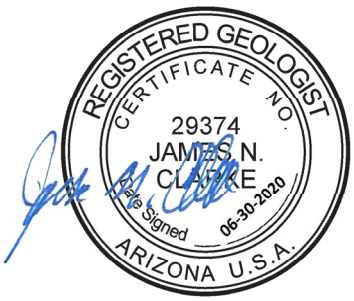
wood.

FEASIBILITY STUDY REPORT
East Central Phoenix
48th Street and Indian School
Water Quality Assurance Revolving Fund Site
Phoenix, Arizona

ADEQ
Arizona Department of Environmental Quality

Remedial Projects Section, Remedial Projects Unit
1110 West Washington Street
Phoenix, Arizona 85007

June 30, 2020



June 30, 2020
Project No. 14-2019-2043

Arizona Department of Environmental Quality
1110 West Washington Street
Phoenix, Arizona 85007

Attn: Lisa Kowalczyk

Re: Feasibility Study Report
48th Street and Indian School Road WQARF Registry Site
Phoenix, Arizona

We certify that this document and attachments presented in this report are accurate and complete. This report was prepared by the staff of Wood Environment and Infrastructure Solutions, Inc. (Wood) under our supervision to ensure that qualified personnel properly gather and evaluate the information submitted. Based on our inquiry of the person or persons who are directly responsible for gathering the information, the information submitted is, to the best of our knowledge and belief, true, accurate and complete.

If you have any questions or comments regarding this report, please contact Jim Clarke at (602) 733-6055.

Respectfully submitted,

Wood Environment &
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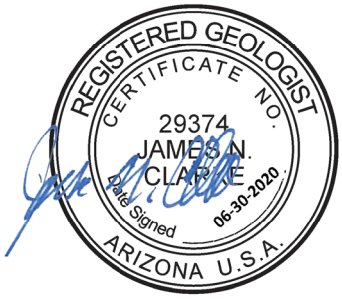
LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	Micrograms per liter
µg/m^3	micrograms per cubic meter
mg/L	milligrams per liter
%	percent
40th & OSB site	40 Street and Osborn Road WQARF site
A.A.C.	Arizona Administrative Code
A.R.S.	Arizona Revised Statutes
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
amsl	above mean sea level
AWQS(s)	Aquifer Water Quality Standard(s)
bgs	below ground surface
btoc	Below top of casing

cis-1,2-DCE	cis-1,2- dichloroethene
COC	contaminant of concern
COP	City of Phoenix
CSM	conceptual site model
DHE	*Dehalococcoides Ethenogenes*
DO	dissolved oxygen
Earth Tech	Earth Technologies, Inc
ECP	East Central Phoenix
ERA	Early response action
ERD	enhanced reductive dechlorination
FOCIS	Feedback Optimized Continuous Injection System
FS	Feasibility Study
ft	feet
ft/ft	feet per foot
ft/yr	feet per year
GPL(s)	Groundwater Protection Level(s)
gpm	gallons per minute
GWET	groundwater extraction and treatment
HP	hydrogen peroxide
IDW	investigation derived waste
IRA	interim remedial action
ISCO	in-situ chemical oxidation
ISCR	in-situ chemical reduction
LAU	Lower Alluvial Unit
lbs	pounds
LGAC	liquified granular activated carbon
LWUS	Land and Water Use Study
MAU	middle alluvial unit
MNA	monitored natural attenuation
O&M	operation & maintenance
ORP	oxidation reduction potential
PCE	tetrachloroethene
PQGWWP	Poor Quality Groundwater Withdrawal Permit
RD	reductive dechlorination
RI	remedial investigation
ROs	remedial objectives
ROW	Right(s)-of-way
RSRL(s)	Residential Soil Remediation Level(s)
Sandy's Cleaners	Sandy's Magic Touch Cleaners
SECOR	SECOR International, Inc.
Site	48th Street and Indian School Road WQARF site

SRP	Salt River Project
SSO	Solid Singlet Oxygen
Stantec	Stantec Consulting Services, Inc.
SVE	soil vapor extraction
TCE	trichloroethene
UAU	upper alluvial unit
USDA	United States Department of Agriculture
VOC	volatile organic compound
VPS(s)	vertical profile sample(s)
Wood	Wood Environment & Infrastructure Solutions, Inc.
WQARF	Water Quality Assurance Revolving Fund



1.0 INTRODUCTION

The purpose of this Feasibility Study (FS) report is to evaluate remedial alternatives and provide a recommendation for a preferred alternative for the 48th Street and Indian School Road Water Quality Assurance Revolving Fund (WQARF) site (Site). The Site is located in Phoenix, Arizona (**Figure 1**) and covers an area of mixed commercial, educational and residential land use. Wood Environment & Infrastructure Solutions, Inc. (Wood) completed the work described in this report under Arizona Superfund Remedial Action Contract Purchase Order Number PO0000116197 with the Arizona Department of Environmental Quality (ADEQ).

1.1 Objectives and Scope of the Feasibility Study Report

The FS is a process used to:

- Identify remedial options and alternatives that will achieve the Site Remedial Objectives (ROs) as outlined in the Remedial Objectives Report (ADEQ, 2019a); and,
- Evaluate the identified remedies and recommend alternatives that comply with the requirements of Arizona Revised Statutes (A.R.S.) §49-282.06.

Based on the purpose and process noted above, this FS presents recommendations for a preferred remedy that:

- Assures the protection of public health, welfare, and the environment;
- To the extent practicable, provides for the control, management, or cleanup of hazardous substances so as to allow for the maximum beneficial use of waters of the state;
- Implements remedial actions which are reasonable, necessary, cost-effective, and technically feasible; and
- Addresses any well (used for municipal, domestic, industrial, irrigation or agricultural purposes) that could produce water that would not be fit for its current or reasonably foreseeable end use without treatment.

This FS report was developed based on data and information from the Remedial Investigation (RI, Wood 2019a). The FS develops and presents a reference remedy and two alternative remedies, and evaluates the remedies to ensure that the remedies meet the following in accordance with Arizona Administrative Code (A.A.C.) R18-16- 407(H):

- Achieves the ROs;
- Is consistent with water management plans and general land use plans; and,
- Is evaluated with comparison criteria including practicability, risk, cost, and benefit.

One of the alternative remedies is less aggressive than the reference remedy and one is more aggressive as required by A.A.C. R18-16-407(E).

In accordance with A.A.C. R18-16-407(I), based on the evaluation of the reference remedy and the alternative remedies, the proposed remedy is developed and described in this FS report. Additionally, this report describes the rationale for selecting the proposed remedy including the following:

- How the proposed remedy will achieve the ROs;
- How the comparison criteria were considered; and
- How the proposed remedy meets the requirements of A.R.S. §49-282.06.

2.0 SITE BACKGROUND

This section presents a summary of the Site history and description of physiographic setting, nature and extent of contamination, and a risk evaluation. This summary is taken in large part from the Remedial Investigation (RI) report (Wood 2019a) and the *FY 2020 Annual Groundwater Monitoring Technical Memorandum, East Central Phoenix 48th Street and Indian School Road Water Quality Assurance Revolving Fund Site, Phoenix, Arizona* dated November 20, 2019 (Wood 2019b). This section also includes a description of the conceptual site model (CSM) for the Site and a problem statement based on the CSM.

2.1 Site Description and History

The Site is bound to the north by Devonshire Avenue, to the east by 48th Street, to the south by Weldon Avenue, and to the west by 42nd Street (**Figure 1**). The Site is located in an area of mixed commercial, educational (Arcadia High School), and residential development.

The investigation of the Site began in 1983 when Salt River Project (SRP) collected groundwater samples from several nearby wells. This included SRP Well 17.9E-7.5N, which is located directly downgradient of the Site and west of the intersection of 40th Street and Osborn Road (**Figure 1**). SRP Well 17.9E-7.5N is located within the downgradient and adjacent 40th Street and Osborn Road WQARF site (40th & OSB site). Water pumped from this well was used for irrigation purposes. Tetrachloroethene (PCE) was detected at a concentration of 53 µg/L in the sample collected from SRP Well 17.9E-7.5N, which is above the Arizona Aquifer Water Quality Standard (AWQS) of 5.0 micrograms per liter (µg/L). SRP subsequently decreased pumping from the well and took it off-line in 1990. The well has been periodically pumped since 1990 to collect groundwater samples. In 1998, PCE was detected at a concentration of 210 ug/L, which was the highest concentration reported to date at SRP Well 17.9E-7.5N.

Based on the results of the SRP well sampling, the East Central Phoenix (ECP) Study Area was established in 1988. The ECP Study Area was bounded by Camelback Road to the north, McDowell Road to the south, 50th Street to the east and 20th Street to the west and included the Site. The Site has historically contained dry cleaning facilities, service stations, and printing shops, with some of the dry cleaners operating since 1962. In 1989, ADEQ performed soil vapor sampling at several facilities within the ECP study area, including facilities within the Site. After investigations, the source area of the PCE was determined to be dry cleaning facilities that operated at the northeast corner of 48th Street and Indian School Road. The facilities were identified as One Hour Martinizing (operated 1966-1987) and Sandy's Magic Tough Cleaners (operated Sandy's Cleaners) (1987-present) (Earth Technologies, Inc. [Earth Tech], 1989). Sandy's Cleaners is currently located in the Arcadia Towne Center, a multi-tenant shopping center. The locations of One Hour Martinizing and Sandy's Cleaners relative to the Site wells and PCE plume are shown on **Figures 2 and 3,** respectively.

In 1997, ADEQ established the WQARF Registry, replacing the WQARF Priority List. In 1998, the ECP Study Area was divided into six individual WQARF Registry sites:

- 48th Street and Indian School Road (Site);
- 40th & OSB site;
- 40th Street and Indian School Road;
- 38th Street and Indian School Road;
- 32nd Street and Indian School Road; and,
- 24th Street and Grand Canal.

The Site was placed on the WQARF Registry List in April 1999. In June 2007, ADEQ initiated the RI for the Site. A RI work plan was prepared and submitted by SECOR International, Inc. (SECOR) in February 2008 (SECOR, 2008).

From 1992 to November 2018 soil borings, vapor monitoring points, and monitoring wells were installed at the Site to assess the areal and vertical extents of PCE contamination. In 2000, Salt River Project (SRP) designed and installed a soil vapor extraction (SVE) system at Sandy's Cleaners to remove vapor contamination from the soil. The SVE system operated from February 2006 until December 2011. The SVE system removed a total of 319 pounds (lbs) of PCE from the soil. The RI was completed on November 13, 2019 with the submittal of the RI Report (Wood, 2019a). An additional monitoring well identified as SMW-17 was installed in April 2020 and samples were collected on May 15, 2020. The purpose of this well was to define the northern extent of the PCE plume. The estimated areal and vertical extents of the PCE plume based on the October 2019 and May 2020 analytical results is shown on **Figures 4 and 5**, respectively.

2.2 Physiographic Setting

A detailed description of the Site physiography is provided in the RI Report (Wood, 2019a). In summary, the Site is located within the eastern portion of West Salt River Valley sub-basin of the Phoenix Active Management Area (AMA), a broad, relatively level alluvial valley filled with layers of unconsolidated sand, gravel, silt, clay. The Site is located within the United States Geologic Survey Topographic 7.5 Minute Phoenix map, which shows a general topographic trend of decreasing elevations from the northeast to southwest across the Site. The ground surface at the Site slopes to the southwest and drops approximately 32 feet (ft) between wells SMW-01 (1,241.21 ft above mean sea level [amsl]) and BMW-12B (1,209.13 ft amsl) (**Figure 5**).

In 1993, the Arizona Department of Water Resources (ADWR) released the results of its modeling study of the Salt River Valley (Corkhill *et al*., 1993). For modeling purposes, the ADWR defined three hydrogeologic units in the basin-fill by differences in grain size that occur throughout most of the Phoenix Basin and are generally correlative with the hydrostratigraphic units defined by the United States Bureau of Reclamation in 1976. These include from the shallowest to deepest: the Upper Alluvial Unit (UAU), the Middle Alluvial Unit (MAU), and the Lower Alluvial Unit (LAU). The MAU and LAU are not present at the Site.

The Site has been assessed to a total depth of 214 ft below ground surface (bgs) in the northeast portion of the Site at well SMW-16B and 261 ft bgs towards the southwest portion of the Site at boring SMW-14B

(**Figures 5**). The lithology below the Site consists predominantly of silt, clay, sand mixed with silt and/or clay, and gravel. The lithology at SMW-16B and SMW-14B is summarized as follows:

Depth (ft bgs)	Summary Description
0-29	silty sand
29-60	silt to sandy silt with occasional gravel
60-77	silty sand
77-83	sandy silt with gravel
83-87	silty sand
87-98	sandy to gravelly silt
98-108	silty sand with gravel, with occasional silt lenses
111-137	silt to sandy silt with occasional gravel
137-148	sand to silty sand with gravel
148-160	sandy silt
160-172	sandy and clayey silt
172-193	silt and sandy silt
193-214	silty sand with gravel
214	bedrock – Upper Camels Head Formation

Notes:
ft bgs – feet below ground surface

The following summarizes the lithology at SMW-14B:

Depth (ft bgs)	Summary Description
0-74	sandy silt with occasional silty sand lenses
74-83	silty sand with occasional gravel
83-157	sandy silt with occasional silty sand lenses
157-185	silty sand with gravel, with occasional silt lenses
185-191	silty gravel with sand
191-194	gravelly silt
194-203	silty sand with gravel, with occasional silt lenses
203-205	clayey silt to sandy silt with occasional gravel
205-210	silty gravel with sand
210-215	silty sand
215-221	sandy silt
221-224	silty sand with gravel
224-237	sandy silt with gravel lens at 228 ft
237-245	silty sand
245-256	gravelly silt
256-261	bedrock – Upper Camels Head Formation

Notes:
ft bgs – feet below ground surface

As indicated above, bedrock, identified as the Camels Head Formation, was encountered at a depth of 214 ft below top-of-casing (btoc) (1,026 ft amsl) at SMW-16B and at a depth of 256 ft btoc at boring SMW-14B (951 ft amsl). Based on the lithology, the MAU and LAU are not considered to be present below the Site. Therefore, the UAU/Camels Head Formation contact drops approximately 75 ft in a southwesterly direction across the area, which is a slope of approximately 0.02 ft per ft (ft/ft) (**Figure 5**).

The hydrostratigraphic units have been defined based on review and evaluation of data generated during groundwater assessments at the ECP WQARF sites. The hydrogeology has been investigated to a maximum depth of approximately 256 ft bgs within the UAU. The base of the UAU was encountered at SMW-16B and SMW-14B. At the Site, the UAU ranges from 214 ft thick at SMW-16B to 256 ft thick at SMW-14B. The UAU at the Site consists of predominantly fine-grained sands, silts and silt with sand, to sandy silts with trace amounts of gravel. The groundwater surface within the Site lies within the UAU.

Monitoring well construction details for the Site are presented in **Table 1**. Groundwater elevations in the UAU at the Site have been monitored since April 1992 (**Table 2**; **Appendix A** - hydrographs). Monitoring wells installed at the Site are screened across both shallow (water table) and deeper intervals within the UAU (**Figure 5** and **Table 1**). Groundwater elevations have generally declined at the Site since early 1994. Depth to groundwater at the Site on May 12, 2020 ranged from 37.71 ft btoc (1,176.56 ft amsl) at BMW-06A to 43.64 ft btoc (1,193.07 ft amsl) at SMW-03-138 (**Table 2 and Figure 6**).

As shown by the groundwater elevation hydrographs in **Appendix A**, water levels have been historically declining at the Site. The longest record of water levels is available for SMW-01, dating to April 21, 1992. Water level declines for SMW-01, ECP-01, SMW-03-60, SMW-07, and BMW-05B are provided as follows:

Well	Maximum GWE (ft AMSL)	Date	Current GWE (ft AMSL)	Date	Change (ft)	Change Rate (ft/yr)
SMW-01	1,222.52	12/15/94	1,200.51	5/12/20	-22.01	-0.85
ECP-01	1,218.41	3/6/02	1,200.02	5/12/20	-18.39	-1.02
SMW-03-60	1,218.05	5/19/94	1,193.16	5/12/20	-24.89	-0.96
SMW-07	1,207.71	4/20/12	1,199.62	5/12/20	-8.09	-1.01
BMW-05B	1,176.63	11/21/14	1,170.14	5/12/20	-6.49	-1.08

Notes:
AMSL – above mean sea level
Ft – foot
GWE – Groundwater elevation in feet above mean sea level (ft AMSL)
ft/yr – feet per year

The current (**Figure 6**) and historical direction of groundwater flow has been to the west-southwest with a current gradient of approximately 0.01 ft/ft. Vertical gradients between the shallow and deeper zones of the UAU monitored at the Site are generally negligible. The estimated horizontal hydraulic conductivity of the UAU at the Site is variable due to the heterogeneity of the UAU. Based on the results of groundwater modeling that has been performed, the horizontal hydraulic conductivity ranges from 21 to 30 ft/day (Fluid Solutions, 2000). Assuming an effective porosity of 0.25, the current groundwater velocity ranges from 0.8 to 1.2 ft/day or 292 to 438 ft/year (ft/yr).

2.3 Nature and Extent of Contamination

The purpose of the RI was to determine the nature and extent of contamination at the Site. The RI also identified present and foreseeable land and water use at the Site that have been or could become impacted by the contamination associated with the Site. A summary of the RI findings and conclusions is presented below (Wood, 2019a):

- The contaminant of concern (COC) at the Site is PCE. Other compounds that have historically been detected above screening and regulatory levels include trichloroethene (TCE) and cis-1,2-dichloroethene (c-1,2-DCE).

- The source of the contamination at the Site includes two dry cleaning facilities (One-Hour Martinizing and Sandy's Cleaners) that operated at the northwest corner of 48th Street and Indian School. As PCE is the COC at the Site, it is used to define the extent of contamination at the Site (**Figures 4 and 5**).

- PCE concentrations in soil at the Site are below the residential soil remediation level (RSRL) and groundwater protection level (GPL.

- PCE concentrations in soil gas at the Site have been remediated to levels that no longer represent a threat to groundwater. Residual PCE and TCE concentrations in soil gas at the Site do not appear to pose a risk to residents and commercial workers at or in the vicinity of the Site.

- PCE concentrations in groundwater beneath the Site currently exceed the AWQS (**Figure 4 and Table 3**).

- Land use at the Site consists of mixed residential and commercial uses. This is not expected to change over the next 100 years.

- Groundwater is currently used intermittently for irrigation in the vicinity of the Site by the Salt River Project (SRP). Over the next 100 years, SRP anticipates these wells will transition from irrigation to municipal service (potable supply). The City of Phoenix may also need to supplement their potable supply should water demand or available supplies change over the next 100 years.

- Additional details of land and water use within the Site are provided in the Final Remedial Investigation Report (Wood, 2019a).

As shown on **Figure 5**, the PCE plume is interpreted as "diving" between wells SMW-03-60 and BMW-05B. This interpretation is based on deeper PCE not being detected in deep upgradient well SMW-03-138 and shallow PCE not being detected in shallow downgradient well BMW-05A. The plume is adequately characterized in the upgradient and southerly directions. The northern extent of the plume is characterized on the northeast. An additional well identified as SMW-17 was drilled during April 2020 and sampled during May 2020 to better define the plume on the north. The location of this well is shown on **Figure 4**. This well has defined the plume on the north.

The lateral extent of the plume is adequately defined to the south by BMW-12B to 185 feet and SMW-14B to 255 feet. The downgradient extent of the plume is defined by BMW-15D to 215 feet.

Due to the distance between SMW-03-60 and BMW-05A, a minimum of two monitoring wells (SMW-18 and SMW-19) within the plume are required to monitor the remedy downgradient (southwest) of SMW-03-60. The proposed locations of these wells are provided on **Figure 4**. Monitoring wells SMW-18 and SMW-19 are tentatively scheduled for installation during FY 2021. These wells and are not necessary to complete

this FS. These wells may be installed as nested wells. A conceptual design for the wells is provided as **Figure 7.**

2.4 Risk Evaluation/Conceptual Site Model

2.4.1 Potential Receptors

Prior to performing the exposure pathway evaluation, potential receptors to Site COCs were identified. The Site boundary (**Figure 4**) includes an area encompassing residential and commercial/industrial settings and Arcadia High School. Potential receptors are identified as current and future residential individuals, commercial/industrial workers, and construction workers occupying areas within the boundary.

Residential individuals include children and adults occupying residential locations within the Site boundary. A residential location is typically one where someone is present for an average of more than eight hours a day. It includes, but is not limited to, schools; dwellings; residences; correctional facilities; any other human activity areas of repeated, frequent use and/or chronic duration; and locations that typically house sensitive populations such as grade schools, hospitals, childcare centers, and nursing homes. Schools are typically evaluated using commercial/industrial criteria because students are only present for about six hours per day and only a portion of a calendar year. As previously discussed, the PCE and TCE in the subsurface do not appear to pose a risk to residents at the Site.

Commercial/industrial workers include adults working at the businesses within the Arcadia Towne Center, which includes Sandy's Cleaners. As previously discussed, the PCE and TCE in the subsurface do not appear to pose a risk to residential use at Arcadia Towne Center, which also is protective of commercial/industrial use.

Construction workers include adults who are performing construction work for a substantial period (e.g., months to years), resulting in sub-chronic exposures for only that period equal to the duration of the project.

One category of potential sensitive receptors, schools, is located near the estimated PCE groundwater plume boundary. This is Arcadia High School and Tutor Time Daycare Center. As shown on **Figure 3**, the estimated southern extent of the PCE groundwater plume boundary crosses the landscaped northwest corner of the Arcadia High School property, where well SMW-03-60 is located. However, the school buildings and majority of the school property are located to the south and outside the plume boundary. The groundwater plume is situated to the south of Tutor Time Daycare Center., Soil vapor and indoor air quality sampling indicates that the PCE and TCE in the subsurface do not appear to pose a risk to sensitive receptors.

2.4.2 Ecological Risk Evaluation

As defined, an ecological receptor is "a specific ecological community, population, or individual organism, protected by federal or state laws and regulations, or a local population that provides an important natural or economic resource, function, and value" (A.A.C. R18-7-201). Wildlife or vegetation that is present in the study area is likely non-native to the area, is habituated to human presence, or has been maintained in a horticultural setting. Areas and land use within the boundary (**Figure 3**) do not contain suitable habitat for the five federally listed species. Due to the presence of COCs at depth, the urban character of the Site, and lack of ecological receptors within the boundary, an evaluation of ecological receptors is not warranted.

2.4.3 Human Risk Evaluation

An exposure or migration pathway is the route by which the potential hazard (identified COCs) migrates from the source (soil vapor, soil, surface water, or groundwater) to a receptor. Pathways can include:

- Inhalation of impacted vapors;
- Dermal contact with impacted soil, groundwater, or surface water; or
- Ingestion of impacted soil, groundwater, or surface water.

An exposure pathway is complete when all four of these components are present: 1) a source and mechanism of chemical release; 2) a retention or transport medium (pathway); 3) an exposure point (i.e., a setting where potential human contact with the chemical-affected medium or media occurs); and 4) a route of exposure at the exposure point (e.g., ingestion, dermal, inhalation).

The land use at the Arcadia Towne Center is commercial/industrial, and at the broader site is commercial/industrial, residential, and public open space. This exposure pathway evaluation, therefore, assesses potential pathways by which long-term commercial workers, short-term construction workers, visitors to the site and residents may be exposed to the Site COC, PCE. This section evaluates whether the pathways are currently complete and if so, assesses the potential risk to receptors based on the concentrations of site COCs.

The Exposure Pathway Model for the Site is provided as **Figure 8.** The exposure pathway for residential individuals, commercial/industrial workers, and construction workers was determined to be incomplete.

2.4.4 Conceptual Site Model

The impacts present at the Site are known to be the direct result of releases of dry cleaning solvents, primarily PCE, at the Former One-Hour Martinizing and current Sandy's Cleaners (**Figures 2 and 3**).

Laboratory analyses determine that vadose zone impacts were detected beneath the dry cleaning facility and that this facility is the source of the COC releases (**Figures 2 and 3**). These impacts have been successfully remediated by SVE implementation as an ERA. The ERA activities are detailed in **Section 4.0** of this FS report.

Based on the assessment work completed, PCE from the dry cleaning facilities, primarily in the vapor-phase, traveled vertically until encountering groundwater at a depth of approximately 15-20 ft bgs. Once in contact with groundwater, the vapor-phase PCE dissolved into the groundwater and migrated in a southwesterly direction under the pumping influence of SRP well 17.9E-7.5N (**Figure 1**), reaching the western edge of the Site (approximately 3,500 ft).

The source of the PCE impact was removed by the ERA SVE system that was operated from 2006-2011, resulting in PCE concentrations being below 5.0 µg/L in groundwater samples collected from source area wells SMW-01 and ECP-01 since 2010 and 2013, respectively. As shown in **Table 3** and **Appendix A**, PCE concentrations in SMW-03-60 increased above 5.0 µg/L in 2007 and increased to a maximum concentration

of 1,400 µg/L by October 2011. This is possibly due to the PCE plume shifting north and returning to the natural, non-pumping flow gradient for the area. Due to removal of the source and natural attenuation, PCE concentrations gradually declined in SMW-03-60 to non-detect by October 2013. The recent slight rebound of PCE concentrations in samples collected from SMW-03-60 is possibly due to migration of residual dissolved PCE from upgradient of SMW-03-60.

As shown on **Figure 5** and discussed in **Section 2.3.1**, the PCE plume is interpreted as being relatively thin and is interpreted as "diving" between wells SMW-03-60 and BMW-05B. This interpretation is based on deeper PCE not being detected in deep upgradient well SMW-03-138 and shallow PCE not being detected in shallow downgradient well BMW-05A. Planned wells SMW-18 and SMW-19 are intended to provide a better understanding of the plume between SMW-03 and BMW-05. The plume is adequately defined aerially.

3.0 FEASIBILITY STUDY SCOPING

This section summarizes the regulatory requirements presented in Arizona statute and rule, delineates the remediation area and presents the ROs (ADEQ, 2019b).

3.1 Regulatory Requirements

The A.R.S. §49-282.06 requires that remedial actions shall:

1. Assure the protection of public health and welfare and the environment.
2. To the extent practicable, provide for the control, management or cleanup of the hazardous substances in order to allow the maximum beneficial use of the waters of the state.
3. Be reasonable, necessary, cost-effective and technically feasible.

Under A.R.S. §49-282-06B, the selected remedial action "shall address, at a minimum, any well that at the time of selection of the remedial action either supplies water for municipal, domestic, industrial, irrigation or agricultural uses or is part of a public water system if the well would now or in the reasonably foreseeable future produce water that would not be fit for its current or reasonably foreseeable end uses without treatment due to the release of hazardous substances. The specific measures to address any such well shall not reduce the supply of water available to the owner of the well."

Under A.R.S. §49-282-06C, while selecting remedial actions, ADEQ shall consider:

1. Population, environmental and welfare concerns at risk.
2. Routes of exposure.
3. Amount, concentration, hazardous properties, environmental fate, such as the ability to bioaccumulate, persistence and probability of reaching the waters of the state, and the form of the substance present.
4. Physical factors affecting human and environmental exposure such as hydrogeology, climate and the extent of previous and expected migration.
5. The extent to which the amount of water available for beneficial use will be preserved by a particular type of remedial action.

6. The technical practicality and cost-effectiveness of alternative remedial actions applicable to a site.
7. The availability of other appropriate federal or state remedial action and enforcement mechanisms, including, to the extent consistent with this article, funding sources established under CERCLA, to respond to the release.

3.2 Delineation of Remediation Areas

The RI report collected samples from soil, soil gas, groundwater, and indoor air and compared the sample results to screening values to identify which media have been impacted by COCs.

The RI Report concluded that the groundwater was the only media with COC concentrations that exceeded a screening value or a regulatory standard. For the October 2019 groundwater sampling event, PCE was detected in three monitoring wells (SMW-03-60, SMW-7, and BMW-05B) at concentrations exceeding the AWQS of 5 µg/L (Wood, 2019b). The PCE plume is interpreted as being relatively thin and is interpreted as "diving" between wells SMW-03-60 and BMW-05B (**Figure 5**). This interpretation is based on deeper PCE not being detected in deep upgradient well SMW-03-138 and shallow PCE not being detected in shallow downgradient well BMW-05A. The PCE plume is on average approximately 10 ft thick through SMW-03-60 and begins to dive at an unknow point between SMW-03-60 and BMW-05B. At BMW-05B, the vertical thickness of this submerged PCE plume is unknown at this location; however, it is expected to be less than the nearly 150 feet thickness at 40th & OSB site well cluster BMW-02C/E. BMW-02C/E is the next closest downgradient well to BMW-05B. Wells SMW-18 and SMW-19 shown on **Figure 4** will be used to evaluate the vertical extent of the PCE plume between SMW-03-60 and BMW-05B .

As shown on **Figure 4**, the PCE plume as defined is approximately 3,360 ft long and a maximum of 350 ft wide. Due to the proximity to the 40th & OSB site, the full extent of the PCE plume is not required to complete the FS and will not affect the remedy.

3.3 Remedial Objectives

ROs have been developed for the Site as part of the RI process (ADEQ 2019b). Pursuant to A.A.C. R18-16-406 (I), the ROs were based on field investigation results, the Land and Water Use Study (LWUS) (Wood, 2020), the screening level risk evaluation, and input from the community during the public comment period on the draft RO Report. ROs are used in this FS to identify appropriate remedial technologies in developing the remedial alternatives.

3.3.1 Remedial Objectives for Land Use/Soil

The impacted soil within the source area at the Site has been remediated with an SVE system. The concentrations of COCs in the soil are below the RSRLs and GPLs. Soil gas and indoor air samples collected off the source area confirm that no other properties at the Site are impacted with soil or soil vapor contamination above regulatory levels. Thus, a RO for land use/soil is not needed at the Site (ADEQ, 2019b).

3.3.2 Remedial Objectives for Groundwater Use

The groundwater use portion of the LWUS Report is a summary of information gathered from the ADWR, water providers, and municipalities. The water providers at the Site are the City of Phoenix (COP) and SRP (Wood, 2020). The Site lies within the Phoenix Active Management Area (AMA), an area where groundwater use is controlled and regulated. ADWR records indicate there are 11 non-exempt and five exempt water supply wells located within approximately one mile of the PCE plume boundary. The non-exempt wells include: (a) nine wells owned and operated by SRP; (b) one well owned by COP; and (c) one well owned by Maricopa County Flood Control District. According to ADWR, the COP owned well was used to fill the swimming pool at Perry Park. The well owned by Maricopa County was used for de-watering purposes. The intended use of the five exempt wells is domestic irrigation. There are no grandfathered rights in the vicinity of the PCE plume boundary. The COP and SRP have service area rights in the vicinity of the Site, however, only SRP is currently pumping groundwater in the vicinity of the PCE plume boundary. The current use of water at the Site is for irrigation water. The future use of groundwater at the Site includes irrigation and municipal (potable supply). The groundwater at the Site is currently contaminated with PCE at concentrations that exceed the AWQS. Thus, the ROs for groundwater use at the Site are as follows (ADEQ, 2019b):

<u>Irrigation Use</u>

Protect against the loss or impairment of irrigation water threatened by the COCs at the 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 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 Site does not prohibit or limit the designated use of groundwater.

<u>Potable Use</u>

Protect against the loss or impairment of potable water threatened by the contaminants of concern at the 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 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 Site does not prohibit or limit the designated use of groundwater.

3.3.3 Remedial Objectives for Surface Water Use

Current surface water use at the Site is irrigation from SRP canals. The water in the SRP canals is supplemented with groundwater pumped from SRP wells. The future use of the surface water in the SRP canals includes irrigation and drinking water. The current and future source of the water in the SRP canals originating from the Site is groundwater pumped by SRP wells. Thus, ROs for surface water use are not needed because the ROs for groundwater use for the water pumped into the canals are applicable (ADEQ, 2019b).

4.0 EARLY RESPONSE ACTION/INTERIM REPONSE ACTION SUMMARY

In 2000, ADEQ and SRP entered into a Governmental Services Contract in which ADEQ funded SRP to conduct an Interim Remedial Action (IRA) at Sandy's Cleaners. As an IRA, SRP designed and installed an SVE system to remove soil vapor contamination from the subsurface. As part of the IRA agreement, SRP installed two groundwater monitor wells east of the Sandy's Cleaners facility and one groundwater extraction well west of the Sandy's Cleaners facility (ECP-1 through ECP-3) in 2001 (**Table 1 and Figure 1**).

An SVE pilot test was performed on ECP-1 and SMW-01 in March 2004. Based on the results of this testing, SVE appeared to be an effective way to remove PCE from the subsurface and minimize additional groundwater contamination. The estimated PCE extraction rate was 3 lbs per day (lbs/day) (Mogollon Environmental Services, LLC, 2004).

In 2004, SRP installed two SVE wells (SVE #1 and SVE #2) west of the Sandy's Cleaners facility (SRP, 2006a). The SVE system was issued a non-title V Air Quality Permit from Maricopa County. The system consisted of a 1.5 horsepower Rotron vacuum blower with extracted vapors treated using granular activated carbon contained in 50-gallons drums. Vapors were extracted from SVE #1, SVE #2, and ECP-1. A pilot test conducted in February 2006 indicated an initial estimated volatile organic compound (VOC) extraction rate of 40 lbs/day. The maximum PCE concentration in soil vapor was 25,000 µg/L or 25,000,000 micrograms per cubic meter (µg/m^3) from SVE #1 (SRP, 2006b). Full operation of the SVE system commenced in April 2006.

The SVE system operated from April 2006 until December 2011, over which time 319 lbs of PCE were removed from the subsurface. PCE was detected at a concentration of 1.2 parts per million vapor volume in the December 2011 sample collected from SVE #1, which converts to 8,140 µg/m^3 (SRP, 2012). SRP decommissioned their SVE system in April 2012.

As shown by the PCE versus time graphs included in **Appendix A**, PCE groundwater concentrations in source area monitoring wells SMW-01 and ECP-01 steadily decreased during operation of the SVE system. PCE concentrations have been below 5.0 µg/L in samples collected from SMW-01 and ECP-01 since June 2010 and October 2013, respectively. Therefore, PCE concentrations in soil gas at the Site have been remediated to levels that no longer represent a threat to groundwater. residual PCE and TCE concentrations in soil gas at the Site do not appear to pose a risk to residents and commercial workers at or in the vicinity of the Site. Therefore, the completed ERA/IRA achieved the basic remedial strategy of source control at the Site described in Section 5.0.

5.0 IDENTIFICATION AND SCREENING OF REMEDIAL MEASURES AND REMEDIAL STRATEGIES

This section presents the evaluation and screening of various remedial measures and strategies related to Site contamination and lists the applicable technologies retained for evaluation as part of the reference and alternative remedies pursuant to A.A.C. R18-16-407 (E) and (F).

Remedial measures are remediation technologies or methodologies that are screened based on anticipated removal or reduction of contaminants at the Site and the ability to achieve the ROs. Remedial strategies incorporate one or more remediation measures/technologies to achieve the RO. The basic remedial strategies summarized in A.A.C. R18-16-407 (F) are:

1. Plume remediation as a strategy to achieve AWQS for contaminants of concern throughout the site.
2. Physical containment as a strategy to contain contaminants within definite boundaries.
3. Controlled migration as a strategy to control the direction or rate of migration of contaminants.
4. Source control as a strategy to eliminate or mitigate a continuing source of contamination.
5. Monitoring as a strategy to observe and evaluate the contamination at the site through the collection of data.
6. No action as a strategy that consists of no action at a site.

For the basic remedial strategies listed above, listed item 2 is not applicable at this Site. The no action strategy will not meet the ROs in a reasonable timeframe. The remaining remedial strategies (plume remediation, controlled migration, source control, and monitoring) are applicable and will be retained for development of the reference remedy and alternate remedies.

Typically, appropriate remediation alternatives and technologies are screened using the following criteria:

- compatibility with current and reasonably foreseeable land use,
- treatment effectiveness for removal of the site COCs,
- regulatory requirements,
- constructability,
- operation and maintenance requirements,
- health and safety considerations,
- generation and management of waste products,
- flexibility/expandability, and
- cost.

The screening presented below does not explicitly evaluate each technology against each of these criteria, rather the intent is to identify fatal flaws or conversely, proven characteristics of technologies in order to develop and assemble the remedial alternatives that are described in **Section 6**. The screening of technologies addresses only groundwater.

5.1 Screening of Groundwater Technologies

The technologies that are described in this section are routinely used for sites with chlorinated solvents dissolved in groundwater. The general approach, limitations and applicability to the Site are considered. The following are remediation limitations for the Site:

- Based on available data, the PCE groundwater plume above 5.0 µg/L is an estimated 3,360 feet long (0.64 miles) and is an estimated 350 feet wide.

- The plume is located mainly downgradient of the source; beneath City of Phoenix streets, a portion of Arcadia High School, and primarily residences, which limits locations to install remedial wells and the remediation system(s).

- Installation of an off-source remediation system will require securing access to an off-source property.
- The most feasible location for a remediation system is Sandy's Cleaners, where access and remedial infrastructure exists.
- Remediation piping/tubing to or from remediation wells will require either extensive installation within City of Phoenix street right-of-way or installation of horizontal wells.

5.1.1 Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) is an approach that involves monitoring VOCs and other parameters in groundwater to identify and track the decrease of contaminant concentrations over time. Processes that can decrease concentrations include dilution, dispersion, volatilization, and biological degradation. Documenting MNA typically includes measurement of various chemical and hydrogeological parameters to provide evidence that MNA is a protective remedy. MNA is usually combined with source control, or selected at sites where the source is substantially depleted. MNA is typically applicable to sites where the contaminant plume is stable or shrinking.

When sufficient biologically appealing organic carbon and hydrogen are available, bacteria will often deplete the supply of available electron acceptors. In this case, anaerobic, non-oxygen breathing, bacteria will utilize chlorinated solvents as electron acceptors, a process that is referred to as reductive dechlorination (RD). Reductive dechlorination is the principal biological process resulting in the degradation of chlorinated solvents in the subsurface. It is rare to find sufficient naturally occurring organic carbon to promote reductive dechlorination. Though the natural fraction of organic carbon in soil plays a role in RD, it is typically present at too low of levels in Arizona soils to promote RD. Therefore, the organic carbon typically originates from a fuel release (i.e., leaking underground storage tank), leachate from a landfill, or added as part of a remedial action. Reductive dechlorination (RD) is evaluated through observation of VOC daughter products, trends in VOC distributions, and trends in natural attenuation parameters. As shown in **Table 3**, the PCE RD daughter products TCE and c-1,2-DCE have not been historically detected at appreciable concentrations in groundwater samples. Therefore, the groundwater analytical data indicates that biologic degradation by reductive dechlorination is not a factor in MNA at the Site.

Based on the above, MNA consisting of physical processes that include advection and dispersion is retained for remedial alternative development. Progress of an MNA remedy can be measured by the following:

- Monitoring to observe changes in concentration with time;
- Use of statistical trend analyses such as the Mann-Kendall statistic to evaluate concentration trends with time; and,
- Use of simple one-dimensional numerical models to obtain natural attenuation rates and to predict future concentrations.

5.1.2 Enhanced Reductive Dechlorination

Enhanced RD (ERD) is a remedial technology based on injecting substrate and/or nutrients and appropriate bacteria into groundwater to promote anaerobic biodegradation of VOCs.

As previously described, under the right conditions, anaerobic RD can be a naturally occurring biodegradation process whereby microbes can degrade chlorinated VOCs in groundwater. However, as previously discussed, the right conditions are typically not naturally present. Groundwater in Arizona is often aerobic, containing greater than 1.0 milligrams per liter (mg/L) of dissolved oxygen (DO). The DO must be decreased below 1.0 mg/L for anerobic conditions to be present. Most applications use a bio-stimulation substrate to provide a carbon source for driving the aquifer redox conditions lower and at the same time provide a fermentation substrate that releases hydrogen to serve as an electron donor (required for the dechlorination reactions). Injected substrates can promote anaerobic biodegradation. The microbes use a primary substrate as a carbon and energy source. Some microbes produce enzymes and other compounds that degrade the target chlorinated compounds present in groundwater. Other microbes called halorespiring microbes breath the chlorinated VOCs, which are degraded internally by the microbes. A variety of compounds have been used as bio-stimulation amendments for ERD applications. Examples of substrates are sugars, alcohols (methanol, ethanol), lactate, benzoate, and Regenesis Hydrogen Releasing Compound. If naturally occurring microbes become active after injection of a substrate, the reaction could stall at any of the below steps:

$$\text{PCE} \xrightarrow{H^+ + e^- - Cl^-} \text{TCE} \xrightarrow{H^+ + e^- - Cl^-} \text{c-1,2-DCE} \xrightarrow{H^+ + e^- - Cl^-} \text{Vinyl Chloride} \xrightarrow{H^+ + e^- - Cl^-} \text{Ethene}$$

If all the remaining residual PCE concentrations in the Site wells were converted to c-1,2-DCE and the reaction stalled, the AWQSs for PCE (5.0 µg/L), TCE (5.0 µg/L), and c-1,2-DCE (70 µg/L) would be achieved. However, if the reaction progressed to vinyl chloride (VC), which has an AWQS of 2.0 µg/L and is very mobile, VC would become a COC requiring remediation. As previously indicated, the only microbe identified to be capable of degrading PCE to ethene is DHE. This is a sulfate reducing microbe that is not commonly naturally occurring. Therefore, bio-augmentation is a subsequent step during which a microbial mixture is injected into groundwater to initiate or accelerate key dechlorination steps. Depending on the contaminants present and the subsurface conditions, a variety of microbial cultures have been developed and are marketed by specialty vendors.

As with any in-situ technology, success depends on the ability to deliver the substrate to the impacted areas and for microbes to contact the dissolved COC. Vertical ERD wells can be located along the plume in Phoenix street right-of-way (ROW). Manual injections of the substrate and microbial cultures will be required. However, due to the low PCE concentrations, ERD is not considered to be practical for the dilute Site plume. Therefore, biological treatment via ERD was not retained as a viable technology for plume treatment.

5.1.3 Injected Liquified Granular Activated Carbon (LGAC)

This technology has recently been used considerably for source control and control migration of chlorinated COCs. It is also referred to as “trap and treat”. The technology involves injecting LGAC into the subsurface.

The two commonly used products are BOS 100 and Regenesis PlumeStop™. Both products contain LGAC that coat the sediments and "trap" the COCs by sorption. BOS 100 also contains metallic elemental iron to "treat" the chlorinated COCs by chemical reduction. Therefore, BOS 100 removes the contaminants and provides both controlled migration and plume remediation. PlumeStop™ only "traps" the contaminants. AWQSs are achieved; however, the contaminants remain in the subsurface. Therefore, PlumeStop™ is considered a controlled migration technology. LGAC will achieve the ROs. However, the requirement for multiple injection points within the plume makes this technology impracticable for the Site. Therefore, this technology was not retained for alternative development.

5.1.4 In-Situ Chemical Oxidation

In-situ chemical oxidation or ISCO involves chemical reactions that convert contaminants into less toxic or inert compounds. ISCO is implemented by injecting a chemical oxidant into groundwater via a series of injection wells (or other injection methods) to destroy or degrade organic compounds. Several different types of oxidants have been used successfully at chlorinated solvent sites including permanganate, persulfate, catalyzed or activated hydrogen peroxide (HP), and ozone. The objective is to form strong oxidizing radicals that are capable of breaking the chemical bonds of the dissolved COCs. Site-specific aquifer oxidation-reduction (redox) conditions and parameters, hydraulic conductivity, along with oxidant-specific characteristics, need to be evaluated to determine the oxidant dosing and other critical design parameters. Although targeted for destruction of dissolved VOCs in water, the oxidizing agent will also react with the soil matrix; therefore, the radius of influence from the injection points may be limited. Pilot testing and/or bench testing is typically necessary to establish the injection spacing, rates, and oxidant dosing.

Pilot tests using the EN Rx reagent™, which is a catalyzed HP reagent, have recently been performed at the 40th Street and Indian School Road and 38th Street and Indian School Road WQARF sites (Wood, 2017 and Wood, 2018). These WQARF sites are located approximately 0.5 miles west of the Site and are characterized with the same COCs and subsurface soil conditions as the Site. Both pilot tests demonstrated that the EN Rx reagent can be effective in oxidizing the COCs. The EN Rx Reagent™ consists of catalyzed HP, which is the oxygen source. The HP is catalyzed by Synergist-D™, which is a proprietary sodium-based activator. Solid Singlet Oxygen (SSO™) can also be applied and adds a slow release mechanism to the oxygen source. Performing the chemical injection without SSO will not change the dosing. However, SSO increases the oxidation-reduction potential (ORP) and adds to the pulsed nature of equilibrium, which results in more efficient and quicker oxidation. The SSO is injected manually during normal operation & maintenance (O&M) visits and is usually 5 percent (%) or less of the total oxidant delivery. Considering the design of the system presented below, SSO will not be used.

The EN Rx Reagent™ was formulated to operate as a modified Fenton's reagent with the objective to create the hydroxyl radical, which is the strong oxidizer required to destroy VOCs. Therefore, it offers the stability of activated persulfate while providing safety benefits at the viscosity and density of water.

Permanganate was applied at two sites (one as a pilot test and the second as a full remedy) and an activated persulfate reagent called PersulfOx has been applied to three fuel impacted sites. Permanganate and persulfate contain manganese and sulfate, respectively, which are introduced contaminants that often exceed their secondary drinking water standards at injection sites. Permanganate and persulfate solutions

are heavier than water; therefore, they must be extensively diluted to avoid sinking to the bottom of an injection point. Permanganate also results in purple groundwater and requires extensive safety protocols during mixing, which may not be feasible if injected to vertical injector wells in residential areas. Hexavalent chromium is also a secondary contaminant that is often associated permanganate injections.

Ozone requires the use of an ozone generator. To be competitive with other chemical oxidants, the ozone must be injected at a high concentration below the dissolved contamination for the radius of influence to be established. Therefore, electrical costs to operate the ozone generator and required compressor to deliver the ozone may not make this technology cost feasible compared to the other ISCO technologies.

Based on the above, the EN Rx reagent was used for the preliminary remedy design. The primary issues associated with this Site are delivery of the EN Rx reagent to the area of dissolved contamination and contact with the dissolved contamination. Collectively, this is referred to as the treatment zone. Based on the locations of the PCE plumes, the lengths and depths of the PCE plumes, and lithology, vertical injector wells would be the most practicable option to deliver the oxidants to the treatment zones.

ISCO using vertical injectors with the EN Rx reagent conveyed using piping and tubing was used in the preliminary design and cost estimate. The EN Rx reagent will be delivered to the injector wells using the EN Rx Feedback Optimized Continuous Injection System (FOCIS).

The injector well spacing design is based on current conditions and accessible well installation locations. Ambient flow velocity is 0.8 to 1.2 ft/day and the EN Rx reagent is reactive for up to 90 days in the subsurface. Therefore, the EN Rx reagent would be expected to travel approximately 90 ft downgradient over 90 days. Shallow and deep vertical injectors are required to remediate the vertical extent of the PCE plume. The estimated cost for a shallow vertical injector well is $29,000 and a deep vertical injector well is $38,000. These costs include permitting, well installation, field oversight, collection/analysis of vertical profile samples, and investigation derived waste (IDW).

Use of the FOCIS as a continuous injection system will decrease the number of injector wells required, possibly a spacing of approximately 60 ft depending on ROW locations and availability. Along the shallow PCE plume, injector well spacing will be greater due to available ROW cutting across the plume instead of along it. Therefore, up to 26 injector wells (six base plus 20 contingency) may be required for the shallow portion of the PCE plume and 13 injector wells will be required for the deep portion of the PCE plume. Six of the furthest downgradient contingency wells for the shallow portion of the PCE plume are designated as possible contingency upgradient wells for the deeper portion of the PCE plume. If these wells are needed for the deeper portion of the PCE plume, they can be installed as dual cased wells to save costs. Conveyance piping/tubing must be installed to the injector wells using COP street ROW. The estimated cost to install piping/tubing within trenches/utility bores within COP ROW is $200/ft. To decrease the cost for piping/tubing installation, the FOCIS for the deeper portion of the PCE plume is proposed to be installed at the commercial property located at the northeast corner of Piccadilly Drive and 44th Street.

5.1.5 In-Situ Chemical Reduction

In situ chemical reduction (ISCR) is intended to reduce VOC concentrations by using materials such as zero-valent iron to degrade the VOCs. This technology is usually implemented in a permeable reactive barrier or

funnel-and-gate configuration where the zero-valent iron can be installed perpendicular to the groundwater flow direction and the base of the barrier can be tied into a low permeability layer. Elemental iron or zero-valent iron was previously discussed.

Due to the apparent thickness of the plume and the logistical complications associated with excavation or vertical injection at the Site, this technology would be infeasible to implement at this Site. As such, this technology was not retained for further consideration.

5.1.6 Groundwater Extraction and Treatment

This remedial technology involves pumping contaminated groundwater from the plume and treating the groundwater ex-situ before discharge. Groundwater extraction and treatment (GWET) removes and decreases contaminant mass from the aquifer but it is generally more effective in controlling or containing the downgradient migration of a VOC plume. Contaminated groundwater can be treated by activated carbon, air stripping, oxidation, or by other means prior to discharge. Discharge options that may be considered include discharge to a sanitary sewer or a storm drain, a beneficial re-use such as irrigation supply, or reinjection into the aquifer at some location away from the plume.

Groundwater extraction and treatment is typically inefficient at reducing contaminant mass because the concentrations in groundwater are low and it is expensive to install. Based on the evaluation of Site conditions, this remedial technology can meet the Site ROs within a reasonable restoration time frame by itself. It can also be an effective plume containment approach. This remedial technology is not a cost-effective technology for the relatively small distributions of low PCE concentrations. However, this FS includes GWET as one element of the remedy considered for the Site. Therefore, this remedial technology has been retained for further evaluation.

5.1.7 Summary of Screening and Technologies Retained

A summary of screening and specific technologies retained for developing the remedial alternatives is provided as follows:

Technology	Media	Comments	Retained?
Monitoring	Groundwater	Typically used when source has been controlled, geochemical parameters are suitable, and plume is stable or shrinking. With the exception of biodegradation indicators, these components are present.	Yes
ERD	Groundwater	Effective where in situ conditions can be manipulated to create reducing conditions and appropriate bacteria exist or can be introduced into groundwater.	No
Injected LGAC	Groundwater	Effective as a source control and controlled migration technology. Requires multiple injection points.	No
ISCO	Groundwater	Effective for limited extent plumes	Yes
ISCR	Groundwater	Effective when groundwater flow can be directed through a treatment zone that is within depths of typical excavation equipment and structures or infrastructure do not interfere with implementation.	No
GWET	Groundwater	Typically used for plume control rather than mass removal due to expense associated with long-term operations.	Yes

6.0 DEVELOPMENT OF REFERENCE REMEDY AND ALTERNATIVE REMEDIES

Based on the retained remedial technologies presented in Section 5, this section develops and presents the recommended Site remedies including a reference remedy along with alternative remedies (less aggressive and more aggressive remedies). The reference remedy and alternate remedies consist of remedial strategies and actions (remedial measures) to achieve ROs for the Site. The ROs established by RI are presented in **Section 3** and the range of remedial strategies considered, from A.A.C. R18-16-407(F), are summarized in **Section 5**.

As noted in **Section 5**, physical containment and no action are unlikely to be applicable at this Site and the other remedial strategies from A.A.C. R18-16-407(F) (i.e., plume remediation, controlled migration, source control, and monitoring) are used to develop the reference remedy and alternate remedies. For groundwater, each remedy has been identified with consideration of the needs of the local water providers (SRP and COP).

Selected remedial measures are combined with the applicable strategies to develop the reference remedy and alternative remedies. For this Site, the reference remedy and each alternative remedy include contingent remedial measures. The contingent remedial measures are included to address the existing uncertainties regarding certain Site conditions, the achievement of ROs, or uncertain timeframes in which ROs will be achieved. Where remedial measures are necessary to achieve ROs, the remedial measures will be required as long as necessary to ensure the continued achievement of those objectives. The areas where remedial alternatives need to address environmental impacts include the plume areas which are above the PCE AWQS of 5.0 µg/L (from the source to suitable downgradient boundaries) (**Figures 4 and 5**).

The reference remedy was developed based upon best engineering, geological, or hydrogeological judgment following engineering, geological, or hydrogeological standards of practice, considering the following:

- The information in the RI;
- The best available scientific information concerning available remedial technologies; and,
- Preliminary analysis of the comparison criteria and the ability of the reference remedy to comply with A.R.S. §49-282.06.

At a minimum, at least two alternative remedies must be developed for comparison with the reference remedy. At least one of the alternative remedies must employ a remedial strategy or combination of strategies that is more aggressive than the reference remedy, and at least one of the alternative remedies must employ a remedial strategy or combination of strategies that is less aggressive than the reference remedy. For the purposes of this FS, a more aggressive strategy is a strategy that requires fewer remedial measures to achieve remedial objectives, a strategy that achieves remedial objectives in a shorter period of time, or a strategy that is more certain in the long term and requires fewer contingencies.

The reference remedy and the alternative remedies are presented in the following sections. Discussion of the remedies includes a discussion of the associated remedial measures and remedial strategies pursuant to A.A.C. R18-16- 407(E). The remedial alternatives presented includes a group of similar and related remedial measures; therefore, the discussion of individual remedial measures is presented after the discussion of the remedial alternatives. Considering that the reference and more aggressive remedies involve monitoring with a contingency remedial measure, the discussion of remedial alternatives is presented in order as follows; less aggressive remedy, more aggressive remedy, and reference remedy.

6.1 Less Aggressive Alternative Remedy

This section describes the Less Aggressive Remedy, which is MNA. Though only requiring a single remedial measure, MNA is identified as the Less Aggressive Remedy because it does not require installation of a remediation system and is considered the longest-term remedy Due to the limited extent of the PCE plume, the remedial strategy for the less aggressive remedy from A.A.C. R18-16-407(F) are:

- Monitoring to observe and evaluate the contamination at the Site through the collection of data; and;
- Contingency remedial measures to address potential uncertainties.

The ultimate remedial strategy is plume remediation, which is expected to be achieved within the foreseeable future. Monitoring wells SMW-18 and SMW-19 are planned to monitor performance of the remedy. Considering planned future groundwater uses in the area, MNA will likely not be approved as a standalone remedy without the inclusion of a contingency active remedial measure. Therefore, the More Aggressive and Reference Remedies evaluated are also MNA with implementation of contingency remedial measures.

6.1.1 Monitoring

As previously stated, PCE concentrations are expected to decrease via physical processes that include advection and dispersion. Measurement of progress and prediction of the time required for natural attenuation to achieve the remedial goals requires statistical trend analysis of data and use of simple one-dimensional numerical models. These will be performed at the remedy design phase. For the purposes of this FS, a pore water volume flushing analysis was performed. Ambient groundwater flow velocity for the aquifer is 0.8 to 1.4 ft/day. An exchange of four pore volumes of water was used to estimate the time required to remove sufficient dissolved and sorbed VOC mass to achieve the cleanup goals. The cross-sectional area for the PCE plume is about 3,500 square feet. Assuming an average flow velocity of 1.0 ft/day, approximately 26,000 gallons of water flows into and out of the PCE remediation area each day or approximately 9,490,000 gallons per year. At an estimated porosity of 30 percent, the volume of water within the PCE plume is 26,289,440 gallons. Four times this amount is 105,157,760gallons. Therefore, the estimated amount of time for four pore volumes of water to move through the remediation area is 11 years.

An additional four years is added to confirm achievement of the remedial goal. For comparison purposes and to simplify cost estimation, a 15 year semi-annual groundwater monitoring program is assumed. This will be revised based on additional data evaluation and numerical modeling performed during the remedial design phase.

6.1.2 Contingencies

Contingencies for the Less Aggressive Remedy are limited to the following:

- A deeper monitoring well may be required if the deep VPS results from SMW-18 and SMW-19 indicate that the point where the PCE plume dives is located further upgradient than depicted in **Figures 4 and 5**.
- Monitoring may continue beyond 15 years.

6.1.3 Permits and Agreements

Permits and/or agreements would be necessary to perform the Less Aggressive Remedy, including:

- Pre-construction notifications (i.e., ADWR Notice of Intent to Drill) and postconstruction reporting (Driller's Reports) would be prepared for any new groundwater 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;
- ADEQ has ROW permits providing access to existing monitoring wells within COP street ROW. ROW permits would be required from COP for installation of new wells within street ROW; and,
- ADEQ has an access agreement with Arcadia Towne Center to monitor on-site wells.

6.2 More Aggressive Alternative Remedy

This section describes the More Aggressive Remedy, which is also MNA. However, a long-term standalone MNA remedy will not be approved without a contingency active remedy. Therefore, the More Aggressive Remedy includes an ISCO component. Considering this remedial alternative includes two remedial measures and is intended as a shorter-term remedy compared to the Less Aggressive and Reference Remedies, it is identified as the More Aggressive Remedy. Due to the extent of the PCE plume, the remedial strategies for the More Aggressive Remedy from A.A.C. R18-16-407(F) are as follows:

- Plume remediation to achieve water quality standards for COCs in waters of the state throughout the Site;
- Monitoring to observe and evaluate the contamination at the site through the collection of data; and,
- Contingency remedial measures to address potential uncertainties.

The factors associated with the success of the contingency ISCO system to achieve the remedial strategy are delivery of the reagent and contact between the reagent and the target COCs.

Proposed ISCO system layouts for the shallow and deeper portions of the defined PCE plume for cost estimating purposes are provided as **Figure 9**. The ISCO remediation component may be implemented if PCE concentrations do not demonstrate a decreasing trend and estimated groundwater flow velocity does not increase within five years. This will be determined using the following:

- Monitoring to observe changes in concentration with time;
- Use of statistical trend analyses such as the Mann-Kendall statistic to evaluate concentration trends with time; and,
- Use of simple one-dimensional numerical models to obtain natural attenuation rates and to predict future concentrations.

If these conditions are observed and predictive modeling indicates that the remedial goals may be achieved within the estimated time that includes the ISCO remedial component, the Less Aggressive Remedy will continue to be implemented until either the cleanup goals are achieved or implementation of the ISCO remedial measure. The design assumes the ISCO component will be implemented during Year 6 of the monitoring program.

6.2.1 Monitoring Program

The monitoring program will be the same as described for the Less Aggressive Remedy.

6.2.2 ISCO System Component

Due to the overall length of the PCE plume, the preliminary design involves installation of two remediation systems; one to remediate the shallow upgradient portion of the plume and one to remediate the deep downgradient end of the plume. **Figure 9** provides the preliminary layout of the injection wells. This is

considered a focused treatment. The EN Rx Reagent™ is proposed to be delivered to the treatment area using the EN Rx FOCIS™. The EN Rx FOCIS™ for the shallow portion of the PCE plume will be located at Arcadia Towne Center. The EN Rx FOCIS™ that will be used for the downgradient deeper portion of the PCE plume will be placed behind the commercial business building located at the northeast corner of Piccadilly Drive and 44th Street.

Along with the existing wells, monitoring wells SMW-18 and SMW-19 previously discussed (**Figure 4**) will be used to monitor the remedy. As discussed in **Section 5.1.4**, delivery of the EN Rx reagent will be conducted using vertical injector wells.

6.2.2.1 System Installation

The ISCO injection well network is shown on **Figure 9**. Monitoring wells SMW-07 and SMW-03-60 will be utilized as full-cycle wells. Specifically, they will be used initially for injection and then used for post-ISCO monitoring. Based on the focused treatment area, the ISCO injection well network for the shallow portion of the PCE plume will consist of six wells, including existing wells SMW-07 and SMW-03-60. Each new injection well will be installed to 60 ft bgs with 2-inch diameter casing and will be screened from 45-60 ft bgs. Three injection wells may be installed on Arcadia High School property and one injection well is planned to be installed in City of Phoenix street ROW. For remedial alternative cost estimation purposes, the estimated cost for each shallow injector well is $29,000 including permits, installation, oversight, and collection of vertical profile samples. Mix water will be obtained by installing a solar powered 12-volt one (1) gallon per minute (gpm) submersible pump in existing well SMW-16B. Therefore, a short trench will be required to run electricity and water lines from the well to the FOCIS™. For cost estimation purposes, 1,200 linear feet of piping/tubing at an estimated cost of $200/ft is required to convey the EN Rx to the six vertical injector wells.

The ISCO injection well network for the deeper downgradient portion of the PCE plume will consist of 13 wells. Each injection well will be installed to 120 ft bgs with 2-inch diameter casing and will be screened from 100-120 ft bgs. The injection wells are planned to be installed in COP street ROW. For remedial alternative cost estimation purposes, the estimated cost for each deep injector well is $38,000 including permits, installation, oversight, collection/analysis of vertical profile samples, and IDW.

To decrease costs to install piping/tubing and increase injection efficiency, the FOCIS™ that will be provided by EN Rx will be installed in an enclosed and secured trailer that will be placed behind the commercial business building located at the northeast corner of Piccadilly Drive and 44th Street. The FOCIS™ will be solar powered; therefore, on-site electricity is not required. Mix water will be obtained from an on-site water supply. Therefore, a short trench will be required to run a water line from an available spigot to the FOCIS™. For cost estimation purposes, 1,700 linear feet of piping/tubing at an estimated cost of $200/ft is required to convey the EN Rx to the 13 vertical injector wells.

The FOCIS™ that will be provided by EN Rx will be installed in an enclosed and secured trailer. The FOCIS™ will be solar powered; therefore, on-site electricity is not required.

6.2.2.2 FOCIS™ Operation and Maintenance

The FOCIS™ pulse injects the EN Rx Reagent™ to the vertical injector wells. The system is remotely web-based monitored and controlled. Each FOCIS™ will be operated continuously for nine months each year over which time 29,025 pounds of the EN Rx reagent will be delivered. This assumes once monthly O&M visits to fill the tanks. There will also be brief once weekly visits to check system operation. For cost estimation purposes, the system will be operated up to three years.

6.2.2.3 Monitoring

Monitoring will be required to evaluate performance of the ISCO remedy and achievement of the remedial goals. For comparison purposes and to simplify cost estimatation, three years of semi-annual groundwater sampling is proposed to monitoring system performance. An additional three year post-remediation bi-annual sampling program is proposed to demonstrate that PCE has been remediated below 5.0 µg/L. Based on results, monitoring wells outside the shallow PCE plume may be eliminated from the sampling program. Therefore, selected vertical injection wells may be included in the post-remediation rebound/closure monitoring program. For cost estimation purposes, a total of 11 years of bi-annual monitoring is estimated to demonstrate the remedial goal has been achieved.

6.2.3 Contingencies

Contingencies for the More Aggressive Alternative Remedy for the PCE plume are limited to the following:

- Based on the results for new wells SMW-18 and SMW-19, the shallow portion of the PCE plume is larger than the focused treatment area of SMW-07 and SMW-03-60. Assuming the entire inferred extent of the plume shown on **Figure 9**, an additional 20 vertical injector wells and 3,100 linear ft of piping is assumed for cost estimation purposes.

- The deeper portion of the PCE plume extends further upgradient than currently estimated. To address this contingency, the six furthest contingency downgradient injection well locations for the shallow PCE plume (**Figure 9**) may be utilized for deep vertical injection wells. An estimated 1,000 ft of additional chemical conveyance piping/tubing is estimated.

- Operation of the ISCO system beyond three years. Cost estimate assumes two additional years.

6.2.4 Permits and Agreements

Permits and/or agreements would be necessary to authorize installation and operation of the More Aggressive Remedy for the shallow PCE plume, including:

- Pre-construction notifications (i.e., ADWR Notice of Intent to Drill) and postconstruction reporting (Driller's Reports) would be prepared for any new groundwater injection/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;

- ROW permits would be required from COP for installation of the vertical injection wells and associated piping/tubing; and,

- Access agreements with Arcadia Towne Center and the owner of the property located at the northeast corner of 44th Street and Piccadilly Drive will be required to install and operate the FOCIS™.

6.3 Reference Remedy

This section describes the Reference Remedy, which is also MNA. However, a long-term standalone MNA remedy will not be approved without an active remedial component. Therefore, the reference remedy includes a GWET component. Considering this remedial alternative includes two remedial measures and is intended as a shorter-term remedy compared to the Less Aggressive Remedy and is a longer term remedy compared to the More Aggressive Remedy, it is identified as the Reference Remedy. Due to the limited extent of the PCE plume, the remedial strategies for the Reference Remedy from A.A.C. R18-16-407(F) are as follows:

- Plume remediation to achieve water quality standards for COCs in waters of the state throughout the Site;
- Monitoring to observe and evaluate the contamination at the site through the collection of data; and,
- Contingency remedial measures to address potential uncertainties.

A common treatment system will be used. Therefore, the Reference Remedy is proposed for the PCE plume.

6.3.1 Monitoring Program

The monitoring program will be the same as described for the less aggressive remedy.

6.3.2 GWET System Component

The GWET remediation component may be implemented if PCE concentrations do not demonstrate a decreasing trend and estimated groundwater flow velocity does not increase within five years. This will be determined using the following:

- Monitoring to observe changes in concentration with time;

- Use of statistical trend analyses such as the Mann-Kendall statistic to evaluate concentration trends with time; and,

- Use of simple one-dimensional numerical models to obtain natural attenuation rates and to predict future concentrations.

If these conditions are observed and predictive modeling indicates that the remedial goals may be achieved within the estimated time that includes the GWET remedial component, the Less Aggressive Remedy will continue to be implemented until either the cleanup goals are achieved or implement the contingency GWET remedial measure. The design assumes the GWET remedial component will be implemented during Year 6 of the monitoring program.

The preliminary design of the GWET system is based on the current distributions of the PCE plume (**Figures 4 and 5**). Two extraction wells are designed with a designed pumping rate of 30 gallons per minute (gpm) from each well. The treated water will be managed by re-injection, which will be re-injected to available monitoring wells at the source location; ECP-01, ECP-02, ECP-03, SMW-01, SMW-07, and SMW-16B. The treatment system, which will consist of granular activated carbon (GAC), will be installed at Arcadia Towne Center at the approximate location of the ERA SVE system. Well SMW-03-60 will be used as an extraction well.

The treatment system will consist of two 2,000 pound (lb) GAC vessels. The vessels will be placed at the approximate location of the former SVE system. For cost estimation purposes, 1,000 ft of injection pipe trenching is estimated at a cost of $200,000.

6.3.3 GWET System Operation and Maintenance

Based on the maximum influent PCE concentration of 31 µg/L and a pumping rate of 60 gpm, the design involves two 2,000 lb GAC vessels connected in series. For cost estiamting purposes, one GAC changeout per year is scoped.

The dissolved mass in the plume is very low at the maximum PCE concentration of 31 µg/L. However, sorbed mass could be up to six times higher. A minimum of four pore volumes of water should be extracted and treated to remove sufficient dissolved and sorbed mass to achieve the cleanup goal. At an estimated porosity of 30 percent, the volume of water within the PCE plume is 26,289,440 gallons. Four times this amount is 105,157,760 gallons. At a pumping rate of 30 gpm, 15,768,000 gallons of water will be pumped per year. Therefore, an estimated 7 years may be required to extract and treat four pore volumes of water.

6.3.4 GWET System Monitoring

Monitoring will be required to evaluate performance of the contingency GWET remedial measure and achievement of the remedial goals. Bi-annual groundwater monitoring will be performed during GWET system operation to monitor performance, a total of 7 years. An additional three year post-remediation bi-annual sampling program is proposed to demonstrate that PCE has been remediated below 5.0 µg/L. Based on results, monitoring wells may be eliminated from the sampling program or the time period decreased. For cost estimation purposes, a total of 10 years of bi-annual monitoring is estimated to demonstrate the remedial goal has been achieved.

6.3.5 Contingencies

Contingencies for the reference remedy for the are limited to the following:

- Downgradient extension of the shallow extraction well based on analytical results for monitoring wells SMW-18 and SMW-19. Cost assumes an additional 800 linear feet of piping to SMW-18.
- Operation of the GWET system beyond seven years. Cost estimate assumes a total of three additional years.

6.3.6 Permits and Agreements

Permits and/or agreements would be necessary to authorize installation and operation of the Reference Remedy, including:

- Pre-construction notifications (i.e., ADWR Notice of Intent to Drill) and postconstruction reporting (Driller's Reports) would be prepared for any new groundwater horizontal/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;
- ROW permits would be required from COP for installation of the horizontal wells below street ROW; and,
- Access agreements with Arcadia Towne Center would be required to install the horizontal wells and associated piping to re-inject treated water to the designated monitoring wells. Access agreements may also be required for private properties that the horizontal wells cross.
- A PQGWWP will be required from ADWR, which will include annual reporting.

6.4 Discussion of Specific Remedial Measures

Based on recent analytical results for SMW-03-60 and BMW-05B, PCE concentrations in samples collected from these wells have generally been steady or increasing. However, it is expected that PCE concentrations should decrease over the next five years as a result of the declining water table for the shallow portion of the PCE plume and a possible increased groundwater flow velocity across the Site due to resumption of downgradient pumping. Based on these conditions, plus the relatively low PCE concentrations observed in groundwater, MNA was evaluated as a standalone Less Aggressive Remedy. However, based on possibly future groundwater uses at and in the vicinity of the Site, MNA as a standalone remedy cannot be selected as the proposed remedy without a contingency remedial measure or combination of remedial measures. Therefore, the More Aggressive and Reference Remedies include a combination of MNA and other remedial measures/technologies as possible components.

7.0 DETAILED COMPARISON OF THE REFERENCE REMEDY AND THE ALTERNATIVE REMEDIES

The following section compares the Reference Remedy and alternative remedies to criteria described in A.A.C R18-16-407H.3.

7.1 Comparison Criteria

In accordance with A.A.C R18-16-407E.3, the FS has been completed to identify a Reference Remedy and alternative remedies that are potentially capable of achieving ROs, and to evaluate the remedies based on the comparison criteria in order to select a remedy that complies with A.R.S §49-282.06. A.A.C R18-16-407H specifies that practicability, risks, costs, and benefits are the primary remedy evaluation criteria.

Practicability includes the assessment of feasibility, short- and long-term effectiveness, and the reliability of the remedial alternative. The risk criteria include 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, O&M, 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.

Table 4 presents a detailed evaluation of the remedies for PCE dissolved in the groundwater with respect to the comparison criteria. 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).

The most aggressive and reference remedial alternatives include contingency measures to the less aggressive remedial alternative, which is monitoring.

7.1.1 Less Aggressive Remedy

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

7.1.1.1 Practicability

The Less Aggressive Alternative Remedy for the plume consists of MNA. MNA is a known and effective remedy given the inferred condition of the PCE plume. Semiannual monitoring will assess effectiveness. Considered a long-term remedy for the Site if current groundwater flow velocity and levels remain unchanged. However, MNA may be a shorter-term remedy if groundwater flow velocity increases. No significant technological or hydrogeological barriers to application are anticipated. This remedy is considered to be feasible.

7.1.1.2 Protectiveness (Risk)

No aquatic or terrestrial biota are at risk from the impacts associated with the plume. The Less Aggressive Alternative Remedy for the Site is protective of human health because groundwater within the Site PCE plume is not currently being used.

7.1.1.3 Cost

Costs for the Less Aggressive Alternative Remedy are presented in **Table 4** and detailed costs are presented in **Appendix B-1**. The capital costs for the groundwater Less Aggressive Alternative Remedy are limited to installation of performance monitoring wells. Capital costs are estimated to be approximately $159,000 and monitoring costs are estimated to be approximately $688,000. The total cost for the Less Aggressive Alternative Remedy including contingencies is approximately $1.03 million (M) over 18 years (15 years plus three contingency years), with a margin of error between $933,000 (-30%) and $1.99M (+50%).

7.1.1.4 Benefits

Under the current ambient groundwater flow velocity, the Less Aggressive Remedy for the PCE plume provides less benefit than the Reference or More Aggressive Remedies for the Site due to the longer anticipated time to achieve the remedial goals. However, if dissolved PCE concentrations demonstrate a decreasing trend due to declining water table and/or increased groundwater flow velocity resulting from resumption of downgradient pumping, remedial goals may be achieved in seven years or less. Under this scenario, the Less Aggressive Remedy may represent the most beneficial remedy due to the significantly lower cost than the More Aggressive and Reference Remedies.

7.1.2 More Aggressive Alternative Remedy

The More Aggressive Remedy is MNA with ISCO components for the PCE plume. This remedial alternative is intended to achieve the remedial goals in the shortest time period. The practicability, risk, cost, and benefits for implementation of the More Aggressive Remedy are discussed in the following subsections.

7.1.2.1 Practicability

The More Aggressive Remedy expands the Less Aggressive Remedy of MNA to include implementation of ISCO components to achieve the remedial goals for the PCE plume. ISCO components may be implemented if PCE concentrations do not demonstrate a decreasing trend and estimated groundwater flow velocity does not increase within five years. If these conditions are observed, the Less Aggressive Remedy will continue to be implemented until either the remedial goals are achieved or implementation of the ISCO remedial measure.

EN Rx reagent injection is a well-established technology for remediation of PCE impacted groundwater. As a result, this remedy is considered feasible. However, there are challenges with installing injection points and conveyance piping within COP ROW. These include COP permitting, temporary disruption of traffic, and installation near residences and businesses.

7.1.2.2 Protectiveness (Risk)

The More Aggressive Remedy for the plume is comparably protective of human health and the environment with the Less Aggressive Remedy.

7.1.2.3 Cost

Costs for the More Aggressive Remedy are presented in **Table 4** and detailed costs are presented in **Appendix B-2**. Capital costs for the More Aggressive Remedy are higher than for the Less Aggressive and Reference Remedies because the general scope includes installation of multiple vertical injection wells with the EN Rx reagent conveyed using piping/tubing installed in City of Phoenix ROW. O&M costs are also higher due to the annual costs of chemicals. Capital costs are estimated to be approximately $1.94M and O&M costs are estimated to be approximately $1.34M. The total estimated cost for the More Aggressive Remedy including contingency is approximately $6.13M, with a margin of error between $4.33M (-30%) and $9.27M (+50%).

7.1.2.4 Benefits

In the event PCE concentrations do not decrease and groundwater flow velocity does not increase within five years, the More Aggressive Remedy expands the Less Aggressive Remedy to include contingency active ISCO treatment of the PCE plumes. A conservative active remediation period of three years has been retained as the More Aggressive Remedy. This is followed by a three-year post-remediation monitoring period to demonstrate PCE concentrations remain below 5.0 µg/L. Total estimated time to achieve the cleanup goal is 11 years (five years monitoring, three years active ISCO, plus three years post-remediation monitoring).

7.1.3 Reference Remedial Alternative

The Reference Remedy is MNA with GWET components for the PCE plume. The Reference Remedy is intended to achieve the remedial goal in a shorter time period than the Less Aggressive Remedy, but in a longer time period than the More Aggressive Remedy. Therefore, MNA with GWET components is presented as the Reference Remedy. The practicability, risk, cost, and benefits for implementation of the Reference Remedy are discussed in the following subsections.

7.1.3.1 Practicability

The Reference Remedy expands the Less Aggressive Remedial Alternative of MNA to include implementation of GWET components to achieve the remedial goals for the PCE plume. The GWET components may be implemented if PCE concentrations do not demonstrate a decreasing trend and estimated groundwater flow velocity does not increase within five years. If these conditions are observed, the Less Aggressive Remedy will continue to be implemented until either the cleanup goals are achieved or implementation of the GWET remedial component.

GWET is a well-established technology for remediation of PCE impacted groundwater. However, it is typically considered a long-term controlled migration technology due to low mass removal rates. As a result, this remedy is considered feasible. However, there are challenges with installing electrical and water

lines within COP ROW. These include COP permitting, temporary disruption of traffic, and installation near residences and businesses.

7.1.3.2 Protectiveness (Risk)

The Reference Remedy is comparably protective of human health and the environment with the Less Aggressive Remedy.

7.1.3.3 Cost

Costs for the Reference Remedy are presented in **Table 5** and detailed costs are presented in **Appendix B-3**. Capital costs for the Reference Remedy are higher than the Less Aggressive Remedy due to installation of piping from extraction wells to the treatment system. Capital costs are estimated to be approximately $1.55M and O&M costs are estimated to be approximately $1.15M. The total estimated cost for the Reference Remedy including contingency is approximately $3.22M, with a margin of error between $2.25M (-30%) and $4.83M (+50%).

7.1.3.4 Benefits

In the event PCE concentrations do not decrease and groundwater flow velocity does not increase within five years, the Reference Remedy expands the Less Aggressive Alternative Remedy to include GWET components to remediate the PCE plumes. A conservative active remediation period of 10 years has been retained as the Reference Remedy for the PCE plume, respectively. This includes a three-year post-remediation monitoring period to demonstrate PCE concentrations remain below 5.0 µg/L.

7.2 Comparison of Remedies

Comparison of the remedies is required under A.A.C R18 16-407(H). The three evaluated remedies are all capable of achieving the ROs for groundwater and result in plume remediation. The differences are the timeframe and cost required to achieve the ROs. **Table 4** presents a ranking of the comparison criteria for each of the remedies. Each remedy was ranked from zero to five, with five indicating the most relative benefit and zero indicating the least relative or no benefit. The following subsections describe the practicability, risk, cost, and benefits comparison for the remedies.

7.2.1 Practicability

There are four considerations for practicability as follows:

- Feasibility involves the ability to put the remedy in place;
- Short-term effectiveness represents how much the remedy removes the PCE and limits the potential for exposure in the short-term;
- Long-term effectiveness represents how much the remedy removes the PCE and limits the potential for exposure in the long-term; and,

- Reliability involves whether the technologies comprising the alternative are expected to perform reliably.

The Less Aggressive Alternative Remedy is considered feasible. A score of 5 was assigned for feasibility. The Less Aggressive Alternative Remedy is a long-term remedy. Therefore, it is not considered effective in the short-term without addition of the contingency remedial measures provided with the Reference and the More Aggressive Remedies. Monitoring is required to demonstrate that the remedial goals have been achieved and rebound will not occur. Therefore, the Less Aggressive Alternative Remedy will provide long-term effectiveness. The Less Aggressive Alternative Remedy may require the longest period of time to achieve the remedial goals. Therefore, a score of 3 was assigned for short/long term effectiveness. However, this score may increase if conditions indicate a shorter timeframe. BMW-05A/B are the furthest downgradient Site wells and are located near the boundary to the adjacent 40th & OSB site. Additional downgradient wells are not required to monitor migration. Therefore, the Less Aggressive Remedy is considered reliable. The Less Aggressive Alternative Remedy had total practicability score of 13.

The More Aggressive Remedy consists of the Less Aggressive Remedy with the possibility of installing ISCO systems for the PCE plume. The remedy is feasible, considered effective in both the short and long term, and is reliable. The More Aggressive Remedy had a practicability score of 15.

The Reference Remedy consists of the Less Aggressive Remedy with the contingency of installing a GWET system. The Reference Remedy is considered feasible. The remedy is considered effective in both the short and long term and is reliable; however, due to it being longer-term than the More Aggressive Alternative Remedy, it was scored a 4. The Reference Remedy had a practicability score of 14.

7.2.2 Protectiveness (Risk)

Due to the extents and low PCE concentrations of the PCE plume, all three evaluated remedial alternatives are expected to achieve the remedial goals within 20 years, which is considered a reasonable timeframe. At the current ambient groundwater flow velocity, the Less Aggressive Remedy will require the most amount of time, particularly for the shallower portion of the PCE plume. However, this time may be decreased if downgradient groundwater pumping resumes. The More Aggressive Alternative Remedy is considered more protective than the Reference Remedy due to the shorter time period to achieve the remedial goal.

7.2.3 Cost

The three remedies have varying capital and O&M costs. Including the capital, O&M, and contingency costs, it is estimated that the Less Aggressive Remedy would cost the least ($1.4M), the Reference Remedy cost would be moderate ($3.5M), and the More Aggressive Alternative Remedy would cost the most ($6.2M).

7.2.4 Benefit

The three evaluated remedies have similar benefits in that the ROs are achieved within a reasonable timeframe of less than 20 years. However, the More Aggressive Remedy scored the highest because the ROs are expected to be achieved in the least amount of time, though this remedy will cost the most. The Less Aggressive Remedy may ultimately prove to be the most beneficial if PCE concentrations begin

decreasing due to resumption of downgradient pumping, which may result in less time and lower costs than the More Aggressive and Reference Remedies.

8.0 PROPOSED REMEDY

8.1 Process and Reason for Selection

As previously discussed, the available remedial technologies to achieve the groundwater ROs are limited due to the sizes and depths of the PCE plume, the hydrogeological and geochemical conditions at the Site, and the highly developed urbanized nature of the Site. The Less Aggressive Remedy requires the inclusion of additional remedial measures to expedite achievement of the groundwater ROs. Therefore, the recommended remedy for the site is the More Aggressive Remedy. The More Aggressive Remedy consists of an initial five-year semi-annual groundwater monitoring program. The following remedial pathways may occur:

- If PCE concentrations decrease within the first five years of the remedy as a result of resumption of downgradient pumping, continue the Less Aggressive Remedy; or,
- If PCE concentrations do not decrease within the first five years of the remedy, implement the ISCO remedial measure.

Semiannual groundwater monitoring will be used to assess the PCE plume stability and monitor decreasing VOC concentrations at the Site. This recommendation is based on what is the best combination of remedial effectiveness, practicability, cost, and benefit for restoration and use of groundwater resources. The groundwater More Aggressive Remedy scored the highest based on current conditions when ranking in accordance with the comparison criteria specified in A.A.C R18 16-407H.3.e (**Section 7**).

8.2 Achievement of Remedial Objectives

The More Aggressive Remedy for PCE in groundwater will achieve the ROs for the Site (**Section 3.3**). It will provide contingency active remediation of the dissolved PCE plumes using ISCO, which, based on current conditions, will result in a decreased number of years required for MNA of the PCE plume concentrations.

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

To meet the remedial action criteria listed in ARS §49-282.06, it is recommended that the More Aggressive Remedy for PCE in groundwater be selected as the Final Remedy for the Site. The More Aggressive Remedy will:

- Provide for adequate protection of public health and welfare and the environment;
- To the extent practicable, provide for the control, management, and cleanup of the dissolved PCE in the groundwater;
- Provide for the beneficial future use of the groundwater resource; and,

- Be reasonable, necessary, cost-effective, and technically feasible.

8.4 Consistency with Water Management and Land Use Plans

The More Aggressive Remedy for groundwater is consistent with water management plans and general land use plans.

9.0 COMMUNITY INVOLVEMENT

ADEQ will issue a Notice to the Public announcing availability of FS Report on ADEQ's website at www.azdeq.gov. The notice may be mailed to the Public Mailing List for the site, water providers, the CAB, and any other interested parties.

ADEQ will issue a Notice to the Public announcing the availability of FS on ADEQ's website at www.azdeq.gov. 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 can be made to review related documentation.

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TABLES

TABLE 1
WELL CONSTRUCTION DATA
EAST CENTRAL PHOENIX WATER QUALITY ASSURANCE REVOLVING FUND SITE 48TH STREET AND INDIAN SCHOOL ROAD SITE

ECP SUB AREA	WELL ID	ADWR REGISTRATION NUMBER	DATE COMPLETED	DRILLING METHOD	BORING DIAMETER (INCHES)	BORING DEPTH (FEET BGS)	CASING MATERIAL/ DIAMETER/ SLOT SIZE (INCHES)	PERFORATED INTERNAL (FEET BGS)	SAND PACK INTERVAL (FEET BGS)	FILTER PACK MATERIAL	BENTONITE SEAL (FEET BGS)	TOP OF CASING ELEVATION (1) (FEET ASML)	GROUND SURFACE ELEVATION (1) (FEET ASML)	LOCATION COORDINATES (2)	
														LATITUDE (DEG)	LONGITUDE (DEG)
48	SRP19E-8.1N	617857	6/1/1971	Cable Tool	18	300	Steel / 18 /Louver	82 - 261	NR	NR	NR	NR	NR		
48	ECP-01	587191	8/2/2001	Dual Tube Rotary	11	71.0	PVC / 6 / 0.020	10 - 70	10 - 71	#10-20 Sand	NR	1241.28	1241.53	33.4953	-111.9802
48	ECP-02	587192	7/19/2001	Sonic	8.625	125.0	PVC / 4 / 0.010	85 - 120	80 - 125	#10-20 Sand	NR	1244.49	1244.74	33.7287	-111.9793
48	ECP-03	587193	7/19/2001	Sonic	8.625	55.0	PVC / 4 / 0.010	10 - 50	10 - 55	#10-20 Sand	NR	1244.35	1244.95	33.4954	-111.9793
48	SMW-01	533298	4/1/1992	Hollow Stem Auger	6.25	55.0	PVC / 4 / 0.010	15 - 55	14 - 55	#10-20 Sand	8 - 14	1241.21	1241.82	33.4953	-111.9802
48	SMW-02	535795	7/31/1992	Hollow Stem Auger	6.25	55.0	PVC / 4 / 0.020	15 - 55	13 - 55	#10-20 Sand	10 - 13	1248.61	1248.88	33.4961	-111.9782
48	SMW-03-060*	543424	5/9/1994	Hollow Stem Auger	8.25	140.0	PVC / 2 / 0.020	13 - 60	11 - 65	#10-20 Sand	9 - 11	1236.71	1237.47	33.6779	-111.9822
48	SMW-03-138*	543424	5/9/1994	Hollow Stem Auger	8.25	140.0	PVC / 2 / 0.020	100 - 140	92 - 140	#10-20 Sand	65 - 92	1236.66	1237.47	33.6779	-111.9822
48	SMW-04	907363	12/11/2007	Sonic	8.625	60.0	PVC / 4 / 0.020	20 - 60	17 - 60	8/12 Sand	15 - 17	1238.40	1238.72	33.4950	-111.9809
48	SMW-05	908628	3/18/2008	Hollow Stem Auger	10	60.0	PVC / 4 / 0.020	20 - 60	18 - 60	8-12 Sand	15 -18	1239.50	1239.76	33.4953	-111.9809
48	SMW-06	914016	4/10/2012	Hollow Stem Auger	10	60.0	PVC / 4 / 0.020	20 - 60	17 - 60	8 - 12 Sand	15 - 17	1227.84	1228.12	33.4932	-111.9831
48	SMW-07	913979	1/12/2012	Hollow Stem Auger	10	60.0	PVC / 4 / 0.020	20 - 60	17 - 60	#10-20 Sand	15 -17	1240.43	1240.75	33.4950	-111.9802
48	SMW-08	913980	1/13/2012	Hollow Stem Auger	10	60.0	PVC / 4 / 0.020	20 - 60	17 - 60	#10-20 Sand	15 - 17	1243.65	1244.02	33.4956	-111.9801
48	BMW-05A	916202	1/9/2014	Sonic	8.625 6.0	66.0 67.0	PVC / 4 / 0.020	29.6 - 64.6	26.3 - 66.0	#10-20 Sand	23.0 - 26.3	1212.81	1213.29	33.4925	-111.9895
48	BMW-05B	916203	1/10/2014	Sonic	8.625 6.0	115.0 116.0	PVC / 4 / 0.020	75.1 - 115.1	68.8 - 115.5	#10-20 Sand	63.2 - 68.8	1212.87	1213.41	33.4925	-111.9895
48	BMW-06A	916204	1/9/2014	Sonic	8.625 6.0	61.0 62.5	PVC / 4 / 0.020	30.3 - 60.3	27.0 - 60.5	#10-20 Sand	23.0 - 27.0	1214.27	1214.73	33.4908	-111.9865
48	BMW-06B	916205	1/10/2014	Sonic	8.625	120	PVC / 4 / 0.020	75.4 - 110.4	72.0 - 111.0	#10-20 Sand	68.0 - 72.0 111.0 - 115.0	1214.50	1215.09	33.4908	-111.9865
48	SMW-11	918939	5/19/2016	Sonic	8.625	165.00	PVC / 4 / 0.020	50.2 - 70.2	48 - 71	#10-20 Sand	42.8 - 48	1221.38	1221.99	33.4929	-111.9856
48	SMW-12	919290	5/27/2016	Sonic	8.625	180.00	PVC / 4 / 0.020	144.9 - 164.9	143 - 166	#10-20 Sand	133.5 - 143	1212.19	1212.70	33.4915	-111.9886
48	SMW-16B	921439	3/16/2018	Sonic	8.25 6.125	214.0 216.0	PVC / 4 / 0.020	90.7 - 130.7	87.8 - 131.2	#10-20 Sand	80.2 - 87.8	1240.24	1240.67	33.4950	-111.9802
48	SMW-17	923913	4/14/2020	Sonic	9.0	120	PVC / 4 / 0.020	30 - 60	27.0 - 60.0	#10-20 Sand	20.0 - 27.0	1230.34	1230.78	33.4962	-111.9858
48	BMW-12B	922019	10/26/2018	Sonic	9.0	185.0	PVC / 4 / 0.020	120.0 - 170.0	118.0 - 172.0	#10-20 Sand	116.0 - 118.0	1209.13	1209.54	33.4746	-111.9904

NOTES:

* wells installed within the same borehole
(1) NAVD88
(2) GRID, NAD83, Arizona Central 202
48 East Cental Phoenix Water Quality Assurance Revolving Fund Site - 48th Street and Indian School Road Site
ADWR Arizona Department of Water Resources
FEET BGS feet below ground surface
FEET AMSL feet above mean sea level
NR Not Reported
Sonic Rotosonic drilling method
SRP Salt River Project

TABLE 2. OCTOBER 2019 AND MAY 2020 GROUNDWATER MONITORING DATA

Well I.D	ADEQ Number	ADWR Number	Date	Measuring Point Elevation (ft. AMSL)	Depth to Groundwater (ft.)	Groundwater Elevation (ft. AMSL)	Change Since Previous (ft.)[1]	Comments
ECP-01	69398	55-587191	10/15/2019	1241.28	40.79	1200.49	-1.09	
			5/12/2020	1241.28	41.26	1200.02	-0.47	
ECP-02	66601	55-587192	10/15/2019	1244.49	41.35	1203.14	-1.05	
			5/12/2020	1244.49	41.88	1202.61	-0.53	
ECP-03	66604	55-587193	10/15/2019	1244.35	41.22	1203.13	-1.06	
			5/12/2020	1244.35	41.74	1202.61	-0.52	
SMW-01	46686	55-533298	10/15/2019	1241.21	40.71	1200.50	NM	
			5/12/2020	1241.21	40.70	1200.51	0.01	
SMW-02	46687	55-535795	10/15/2019	1248.61	41.05	1207.56	-1.12	
			5/12/2020	1248.61	41.68	1206.93	-0.63	
SMW-03-060	46749	55-543424	10/15/2019	1236.66	43.10	1193.56	-1.15	
			5/13/2020	1236.66	43.50	1193.16	-0.40	
SMW-03-138	46748	55-543424	10/15/2019	1236.71	43.29	1193.42	-1.23	
			5/13/2020	1236.71	43.64	1193.07	-0.35	
SMW-04	71392	55-907363	10/15/2019	1238.40	40.32	1198.08	-1.14	
			5/12/2020	1238.40	40.74	1197.66	-0.42	
SMW-05	71393	55-908628	10/15/2019	1239.49	40.92	1198.57	-1.07	
			5/12/2020	1239.49	41.39	1198.1	-0.47	
SMW-06	78143	55-914016	10/15/2019	1227.84	38.72	1189.12	NM	
			5/12/2020	1227.84	38.97	1188.87	-0.25	
SMW-07	78144	55-913979	10/15/2019	1240.43	40.30	1200.13	-1.10	
			5/12/2020	1240.43	40.81	1199.62	-0.51	
SMW-08	78145	55-913980	10/15/2019	1243.65	42.39	1201.26	-1.17	
			5/12/2020	1243.65	42.83	1200.82	-0.44	
SMW-11	81221	55-918939	10/17/2019	1221.38	40.07	1181.31	-1.27	Vehicle over well 10/15/19
			5/12/2020	1221.38	40.42	1180.96	-0.35	

TABLE 2. OCTOBER 2019 AND MAY 2020 GROUNDWATER MONITORING DATA

Well I.D	ADEQ Number	ADWR Number	Date	Measuring Point Elevation (ft. AMSL)	Depth to Groundwater (ft.)	Groundwater Elevation (ft. AMSL)	Change Since Previous (ft.)[1]	Comments
SMW-12	81222	55-919290	10/15/2019	1212.19	39.84	1172.35	-1.07	
			5/12/2020	1212.19	40.38	1171.81	-0.54	
SMW-16B	81658	55-921439	10/15/2019	1240.24	40.11	1200.13	-1.01	
			5/12/2020	1240.24	40.60	1199.64	-0.49	
SMW-17	81927	55-923913	5/12/2020	1230.34	47.16	1183.18		First Water Level
BMW-05A	79629	55-916202	10/15/2019	1212.81	42.12	1170.69	-1.07	
			5/12/2020	1212.81	42.70	1170.11	-0.58	
BMW-05B	79630	55-916203	10/15/2019	1212.87	42.12	1170.75	-1.08	
			5/12/2020	1212.87	42.73	1170.14	-0.61	
BMW-06A	79641	55-916204	10/15/2019	1214.27	37.35	1176.92	-1.36	
			5/12/2020	1214.27	37.71	1176.56	-0.36	
BMW-06B	79642	55-916205	10/15/2019	1214.50	37.42	1177.08	-1.33	
			5/12/2020	1214.50	37.77	1176.73	-0.35	
BMW-12B	81659	55-922024	10/15/2019	1,209.13	40.99	1168.14	-1.14	
			5/13/2020	1,209.13	40.55	1168.58	0.44	

Notes:

1. Change since previous based on groundwater elevation.

NM - not measured. Water level measurement was attempted, but was determined to be incorrect due to roots in well.

Table 3
PCE, TCE, c-1,2-DCE, and Chloroform Analytical Results, October 2019 and May 2020

Well Name	Depth Sampled (ft BMP)[1]	MP Elevation (ft AMSL)[2]	Sample Elevation (ft AMSL)[3]	Sample Date	Results[4-6] PCE	TCE	c-1,2-DCE	Chloroform	Comments
Aquifer Water Quality Standard					5.0	5.0	70	100	
ECP-01	41	1241.28	1200.28	10/17/2019	2.2	<2.0	<2.0	<2.0	Changed due to lower water level
	Δ Last				-2.6	NC	NC	NC	
	44	1241.28	1197.28	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				-2.3	NC	NC	NC	
ECP-02	88	1244.49	1156.49	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	-6.8	
ECP-03	42	1244.35	1202.35	10/17/2019	<2.0	<2.0	<2.0	<2.0	Changed due to lower water level
	42		1202.35	10/17/2019 (D)	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	NC	
SMW-01	43	1241.21	1198.21	10/17/2019	NS	NS	NS	NS	Changed due to lower water level.
	Δ Last				NC	NC	NC	NC	
	53	1241.21	1188.21	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	NC	
SMW-02	46	1248.61	1202.61	10/17/2019	<2.0	<2.0	<2.0	<2.0	Changed due to lower water level
	46		1202.61	10/17/2019 (D)	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	NC	
SMW-03-60	46	1236.66	1190.66	10/17/2019	**31**	<2.0	<2.0	<2.0	Changed due to lower water level
	46		1190.66	10/17/2019 (D)	**21**	<2.0	<2.0	<2.0	Changed due to lower water level
	Δ Last				-10.0	NC	NC	NC	
SMW-03-138	102	1236.71		10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	NC	
SMW-04	40	1238.4	1198.4	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				-2.5	NC	NC	NC	
	52	1238.4	1186.4	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	NC	
SMW-05	43	1239.49	1196.49	10/17/2019	<2.0	<2.0	<2.0	<2.0	Changed due to lower water level
	Δ Last				NC	NC	NC	NC	
SMW-06	40	1227.84	1187.84	10/17/2019	<2.0	<2.0	<2.0	<2.0	Changed due to lower water level
	Δ Last				NC	NC	NC	-5.7	
SMW-07	42	1239.49	1197.49	10/17/2019	**5.6**	<2.0	<2.0	3.5	Changed due to lower water level
	Δ Last				-2.0	NC	NC	0.1	
	48			10/17/2019	<2.0	<2.0	<2.0	3.6	
	Δ Last				-3.1	NC	NC	0.2	
	58	1239.49		10/17/2019	<2.0	<2.0	<2.0	3.0	
	Δ Last				NC	NC	NC	-0.1	

Table 3
PCE, TCE, c-1,2-DCE, and Chloroform Analytical Results, October 2019 and May 2020

Well Name	Depth Sampled (ft BMP)[1]	MP Elevation (ft AMSL)[2]	Sample Elevation (ft AMSL)[3]	Sample Date	Results[4-6] PCE	TCE	c-1,2-DCE	Chloroform	Comments
Aquifer Water Quality Standard					5.0	5.0	70	100	
SMW-08	44	1243.65	1199.65	10/17/2019	<2.0	<2.0	<2.0	<2.0	Changed due to lower water level
	Δ Last				NC	NC	NC	NC	
SMW-11	60	1221.38	1161.38	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	NC	
SMW-12	155	1212.19	1057.19	10/17/2019	<2.0	<2.0	<2.0	<2.0	
			1057.19	10/17/2019 (D)	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	NC	
SMW-16B	100	1240.24	1140.24	10/17/2019	<2.0	<2.0	<2.0	5.0	
	Δ Last				NC	NC	NC	-0.7	
	120	1240.24	1120.24	10/17/2019	<2.0	<2.0	<2.0	4.7	
	Δ Last				NC	NC	NC	-0.7	
SMW-17	45	1230.34	1185.34	5/15/2020	<2.0	<2.0	<2.0	2.2	
BMW-05A	45	1212.81	1167.81	10/17/2019	<2.0	<2.0	<2.0	<2.0	Changed due to lower water level
	Δ Last				NC	NC	NC	NC	
BMW-05B	77.5	1212.87		10/17/2019	4.7	<2.0	<2.0	<2.0	
	Δ Last				0.9	NC	NC	-2	
	111.7	1212.87	1101.17	10/17/2019	**11**	<2.0	<2.0	<2.0	
	Δ Last				3.9	NC	NC	NC	
BMW-06A	43	1214.27	1171.27	10/17/2019	<2.0	<2.0	<2.0	<2.0	Changed due to lower water level
	Δ Last				NC	NC	NC	NC	
BMW-06B	77.9	1214.50	1136.60	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	NC	
	107.1	1214.50	1107.40	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				NC	NC	NC	NC	
BMW-12B	125	1209.13	1084.13	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				-3.9	NC	NC	NC	
	145	1209.13	1064.13	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				-3.4	NC	NC	NC	
		1209.13	1044.13	10/17/2019	<2.0	<2.0	<2.0	<2.0	
	Δ Last				-3.5	NC	NC	NC	

Notes:
1. Sample Depth - feet below measuring point (MP).
2. MP Elevation in feet above mean sea level (AMSL)
3. Sample elevation in feet AMSL
4. Volatile organic compound (VOC) concentrations reported in micrograms per liter (ug/L). DCE - dichloroethene, PCE -tetrachloroethene, TCE - trichloroethene. **BOLD** indicates exceeds
5. (D) denotes duplicate result
6. Δ denotes change since last sampling event. NC denotes not calculated due to non-detect data

Table 4 - Remedy Evaluation
Feasibility Study Report
48th Street and Indian School Road WQARF Site
Phoenix, Arizona

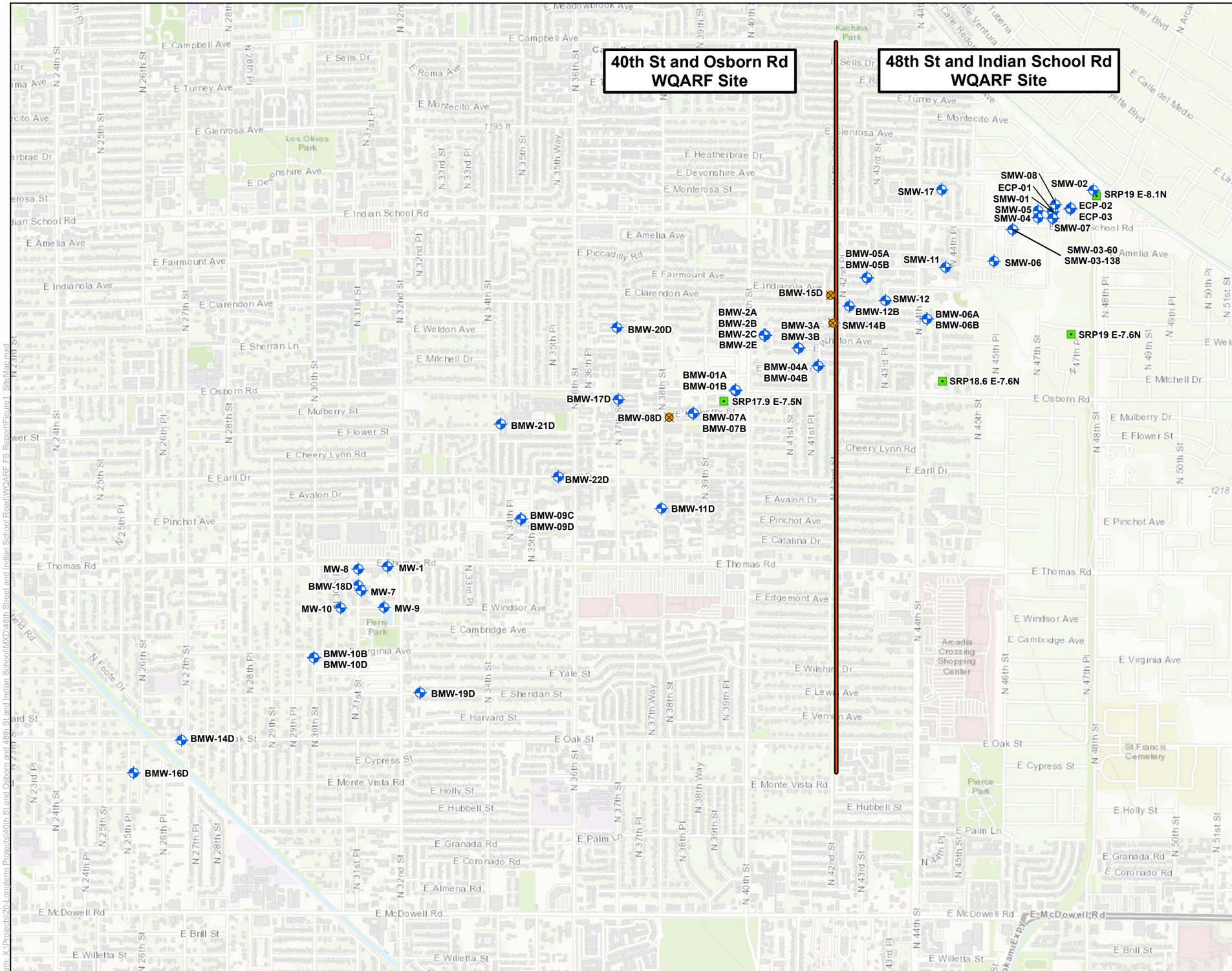
Remedial Alternative	Groundwater	Will Alternative Meet Remedial Objectives?	Practicability			Protectiveness (Risk)	Benefits	Regulatory/Public Acceptance	Estimated Cost (w/o Contingency)	Estimated Contingency Costs	Total Remedy Estimated Cost Including Contingency			Cost Score	Total Score
			Feasibility	Short/Long Term Effectiveness	Reliability						Total Cost	(-30%)	(+50%)		
Less Aggressive Remedy	**Semiannual Monitoring of Groundwater Well Network**	Yes	Monitoring is very feasible as groundwater monitoring is currently conducted at the site. Monitoring of the current well network is feasible considering the current conditions of the plume. **Score = 5**	Monitoring is a known and effective remedy given the condition of the plume; semiannual monitoring will assess effectiveness. Considered a long-term remedy for the Site if current groundwater flow velocity and levels remain unchanged. However, may be a shorter term remedy if groundwater flow velocity increases. **Score = 3**	Monitoring is a known and reliable remediation technology. **Score = 5**	The Less Aggressive Remedy is protective, in that it continues to monitor and evaluate Site contamination through the collection of data. **Score = 3**	Under the current conditions, provides less benefit than the Reference or More Aggressive Alternative Remedies for the Site because it can be anticipated to take the longest period of time to remediate groundwater impacts. However, if conditions change, may become more beneficial than the More Aggressive and Reference Remedies in that remedial goals may be achieved in seven years or less at a significantly lower cost. **Score = 4**	Moderately unlikely unless trends after five years indicate cleanup goals may be achieved within the timeframes presented for the More Aggressive and Reference Remedies	**$871,000**	**$178,000**	**$1,049,000**	**$950,000**	**$2,035,000**	**5**	**25**
More Aggressive Remedy	**Five Year Semiannual Monitoring of Groundwater Well Network plus ISCO Component**	Yes	Five year monitoring program will be used to decide if implementation of ISCO component is required. Use of the EN Rx reagent is a well documented remedy for PCE plumes of manageable size such as those associated for the Site. **Score = 5**	If implemented as an additional remedial measure, the application of the EN Rx reagent will decrease PCE concentrations in the groundwater, and decrease the amount of time needed to achieve the cleanup goals compared to the Less Aggressive Remedy. **Score = 5**	ISCO and monitoring are known and reliable remediation technologies. **Score = 5**	The More Aggressive Remedy is protective, in that it will decrease PCE concentrations to below cleanup goals and continues to monitor and evaluate Site contamination through the collection of data. **Score = 5**	ISCO will result in achieving the cleanup goal within a relatively short period of time compared to the Less Aggressive and Reference Remedies. **Score = 5**	Likely.	**$3,286,000**	**$2,846,000**	**$6,132,000**	**$4,334,000**	**$9,268,000**	**3**	**28**
Reference Remedy	**Five Year Semiannual Monitoring of Groundwater Well Network plus GWET Component**	Yes	Five year monitoring program will be used to decide if implementation of GWET component is required. Use of GWET is a well documented remedy for PCE plumes; however, it is typically used more for plume containment than plume remediation. **Score = 5**	If implemented as an additional remedial measure, GWET is a known and effective remedy and may possibly decrease the number of yearsto achieve the cleanup goals; continued semiannual groundwater monitoring of existing monitoring well network will assess effectiveness. **Score = 4**	GWET and monitoring are known and reliable remediation technologies. **Score = 5**	The reference remedy is protective, in that it will decrease PCE concentrations across the Site and control migration, and will continue to monitor and evaluate Site contamination through the collection of data. **Score = 4**	GWET may result in achieving the cleanup goal within a relatively shorter period of time compared to the Less Aggressive Remedy. **Score = 4**	Public - Likely. Regulatory - ADEQ is currently limiting use of GWET to cases where no other technologies are available or GWET is the most effective and cost efficient remedy.	**$2,700,000**	**$517,000**	**$3,217,000**	**$2,254,000**	**$4,829,000**	**4**	**26**

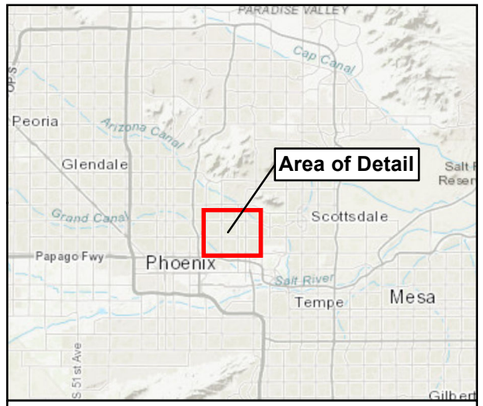
Abbreviations:
WQARF = Water Quality Assurance Revolving Fund
ISCO - In-situ Chemical Oxidation
GWET - Groundwater Extraction and Treatment
O&M - Operation and Maintenance
PCE = Tetrachloroethene
O&M = operations and maintenance
% = percent
$ = United States dollars

Scoring:
Scores ranged from zero to five, with five indicating the most relative benefit and zero indicating the least relative or no benefit.

Notes:
Costs are rounded off to the nearest thousand
Costs are based on 2020 dollar values
Costs for O&M and contingencies include an assumed Net Present Value of 3%

FIGURES





Area of Detail

Legend

- Groundwater Monitoring Well
- SRP Production Well
- Boring Location - Abandoned

Notes:

BMW-14D	Groundwater Monitoring Well Identification
SRP	Salt River Project
WQARF	Water Quality Assurance Revolving Fund

0 750 1,500 Feet

N

Feasilbility Study Report
48th Street & Indian School Road
WQARF Site

FIGURE **1** — **Site Map**

Job No.	14-2019-2043
PM:	JC
Date:	6/9/2020
Scale:	1"= 1500'

wood.

Path: X:\Projects\20-Longterm Projects\40th St and Osborn and 48th St and Indian School\MXD\48th Street and Indian School Road\WQARF FS ReportFigure1_SiteMap.mxd

0 75 150
Feet

Job No.	14-2019-2043
PM:	JC
Date:	3/19/2020
Scale:	1" = 150'

N

The map shown here has been created with all due and reasonable care and is strictly for use with Wood Environment & Infrastructure Solutions, Inc. Project Number 14-2019-2043. This map has not been certified by a licensed land surveyor, and any third party use of this map comes without warranties of any kind. Wood Environment & Infrastructure Solutions, Inc. assumes no liability, direct or indirect, whatsoever for any such third party or unintended use.

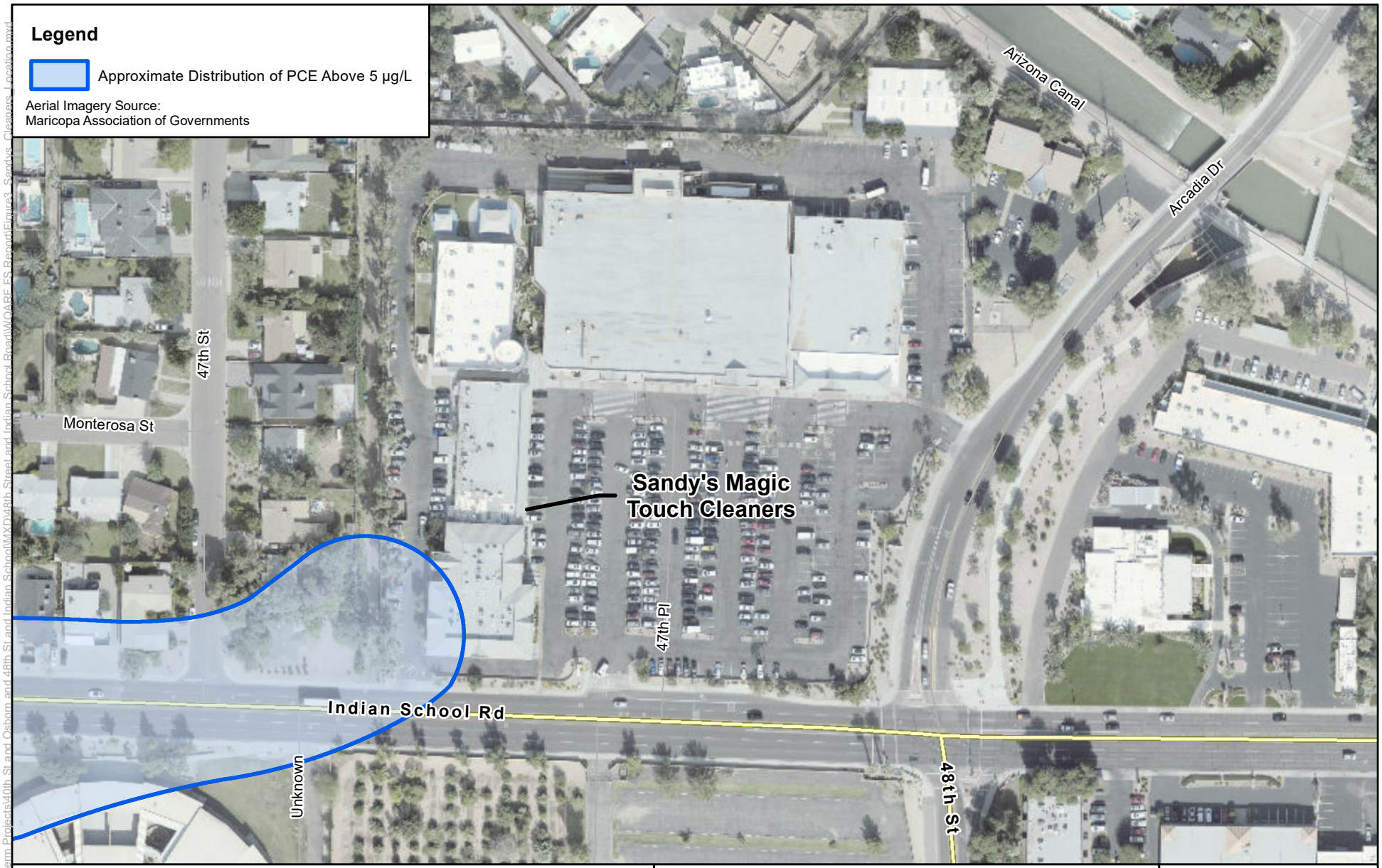
Feasibility Study Report
48th Street and Indian School Road
WQARF Site

One Hour Martinizing Location

FIGURE
2

wood.

Path: X:\Projects\20\Longterm Projects\40th St and Osborn and 48th St and Indian School\MXD\48th Street and Indian School Road\WQARF FS Report\Figure2_1Hour_Martinizing_Location.mxd



0 75 150
Feet

Job No.	14-2019-2043
PM:	JC
Date:	3/19/2020
Scale:	1" = 150'

N

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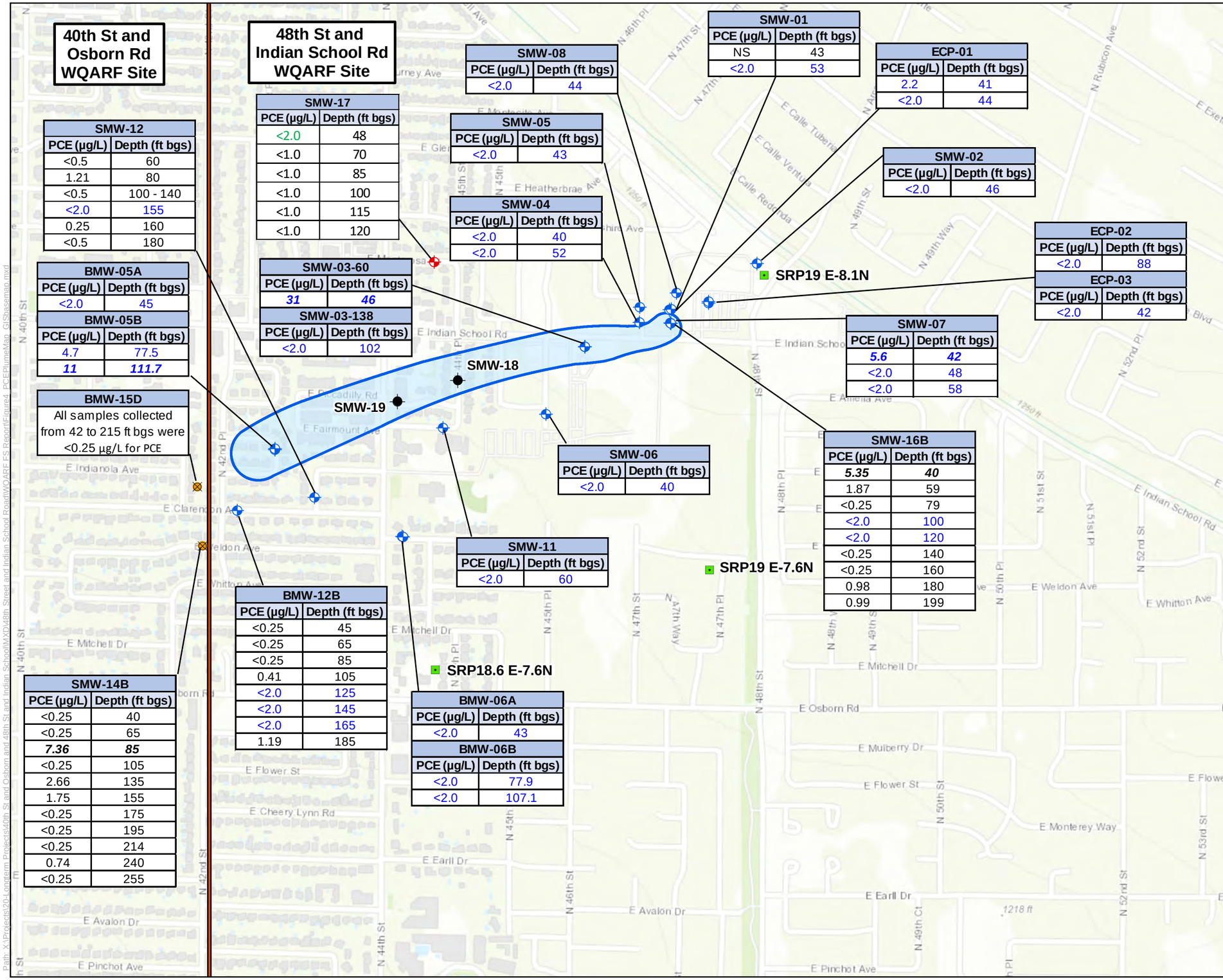
Feasibility Study Report
48th Street and Indian School Road
WQARF Site

Sandy's Cleaners Location

FIGURE
3

wood.

Path: X:\Projects\20Longterm Projects\40th St and Osborn and 48th St and Indian School\MXD\48th Street and Indian School Road\WQARF FS Report\Figure3_Sandys_Cleaners_Location.mxd



Area of Detail

Legend

- Planned Groundwater Monitoring Well
- Groundwater Monitoring Well
- Groundwater Monitoring Well Sampled in May 2020
- SRP Production Well
- Boring Location - Abandoned
- Approximate Distribution of PCE Above 5 µg/L (Dashed Where Inferred)

Notes:

SMW-16B	Groundwater Monitoring Well Identification
1.87	Results that are black are from historic PCE sampling
<2.0	Results that are blue are from October 2019
<2.0	Results that are green are from May 2020
5.35	Results that are ***bolded and italicized*** exceed the Aquifer Water Quality Standard of 5 µg/L
µg/L	Microgram per liter
ft	Feet
bgs	Below Ground Surface
PCE	Tetrachloroethene
WQARF	Water Quality Assurance Revolving Fund

0 350 700 Feet

N

Feasibility Study Report
48th Street & Indian School Road
WQARF Site

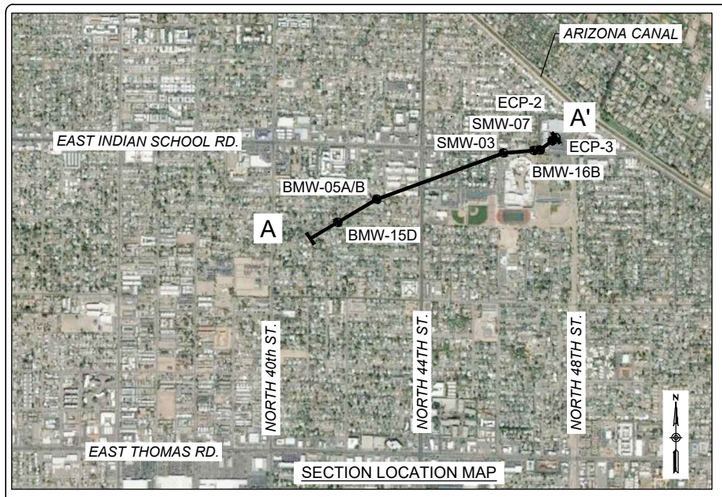
FIGURE 4

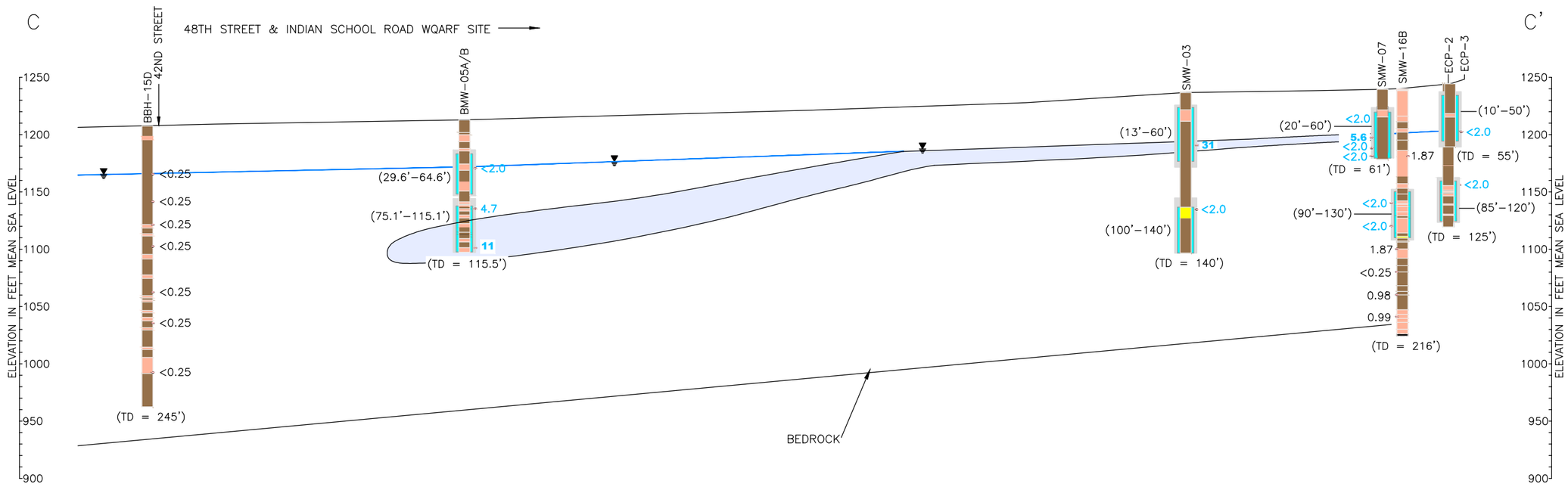
October 2019 and May 2020 Groundwater PCE Distribution Map

Job No. 14-2019-2043
PM: JC
Date: 6/24/2020
Scale: 1"= 700'

wood.

Path: X:\Projects\20-Longterm Projects\40th St and Osborn and 48th St and Indian School\MXD\48th Street and Indian School Road\WQARF FS Report\Figure4_PCEPlumeMap_GISbasemap.mxd





EXPLANATION

- ● BORING LOCATION
- GROUNDWATER WELL LOCATION
- * DEPTH-DISCRETE GROUNDWATER SAMPLE (e.g. SIMULPROBE/HYDROPUNCH OR HYDROPUNCH SAMPLER)
- 3.6 RECENT CONCENTRATION OF TETRACHLOROETHYLENE (PCE) DETECTED IN VERTICAL PROFILE GROUNDWATER SAMPLE IN MICROGRAMS PER LITER (ug/l), DECEMBER 2015 TO AUGUST 2016, BOLD IF EXCEDES 5.0 ug/l
- 3.6 OCTOBER 2019 CONCENTRATION OF TETRACHLOROETHYLENE (PCE) DETECTED IN GROUNDWATER IN MICROGRAMS PER LITER (ug/l), BOLD IF EXCEEDS 5.0 ug/l
- WATER LEVEL ELEVATION MEASURED ON OCTOBER 15, 2019
- — ?— —? — WHERE INFERRED
- (TD = XX) TOTAL DEPTH
- (XX-XX) DEPTH OF SCREEN INTERVAL

BOREHOLE LITHOLOGY

- SILTY OR CLAYEY SAND AND GRAVEL; AND SAND MIXTURES
- PREDOMINANTLY SAND OR GRAVEL
- PREDOMINANTLY SILT AND CLAY
- SITE PCE PLUME ABOVE >5.0 ug/L

FILTER PACK

SCREENED INTERVAL

VERTICAL SCALE: 100, 50, 0 FEET

FEET HORIZONTAL SCALE: 200, 100

REVISIONS:

Environment & Infrastructure Solutions, Inc.
4600 E. WASHINGTON STREET, SUITE 600
PHOENIX, ARIZONA 85034
PHONE: 602-733-6000
FAX: 602-733-6100
wood.

Cross-Section, Feasibility Study Report

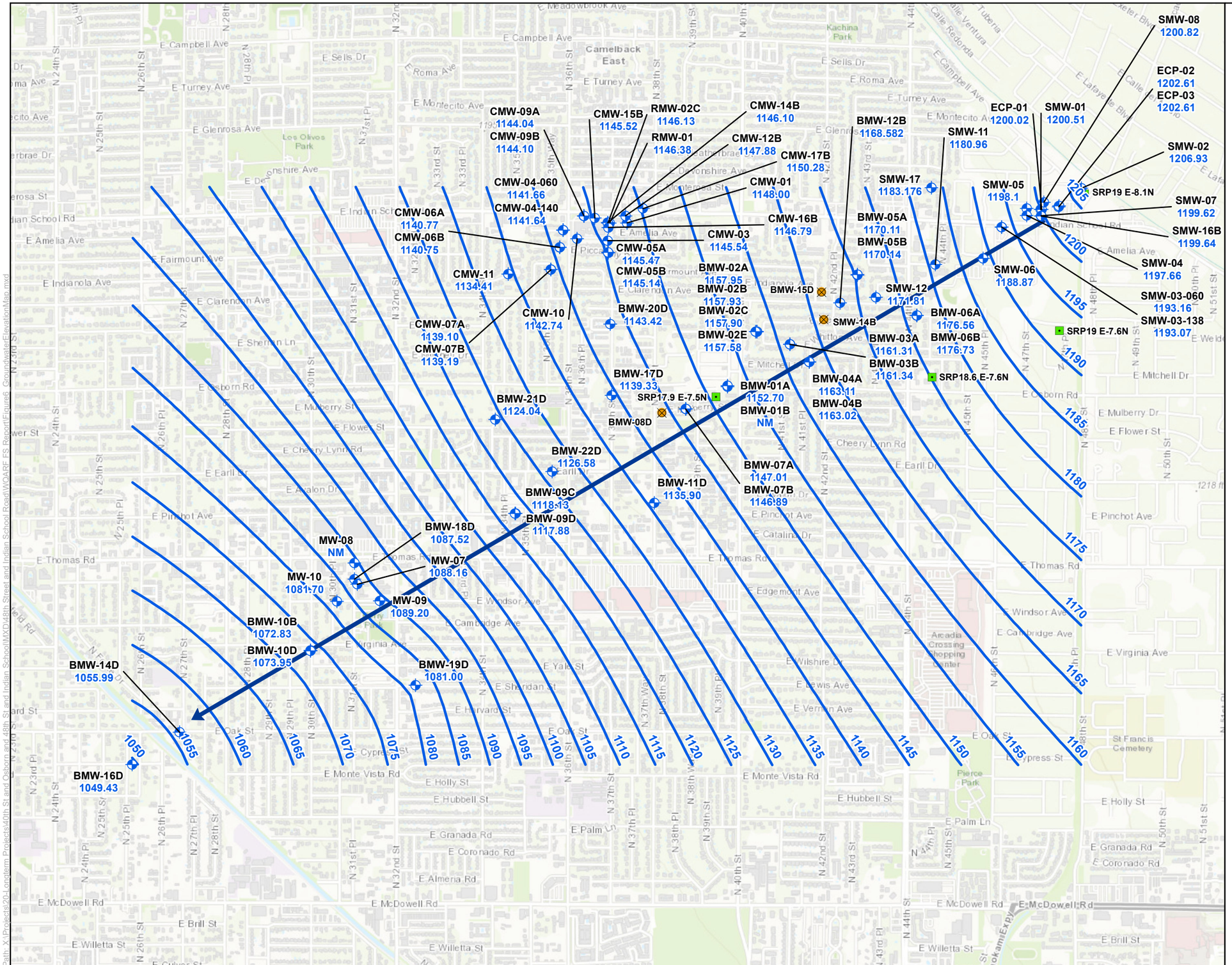
PROJECT: 48th Street and Indian School Road WQARF Site
Phoenix, Arizona

DESIGNED BY: JC
DRAWN BY: GWH
CHECKED BY: JC

PROJECT NO. 14-2019-2043

DRAWING NAME 5

PRELIMINARY NOT FOR CONSTRUCTION OR RECORDING



Area of Detail

Legend

- Groundwater Monitoring Well
- SRP Production Well
- Boring Location - Abandoned
- Groundwater Flow Direction
- Groundwater Elevation Contour (ft amsl)

Notes:

BMW-16D	Groundwater Monitoring Well Identification
1049.43	Groundwater Elevation (ft amsl)
amsl	above mean sea level
ft	feet
NM	Not Measured
WQARF	Water Quality Assurance Revolving Fund

0 750 1,500 Feet

N

Feasibility Study Report
48th Street and Indian School Road
WQARF Site

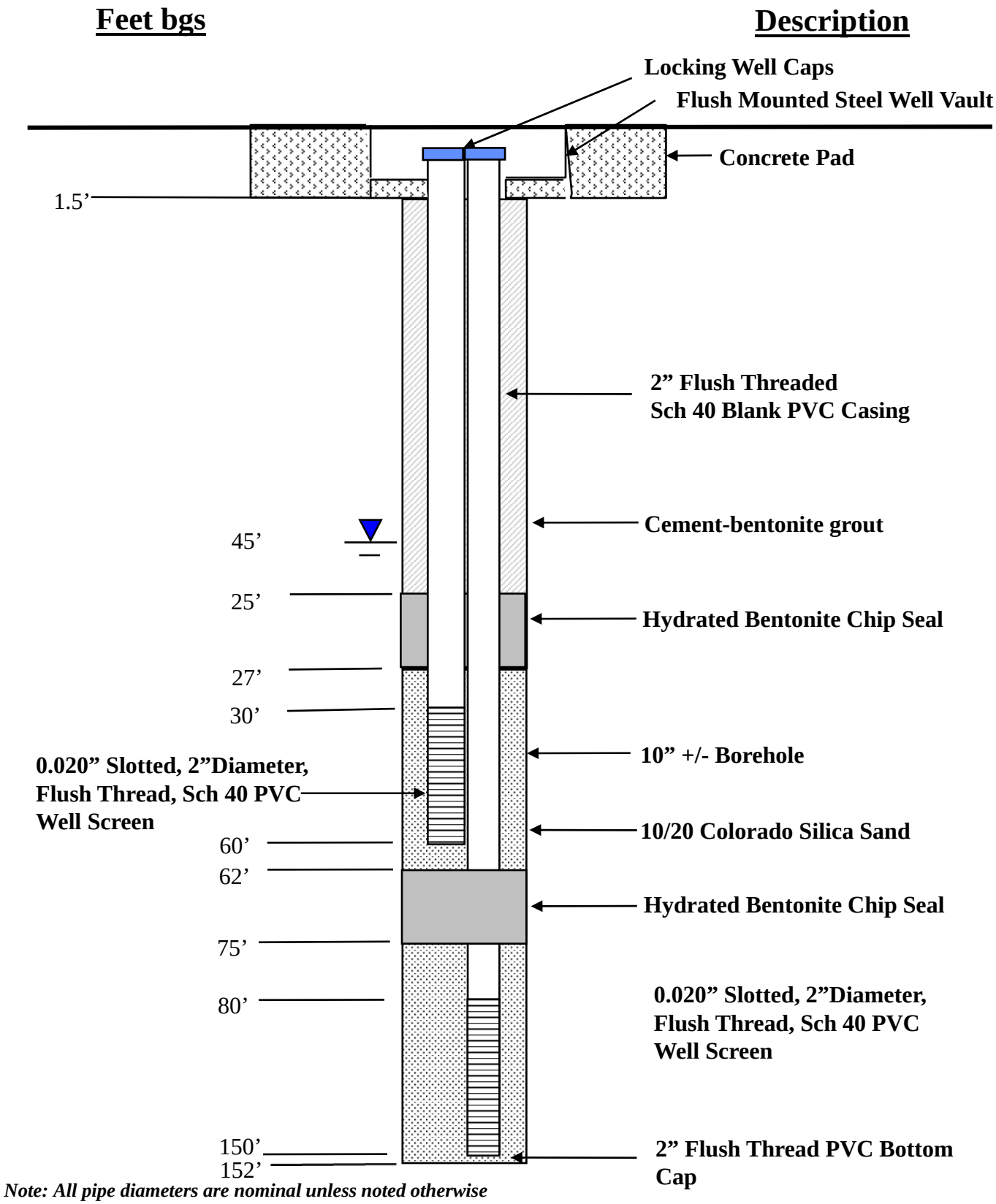
FIGURE 6

Groundwater Elevation Map

Job No.	14-2019-2043
PM:	JC
Date:	6/10/2020
Scale:	1"= 1500'

wood.

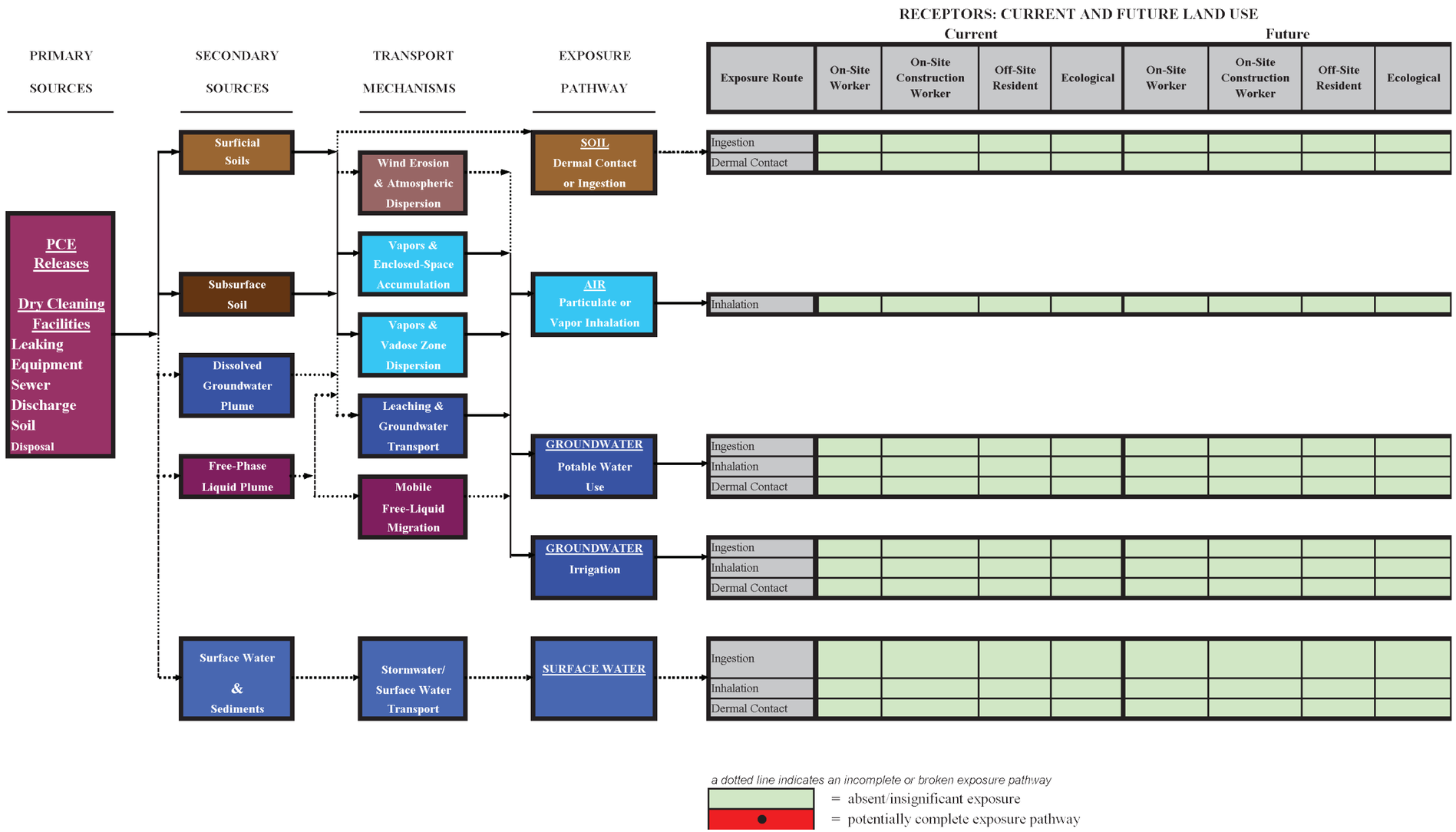
Path: X:\Projects\20-Longterm Projects\40th St and Osborn and 48th St and Indian School\MXD\48th Street and Indian School Road\WQARF FS Report\Figure6_GroundwaterElevationMap.mxd



Note: All pipe diameters are nominal unless noted otherwise

wood.

Figure 7
SMW-18 & SMW-19 Well Construction Diagram



2/25/2019
CSM-48IS

Scale: At Shown

Job No.	14-2019-2043
PM:	JC
Date:	6/9/2020
Scale:	As Shown

N

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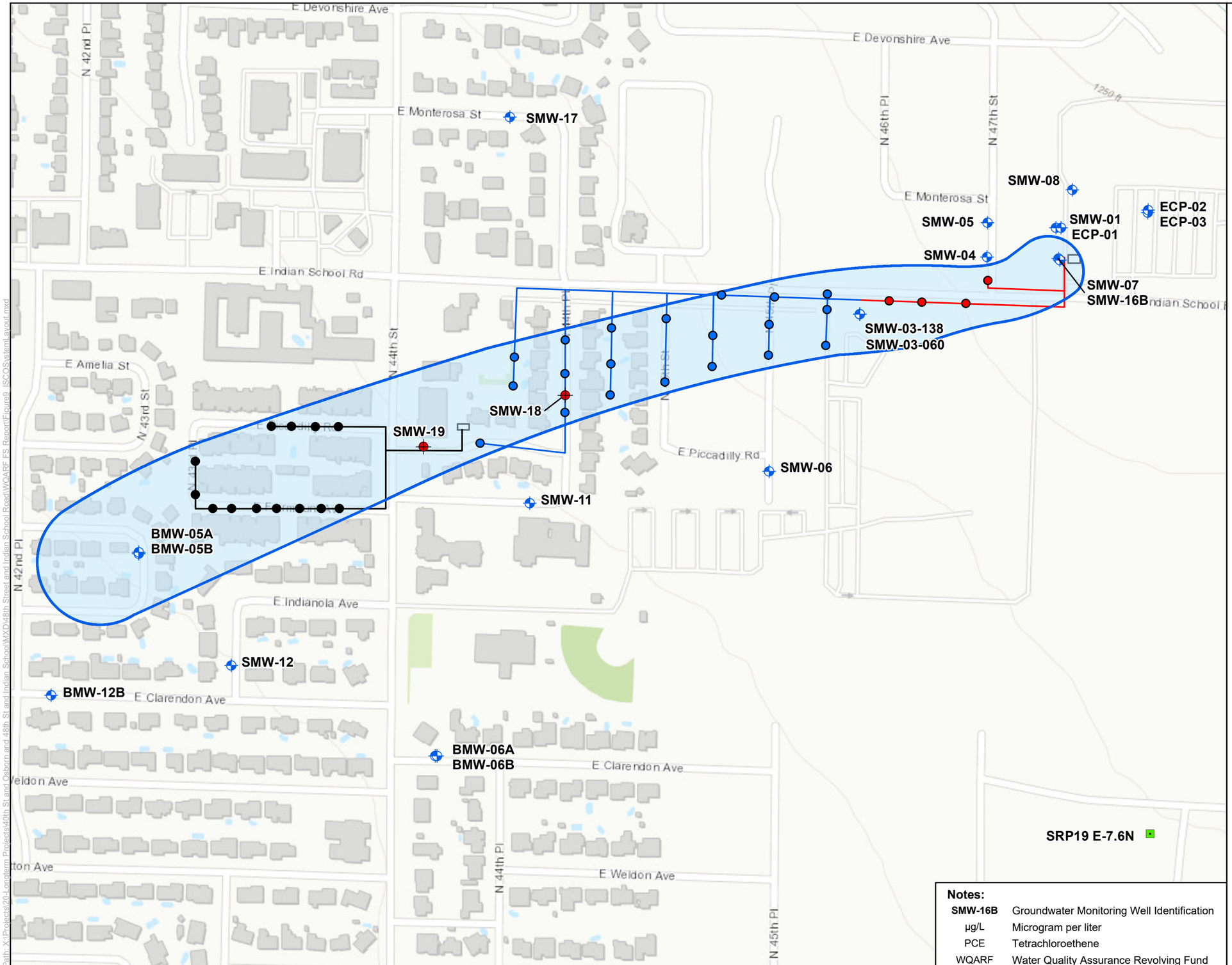
Feasibility Study Report
ECP 48th St & Indian School Rd WQARF Site
Phoenix, Arizona

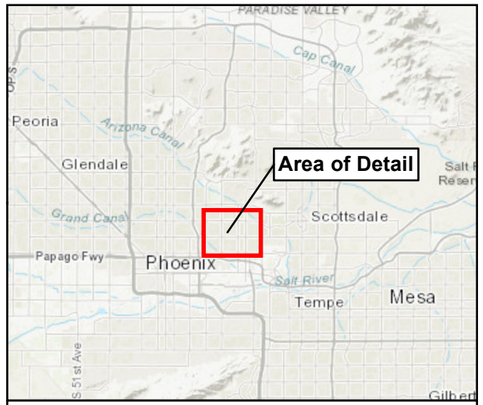
Exposure Pathway Model

FIGURE
8

wood.

X:\Projects\20-Longterm Projects\40th St and Osborn and 48th St and Indian School\MXD\48th Street and Indian School Road\WQARF FS Report\Figure8_ExposurePathwayModel.AI





Area of Detail

Legend

- Planned Groundwater Monitoring Well Location
- Groundwater Monitoring Well Location
- SRP Production Well
- Boring Location - Abandoned
- Shallow Injection Well
- Shallow Pipe/Tubing Route
- Contingency Shallow Injection Well
- Contigngency Shallow Pipe/Tubing Route
- Deep Injection Well
- Deep Pipe/Tubing Route
- FOCIS Unit
- Approximate Distribution of PCE Above 5 µg/L (Dashed Where Inferred)

0 150 300 Feet

N

Notes:

SMW-16B	Groundwater Monitoring Well Identification
µg/L	Microgram per liter
PCE	Tetrachloroethene
WQARF	Water Quality Assurance Revolving Fund

Feasibility Study Report
48th Street and Indian School Road
WQARF Site

FIGURE 9

ISCO System Layout

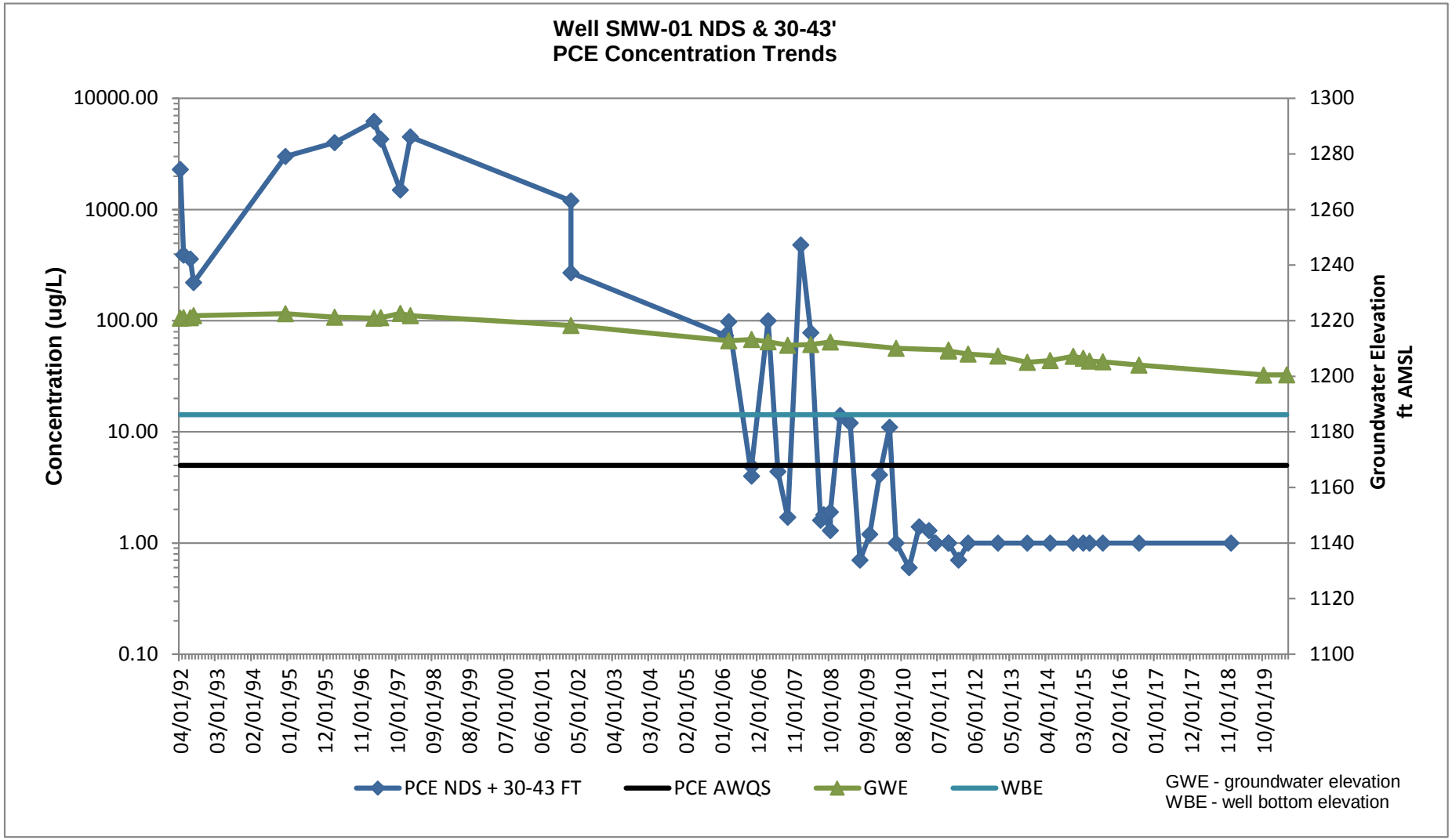
Job No. 14-2019-2043
PM: JC
Date: 6/24/2020
Scale: 1"= 300'

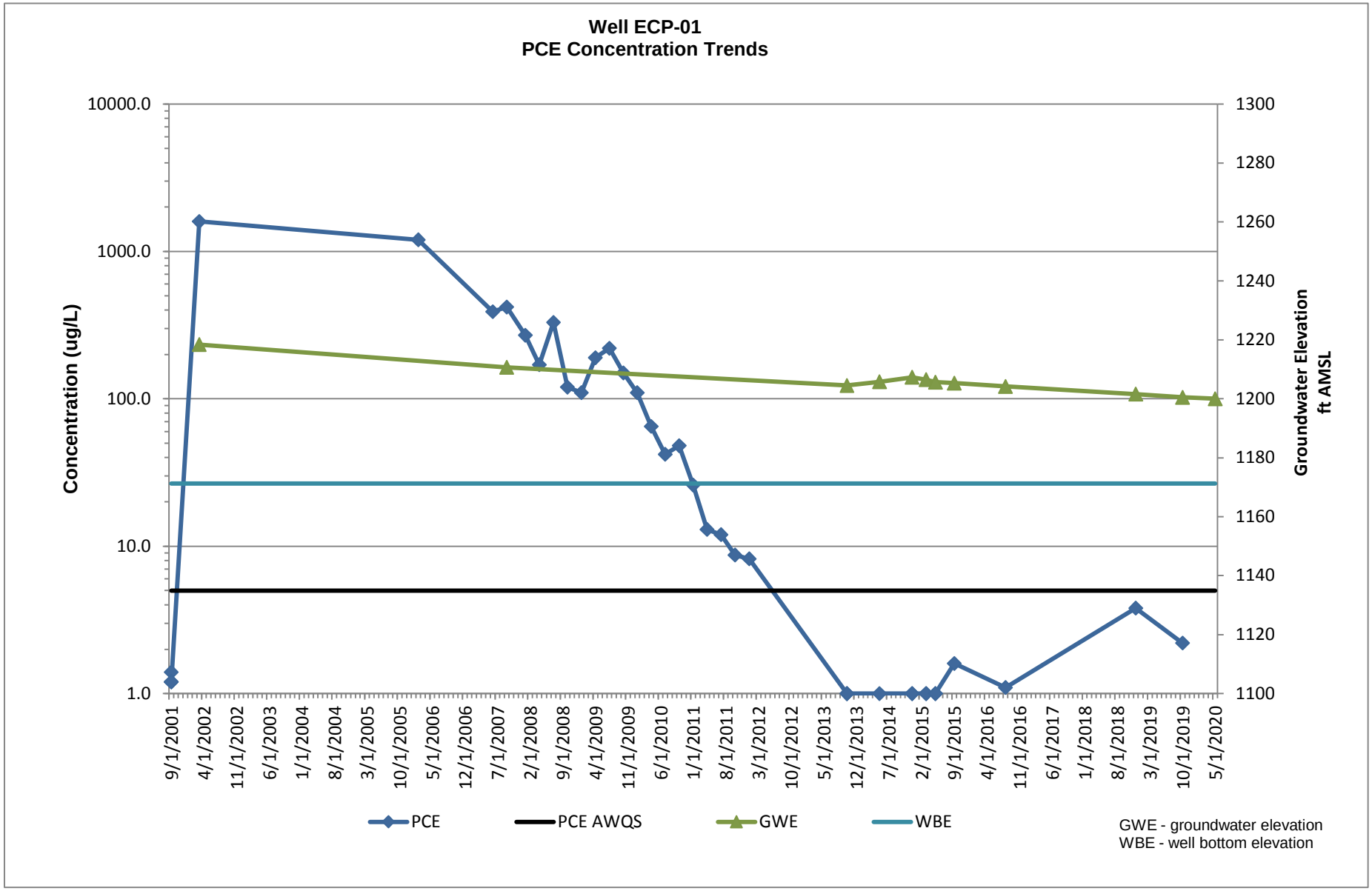
wood.

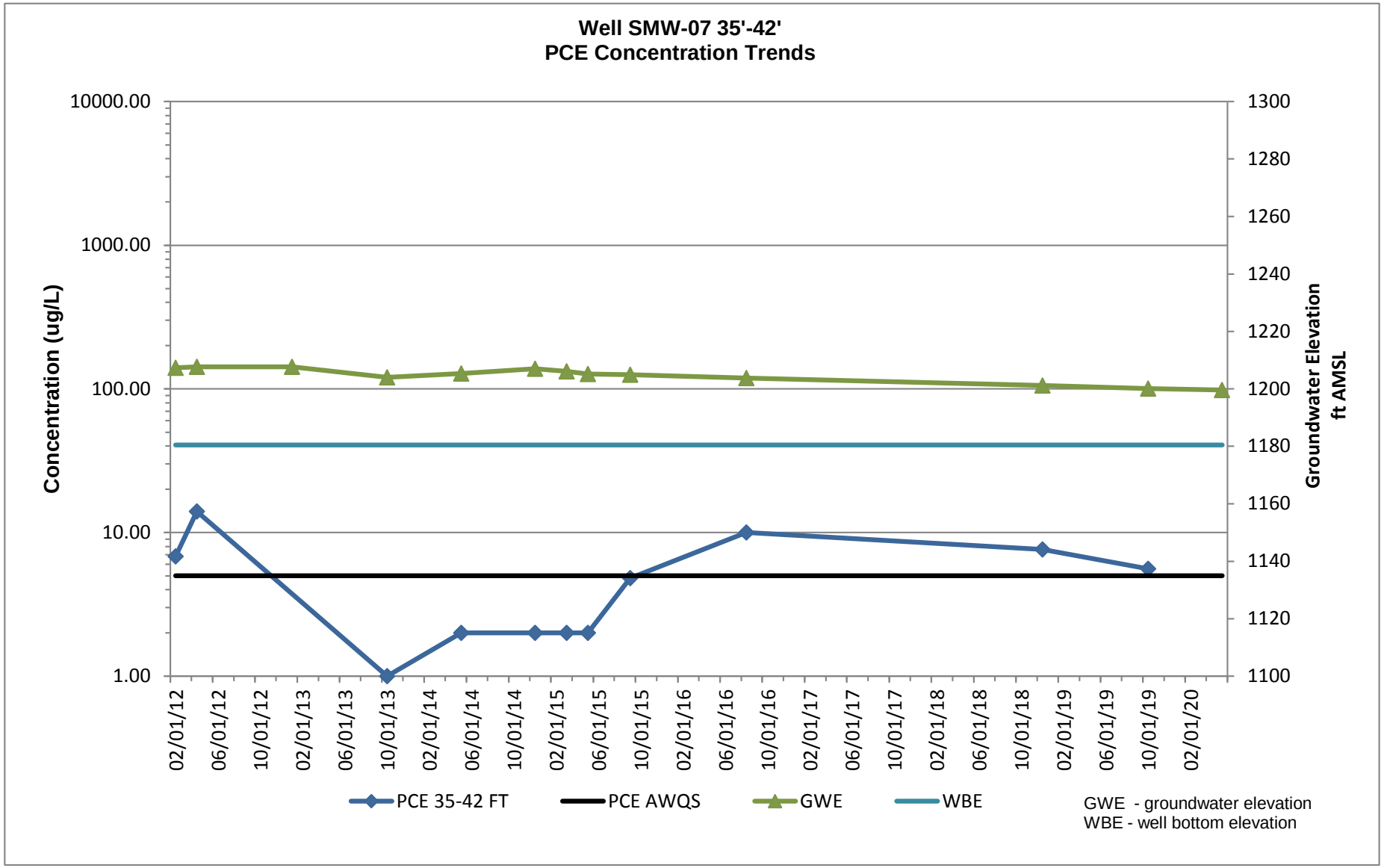
Path: X:\Projects\20-Longterm Projects\40th St and Osborn and 48th St and Indian School\MXD\48th Street and Indian School Road\WQARF FS Report\Figure9_ISCOSystemLayout.mxd

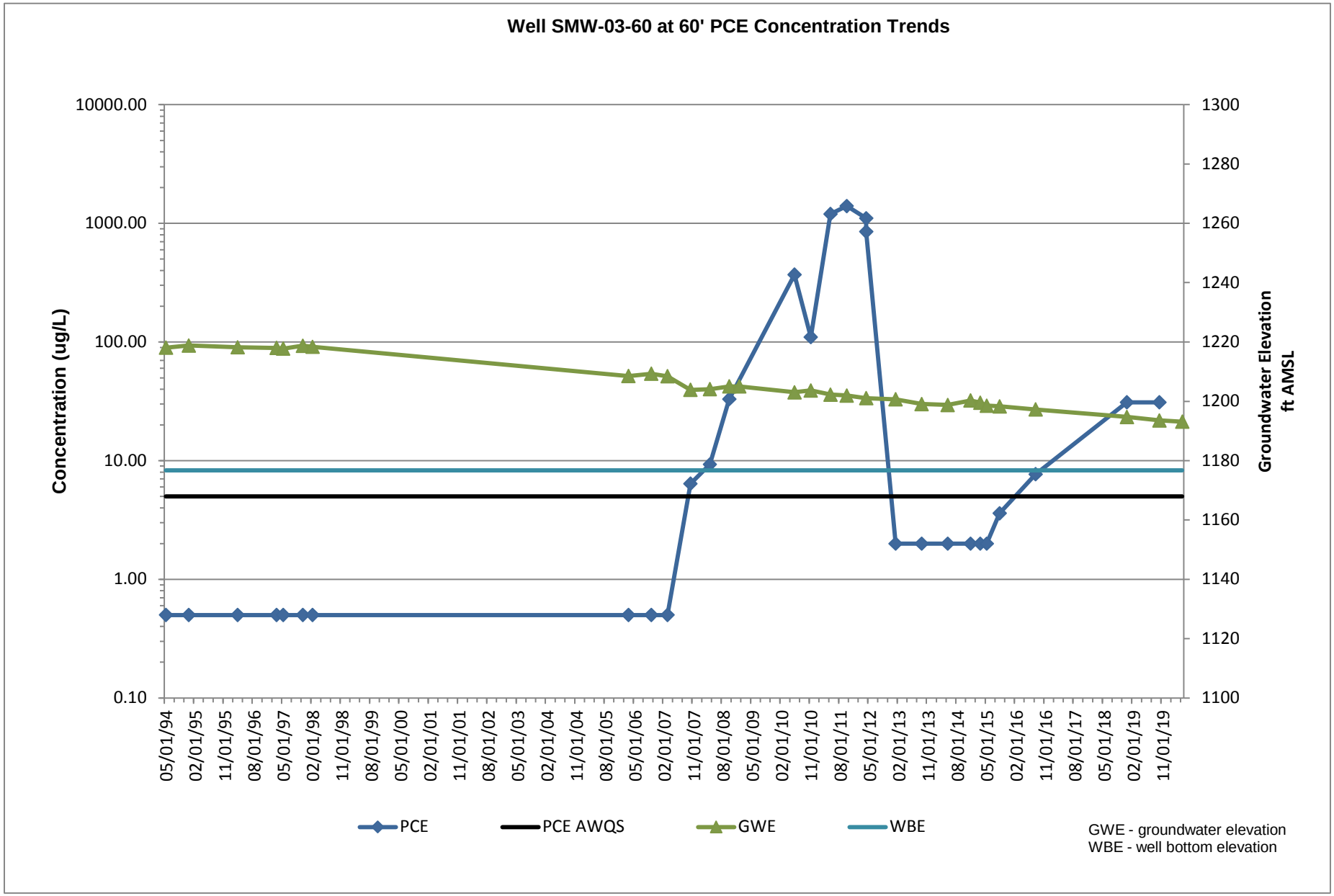
APPENDIX A

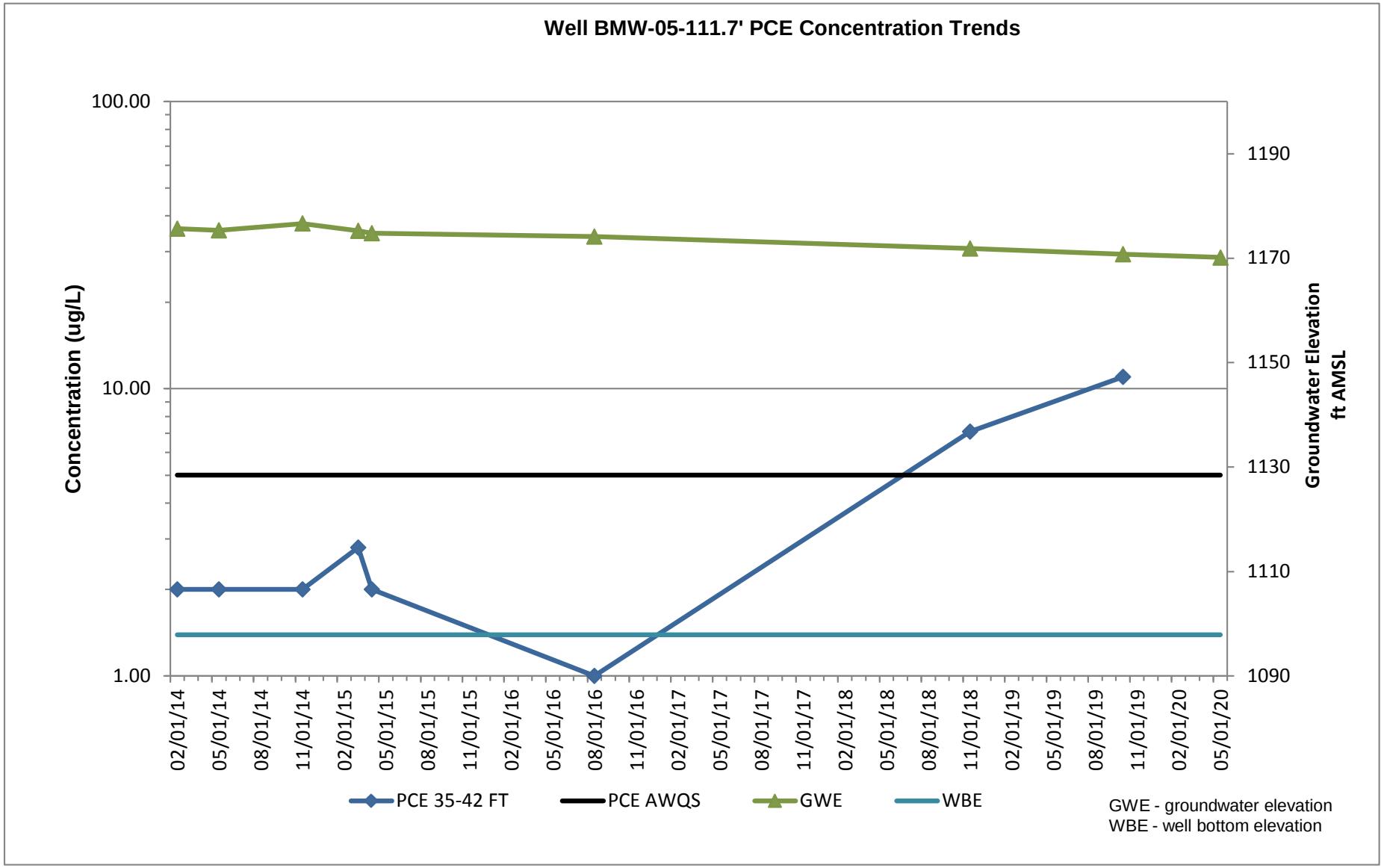
Hydrographs and PCE Concentration Versus Time Graphs


Well SMW-01 NDS & 30-43'
PCE Concentration Trends
Concentration (ug/L)
10000.00
1000.00
100.00
10.00
1.00
0.10
Groundwater Elevation ft AMSL
1300
1280
1260
1240
1220
1200
1180
1160
1140
1120
1100
04/01/92
03/01/93
02/01/94
01/01/95
12/01/95
11/01/96
10/01/97
09/01/98
08/01/99
07/01/00
06/01/01
05/01/02
04/01/03
03/01/04
02/01/05
01/01/06
12/01/06
11/01/07
10/01/08
09/01/09
08/01/10
07/01/11
06/01/12
05/01/13
04/01/14
03/01/15
02/01/16
01/01/17
12/01/17
11/01/18
10/01/19
PCE NDS + 30-43 FT
PCE AWQS
GWE
WBE
GWE - groundwater elevation
WBE - well bottom elevation


Well ECP-01
PCE Concentration Trends
Concentration (ug/L)
10000.0
1000.0
100.0
10.0
1.0
Groundwater Elevation ft AMSL
1300
1280
1260
1240
1220
1200
1180
1160
1140
1120
1100
9/1/2001
4/1/2002
11/1/2002
6/1/2003
1/1/2004
8/1/2004
3/1/2005
10/1/2005
5/1/2006
12/1/2006
7/1/2007
2/1/2008
9/1/2008
4/1/2009
11/1/2009
6/1/2010
1/1/2011
8/1/2011
3/1/2012
10/1/2012
5/1/2013
12/1/2013
7/1/2014
2/1/2015
9/1/2015
4/1/2016
11/1/2016
6/1/2017
1/1/2018
8/1/2018
3/1/2019
10/1/2019
5/1/2020
PCE
PCE AWQS
GWE
WBE
GWE - groundwater elevation
WBE - well bottom elevation


Well SMW-07 35'-42'
PCE Concentration Trends
Concentration (ug/L)
10000.00
1000.00
100.00
10.00
1.00
Groundwater Elevation ft AMSL
1300
1280
1260
1240
1220
1200
1180
1160
1140
1120
1100
02/01/12
06/01/12
10/01/12
02/01/13
06/01/13
10/01/13
02/01/14
06/01/14
10/01/14
02/01/15
06/01/15
10/01/15
02/01/16
06/01/16
10/01/16
02/01/17
06/01/17
10/01/17
02/01/18
06/01/18
10/01/18
02/01/19
06/01/19
10/01/19
02/01/20
PCE 35-42 FT
PCE AWQS
GWE
WBE
GWE - groundwater elevation
WBE - well bottom elevation


Well SMW-03-60 at 60' PCE Concentration Trends
Concentration (ug/L)
10000.00
1000.00
100.00
10.00
1.00
0.10
Groundwater Elevation ft AMSL
1300
1280
1260
1240
1220
1200
1180
1160
1140
1120
1100
05/01/94
02/01/95
11/01/95
08/01/96
05/01/97
02/01/98
11/01/98
08/01/99
05/01/00
02/01/01
11/01/01
08/01/02
05/01/03
02/01/04
11/01/04
08/01/05
05/01/06
02/01/07
11/01/07
08/01/08
05/01/09
02/01/10
11/01/10
08/01/11
05/01/12
02/01/13
11/01/13
08/01/14
05/01/15
02/01/16
11/01/16
08/01/17
05/01/18
02/01/19
11/01/19
PCE
PCE AWQS
GWE
WBE
GWE - groundwater elevation
WBE - well bottom elevation


Well BMW-05-111.7' PCE Concentration Trends
Concentration (ug/L)
100.00
10.00
1.00
Groundwater Elevation ft AMSL
1190
1170
1150
1130
1110
1090
02/01/14
05/01/14
08/01/14
11/01/14
02/01/15
05/01/15
08/01/15
11/01/15
02/01/16
05/01/16
08/01/16
11/01/16
02/01/17
05/01/17
08/01/17
11/01/17
02/01/18
05/01/18
08/01/18
11/01/18
02/01/19
05/01/19
08/01/19
11/01/19
02/01/20
05/01/20
PCE 35-42 FT
PCE AWQS
GWE
WBE
GWE - groundwater elevation
WBE - well bottom elevation

APPENDIX B

Detailed Cost Estimates

Table B-1
Estimated Costs for Less Aggressive Remedy
Feasibility Study Report
48th St and Indian School Rd WQARF Site

	Quantity	Unit	Unit Cost	Total Cost	Estimated Low Range (-30%)	Estimated Upper Range (+50%)
15 Year Semi-Annual Monitoring						
Estimated Capital Costs						
Work Plan/Design	1	LS	$24,000	$24,000	$17,000	$36,000
Downgradient Performance Well Installation						
Monitoring Well Installation and Oversight (includes vertical profile)	2	LS	$40,000	$80,000	$56,000	$120,000
Survey, Permitting, Sampling and IDW Disposal	2	LS	$25,000	$50,000	$35,000	$75,000
Tech Memo	1	LS	$9,000	$9,000	$6,000	$14,000
Project Management/Oversight/Administration	15%	n/a	n/a	$20,000	$14,000	$30,000
Capital Costs Subtotal				**$183,000**	**$128,000**	**$275,000**
Estimated GW Monitoring Annual Costs						
Semiannual GW Monitoring/Reporting (all wells)	2	LS	$16,000	$32,000	$22,000	$48,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$5,000	$4,000	$8,000
Annual Cost for GW Monitoring Subtotal				**$37,000**	**$26,000**	**$56,000**
15 Year Total GW Monitoring Costs (Net Present Value - Discounted 3%)				**$688,000**	**$697,000**	**$1,493,000**
Less Aggressive Alternative Remedy Capital and Monitoring Costs				**$871,000**	**$825,000**	**$1,768,000**

Estimated Contingency Costs						
Estimated Additional 3 Years GW Monitoring Costs						
Total GW Monitoring Costs for 3 Additional Years (Net Present Value - Discounted 3%)				**$178,000**	**$125,000**	**$267,000**
Contingency Costs Subtotal				**$178,000**	**$125,000**	**$267,000**
Total Less Aggressive Alternative Remedy Costs (Including Contingencies)				**$1,049,000**	**$950,000**	**$2,035,000**

Abbreviations:

WQARF = Water Quality Assurance Revolving Fund
% = percent
LS = lump sum
GW - groundwater
IDW - Investigation Derived-Wastes
n/a - not applicable

Notes:

1. Total costs are rounded up to the nearest thousand dollars ($1000).
2. Pricing is subject to commodity pricing increases. Contingencies for possible price escalation due to steel or other tariffs is not included.
3. No estimated costs have been included for taxes or other fees relative to the project.
4. Net Present Value - The labor, materials or equipment value in the present of a sum of money, in contrast to a future value when it has been invested at compound interest (assumed at 3%).

Table B-2
Estimated Costs for More Aggressive Remedy
Feasibility Study Report
48th St and Indian School Rd WQARF Site

	Quantity	Unit	Unit Cost	Total Cost	Estimated Low Range (-30%)	Estimated Upper Range (+50%)
Five Year Semi-Annual Monitoring + ISCO Component						
Estimated Capital Costs						
Performance Well Installation						
Monitoring Well Installation and Oversight (includes vertical profile)	2	LS	$40,000	$80,000	$56,000	$120,000
Survey, Permitting, Sampling and IDW Disposal	2	LS	$10,000	$20,000	$14,000	$30,000
Tech Memo	1	LS	$9,000	$9,000	$7,000	$14,000
ISCO System Remedy Final Design						
ISCO System Remedy Final Design	1	LS	$50,000	$50,000	$35,000	$75,000
System Installation						
Shallow injection well (includes permitting, oversight, installation, vertical profile, and IDW)	4	LS	$29,000	$116,000	$82,000	$174,000
Earthwork, Trenching and Pipe Installation from Arcadia Towne Center	1200	LF	$200	$240,000	$168,000	$360,000
Deep injection well (includes permitting, oversight, installation, vertical profile, and IDW	13	LS	$39,000	$507,000	$355,000	$761,000
Earthwork, Trenching and Pipe Installation (44th Street & Piccadilly)	700	LF	$200	$140,000	$98,000	$210,000
System mobilization, setup, and startup	1	LS	$24,000	$24,000	$17,000	$36,000
ISCO System Installation Report (includes as-built drawings)	1	LS	$15,000	$15,000	$11,000	$23,000
ISCO System O&M Plan	1	LS	$5,000	$5,000	$4,000	$8,000
EN Rx Shallow System O&M - Year 1 (system rental, chemicals, and annual maintenance)	1	LS	$216,000	$216,000	$152,000	$324,000
EN Rx Deep System O&M - Year 1 (system rental, chemicals, and annual maintenance)	1	LS	$204,000	$204,000	$143,000	$306,000
EN Rx O&M Labor and Reporting - Year 1	1	LS	$60,000	$60,000	$42,000	$90,000
Year 1 Remedial Progress Report	1	LS	$5,000	$5,000	$4,000	$8,000
Project Management/Oversight/Administration	15%	n/a	n/a	$252,000	$178,200	$379,000
Capital Costs Subtotal				**$1,943,000**	**$1,366,000**	**$2,918,000**
Estimated O&M Annual Costs						
EN Rx Shallow System Annual O&M - Year 2	1	YR	$156,000	$156,000	$110,000	$234,000
EN Rx Deep System Annual O&M - Year 2	1	YR	$156,000	$156,000	$110,000	$234,000
EN Rx O&M Labor and Reporting - Year 2	1	LS	$60,000	$60,000	$42,000	$90,000
O&M Project Management/Oversight/Administration	15%	n/a	n/a	$56,000	$40,000	$84,000
Annual Costs for ISCO O&M Subtotal				**$428,000**	**$302,000**	**$642,000**
Total O&M Costs for 2 Years (Net Present Value - Discounted 3%)				**$869,000**	**$641,000**	**$1,367,000**
Estimated GW Monitoring Annual Costs						
Semiannual GW Monitoring/Reporting (all wells)	2	LS	$16,000	$32,000	$23,000	$48,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$5,000	$4,000	$8,000
Annual Cost for GW Monitoring Subtotal				**$37,000**	**$27,000**	**$56,000**
Eleven Year Total GW Monitoring Costs (Net Present Value - Discounted 3%)				**$474,000**	**$332,000**	**$711,000**
O&M and Monitoring Costs Subtotal				**$1,343,000**	**$973,000**	**$2,078,000**
More Aggressive Alternative Remedy Capital, O&M and Monitoring Costs				**$3,286,000**	**$2,339,000**	**$4,996,000**

Table B-2
Estimated Costs for More Aggressive Remedy
Feasibility Study Report
48th St and Indian School Rd WQARF Site

Estimated Contingency Costs						
Estimated Capital Costs						
Additional Injection Wells						
Shallow injection well (includes permitting, oversight, installation, vertical profile, and IDW)	20	LS	$29,000	$580,000	$406,000	$870,000
Additional Earthwork, Trenching and Pipe Installation from Arcadia Towne Center	3100	LF	$200	$620,000	$434,000	$930,000
Contingency Deep PCE Plume Treatment East of 44th Street						
Deep injection well (includes permitting, oversight, installation, vertical profile, and IDW)	6	LS	$39,000	$234,000	$164,000	$351,000
Earthwork, Trenching and Pipe Installation (44th Street & Piccadilly)	700	LF	$200	$140,000	$98,000	$210,000
Project Management/Oversight/Administration	15%	n/a	n/a	$246,000	$174,000	$372,000
Capital Costs Subtotal				**$1,820,000**	**$1,276,000**	**$2,733,000**
Estimated Additional ISCO O&M Costs - assume 2 years						
EN Rx Shallow System Annual O&M - Year 2	1	YR	$156,000	$156,000	$110,000	$234,000
EN Rx Deep System Annual O&M - Year 2	1	YR	$156,000	$156,000	$110,000	$234,000
EN Rx O&M Labor and Reporting - Year 2	1	LS	$60,000	$60,000	$42,000	$90,000
O&M Project Management/Oversight/Administration	15%	n/a	n/a	$56,000	$40,000	$84,000
Annual Costs for ISCO O&M Subtotal				**$428,000**	**$302,000**	**$642,000**
Total O&M Costs for Years 4-5 (Net Present Value - Discounted 3%)				**$922,000**	**$646,000**	**$1,383,000**
Estimated Additional 2 Years GW Monitoring Costs						
Total GW Monitoring Costs for 2 Additional Years (Net Present Value - Discounted 3%)				**$104,000**	**$73,000**	**$156,000**
O&M and Monitoring Costs Subtotal				**$1,026,000**	**$719,000**	**$1,539,000**
Contingency Costs Subtotal				**$2,846,000**	**$1,995,000**	**$4,272,000**
Total More Aggressive Alternative Remedy Costs (Including Contingencies)				**$6,132,000**	**$4,334,000**	**$9,268,000**

Abbreviations:

WQARF = Water Quality Assurance Revolving Fund
% = percent
ISCO = in-situ chemical oxidation
GW = groundwater
IDW = Investigation Derived-Wastes
LF = linear feet
n/a = not applicable
LS = lump sum
O&M = operations and maintenance

Notes:

1. Total costs are rounded up to the nearest thousand dollars ($1000).
2. Pricing is subject to commodity pricing increases. Contingencies for possible price escalation due to steel or other tariffs is not included.
3. No estimated costs have been included for taxes or other fees relative to the project.
4. Net Present Value - The labor, materials or equipment value in the present of a sum of money, in contrast to a future value when it has been invested at compound interest (assumed at 3%).

Table B-3
Estimated Costs for Reference Remedy
Feasibility Study Report
48th St and Indian School Rd WQARF Site

	Quantity	Unit	Unit Cost	Total Cost	Estimated Low Range (-30%)	Estimated Upper Range (+50%)
Five Year Semi-Annual Monitoring + GWET Component						
Estimated Capital Costs						
Downgradient Performance Well Installation						
Monitoring Well Installation and Oversight (includes vertical profile)	2	LS	$40,000	$80,000	$56,000	$120,000
Survey, Permitting, Sampling and IDW Disposal	2	LS	$25,000	$50,000	$35,000	$75,000
Tech Memo	1	LS	$9,000	$9,000	$7,000	$14,000
GWET System Remedy Final Design						
GWET System Remedy Final Design	1	LS	$50,000	$50,000	$35,000	$75,000
GWET Installation						
Earthwork, Trenching and Pipe Installation (Arcadia Towne Center)	5700	LF	$200	$1,140,000	$798,000	$1,710,000
LGAC Cannister Purchase	2	EA	$9,000	$18,000	$13,000	$27,000
Virgin LGAC fill	2	EA	$3,000	$6,000	$5,000	$9,000
GWET System Installation Report (includes as-built drawings)	1	LS	$15,000	$15,000	$10,000	$23,000
GWET System O&M Plan	1	LS	$5,000	$5,000	$4,000	$8,000
Poor Quality Groundwater Withdrawal Permit	1	LS	$3,000	$3,000	$2,000	$5,000
Project Management/Oversight/Administration	15%	n/a	n/a	$175,000	$123,000	$263,000
Capital Costs Subtotal				**$1,551,000**	**$1,088,000**	**$2,329,000**
Estimated O&M Annual Costs						
GWET System O&M costs (LGAC and electricity)	1	LS	$14,000	$14,000	$10,000	$21,000
GWET System monitoring analytical fees	1	LS	$2,000	$2,000	$2,000	$3,000
GWET O&M Labor and Reporting	1	LS	$11,000	$11,000	$8,000	$17,000
Remedial Progress Report	1	LS	$5,000	$5,000	$4,000	$8,000
Annual Groundwater Withdrawal and Use Report	1	LS	$2,000	$2,000	$1,000	$3,000
O&M Project Management/Oversight/Administration	15%	n/a	n/a	$6,000	$4,000	$8,000
Annual Costs for GWET O&M Subtotal				**$40,000**	**$29,000**	**$60,000**
Total O&M Costs for 10 Years (Net Present Value - Discounted 3%)				**$460,000**	**$322,000**	**$690,000**
Estimated GW Monitoring Annual Costs						
Semiannual GW Monitoring/Reporting (all wells)	2	EA	$16,000	$32,000	$23,000	$48,000
Project Management/Oversignt/Administration	15%	n/a	n/a	$5,000	$4,000	$8,000
Annual Cost for GW Monitoring Subtotal				**$37,000**	**$27,000**	**$56,000**
Total GW Monitoring Costs for 15 Years (Net Present Value - Discounted 3%)				**$689,000**	**$482,000**	**$1,034,000**
O&M and Monitoring Costs Subtotal				**$1,149,000**	**$804,000**	**$1,724,000**
Reference Remedy Capital, O&M and Monitoring Costs				**$2,700,000**	**$1,892,000**	**$4,053,000**

Table B-3
Estimated Costs for Reference Remedy
Feasibility Study Report
48th St and Indian School Rd WQARF Site

Estimated Contingency Costs						
Estimated Capital Costs						
Install Extraction Pump in SMW-18						
Additional Earthwork, Trenching and Pipe Installation	800	LF	$200	$160,000	$112,000	$240,000
Project Management/Oversight/Administration	15%	n/a	n/a	$24,000	$17,000	$36,000
Capital Costs Subtotal				**$184,000**	**$129,000**	**$276,000**
Estimated Additional GWET O&M Costs - assume 3 years						
Total O&M Costs for Years 11-13 (Net Present Value - Discounted 3%)				**$154,000**	**$108,000**	**$231,000**
Estimated Additional 3 Years GW Monitoring Costs						
Total GW Monitoring Costs for 3 Additional Years (Net Present Value - Discounted 3%)				**$179,000**	**$125,000**	**$269,000**
O&M and Monitoring Costs Subtotal				**$333,000**	**$233,000**	**$500,000**
Contingency Costs Subtotal				**$517,000**	**$362,000**	**$776,000**
Total More Aggressive Alternative Remedy Costs (Including Contingencies)				**$3,217,000**	**$2,254,000**	**$4,829,000**

Abbreviations:

WQARF = Water Quality Assurance Revolving Fund
% = percent
GWET - groundwater extraction and treatment
GW - groundwater
IDW - Investigation Derived-Wastes
n/a - not applicable
LF = linear feet
LGAC = liquid phase granular activated carbon
LS = lump sum
O&M = operations and maintenance
EA - each

Notes:

1. Total costs are rounded up to the nearest thousand dollars ($1000).
2. Pricing is subject to commodity pricing increases. Contingencies for possible price escalation due to steel or other tariffs is not included.
3. No estimated costs have been included for taxes or other fees relative to the project.
4. Net Present Value - The labor, materials or equipment value in the present of a sum of money, in contrast to a future value when it has been invested at compound interest (assumed at 3%).

Contingency GWET Assumptions:

1. Estimated costs do not include land acquisition and/or access agreements.
2. LGAC system includes two, 2,000-pound lead/lag systems in series for maximum flowrate of up to 60 gallons per minute.
3. Treated water injected to six existing monitoring wells @ 10 gpm each.
4. Installation of a new electrical service will not be required.