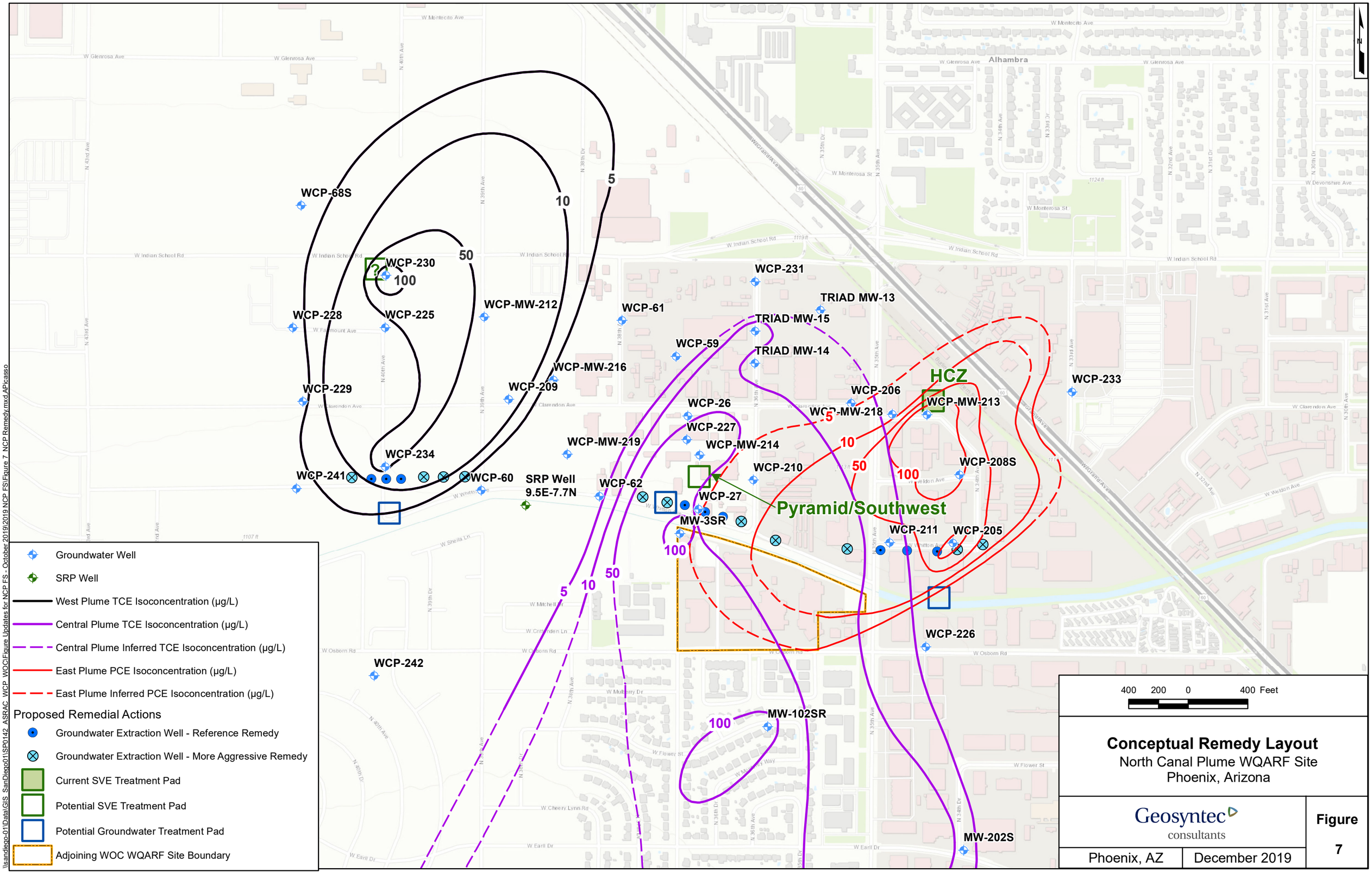
WCP-68S
WCP-230
WCP-228
WCP-225
WCP-MW-212
WCP-61
WCP-231
TRIAD MW-13
TRIAD MW-15
WCP-59
TRIAD MW-14
WCP-MW-216
WCP-209
WCP-229
WCP-26
WCP-206
WCP-MW-218
WCP-233
HCZ
WCP-MW-213
WCP-227
WCP-MW-219
WCP-MW-214
WCP-210
WCP-208S
WCP-234
WCP-241
WCP-60
SRP Well
9.5E-7.7N
WCP-62
WCP-27
Pyramid/Southwest
MW-3SR
WCP-211
WCP-205
WCP-226
WCP-242
MW-102SR
MW-202S
5
10
50
100
Alhambra
W Montecito Ave
W Glenrosa Ave
W Indian School Rd
W Fairmount Ave
W Clarendon Ave
W Monterosa St
W Devonshire Ave
W Osborn Rd
W Flower St
W Earll Dr
W Cheery Lynn Rd
W Mitchell Dr
W Sheila Ln
W Weldon Ave
N 43rd Ave
N 40th Ave
N 39th Ave
N 38th Dr
N 36th Dr
N 35th Ave
N 34th Ave
N 33rd Dr
N 32nd Ave
N 31st Dr
N 30th Dr
Groundwater Well
SRP Well
West Plume TCE Isoconcentration (µg/L)
Central Plume TCE Isoconcentration (µg/L)
Central Plume Inferred TCE Isoconcentration (µg/L)
East Plume PCE Isoconcentration (µg/L)
East Plume Inferred PCE Isoconcentration (µg/L)
Proposed Remedial Actions
Groundwater Extraction Well - Reference Remedy
Groundwater Extraction Well - More Aggressive Remedy
Current SVE Treatment Pad
Potential SVE Treatment Pad
Potential Groundwater Treatment Pad
Adjoining WOC WQARF Site Boundary
400 200 0 400 Feet
Conceptual Remedy Layout
North Canal Plume WQARF Site
Phoenix, Arizona
Geosyntec consultants
Phoenix, AZ
December 2019
Figure
7
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