ADEQ
Arizona Department of Environmental Quality

Final Feasibility Study

20th Street & Factor Avenue

Water Quality Assurance Revolving Fund (WQARF) Site
Yuma, Arizona

August 11, 2016
Contract Number ADEQ14-077538

CALIBRE

Matrix DESIGN GROUP

Final Feasibility Study

20th Street & Factor Avenue
Water Quality Assurance Revolving Fund Site
Yuma, Arizona
Arizona Superfund Response Action
Contract Contract Number: ADEQ14-077538

Prepared for:

Arizona Department of Environmental Quality

1110 W Washington St

Phoenix, AZ 85007

Prepared by:

August 11, 2016

FEASIBILITY STUDY

20th Street and Factor Avenue WQARF SITE

August 11, 2016

CERTIFICATION

All information, conclusions, and recommendations in this document have been prepared under the supervision of and reviewed by a Registered Professional Engineer.

Registered Professional Engineer (Civil)
CERTIFICATE NO.
59816
THOMAS
McKEON
Date Signed 08/11/16
ARIZONA U.S.A.

Expires: 04/01/2018

Thomas McKeon, P.E.

Registered Professional Engineer (59816)

Table of Contents

EXECUTIVE SUMMARY 1
1.0 INTRODUCTION 1
1.1 REPORT ORGANIZATION 1
2.0 SITE BACKGROUND AND CONCEPTUAL SITE MODEL 3
2.1 SITE BACKGROUND 3
2.2 CONCEPTUAL SITE MODEL 3
2.2.1 Site/Facility History 4
2.2.2 Geology and Hydrogeology 7
2.2.3 Source Area Delineation 9
2.2.4 Delineation of Groundwater Contamination 9
2.2.5 Fate and Transport 11
2.2.6 Potential Receptors and Exposure Pathways 12
2.2.7 Contaminants of Concern and Applicable Standards 12
3.0 IDENTIFICATION AND SCREENING OF REMEDIAL MEASURES 13
3.1 REMEDIAL OBJECTIVES 13
3.2 ALTERNATIVES SCREENING 14
3.3 DESCRIPTION OF POTENTIAL REMEDIAL MEASURES 14
3.3.1 Remedial Measure 1: No Action 15
3.3.2 Remedial Measure 2: Soil Vapor Extraction 15
3.3.3 Remedial Measure 3: In-Situ Chemical Oxidation 15
3.3.4 Remedial Measure 4: Biological Treatment/Enhanced Reductive Dechlorination (ERD) 16
3.3.5 Remedial Measure 5: In Situ Biological Treatment for Cyanide 17
3.3.6 Remedial Measure 6: Groundwater Extraction and Treatment 17
3.3.7 Remedial Measure 7: Water Supply Replacement 18
3.3.8 Remedial Measure 8: Well-head Treatment 18
3.3.9 Remedial Measure 9: Monitored Natural Attenuation 19
3.3.10 Remedial Measure 10: Cap Inspection, Maintenance, and Replacement 19
3.4 RETAINED REMEDIAL MEASURES 19
4.0 REFERENCE REMEDY AND ALTERNATIVE REMEDIES 21
4.1 REFERENCE REMEDY 21
4.1.1 Saturated Zone Source/Plume Remediation: In Situ Biological Treatment 21
4.1.2 Plume Control/Monitoring: Monitored Natural Attenuation 22
4.1.3 Cap Inspection, Maintenance, and Replacement 23
4.1.4 Vadose Zone Source Control: Soil Vapor Extraction 23

4.2 MORE AGGRESSIVE REMEDIAL ALTERNATIVE 24
4.2.1 Plume Remediation: Enhanced Reductive Dechlorination 24
4.2.2 Plume Containment: Groundwater Extraction and Treatment 25
4.2.3 Cap Inspection, Maintenance, and Replacement 25
4.2.4 Vadose Zone Source Control: SVE Operations 25
4.3 LESS AGGRESSIVE REMEDIAL ALTERNATIVE 25
4.3.1 Monitoring/Monitored Natural Attenuation 26
4.3.2 Water Supply Replacement 26
4.3.3 Cap Inspection, Maintenance, and Replacement 27
5.0 COMPARISON OF THE REFERENCE REMEDY AND ALTERNATIVE REMEDIES 28
5.1 THRESHOLD CRITERIA 28
5.2 COMPARISON CRITERIA: PRACTICABILITY, RISK, COST, AND BENEFIT 29
5.2.1 Practicability 29
5.2.2 Risk 30
5.2.3 Cost 31
5.2.4 Benefit 33
6.0 RECOMMENDED REMEDY AND BASIS FOR SELECTION/RECOMMENDATION 35
6.1 COMPARISON CRITERIA 35
6.2 ACHIEVEMENT OF THE SITE REMEDIAL OBJECTIVES 35
6.3 REQUIREMENTS OF A.R.S. § 49-282.06 36
6.4 COMMUNITY INVOLVEMENT 36
7.0 REFERENCES 37

APPENDIX A Evaluation of Site conditions and the Need for Soil Vapor Extraction

APPENDIX B Backup Details of Cost Estimates for Each Remedy

List of Tables

Table 2-1 Soil Vapor Screening Levels
Table 2-2 Summary Soil and Groundwater Standards for Primary Contaminants of Concern
Table 5-1 Summary of Comparison of Reference Remedy and Alternative Remedies
Table 5-2 Summary of Relative Cost Comparisons for Remedial Alternatives

List of Figures

Figure 1-1 Site Location Map
Figure 1-2 Facility Layout
Figure 2-1 Extent of Groundwater Contamination (February 2016)
Figure 2-2 Conceptual Site Model
Figure 2-3 Monitoring Well Network
Figure 2-4 PCE Plume in Vadose Zone at 20 feet bgs (January 2011)
Figure 2-5 PCE in Zone A (February 2016)
Figure 2-6 Cyanide in Zone A (February 2016)
Figure 2-7 PCE in Zone B (February 2016)
Figure 2-8 Cyanide in Zone B (February 2016)
Figure 2-9 TCE in Zone A (February 2016)
Figure 2-10 TCE in Zone B (February 2016)
Figure 2-11 PCE and TCE trends in selected monitoring wells
Figure 2-12 Primary Degradation Pathways for Chlorinated Ethenes
Figure 4-1 Elements of the Reference Remedy
Figure 4-2 Elements of the More Aggressive Remedy
Figure 4-3 Elements of the Less Aggressive Remedy

Abbreviations and Acronyms

A.A.C.	Arizona Administrative Code
ADEQ	Arizona Department of Environmental Quality
A.R.S	Arizona Revised Statutes
AWQS	Aquifer Water Quality Standard
bgs	below ground surface
COC	chemicals of concern
CSM	conceptual site model
1,1-DCE	1,1-dichloroethene
EPA	U.S. Environmental Protection Agency
ERA	Early Response Action
ERD	enhanced reductive dechlorination
FS	Feasibility Study
Ft	feet
GPL	groundwater protection level
gpm	gallons per minute
HIL	Houston International, Limited
HPP	Houston Photo Products
HWS	Hazardous Waste Section

ISCO	in-situ chemical oxidation
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µg/m^3	micrograms per cubic meter
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNA	monitored natural attenuation
NOI	notice of intent
O&M	Operations and Maintenance
PCE	tetrachloroethene
PRAP	Proposed Remedial Action Plan
redox	oxidation-reduction
RI	Remedial Investigation
RO	remedial objective
ROD	Record of Decision
SRL	soil remediation level
SVE	soil vapor extraction
TCE	trichloroethene
UIC	underground injection control
UST	underground storage tank
USGS	United States Geological Survey
VOC	volatile organic compound
WQARF	Water Quality Assurance Revolving Fund

EXECUTIVE SUMMARY

This report presents a Feasibility Study (FS) for the 20th Street and Factor Avenue Water Quality Assurance Revolving Fund (WQARF) Site (the Site), located in Yuma, Arizona (Figure 1-1). This FS has been prepared for the Arizona Department of Environmental Quality (ADEQ) under contract number ADEQ14-077538. The FS has been prepared in accordance with Arizona Administrative Code (A.A.C.) R-18-16-407.

The source of contamination at the Site is associated with waste disposal activities at a former photo processing facility (the Facility). Chemicals used at the Facility include tetrachloroethene (PCE) and cyanide. PCE breaks down in the environment to trichloroethene (TCE) and 1,1-dichloroethene (1,1-DCE), which are also chemicals of concern (COCs) at the Site. Over 25 years of environmental investigations have been undertaken at the Site to characterize the nature and extent of contamination in soil, soil vapor, and groundwater. A Remedial Investigation (RI) report presented this information and characterized the risk to human health and the environment (Tetra Tech, 2014). The media of primary concern is groundwater, where COCs have migrated up to 4,500 feet from the facility to the west-northwest. An early response action (ERA) was completed at the Facility in 2002, in which shallow soil containing elevated levels of cyanide was removed from the site and a cap was placed over the excavation area. Liquids and sludge containing PCE were also removed from septic systems at the Facility.

In the RI, remedial objectives (ROs) were developed for soil and groundwater:

- **ROs for soils and land use in the area of the Site:** *To restore soil conditions to the remediation standards for non-residential or residential use.*
- **ROs for current and reasonably foreseeable future groundwater use in and near the Site:** *To restore and protect for the use of the groundwater supply by private well owners in the vicinity of the site from contamination at the site.*

Land use at the Site includes a mixture of industrial (near and around the Facility), commercial, and residential. Currently, there are no production or private wells using groundwater from the site. There are irrigation wells at three schools that are located beyond the current extent of contamination that could be affected if the plume continues to migrate unchecked. These schools are St. Francis of Assisi School, Alice Byrne Elementary School, and the O.C. Johnson Elementary School. The first two are within a half mile of the nearest monitoring well with contaminated groundwater. The third (O.C. Johnsen Elementary) is approximately one mile down gradient and is located slightly north of the projected plume flow path.

The FS considered ten remedial measures that could be implemented to address one or more contaminated media at the site. These included:

1. No action (as a baseline);
2. Soil Vapor Extraction (SVE);
3. In-situ chemical oxidation (ISCO);
4. Biological treatment/enhanced reductive dechlorination (ERD);
5. In Situ biological treatment for cyanide;
6. Groundwater extraction and treatment;
7. Water supply replacement;
8. Well-head treatment;
9. Monitored Natural Attenuation (MNA); and
10. Cap inspection, maintenance, and replacement.

Several of these were eliminated from further consideration, others were retained and combined into three remedies that were carried forward for evaluation: the reference remedy, the more aggressive remedy, and the less aggressive remedy.

The reference remedy includes ERD at locations within the groundwater plume that have the greatest PCE or TCE concentrations. Biological treatment using ERD would be implemented in new wells where a solution containing sugar would be injected into wells in order to promote biochemical reactions that transform PCE, TCE, and 1,1-DCE into less toxic chemicals. This would include installation of a cross-plume transect line of ERD wells (bio-barrier wells) near the leading edge of the plume to control migration of contaminated groundwater further to the west northwest. A similar approach would be used to degrade cyanide in wells that are on, or closer, to the Facility. The progress of this technology would be monitored and adjusted as appropriate by periodically collecting groundwater samples. Additionally, the asphalt cap, which covers the soil removal area at the Facility, would be inspected, maintained, and repaired as necessary. SVE is included solely as a contingency and would only be implemented in the event that future monitoring indicated that COCs from above the water table were acting as an ongoing source of contamination that prevented achieving the RO for groundwater. Estimated costs for the reference remedy are $5.4 million. Accounting for the time value of expenditures over the 20 year estimated lifetime of the project, using a 7% interest rate, the net present value of the reference remedy is $3.8 million.

The more aggressive remedy is similar to the reference remedy with the exception that three extraction wells would be used to control migration of the plume rather than the bio-barrier wells. A pipeline would convey the extracted water to a treatment facility that would be designed to remove

PCE, TCE, 1,1-DCE, and cyanide from the water, which would then be discharged to a sanitary or storm sewer system or possibly reused. Other components of the remedy are essentially the same as the reference remedy. Estimated costs for the more aggressive remedy are $9.2 million. Accounting for the time value of expenditures over the 30 year estimated lifetime of the project, using the same 7% interest rate, the net present value of the more aggressive remedy is $5.9 million.

The less aggressive remedy relies on monitored natural attenuation to track the progress of the groundwater plume. In the event that COCs approach the schools, the existing irrigation wells would be taken offline and municipal water from the City of Yuma would be used to irrigate playfields. Based on the observed plume flow direction and the position of the schools at differing angles from the source area, it is anticipated that two of the three schools could potentially be impacted, but it is unlikely that all three would be impacted. The cost of purchasing the water is substantial because the schools pump on the order of 1,000 gallons per minute (gpm). Cap inspection, maintenance and repair are also included with the less aggressive alternative. Estimated cost for the less aggressive remedy is $9.4 million. Accounting for the time value of expenditures over the 30 year estimated lifetime of the project, again using a 7% interest rate, the net present value of the less aggressive remedy is $3.8 million.

The three remedies were evaluated against criteria including practicability, risk, cost, and benefit. The alternatives are similar on most criteria except that the more aggressive alternative is slightly less practical because of the complications associated with constructing a conveyance pipeline and treatment plant which would require either easements or land purchases. The benefit associated with the less aggressive remedy is perceived to be lower than for the others because there may be resistance from school management or parent groups to modifying the existing irrigation systems. The costs presented in the previous paragraphs indicate that the reference remedy is the most cost-effective approach.

Based on the Site conditions and information presented in this FS, the reference remedy is the recommended remedy at the Site. The next steps involve preparation of a Proposed Remedial Action Plan (PRAP), a document describing the justification for selection of the remedy, which is available for public comment. Comments are then reviewed and addressed and a Record of Decision (ROD) is issued which documents selection of the final remedy. Subsequently, remedial design and remedial implementation would be conducted. In the meantime, ADEQ may implement ERAs to accelerate the cleanup process.

1.0 INTRODUCTION

This report presents a Feasibility Study (FS) for the 20th Street and Factor Avenue Water Quality Assurance Revolving Fund (WQARF) Site (the Site), located in Yuma, Arizona (Figure 1-1). The Site has been under study for decades because of releases from the former Houston Photo Products Facility (the Facility), which is shown on Figure 1-2. This FS has been prepared for the Arizona Department of Environmental Quality (ADEQ) as Task Orders 17 and 22 under contract number ADEQ14-077538. The FS has been prepared in accordance with Arizona Administrative Code (A.A.C.) R-18-16-407.

The FS is part of a process to evaluate and cleanup contamination at the Site under the process defined in A.A.C. R-18-16. The main components of the process are:

- Remedial Investigation (RI) to study the history of releases and nature and extent of contamination, and identify potential impacts to public health and the environment, which was completed in 2014 (Tetra Tech, 2014);
- FS report to identify a reference remedy, and alternative remedies that appear to be capable of achieving remedial objectives (ROs) and to evaluate them based on certain comparison criteria defined in A.A.C. R-18-16-407(H)(3);
- Proposed Remedial Action Plan that proposes and justifies a remedy for the Site and provides an opportunity for public involvement;
- Record of Decision by ADEQ that documents the remedy selection and provides a responsiveness summary of all public comments;
- Remedial Design and Implementation of the remedy; and
- Determination of No Further Action when ADEQ finds that the Site or portion of the Site does not present a significant risk to the public health, welfare, or the environment.

The FS builds on a report outlining several potential remedies for the site (Matrix-CALIBRE, 2015a).

1.1 REPORT ORGANIZATION

This FS is organized into the following Sections:

- Section 1.0 – Introduction – This section presents a summary of the FS objectives and report organization.
- Section 2.0 – Site Background and Conceptual Site Model – This section presents a summary of the Site conditions, nature and extent of contamination, remedial action history, regulatory requirements, and conceptual site model (CSM).

- Section 3.0 – Identification and Screening of Remediation Technologies and Alternatives – This section presents the ROs, the identification and screening of remedial alternatives considered, and the remedial alternatives retained for further consideration.
- Section 4.0 – Development of a Reference Remedy and Alternative Remedies – This section carries forward remedial alternatives retained from Section 3.0 and presents a reference remedy, a more aggressive remedy, and a less aggressive remedy.
- Section 5.0 – Comparison of the Reference Remedy and Alternative Remedies – This section compares the remedies developed in Section 4.0 against criteria including demonstration of RO achievement, consistency with water management plans, practicability, risk, cost, and benefit.
- Section 6.0 – Proposed Remedy – This section outlines the recommended remedy based on the comparison of the remedies in Section 5.0.
- Section 7.0 – References – This section presents the references cited in this FS.

2.0 SITE BACKGROUND AND CONCEPTUAL SITE MODEL

This section summarizes the Site background and presents a CSM that is used to guide development of appropriate remedial measures.

2.1 SITE BACKGROUND

The Site is in an area of Yuma that includes a mixture of commercial and light industrial businesses, warehouses, residential neighborhoods, and three schools encompassing an area of approximately 80 acres. The Site is roughly bounded by 17th Street to the north, 21st Street to the south, 4th Avenue to the west, and Kennedy Lane to the east (Figure 2-1). Releases of volatile organic compounds (VOCs) and cyanide are documented at the former Houston Photo Products Facility (Facility) (Tetra Tech, 2014). To date, no other sources of VOCs and cyanide have been identified in the area. The Facility is located near the southeast corner of the 20th Street and Factor Avenue intersection. Based on 2016 groundwater monitoring data, the contaminant plume extends approximately 4,500 feet (ft) to the northwest down-gradient from the Facility.

Floating petroleum hydrocarbon free product has been observed intermittently in several wells on the north side of 20th Street (Figures 1-1 and 2-1), which is probably related to a diesel release from a Union Pacific Yuma Yard facility, also known as the Dieselville site, located to the east of the Facility.

Tetrachloroethene also known as tetrachloroethylene (PCE) is the primary chemical of concern (COC) identified at the Site; other COCs identified in the 2014 RI include trichloroethene or trichloroethylene (TCE) and 1,1-dichloroethene or 1,1-dichloroethylene (1,1-DCE) and cyanide. The COCs have been detected in soil, soil vapor, and groundwater. Based on the areal extent of COCs above the Aquifer Water Quality Standards (AWQSs), groundwater is the most significantly impacted environmental media. As of 2016, the extent of the VOC plume in groundwater covers approximately 64 acres.

2.2 CONCEPTUAL SITE MODEL

A CSM has been developed for this FS based on information from the Site RI. The CSM presented in Figure 2-2 provides a graphical illustration of Site conditions applicable to the primary contaminant released at the Site and the related soil and groundwater contamination present. The CSM discussion presented herein differs somewhat from the CSM discussion presented in the RI Report (Tetra Tech, 2014); this CSM is revised/streamlined to focus on information relevant to Site remediation. This CSM includes information on operational history, site-specific geology and hydrogeology, contaminated media and potential source areas, groundwater quality, groundwater transport at the Site, potential receptors and exposure pathways, and contaminants of concern and applicable

standards. The CSM will ultimately be used in the future to test the performance of implemented remedies and is intended to evolve as performance monitoring data are collected during remedial actions.

2.2.1 Site/Facility History

From 1989 to the present, multiple Site investigations and cleanup actions have been implemented at the different facilities within the Site. The chronology listed below is summarized from the RI report (Tetra Tech, 2014) and the project website (ADEQ, 2016).

1966 - 1988: Houston Photo Products (HPP) operated a motion picture laboratory and a facility which also manufactured photographic film and paper processing equipment for the photo industry. In 1988, HPP changed its name to Houston International, Limited (HIL). The chemicals used at the facility include standard photographic chemicals, namely PCE, small amounts of various other photographic chemicals and water. The wastewater at the facility was treated to recover silver. The treated wastewater was disposed in three ways:

- Some of the wastewater was discharged to a 1,000-gallon concrete underground sump on the east side of the property. When this sump was full, it was discharged to a disposal pond on the east side of the property. Wastewater from this disposal pond overflowed onto the adjacent property to the east of the Site;
- Wastewater was used to water plants in landscaped areas at the front of the building; and
- Wastewater was discharged to the ground in the southwest portion of the property by a sprinkler system and later to a sump.

Beginning in 1975, HPP/HIL used PCE to clean stainless steel machine parts. On one occasion in 1978, PCE was discharged to the 1,000-gallon concrete underground tank.

1990 - 1995: HIL reported a leaking tank to the ADEQ Underground Storage Tanks (UST) Section. The ADEQ UST Section referred the facility to the ADEQ Water Pollution Compliance Unit. Consultants for HIL conducted soil and groundwater investigations under the oversight of the Water Pollution Compliance Unit.

In 1990, PCE and metals were detected in on-site soils. Subsequent soil investigations indicated that PCE was present in soil at concentrations below the Arizona residential soil remediation level (SRL) of 53,000 micrograms per kilogram (µg/kg) enforced at that time. In 1991, HIL began to use Industroclean (which contains ethylene glycol monobutyl ether) in place of PCE. Consultants for HIL installed three groundwater monitor wells (MW-1, MW-2, and MW-3) and performed groundwater

sampling in 1993. The PCE concentrations exceeded the AWQS for PCE of 5.0 micrograms per liter (µg/l).

Also in 1993, the ADEQ Hazardous Waste Section (HWS) inspected the facility, and in 1994, HIL and the ADEQ HWS entered into a compliance order. Consultants for HIL conducted additional soil and groundwater investigations under the compliance order. In 1994, a soil vapor survey was conducted. Elevated concentrations of PCE were present in the soil vapor samples. TCE and 1,1,1-trichloroethane were also detected in soil vapor samples. HIL moved its motion picture laboratory operation off-site. The facility is currently occupied by the offices of Houston Film Labs and a dance studio. This operation does not generate wastewater.

1996: One nested groundwater monitoring well (MW-102) and one up-gradient monitor well (MW-101) were installed at the Site (Figure 1-2). The maximum PCE concentration detected was 520 µg/L in MW-2 at 140 to 150 ft below ground surface (bgs).

1998 - 2000: In 1998, the ADEQ HWS referred the facility to the ADEQ Superfund Programs Section, Site Assessment Unit. The Site was placed on the WQARF Registry in March 2000 with a score of 31 out of a possible 120.

2001: ADEQ began Site investigation activities at the facility. A review of the Material Safety Data Sheets of the chemicals used at the facility indicated that two cyanide compounds, potassium ferricyanide and sodium thiocyanate, were also used at the facility. Both of the cyanide compounds used at the facility can degrade to hydrogen cyanide in sunlight or in an environment with a near neutral pH. Analyses of wastewater in the septic systems indicated that elevated cyanide concentrations were present in the wastewater disposal system. Cyanide was also detected in groundwater samples above the AWQS of 0.2 milligrams per liter (mg/L).

ADEQ completed the characterization of cyanide-contaminated soils at the Site. Several areas on the Site exceed the non-residential SRL of 35 milligrams per kilogram (mg/kg) for hydrogen cyanide.

2002: ADEQ completed an early response action (ERA) at the Site, which included excavation and disposal of the upper foot of cyanide-contaminated surface soils. Approximately 1,700 tons of contaminated soils were removed from the Site. A one-foot cap of aggregate base coarse material was placed over the remaining cyanide-contaminated soils. This cap helps prevent direct exposure to the underlying contaminated soils remaining at the Site. The ERA also included the removal of two unused sumps and the cleaning of three active septic systems at the Site. PCE and cyanide-contaminated wastewater and sludge were removed from the disposal system. The removal of this source material addressed a continuing source of groundwater contamination.

2003: Soil and soil vapor samples were collected from six borings at the Site. Samples were collected to evaluate the vertical extent of PCE contamination. Sampling results indicated that the concentrations of PCE remaining in the soil did not exceed regulatory standards.

2004: ADEQ collected indoor air data from the buildings on the property and one building adjacent to the property. These data were collected as part of a risk assessment of the indoor air at the Site. ADEQ also drilled and sampled four deep borings beneath two of the remaining septic tanks and the former disposal pond area. The purpose of these borings was to evaluate the cyanide contamination at depth in these areas. Cyanide contamination above the non-residential SRL extends to a depth of approximately 17 ft bgs in some areas of the Site. ADEQ used these data and other information to develop groundwater protection levels (GPLs) for the cyanide contaminated soils remaining in place. In this time period, ADEQ also drilled and sampled two deep groundwater monitoring wells at the Site. Analysis of groundwater samples from these deep wells did not indicate PCE or cyanide contamination above their respective AWQS.

2005 - 2006: ADEQ drilled and sampled ten additional groundwater monitoring wells to further define the extent of the contaminant plume. Laboratory analyses from these monitoring wells indicate that the contaminant plume extends approximately ½ mile downgradient of the Site. The lateral extent of the plume was not yet fully characterized.

2007: Installation of additional deep groundwater monitoring wells indicated that groundwater was present in three distinct zones: shallow (50 to 90 ft bgs); middle (105 to 170 ft bgs) and deep (starting at 170 ft bgs). Each zone is divided by separate clay units. Groundwater samples from each zone indicated that the majority of the contaminant plume was located within the middle zone.

2008: ADEQ installed one groundwater extraction well in the middle of the contaminant plume. An aquifer test was completed to determine aquifer characteristics. The last remaining septic system on the HIL property was taken out of service and replaced with a new system and leach field located away from contaminated soil. Additional information was gathered north of the HIL property to locate potential sources areas.

2009 - 2011: A soil vapor investigation was performed which included the installation of several permanent soil vapor monitoring probes and a soil vapor survey in order to help identify potential source areas. Additional permanent soil vapor monitoring probes were installed and groundwater samplings were conducted. ADEQ continued to investigate the Site to identify the extent of the groundwater contamination. Groundwater sampling results indicated the PCE plume extends over 4,000 ft down-gradient from the Site.

2012: ADEQ continues to investigate the Site to identify the extent and severity of the groundwater contamination. ADEQ finalized plans to install a permanent asphalt based cap over the one-foot cap of aggregate base coarse mater covering the cyanide impacted soils still remaining at the Site.

2013: ADEQ completed the installation of a permanent asphalt based cap over the cyanide impacted soils. This cap will limit human access to these soils and limit further impacts to the groundwater beneath the Site by minimizing the amount of cyanide leaching from cyanide contaminated soils. ADEQ installed three additional monitoring wells down gradient of the Site.

2014: During 2014 ADEQ installed seven additional soil vapor monitor wells at the Site. A round of soil vapor sampling was also conducted. Soil vapor samples were analyzed for hydrogen cyanide and VOCs including PCE and TCE. Hydrogen cyanide was not detected in any of the samples. PCE and TCE were detected at concentrations below ADEQ's suggested soil vapor screening levels (Table 2-1). ADEQ completed the draft RI report, solicited comments on the draft RI and on the Proposed ROs.

2015: During March 2015, ADEQ completed one round of groundwater monitoring at the Site. PCE concentrations and distribution in the upper part of the aquifer (Zone A) remained relatively constant with the highest PCE levels detected at a concentration of 54 micrograms per liter (µg/L). In the middle portion of the aquifer (Zone B), PCE concentrations and distribution also remained relatively constant with the exception of monitoring well MW-18B, where concentrations continued to rise and PCE was detected at 1,000 µg/L.

In the upper part of the aquifer (Zone A), cyanide concentrations remain above the AWQS of 0.2 mg/L in one monitoring well, MW-5A. In the middle part of the aquifer (Zone B), cyanide is present at 0.2 mg/L in one monitoring well, MW-18B. Cyanide concentrations in the middle part of the aquifer continue to separate from the source area.

No contaminants were detected above standards in the deeper part of the aquifer (Zone C).

2016: One new monitoring well (MW-31B) was installed and one round of groundwater monitoring was completed at the Site, as described in Section 2.2.4. Figure 2-3 shows the monitoring well network for the Site as well as the location of the irrigation wells at the Saint Francis Assisi and Alice Byrne schools.

2.2.2 Geology and Hydrogeology

The Site lies on the Yuma Mesa at approximately 200 ft above sea level, which is approximately 100 ft higher than the Yuma Valley (Dickinson, et al., 2006). From oldest to youngest, the sediments underlying the Site are the wedge zone, coarse-gravel zone, and the upper fine-grained zone

(Olmsted, et al., 1973). Clay A and Clay B, which are within the upper fine-grained zone may be present in localized areas beneath the Site (Dickinson, et al. 2006). The wedge zone is composed of fluvial and deltaic deposits of sand, silt, clay, and gravel from the Colorado and Gila Rivers.

The coarse-gravel zone is a complex of gravel bodies of different ages deposited by the Colorado and Gila Rivers (Olmsted, et al. 1973). The zone ranges in thickness from 0 to possibly more than 150 ft; the top lies at an average depth of 100 ft beneath the valleys and 170-180 ft beneath the Yuma Mesa. The earliest identification of the coarse-gravel zone described it as a widespread, blanket-like deposit underlying most of the Upper Mesa, the intervening Yuma Mesa and river valleys. Later more detailed studies by the U.S. Bureau of Reclamation and the United States Geological Survey (USGS) demonstrated that the coarse-gravel zone is a complex series of multiple gravel bodies of different ages. As a consequence, the top and bottom of the coarse-gravel zone are at different elevations from place to place.

Some well logs used by the USGS to identify the coarse-gravel zone include descriptions such “coarse gravel, clean gravel, sandy gravel, or pea gravel”, but also generally include multiple inter-bedded sequences of sands/silts and clays within the unit. Other well logs include descriptions such “Sand and gravel, gravelly sand; Sand and scattered gravel; Sandstone cemented sand; and Sand”, and also include multiple inter-bedded sequences of silts and clays within the unit.

Most of the monitoring wells drilled during the RI were terminated within the upper, fine-grained zone (sand and silt). Two distinct fine-grained beds are identified in the upper portions of the upper fine-grained zone (Olmsted, et al. 1973). These fine-grained beds are identified in many wells beneath portions of eastern Yuma Valley and western Yuma Mesa. The lower fine-grained bed, informally designated as the “Clay A” is a marker that is described as “not far above the coarse-gravel zone beneath Yuma Valley and adjacent parts of Yuma Mesa”. The Clay A unit is at a depth of approximately 175 ft bgs in areas located to the northwest of the Site (Olmsted, et al. 1973). The Clay A unit, along with the Clay B unit at about 100 ft bgs, is identified in many well logs and the cross sections for the Site.

Groundwater level maps presented in the RI report indicate that groundwater flows to the west northwest. The hydraulic gradient is approximately 0.001 ft/ft. Groundwater is between 70 to 75 ft bgs at the Facility and is 80 to 85 ft bgs in wells at the west end of the Site. The RI Report assigned wells screened above Clay B, to a depth of 105 ft, to “Zone A”. Wells screened below this, to a depth of 170 ft, above Clay A, were assigned to “Zone B”. Wells screened below 170 ft were assigned to “Zone C”. Although monitoring wells have been classified into Zone A, Zone B, and Zone C based on the depth of the screen intervals, the depth to groundwater in each zone is similar, suggesting that the Clay A and Clay B units, where present, are not acting as aquitards over the scale of the Site.

A range of estimates for groundwater and contaminant transport velocities have been developed for the site. A velocity of 100 ft/yr for Zone B was estimated based on a groundwater model (GeoTrans 2008). An empirical contaminant transport velocity of 280 ft/yr was estimated in a technical memorandum based on the travel time for peak concentrations between wells on the centerline of the plume (Matrix-CALIBRE, 2015b).

2.2.3 Source Area Delineation

As noted in the prior sections, multiple investigations and ERAs have been implemented at the Site to target potential areas with soil contamination.

A vadose zone vapor plume of PCE at a depth of 20 ft is shown in Figure 2-4. This figure is reproduced from the RI report and is based on soil gas samples collected in 2011 (Tetra Tech, 2014). Data in the RI Report indicates that the soil vapor, from other depth intervals, are similar but generally less than at the 20 ft interval. The highest soil gas total VOC concentration detected in 2011 was PCE at 15,600 micrograms per cubic meter ($\mu g/m^3$) in SVMW-18, at a depth of 60 ft bgs. The risk analysis in the RI indicated that the soil gas was not likely to be a significant human health risk factor via infiltration to buildings or other transport pathways. There is a potential that soil gas or associated pockets of contaminated soil are acting as an ongoing source to groundwater, however, the contribution if any, is believed to be small (compared with the contribution decades ago when waste disposal operations were occurring). Appendix A provides an analysis of the estimated mass of PCE in the vadose zone and compares it to the mass of PCE and TCE in the saturated zone.

2.2.4 Delineation of Groundwater Contamination

Contaminated groundwater associated with releases from the Facility has primarily impacted Zone A and Zone B of the aquifer. VOCs, including PCE and degradation products (mainly TCE), and cyanide are the primary COCs. This section describes the extent of groundwater contamination as it relates to the need for remedial actions at the Site. The groundwater contamination is described for Zone A and then Zone B.

Figure 2-5 shows the PCE plume in Zone A based on samples collected in February 2016. The greatest PCE concentration detected in Zone A was in well MW-14A at a concentration of 75 µg/L. The PCE plume extends just to the west northwest of MW-18A, where the concentration was 7.7 µg/L. The PCE concentrations near the Facility are relatively low: MW-6A has a PCE concentration of 17 µg/L. PCE concentrations in the first wells installed at the Site have decreased from over 10,000 µg/L in MW-1A, MW-2A and MW-3B to near or below the AWQS since the early 1990s (discussed in more detail at the end of this section and illustrated on Figure 2-11). This pattern of substantial concentration decreases at the source area and concentration increases at wells distal from the

source area can be characterized as a "detached plume". The length of the PCE plume in Zone A at concentrations exceeding the AWQS is approximately 2,700 ft.

Figure 2-6 shows the cyanide plume in Zone A based on samples collected in February 2016. The greatest total cyanide concentration (10.5 mg/L) detected in a Zone A was in well MW-5A, which is located on the Facility. The most distal detection exceeding the AWQS of 0.2 mg/L was in well MW-14A at a concentration of 0.256 mg/L. The cyanide plume in Zone A where it exceeds the AWQS is approximately 1,300 ft long.

Figure 2-7 shows the PCE plume in Zone B based on samples collected in February 2016. The greatest PCE concentration detected in Zone B was in well MW-18B at a concentration of 1,400 µg/L. PCE in MW-18B had been near or less than the AWQS until January 2012 when it was detected at a concentration of 560 µg/L, and the PCE concentration has been consistently increasing with only a single exception in 2013. This pattern suggests transport of a slug of PCE towards and past MW-18B. PCE has not reached MW-21B, which is located approximately 800 ft to the west-northwest of MW-18B. There are not many Zone B wells near the source area, but in MW-102B1 the PCE concentrations have been less than 100 µg/L for over a decade. The PCE plume in Zone B is approximately 2,800 ft long.

It should be noted that near the northwest edge of the plume, there is uncertainty in the width and leading edge of the plume because of the relatively wide spacing of the wells in those areas. For example, the north-south extent of PCE contamination in Zone B at MW-18B as illustrated by the 5 µg/L contour is approximately 500 ft wide, but it could be narrower, or wider. Additional wells planned as part of the remedy implementation in this area will be used to fully define the area requiring treatment.

Figure 2-8 shows the cyanide plume in Zone B based on samples collected in February 2016. One Zone B well had a detection of cyanide exceeding the AWQS; MW-18B at a concentration of 1.22 mg/L.

Figure 2-9 shows the distribution of TCE in Zone A and Figure 2-10 shows the TCE distribution in Zone B based on samples collected in February 2016. TCE is only present in a few wells at concentrations above the AWQS. MW-21B (Figure 2-10) is the well of most concern because the TCE concentrations have been rising significantly over the last several years.

An examination of time series plots of PCE and TCE for six wells, two in Zone A (MW-1A and MW-14A) and four in Zone B (MW-8B, MW-18B, MW-21B, and MW-22B) along the approximate centerline of the plume is useful for visualizing the evolution and movement of the plume (Figure 2-11). Note that the concentration scale is 0 to 1,400 µg/L for MW-8B, MW-18B, and MW-22B. The concentration

scale is different for the other three wells. Also, the time scale is different for MW-1A, which was first sampled in 1992, while the other five wells were first sampled beginning in 2006 or later. The first several PCE samples from MW-1A were approximately 20,000 µg/L, after which time the concentrations dropped dramatically. The PCE data for MW-14A are irregular with a maximum of 240 µg/L in 2013. The PCE data for MW-22B show a maximum of 1,200 µg/L in 2008 and rapidly decline thereafter. The PCE data for MW-8B also show a peak in 2008 of 1,300 µg/L followed by a significant decrease. MW-8B also has significant concentrations of TCE, presumably representing the degradation of PCE. MW-18B had relatively low concentrations of PCE and TCE through 2008. Sampling in that well was suspended until 2012 and the concentration of both PCE and TCE have been increasing at a fairly steady rate since 2013. This pattern is consistent with plume migration. MW-21B is dominated by TCE and since 2014 the concentrations are demonstrating a steep increase. Neither PCE nor TCE have been detected at MW-30B or MW-31B, however these wells are relatively new and are located approximately 1,200 ft downgradient from MW-21B.

Figure 2-1 is a combined plume map showing the outer extent of contamination above an AWQS for PCE, TCE, and or cyanide, as of spring 2016.

In general, the existing data indicate that the VOC plume does not extend below Zone B into Zone C, but there is some uncertainty in this conclusion because there are relatively few Zone C wells.

2.2.5 Fate and Transport

Chlorinated VOCs can be persistent in the environment and can travel downgradient significant distances with limited attenuation. Attenuation can occur by adsorption to soil, by biodegradation, or by dispersion from the core of the plume into surrounding groundwater as it travels downgradient. With biodegradation, the presence of biodegradation “daughter products” such as TCE, 1,1-DCE, and vinyl chloride generally indicate that biodegradation is occurring within the plume. Figure 2-12 shows the degradation pathways for PCE.

As described in Section 2.1, free product diesel has been measured in monitoring wells located on 20th Street that is likely related to the Dieselville site. Diesel can have a confounding effect at sites with chlorinated solvents because the solvents can partition into the free-phase diesel and remain trapped in the free product.

A groundwater flow model was developed for the site to estimate contaminant travel times and well extraction rates that might be required to capture and contain the plume (GeoTrans, 2008). That calibrated model indicated that groundwater velocity is approximately 100 ft/year. Two pumping scenarios were simulated, which suggested that between 70 and 100 gallons per minute, extracted from two or three wells should be sufficient to control migration of the plume.

2.2.6 Potential Receptors and Exposure Pathways

Currently, there are no entities either private or public, extracting groundwater from areas where the aquifer is known to be contaminated. The one-foot of aggregate base coarse material and asphalt cap placed over the cyanide contaminated soil at the Facility prevents exposure from soil ingestion and vapor inhalation. The risk assessment described in the RI report indicates that vapors in the vadose zone do not present an unacceptable risk to workers in the industrial building located over the vapor plume as it was measured in 2011.

Potential future exposure pathways at the Site include groundwater use for irrigation purposes. Other potential exposure pathways are human contact with soil (construction scenario) and inhalation of vapor if vapor intrusion were to occur.

Groundwater is not currently used as a potable water source in the area of contamination; however, the resource is designated as a potential source of potable water. It is possible, but considered unlikely, that the City of Yuma could expand their groundwater extraction network in an area impacted by Site COCs. The City's water conservation plan indicates that there is sufficient water supply capacity for the foreseeable future (City of Yuma, 2015).

2.2.7 Contaminants of Concern and Applicable Standards

As noted previously, the COCs for the Site are PCE, TCE, and 1,1-DCE. Additionally, cyanide quantified as total, free, or amenable, are COCs[1].

The relevant soil and groundwater standards for the COCs are shown in Table 2-2.

[1] Cyanide is the molecule CN (carbon and nitrogen). Free cyanide includes both CN and hydrogen cyanide (HCN). Amenable cyanide is an analytical procedure that measures common metal cyanide compounds that are amenable to chlorination. Total cyanide includes all forms of cyanide (Britton, P, J. Winter, and R.C. Kroner, 1984).

3.0 IDENTIFICATION AND SCREENING OF REMEDIAL MEASURES

This section provides a description of the remedial measures (i.e., specific technologies) that were screened as part of this FS. The proposed remedial measures include representative active and passive remedial strategies. The active remedial strategies that were evaluated include soil vapor extraction (SVE), in-situ groundwater treatment via reduction or oxidation, groundwater extraction and treatment, and water supply replacement and treatment. The passive remedial strategy (i.e., one that allows contaminants to biologically or chemically degrade over time with no injection of amendments) is monitored natural attenuation (MNA).

Based on these conditions, the general remedial strategies considered in developing alternatives for this FS included the following (adapted from Arizona Revised Statutes [A.R.S.] § 49-282.06):

1. Plume remediation to achieve water quality standards for COCs throughout the Site.
2. Physical containment to contain COCs within definite boundaries.
3. Controlled migration to control the direction or rate of migration of COCs in groundwater.
4. Source control to eliminate or mitigate a continuing source of contamination.
5. Monitoring to observe and evaluate the contamination at the Site through the collection of data.
6. No action that consists of no action at the Site.

3.1 REMEDIAL OBJECTIVES

The following ROs developed by ADEQ for the Site are described in the RI Report (Tetra Tech, 2014):

- **ROs for soils and land use in the area of the Site:** *To restore soil conditions to the remediation standards for non-residential or residential use specified in A.A.C. R18-7-203 (specifically background remediation standards prescribed in R18-7-204, predetermined remediation standards prescribed in R18-7-205, or site specific remediation standards prescribed in R18-7-206) that are applicable to the hazardous substances identified. This action is needed for the present time and for as long as the level of contamination in the soil threatens its use as a residential or non-residential property.*

- **<u>ROs for current and reasonably foreseeable future groundwater use in and near the Site:</u>** *To restore and protect for the use of the groundwater supply by private well owners in the vicinity of the site from contamination at the site. This action is currently needed and will be needed for as long as private well owners use water for domestic use. This action is currently needed and will be needed as long as private well owners use water for irrigation. This action will be needed should the City of Yuma develop groundwater resources in the area of the site for municipal drinking water uses. This action will be needed for as long as the level of contamination in the groundwater threatens the use of the regional groundwater for municipal drinking water uses.*

3.2 ALTERNATIVES SCREENING

This section summarizes the criteria used to compare remedial measures/technologies in accordance with A.R.S § 49-282.06 and A.A.C R18-16-407(H). A comparative analysis process was used to evaluate and compare the ability of remedial alternatives to achieve the Site ROs. Each remedy is evaluated based on comparison criteria including practicability, cost, risk, and benefit and the capability of achieving the Site ROs. Specific actions (i.e., remedial measures) to be implemented with remedial strategies are described in the following sections.

Based on A.R.S § 49-282.06(A), the 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.

3.3 DESCRIPTION OF POTENTIAL REMEDIAL MEASURES

The remedial measures that were screened as part of this FS include:

1. No action (as a baseline);
2. SVE;
3. In-situ chemical oxidation (ISCO);
4. Biological treatment/enhanced reductive dechlorination (ERD);
5. In Situ biological treatment for cyanide;
6. Groundwater extraction and treatment;

7. Water supply replacement;
8. Well-head treatment;
9. MNA; and
10. Cap inspection, maintenance, and replacement.

A brief description of each remedial measure is presented in the following subsections.

3.3.1 Remedial Measure 1: No Action

This action would neither involve the implementation of remedial actions to address groundwater contamination nor prevent human or ecological exposure to groundwater contamination. The "no-action" alternative is included for use as a baseline for comparison to other potential remedial alternatives, but is not retained for further evaluation because it would not achieve the ROs.

3.3.2 Remedial Measure 2: Soil Vapor Extraction

SVE is a proven and effective remedial action that removes VOCs from subsurface soils in the unsaturated (vadose) zone. SVE uses a vacuum applied to the unsaturated zone by extraction wells near the source of soil contamination. With the applied vacuum, soil vapor containing VOCs is drawn toward the extraction wells, and the extracted vapors are then treated at the surface prior to discharge to the atmosphere.

SVE has been retained as a remedial measure for further consideration because it is a proven technology for the removal of chlorinated VOCs from the vadose zone. The geologic conditions at the Site are conducive to SVE because the vadose zone soils consist primarily of permeable sands. SVE is less effective at removing VOCs from finer grained material, such as silt layers/lenses. However, there are several reasons why SVE is not considered a primary/necessary remedy for the Site. Those are described in more detail in Appendix A. At this time, it is anticipated that SVE would only be implemented if future monitoring data indicated that a groundwater remedy alone was unable to achieve ROs.

3.3.3 Remedial Measure 3: In-Situ Chemical Oxidation

This remedial technology is a technology that involves the injection of a chemical oxidant into groundwater via a series of injection wells (or other injection methods) to destroy or degrade organic compounds. ISCO consists of chemical reactions that convert contaminants into less toxic or inert compounds. Several different types of oxidants have been used successfully at chlorinated solvent sites, including permanganate, persulfate, hydrogen peroxide and iron, and ozone. 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. Pilot testing and/or bench testing is necessary to establish the injection spacing, rates, and oxidant dosing. 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 will be limited.

ISCO has not been retained because, at this Site, it is not considered a cost-effective or feasible technology due to complexities associated with oxidant demand from the soil, the depth and size of the plume, and the depth to groundwater at the Site.

3.3.4 Remedial Measure 4: Biological Treatment/Enhanced Reductive Dechlorination (ERD)

ERD is a remedial technology based on injecting substrates/nutrients into groundwater to promote anaerobic biodegradation. Anaerobic reductive dechlorination is a naturally occurring biodegradation process whereby microbes can degrade chlorinated VOCs in groundwater. The microbes use a primary substrate as a carbon and energy source, producing enzymes and other compounds that degrade the target chlorinated compounds present in groundwater. 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). A variety of compounds have been used as bio-stimulation amendments for ERD applications. Bio-augmentation is a subsequent step, required for some but not all sites, 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 reagent to the impacted areas. ERD is only applicable to the saturated zone, and typically it must be combined with source zone treatment of any VOC residues in the vadose zone. However, with an effective ERD treatment zone in groundwater, the extent of the vadose zone treatment may be reduced because the rapid degradation in groundwater is less sensitive to continuing contributions from the vadose zone.

ERD wells can be located at source areas or hotspots within a groundwater plume. In this configuration, ERD is implemented to maximize concentration reduction of COCs. An alternate configuration is to install ERD wells in a line perpendicular to the groundwater flow direction near the leading edge of the plume. In this configuration, the wells are sometimes called “bio-barrier wells”

and the goal is to reduce COC concentrations to acceptable levels as groundwater is transported through the line of wells.

Biological treatment via ERD has been retained as a viable technology for plume treatment because it has been proven to be effective for enhancing and accelerating the reduction of PCE concentrations in groundwater at similar sites. The presence of TCE and 1,1-DCE indicates that natural dechlorination processes are occurring in downgradient portions of the Site plume, so this technology applied in hot spots would likely accelerate dechlorination processes in other areas of the plume (over a much larger footprint and as a complement to the MNA portion of a remedy). ERD implementation involves periodic injection of substrates and nutrients by means of injection wells and may include bio-augmentation.

3.3.5 Remedial Measure 5: In Situ Biological Treatment for Cyanide

Cyanide solutions have been successfully treated under methanogenic conditions (strongly reducing conditions) using a variety of carbon sources including ethanol, phenol, or methanol as the primary reduced carbon source. This basic treatment process is parallel to the steps taken to promote enhanced reductive dechlorination of VOCs; the microbial degradation processes are different but the steps to promote/accelerate the degradation processes are the same.

Microbial destruction of cyanide and its related compounds is an important biotechnology used to treat process/tailings solutions at precious metals mining and recovery operations; full-scale bio-treatment processes have been used effectively for many years. Research and field applications have demonstrated that a variety of microbial species (bacteria) can detoxify cyanide to environmentally acceptable levels. In the presence of microorganisms and oxygen, cyanide undergoes degradation through an aerobic biological process which has been implemented at multiple wastewater treatment systems. Cyanide also degrades biologically through anaerobic processes. Anaerobic biodegradation of cyanide is restricted to moderately to strongly reduced conditions and is accelerated if sulfur compounds [such as $H_2S(aq)$] are present. The degradation products through an anaerobic pathway include NH_3, H_2S and CO_2. In comparison to aerobic biodegradation, anaerobic degradation of cyanide is much slower and if the cyanide concentrations are high (in the range of 10 to 1,000 of mg/L) the anaerobic bacteria may be inhibited by the cyanide toxicity. This remedial measure is retained for further consideration.

3.3.6 Remedial Measure 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 removes and reduces contaminant mass from the aquifer but it is generally more effective in controlling or

containing the downgradient migration of the VOC plume. Contaminated groundwater can be treated by activated carbon, air stripping, oxidation, or by some 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. Discharge options with a beneficial re-use would be strongly preferred due to the importance of water as a resource.

Groundwater extraction and treatment is not capable of significantly reducing contaminant mass at DNAPL sites and, therefore, cannot meet the Site ROs within a reasonable restoration time frame by itself. However, it is an effective plume containment approach. This FS includes groundwater extraction and treatment as one element of the long-term remedy considered for the Site, and this remedial measure has been retained for further evaluation.

3.3.7 Remedial Measure 7: Water Supply Replacement

Water supply replacement is an action to provide an alternative source of water for a user with a well impacted by chemical releases from the Site. There are three schools, St. Francis of Assisi School, Alice Byrne Elementary School, and O.C. Johnson Elementary School, located to the northwest of the Facility that irrigate playfields with groundwater extracted from wells located at each school. Although the groundwater from these wells is not currently contaminated, it is prudent to have a plan to ensure that uncontaminated water is available to irrigate at the schools. Water from the City of Yuma municipal water system could be used for this purpose.

Water supply replacement is a feasible technology for providing safe water to irrigate school playfields and has been retained for further consideration.

3.3.8 Remedial Measure 8: Well-head Treatment

Well-head treatment is a remedial action that involves treating extracted groundwater with an appropriate method (activated carbon, air stripping, oxidation, or some other means) to meet the applicable criteria for safe drinking water. Typically, this remedial measure is used only when the groundwater resource is currently used as a potable water supply, but may also be used for irrigation supply wells if the end use at that time exceeds the applicable standards. Groundwater at the Site is not currently used as a potable water supply.

Well-head treatment is a feasible technology for treatment of a water supply. Well-head treatment has not been retained for further consideration, because the City of Yuma has indicated that future municipal supply wells, if any, would be located in the vicinity of existing municipal wells, which are located several miles to the east of the Site.

3.3.9 Remedial Measure 9: Monitored Natural Attenuation

MNA is a remedial measure that involves routine groundwater sampling and analysis to monitor the results of one or more naturally occurring physical, chemical, or biological processes that reduce the mass, toxicity, volume, or concentration of chemicals in groundwater. Natural attenuation is a mechanism by which COCs are reduced (often slowly) by natural means without other control, removal, treatment, or aquifer-modifying activities. These in-situ processes may include biodegradation, dispersion, dilution, sorption, and volatilization of contaminants. This remedial measure typically requires groundwater monitoring over a period of many years to verify that attenuation is occurring and to ensure that progress is made in terms of meeting the ROs.

Natural dechlorination is occurring in some downgradient portions of the plume as evidenced by the presence of PCE daughter products (TCE and 1,1-DCE). These processes causing dechlorination are likely to persist. However, the plume is actively moving at the Site such that ROs cannot be met within a reasonable restoration time frame. Therefore, MNA is not a viable stand-alone measure. However, the monitoring component of MNA is retained as an element of the long-term remedy considered for the Site, particularly for downgradient portions of the plume.

3.3.10 Remedial Measure 10: Cap Inspection, Maintenance, and Replacement

As described in the Site background, a one-foot cap of aggregate base coarse material was placed after soil containing cyanide was removed in 2002, and an asphalt cap was placed in 2013. The cap is in an “L-shaped” configuration on the east and south sides of the facility with an area of just under one acre. There is an associated stormwater collection and filtration system to collect and treat stormwater that falls on the cap. This remedial measure includes periodic inspection of the integrity of the cap to evaluate whether minor repairs such as crack sealing are required or whether the cap needs to be replaced due to degradation from the exposure to the elements or vehicle traffic. This remedial measure is retained for further consideration.

3.4 RETAINED REMEDIAL MEASURES

Seven remedial measures have been retained for further evaluation:

1. SVE;
2. Biological treatment/ERD for VOCs;
3. Biological treatment for cyanide;
4. Groundwater extraction and treatment;
5. Water supply replacement;
6. MNA; and

7. Cap inspection, maintenance, and replacement.

These remedial measures have been evaluated, assembled as alternatives and further screened in subsequent sections of this FS. The retained remedial measures are used to develop the proposed reference remedy and the more aggressive and less aggressive alternative remedies. Section 4.0 provides a more detailed evaluation of each of the remedies, including their ability to achieve the groundwater ROs, their compatibility with applicable regulations, their effectiveness at treating the target contaminants, their operational and maintenance requirements, and their overall costs.

4.0 REFERENCE REMEDY AND ALTERNATIVE REMEDIES

This section includes descriptions of a reference remedy (Section 4.1) and two alternative remedies (more aggressive and less aggressive, Sections 4.2 and 4.3, respectively) that were developed to achieve the Site ROs and to satisfy the requirements of A.R.S. § 49-282-06(A &B).

4.1 REFERENCE REMEDY

The reference remedy includes a combination of the remedial measures identified in Section 3.0 that, when combined, are capable of achieving the Site ROs. The proposed reference remedy, as shown on Figure 4-1, includes:

1. Saturated zone source/plume treatment (using biological treatment/ERD for in-situ VOC and cyanide plume treatment in groundwater), and
2. Plume migration control via biological treatment bio-barrier wells near the leading edge of the plume with monitoring to verify degradation of COCs and plume stability.
3. Inspection, maintenance, and periodic replacement of the asphalt cap over the soil removal area at the Facility.
4. Vadose zone source control (a contingency of SVE in the source area if future monitoring data indicate it is necessary to meet the groundwater RO).

Following the requirements of A.A.C. R18-16-407, the reference remedy for the Site was developed using engineering, geological, and/or hydrogeological standards of practice. The reference remedy considers the information and analytical data presented in the RI and subsequent monitoring, the best available scientific information regarding applicable remedial technologies, and a preliminary review of the comparison criteria.

4.1.1 Saturated Zone Source/Plume Remediation: In Situ Biological Treatment

Implementation of an ERD remedy for groundwater plume remediation is proposed for the area of the plume with PCE concentrations greater than 500 µg/L. Currently, MW-18B is the only well where PCE exceeds this concentration. The existing well spacing in Zone B around MW-18B is relatively coarse and the extent of the “hot spot” will be better defined during remedial design/implementation by installing approximately 10 wells that would initially be used to better define the horizontal and vertical extent of contamination and would subsequently be used as injection wells. It is anticipated that each well would have two to three screened intervals to allow substrate injection at specific depth intervals.

Biological treatment would consist of the injection of a carbon-source electron donor substrate such as a soluble food-grade sucrose-based solution or edible oil substrate. Bio-augmentation would likely be necessary after substrate injection and would involve the injection of dechlorinating bacteria directly into the aquifer. A pilot test would be necessary to determine the most-appropriate substrate for the Site and the extent of bio-augmentation needed. Based on experience at other sites, it is likely that substrate injections would occur up to six times over a period of 2 years (depending on the type of substrate chosen) and then would decrease in frequency or cease once the VOC concentrations have decreased to levels sufficient for MNA processes to control the remaining plume . The treatment timeframe for the remedy is set at 20 years, based on the travel time from MW-22B, near the trailing edge of the plume to MW-21B, near the leading edge of the plume, which are located approximately 2,700 feet apart. Using a contaminant transport velocity of 280 ft/yr and a safety factor of two gives a remediation time frame of approximately 20 years. This is viewed to be a conservatively long timeframe because once conditioned for ERD are established, the COCs are anticipated to continue degrading within the plume such that active treatment will not be required at some point in time.

In situ biological treatment for cyanide is also included in the reference remedy. This would be initiated with bench scale tests to evaluate appropriate substrate application rates and to identify what microbes were effective in degrading cyanide. The field application would focus on wells with the greatest cyanide concentrations, which are located at or near the Facility. It is likely that existing wells including MW-4A and or MW-5A would be used for injection purposes, but additional injection wells would be installed as necessary as a contingency. This alternative includes a provision for installation of up to five wells for cyanide treatment.

4.1.2 Plume Control/Monitoring: Monitored Natural Attenuation

It is also proposed that a line of wells (bio-barrier wells) be installed further west of the hot spot at MW-21B to reduce or eliminate the westward migration of contaminants. The line of wells is intended to treat groundwater that is in the vicinity of MW-21B or will migrate in that direction from the east over the next several years. The concentration of COCs migrating to the west from the line of bio-barrier wells is anticipated to be reduced to the extent that it no longer threatens groundwater users, including the schools with irrigation wells, further to the west.

Degradation is currently occurring in the downgradient portions of the plume, as documented by the presence of PCE daughter products (TCE and 1,1-DCE). The progress of degradation will need to be monitored until the cleanup levels are achieved, which is estimated to occur in 10 years based on recent COC migration rates or more conservatively to occur in 20 years with a safety factor of two. (20 years is used in cost estimates). The combination of MNA in areas of the plume with lower COC

concentrations and more active source control (SVE as a contingency) and plume remediation (ERD) in areas of the plume with higher concentrations is an approach capable of achieving groundwater ROs at the Site.

MNA as part of the reference remedy would involve routine groundwater sampling of key monitoring wells, including monitoring of natural attenuation parameters and the collection of analytical data for chlorinated VOCs. This is expected to include semi-annual monitoring of key monitoring wells (assumed to be 20 monitoring wells) and annual monitoring that includes a more comprehensive monitoring well network, primarily in Zone A and Zone B (assumed to be approximately 75 monitoring wells) for a period of 10 years. After 10 years of monitoring, the well network would be revised to include a more focused subset of monitoring wells (assumed to be 30), and after 20 years the sampling network would be reduced to 10 wells. As an estimate, this FS assumes that it may be necessary to install five additional monitoring wells for sufficient monitoring in selected areas of the plume. The implementation of ERD combined with MNA in the reference remedy is anticipated to have significant synergistic effects. The benefits from the ERD portion of the remedy are expected to include a 99 percent concentration reduction in hot spot concentrations based on experience at other sites and, at the same time, more rapid dechlorination rates over a wider footprint of the plume, where the MNA will be implemented. The general layout of monitoring wells that may be considered for the MNA element of this remedy is shown in Figure 4-1. The monitoring well network will be refined during remedial design and would be adjusted as the remedy is implemented based on monitoring results.

4.1.3 Cap Inspection, Maintenance, and Replacement

The asphalt cap covering the soil removal area will be inspected every other year under this element of the remedy. The cap was inspected in 2016 and found to have small cracks that are not currently compromising its integrity. The cap will be maintained as needed by patching cracks that may compromise the integrity of the cap. It is assumed that this type of maintenance will be required every five years. It is also assumed that the cap will need to be replaced every 15 years, or twice during 30 years. Beyond 30 years, the costs of inspection and repair on a present value basis are relatively small and do not impact the FS remedial action selection.

4.1.4 Vadose Zone Source Control: Soil Vapor Extraction

Installation and operation of a SVE system at the Facility would remove VOC mass present in the vadose zone. As described in Appendix A, various lines of evidence suggest that the vadose zone is not currently a significant source of contamination to the saturated zone. In the event that future data or a subsequent analysis contradicts this finding, it may be prudent to implement SVE. The

benefit derived from this SVE operation is primarily the control/removal of PCE residues from the vadose zone that would otherwise serve as a potential long-term source of groundwater contamination. As described earlier, there is evidence that the plume is detached from the former source area such that SVE may only be needed for a relatively short time. It is anticipated that one or more SVE wells would be evaluated in a pilot test mode to assess the mass removal capability of such a system. The SVE system would be run as long as a significant mass of vapor-phase COCs are being removed.

4.2 MORE AGGRESSIVE REMEDIAL ALTERNATIVE

Development of the more aggressive remedial alternative includes evaluating a combination of strategies that are primarily intended to achieve the Site ROs in a shorter time period. As proposed, the more aggressive remedial alternative includes elements of the reference remedy with different modifications/enhancements.

The reference remedy includes a combination of remedial measures that, when combined, are capable of achieving the Site ROs. The more aggressive remedy includes:

1. Saturated zone source/plume treatment (using biological treatment/ERD) for the VOC plume out to an estimated level of the 100 µg/L contour and biological treatment for cyanide near the Facility;
2. Plume migration control/monitoring using groundwater extraction and treatment;
3. Inspection, maintenance, and periodic replacement of the asphalt cap over the soil removal area at the Facility.
4. Vadose zone source control (a contingency for SVE in the source area if future monitoring data indicate it is necessary to meet the groundwater RO).

The elements of the more aggressive alternative are shown on Figure 4-2.

4.2.1 Plume Remediation: Enhanced Reductive Dechlorination

Consistent with the reference remedy, biological treatment/ERD would be applied in the saturated zone. The proposed approach for implementing ERD in the more aggressive remedy is similar to that previously presented in the reference remedy (Section 4.1.1) except that the ERD treatment would target PCE concentrations greater than 100 µg/L. Substrate injections would occur up to several times over a period of 2 years (depending on the type of substrate chosen), and then the frequency would decrease or the injections would cease once the VOC concentrations have decreased to levels sufficient for other elements of the remedy to control the remaining plume (calculated to be within a 5 to 10 year time frame).

Also consistent with the reference remedy, the aggressive remedy includes in situ biological treatment for cyanide.

4.2.2 Plume Containment: Groundwater Extraction and Treatment

A groundwater extraction and treatment system would be used for plume containment (as opposed to the barrier wells used in the reference remedy). Multiple extraction wells (three are included in the conceptual design) would be used to contain the plume (the hot spot area would be treated by ERD, as described previously). The extraction wells would be aligned on the approximate center line of the plume, based on analysis done in a groundwater model of the site (GeoTrans, 2008). The extracted groundwater (an approximate total of 100 gallons per minute (gpm) for plume containment) would be treated with granular activated carbon before discharge. The potential range of discharge options includes a nearby storm water conveyance system, piping and discharge to the sanitary sewer system, or reinjection to groundwater outside the plume area. The preferred discharge option would be established in the remedial design (based on feasibility and cost considerations with a strong preference for beneficial reuse of the water).

4.2.3 Cap Inspection, Maintenance, and Replacement

The asphalt cap will be inspected, maintained and repaired as described in the reference alternative (Section 4.1.3).

4.2.4 Vadose Zone Source Control: SVE Operations

The SVE system envisioned for the more aggressive remedy is identical to that described for the reference remedy (Section 4.1.4) and would be installed, if needed, on a contingent basis.

4.3 LESS AGGRESSIVE REMEDIAL ALTERNATIVE

In accordance with A.A.C. R18-16-407 (E)(3), one of the alternative remedies must use a remedial strategy or combination of strategies that is less aggressive than the reference remedy, but still be capable of achieving the defined Site ROs, and it may use less intensive or fewer remedial measures than the reference remedy. The proposed less aggressive remedial alternative includes some elements of the reference remedy but relies more heavily (and for a longer term) on MNA for the protection of human health and the environment. A general depiction of the components for the less aggressive remedy is shown in Figure 4-3.

The less aggressive remedy includes a combination of remedial measures that, when combined, are expected to be capable of achieving the Site ROs. The less aggressive remedy includes:

1. Plume monitoring/MNA to verify degradation of COCs and plume stability;
2. Water supply replacement for two school irrigation wells; and
3. Inspection, maintenance, and periodic replacement of the asphalt cap over the soil removal area at the Facility.

4.3.1 Monitoring/Monitored Natural Attenuation

For the less aggressive remedial alternative, monitoring/MNA would be relied upon for degradation of chlorinated VOCs for the entire extent of the plume. Monitoring/MNA would involve routine groundwater monitoring of key monitoring wells, including monitoring of natural attenuation parameters and the collection of analytical data for chlorinated VOCs. This is expected to include annual monitoring that involves a monitoring well network, primarily in Zone A and Zone B (assumed to include 40 wells) for a period of 10 years. After 10 years of monitoring, the well network would be reduced to a more focused subset of monitoring wells (assumed to include 20 wells), and sampling would continue annually for an additional 20 years. Potential wells to be included in the MNA monitoring well network provided in Figure 4-3. As an estimate, this FS assumes that five additional monitoring wells may need to be installed for sufficient monitoring of portions of the plume. The locations for the new wells will be determined in remedial design.

Full restoration of the Site plume relying on monitoring/MNA will be a long process. The monitoring/MNA element is calculated to continue over a 30-year period. Monitoring/MNA is not expected to fully restore the groundwater at the Site and is not considered capable of achieving the AWQSs within the highest concentration areas of the plume within a reasonable time frame.

4.3.2 Water Supply Replacement

Based on the expectation that the plume will continue to migrate to the west northwest without an active remedial component, this remedy included replacing irrigation water at one or two of the down-gradient schools with water obtained from the City of Yuma municipal water supply. The apparent plume flow direction, as shown on Figure 2-1, was used to evaluate the number of existing irrigation wells that might need replacement water. The Alice Byrne Elementary School is most directly aligned with the flow direction and is considered the most likely to be impacted. The St. Francis of Assisi School is located somewhat to the south of the primary flow direction, but has had low-level detections of cyanide (below the AWQS) in 2007 and 2015, and as such, is considered to be the next most likely to be impacted. The O.C. Johnson Elementary School is north of the flow path and is considered the least likely to be impacted. If the irrigation well at the O.C. Johnson Elementary School was impacted (in the future), it would mean that the plume was moving north of its projected trajectory, likely avoiding the St. Francis of Assisi School. Based on these data it is assumed for

costing purposes that irrigation wells would be replaced at only two schools; the Alice Byrne Elementary School and the St. Francis of Assisi School. It should be noted that the water from both irrigation systems has been tested and the concentrations of COCs have always been less than AWQS and almost always non-detect. This element of the remedy would be implemented if and when monitoring data indicated that the wells were pumping water at one-half of an AWQS for any Site COCs.

This remedy would require coordination with the City of Yuma to obtain a tie-in for a large capacity water meter at each school, plumbing the meter to the existing irrigation system, and the cost to purchase water from the City of Yuma for an estimated period of 30-years. It should be noted that the remedy at one or more schools would be implemented when monitoring data indicate that a Site COC has reached one-half its AWQS. To date, contamination has not been detected in the school wells above one-half of the AWQS. There have been no detections in the nearest monitoring wells, MW-30B and MW-31B. Assuming that the plume reaches MW-30B or MW-31B soon, and that contaminant migration is approximately 280 ft/yr, it is estimated that alternative source of irrigation water would be required in four years from the current date (summer 2016). The present value cost analysis was calculated using this estimated arrival time.

4.3.3 Cap Inspection, Maintenance, and Replacement

The asphalt cap will be inspected, maintained and repaired as described in the reference alternative.

5.0 COMPARISON OF THE REFERENCE REMEDY AND ALTERNATIVE REMEDIES

This section presents a comparative analysis of the remedies evaluated for the Site. The comparative analysis includes an evaluation of the reference remedy, the less aggressive remedy, and the more aggressive remedy in terms of performance relative to the specific evaluation criteria summarized in A.A.C. R18-16-407. No active supply wells are presently impacted, but this could change in the future as the contaminant plume in groundwater migrates to the northwest. The comparative analysis from this Section is summarized in Tables 5-1 and 5-2.

5.1 THRESHOLD CRITERIA

Each remedial alternative must meet two threshold requirements:

1. The remedy must achieve the Site ROs listed in Section 3.1 in accordance with A.A.C. R18-16-407(H)(1);
2. The remedy must include an evaluation of the consistency with water management plans of affected water providers and the general land use plans of local governments with land use jurisdiction in accordance with A.A.C. R18-16-407(H)(2).

The discussion in this section applies to each of the remedial alternatives evaluated. All of the remedies presented have been developed to meet the Site ROs. Based on the Site conditions and relevant exposure pathways, this FS focuses on soil and groundwater contamination. Prior remedial actions have been implemented as ERAs under A.A.C. R18-16-405 including emptying and cleaning of prior waste discharge system tanks/components, shallow soil excavation, and soil capping at the Facility. All remedies are anticipated to be consistent with the City of Yuma's water conservation plan (City of Yuma, 2015). No active supply wells are impacted by the plume and remedial actions are proposed to restore water quality. The less aggressive alternative includes costs to replace water supply at two irrigation wells projected to be in the plume flow path, if they were to be impacted.

With regards to land use impacts, the proposed remedial actions are expected to be consistent with the existing land use which includes both commercial and residential areas. The detailed summary of each remedy is presented in Section 4 and the comparative evaluation is summarized in the following Sections.

5.2 COMPARISON CRITERIA: PRACTICABILITY, RISK, COST, AND BENEFIT

Based on the objectives outlined in A.A.C. R18-16-407 (H), each remedy is evaluated for practicability, risk, cost and benefit. The following sections describe the evaluation and comparison of the remedies.

5.2.1 Practicability

Each remedy is evaluated in terms of its practicability, including its feasibility, short- and long-term effectiveness, and reliability, considering the site-specific conditions, the characteristics of the contamination resulting from the release, the performance capabilities of available technologies, and institutional factors.

Reference Remedy: The reference remedy includes:

1) Plume treatment (bioremediation in groundwater in hot spots with the highest concentrations);
2) Plume control (bio-barrier wells for bioremediation/containment near the leading edge of plume);
3) Cap inspection and maintenance; and
4) Source control (SVE at the source area as a contingent measure).

This reference remedy is a feasible and practicable remedial approach for the Site. Permits would be required to implement bioremediation. These include applying for notice of intents (NOIs) with the Arizona Department of Water Resources (ADWR), filing a traffic control plan with the City of Yuma, and filing an application for an Underground Injection Control (UIC) with the Environmental Protection Agency. Existing groundwater data indicate that down-gradient portions of the plume demonstrate natural dechlorination processes based on the presence of intermediate degradation products (TCE and 1,1- DCE). Based on these Site conditions and the performance capabilities of biological treatment, this remedy is considered effective (both short and long-term) and reliable.

This remedy is expected to be consistent with potentially affected water providers and their long-term plans (plume migration is contained and the aquifer is restored).

More Aggressive Remedy: The more aggressive remedy includes:

1) Plume treatment (bioremediation in groundwater in hot spots with the highest concentrations);
2) Groundwater extraction and treatment for plume control;
3) Cap Inspection and maintenance; and

4) Source control (SVE at the source area as a contingent measure).

The practicability of the more aggressive remedy is lower than the reference remedy discussed previously (reliable short-term and long-term effectiveness/performance). The permitting requirements would include those listed for the reference remedy and would also require Poor Quality Groundwater Withdrawal Permit (PQGWD) from ADWR and building permits for the treatment system and conveyance piping. Additionally, there may be challenges and delays associated with purchasing a property for the treatment plant in a suitable location.

Groundwater extraction and treatment for plume control is considered a practicable remedial solution particularly if a beneficial re-use of the treated water were identified. Extraction and treatment is expected to be generally consistent with potentially affected water providers and their long-term plans. However, more specific details would need to be established at such time as a future water supply might be developed. The more aggressive remedy is considered to be reliable based on the site-specific conditions, nature of the plume and institutional considerations.

Less Aggressive Remedy: The less aggressive remedy includes:

1) Groundwater Monitored Natural Attenuation;
2) If/when impacted; replacement of Irrigation Water Supply with City water) at two schools (Alice Byrne Elementary School and St. Francis of Assisi School); and
3) Cap inspection and maintenance.

The less aggressive remedy is considered practicable but ranks lower than the reference remedy in regards to short-term and long-term effectiveness/performance, with the exception of permitting, which would be easier. The monitoring/MNA component of the less aggressive remedy is easily implemented, but existing Site data indicate the plume is continuing to migrate. Based on this condition, the objective of the monitoring is to predict/identify when impacts to existing supply wells is likely to occur. If impacts of one-half an AWQS for a Site COC are observed, then the primary remedial action/risk reduction would be water supply replacement for those wells.

5.2.2 Risk

Each remedy is evaluated for risk, including the overall protectiveness of public health and aquatic and terrestrial biota under reasonably foreseeable scenarios for future use and end uses of water. Pursuant to A.A.C. R18-16-407(H)(3)(b), the comparative analysis of this factor considers the following aspects:

1. Fate and transport of contaminants and concentrations and toxicity over the life of the remediation;
2. Current and future land and resource use;
3. Exposure pathways, duration of exposure, and changes in risk over the life of the remediation;
4. Protection of public health and aquatic and terrestrial biota while implementing the remedial action and after the remedial action; and
5. Residual risk in the aquifer at the end of remediation.

Presently, groundwater in the vicinity of the Site is not being used for drinking water; however, groundwater is designated as a potable resource for the future, if needed. Additionally, there are three down gradient irrigation wells that may be impacted in the future. Given the existing land use and COCs detected, the exposure threat from contamination in the Site subsurface soils is minimal. Lastly, exposure to the COCs via air pathway is also considered incomplete due to the low concentrations of VOCs in the upper 5 feet of soils.

Reference Remedy: This remedy is considered protective of public and ecological health; the current exposure pathway to Site groundwater is incomplete and active measures with monitoring would be implemented to restore water quality. Since the fate and transport of Site contaminants is reasonably well known (see Section 2.2.5), and remedial actions are implemented to restore water quality to levels below AWQS standards, the residual risk to the aquifer is anticipated to be low.

More Aggressive Remedy: The various factors described above for the reference remedy are essentially similar for the more aggressive remedy. The risk associated with its implementation is similar to the reference remedy with the potential additional risk associated with leakage from conveyance piping between the extraction wells and the treatment plant.

Less Aggressive Remedy: The current risk factors described above for the reference remedy are similar for the less aggressive remedy (the current exposure pathway to Site groundwater is incomplete and exposure to subsurface soils is minimal). The less aggressive remedy addresses future risks through water supply replacement, and therefore is ranked lower in risk on the other selected factors (exposure pathways/duration of exposure, protection of public health after the remedial action, and residual risk in the aquifer at the end of remediation).

5.2.3 Cost

Each remedy is evaluated in terms of its costs including capital costs, operating costs, maintenance costs, transactional costs necessary for implementation, and life-cycle costs. Cost comparisons for the reference remedy, more aggressive remedy, and less aggressive remedy are summarized in Table

5-2. For purposes of cost development, it is estimated that the reference and more aggressive remedy will require 20 years to achieve RAOs, while the less aggressive remedy will require 30 years. Detailed cost estimates for each remedy are included in Appendix B.

The remedial actions described in this FS include construction costs that are expended at the initiation of the project (e.g., capital construction costs in a specific year) and costs in subsequent years that are required to implement and maintain the remedy after the initial construction period (e.g., annual operations and maintenance [O&M] costs and other periodic costs). Present value analysis is the common economic method used to evaluate expenditures, including both capital and O&M costs, which occur over different time periods. This standard methodology allows for cost comparisons of different remedial alternatives on a single, comparable cost basis (i.e., the Net Present Value).

For long-term projects, U.S. Environmental Protection Agency (EPA) guidance for FS costing recommends that the cost evaluation also include a present value analysis with a "no discounting" scenario (EPA, 2000). The non-discounted constant dollar cash flow over the project duration is important to illustrate the impact of a discount rate on the total present value cost and the relative amounts of future annual expenditures (i.e., the real costs to be funded in the future). This FS presents costs as both the non-discounted constant dollar cash flow (i.e., sum of all project expenses over the duration) and the Net Present Value using a discount rate[2] of 7%.

Reference Remedy: The technologies included in the reference remedy represent a proven, cost-effective remedial alternative. The estimated cost associated with the implementation of the reference remedy over a 20-year period is approximately $5,400,000, which includes $500,000 as a contingency for installing SVE at the Facility. Considering the timing of expenses and present value evaluation (with a discount rate of 7 percent), the corresponding Net Present Value is approximately $3,800,000 (including the contingent SVE system). Note that the asphalt cap inspection, maintenance, and replacement element may need to be performed indefinitely, beyond the 30 years that were used in the cost estimate. The undiscounted cost for this activity is approximately $170,000 every 15 years. The net present value of this action is small because of the effect of discounting an activity so far in the future.

[2] The National Contingency Plan suggests the use of a discount rate of 7 percent in the development of present value cost estimates for remedial action alternatives during a FS. This specified rate of 7 percent represents a "real" discount rate in that it approximates the marginal pretax return on an average investment in the private sector, and it is adjusted to eliminate the effect of expected inflation. The recommended 7 percent rate should, therefore, be used with "constant" or "real" dollars that have not been adjusted for inflation.

More Aggressive Remedy: The cost for the more aggressive alternative includes several elements from the reference remedy and it also includes groundwater extraction and treatment for plume containment. Groundwater extraction and treatment includes a long-term O&M cost until contaminants in the groundwater are no longer a threat to human and ecological heath. The overall costs of installation, and O&M over a 20-year period would be approximately $9,200,000, which includes $500,000 as a contingency for installing SVE at the Facility. Considering the timing of expenses and present value evaluation (with a discount rate of 7 percent), the corresponding Net Present Value is approximately $5,900,000 (including the contingent SVE system). The cost of inspecting, maintaining, and repairing the asphalt cap past the 30-year timeframe is the same as that described for the reference alternative.

Less Aggressive Remedy: The cost for the less aggressive alternative includes MNA and replacement of water supply for two school irrigation wells that lie within the projected plume flow path in four years. Each of the schools use wells with a capacity of approximately 1,000 gpm for irrigation of their playfields and other grounds. The cost for this alternative depends heavily on the quantity of City water purchased for irrigation; all quantity estimates and frequency of irrigation at the schools are based on data provided by the schools. The projected 30-year cost for this alternative is up to $9,400,000 (assuming two schools need replacement water) and the net present value cost for this alternative is $3,800,000. The cost of inspecting, maintaining, and repairing the asphalt cap past the 30-year timeframe is the same as that described for the reference alternative.

5.2.4 Benefit

Each proposed remedy is evaluated in terms of the benefit, or value, of the remediation. Pursuant to A.A.C. R18-16-407(H)(d), this comparative analysis includes the following factors:

1. Lowered risk to human and aquatic and terrestrial biota;
2. Reduced concentration and reduced volume of contaminated water;
3. Decreased liability; acceptance by the public;
4. Aesthetics; preservation of existing uses;
5. Enhancement of future uses; and
6. Improvements to local economies.

Reference Remedy: The reference remedy uses proven remedial technologies that have been implemented at many sites and have been publicly accepted. This remedy is not anticipated to impact the current or projected future use of the Site. As noted in Section 5.2.2, the risk to human and ecological receptors associated with is low. Additionally, both the concentrations and the

volume of contaminated water will be reduced over time. Monitoring and documenting Site cleanup will decrease liability associated with the Site. The aesthetics of this remedy are anticipated to be compatible with the existing and future land use. This remedy is considered to have a positive impact in terms of enhancement of future land uses and impacts on local economies.

More Aggressive Remedy: The benefits of the more aggressive remedy are similar to the reference remedy with the addition of groundwater extraction and treatment for plume control. This remedy includes publicly accepted remedial technologies that reduce risk to human and ecological receptors by treating groundwater prior to either being made available for beneficial re-use (if feasible), or reinjection. The concentrations and the volume of contaminated water will be reduced over time. Groundwater extraction/treatment, monitoring and documenting Site cleanup will decrease liability associated with the Site. The aesthetics of this remedy are anticipated to be compatible with the existing and future land use. This remedy is considered to have a positive impact in terms of enhancement of future land uses and impacts on local economies; if a future beneficial re-use of the extracted/treated water is identified, this may provide more of a positive benefit to the local economy (expected to be minor).

Less Aggressive Remedy: The Less Aggressive Remedy (MNA plus replacement of water supply at wells impacted in the future) offers the least benefit of all of the remedial alternatives considered. There will be a lowered risk to human and ecological receptors as the plume COC concentrations slowly decrease over time, but the primary risk reduction is derived from providing a replacement water supply if and when irrigation wells at the schools are impacted. The concentrations of contaminated water will be reduced slowly over time, but the plume volume is expected to increase as the plume disperses laterally and migrates to the northwest. The aesthetics of the remedy are anticipated to be compatible with the existing and future land use. This remedy is considered to have a neutral impact in terms of enhancement of future land uses and impacts on local economies.

6.0 RECOMMENDED REMEDY AND BASIS FOR SELECTION/RECOMMENDATION

Based on the results of the comparative analysis presented in this FS, the reference remedy is the proposed remedy for the Site. Remedial components of the reference remedy include:

1. Saturated zone source/plume treatment (using biological treatment/ERD for in-situ VOC and cyanide plume treatment in groundwater), and
2. Plume migration control via biological treatment barrier wells near the leading edge of the plume with monitoring to verify degradation of COCs and plume stability.
3. Inspection, maintenance, and periodic replacement of the asphalt cap over the soil removal area at the Facility.
4. Vadose zone source control (a contingency of SVE in the source area if future monitoring data indicate it is necessary to meet the groundwater RO).

As specified in A.A.C. R18-16-407, the rationale for selecting the proposed remedy shall include:

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

6.1 COMPARISON CRITERIA

The evaluation criteria, including achievement of the Site ROs, consistency with management plans of local water providers, practicability, risk, cost and benefit, were considered for each of the alternative remedies and discussed in Section 5. The comparison of these criteria, as evaluated in relation to each other, is included in Table 5-1.

All of the remedies considered meet the minimum threshold requirements (meet the ROs, and consider the needs of local water providers that may be impacted in the future). All of the remedies considered effectively address current and anticipated future Site risks. The reference remedy provides the best balance of the practicability, risk, cost and benefit considerations.

6.2 ACHIEVEMENT OF THE SITE REMEDIAL OBJECTIVES

As noted in Section 1.0, the objective of this FS is to identify and evaluate remedial alternatives to address COCs in soil and groundwater at the Site. Based on the Site conditions and relevant exposure pathways, this FS focuses primarily on groundwater contamination, but the reference and more aggressive remedies also include treatment of soil vapor in the primary source area as a contingency.

The reference remedy meets the Site ROs. The SVE component, if needed, will protect against possible exposure to hazardous substances in subsurface soils that may occur during typical industrial uses. The groundwater components of the remedy (barrier wells, ERD, and MNA) are capable of restoring groundwater quality (the components include source control for mass removal and plume monitoring/migration control).

6.3 REQUIREMENTS OF A.R.S. § 49-282.06

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

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

As discussed in this FS Report, the reference remedy meets these requirements. Barrier wells, ERD, and SVE (as a contingency) will remove the majority of hazardous substances from soil and groundwater providing for the control and cleanup necessary to allow maximum beneficial use of the groundwater resource. Implementing the reference remedy will be protective of public health and welfare, and the environment. In addition, the reference remedy is reasonable, cost-effective and technically feasible.

It may be appropriate to implement portions of the reference remedy as an ERA as soon as funding is available. Specific actions that would be beneficial in this context are installation of wells that can be used for ERD in the hot spot and initiation of ERD and associated monitoring at these wells. The advantages of such an approach are that the actions would begin destruction of Site COCs sooner thereby slowing down their downgradient migration, and provide additional geological and performance monitoring data that would help in remedial design and implantation.

6.4 COMMUNITY INVOLVEMENT

The FS Work Plan (ADEQ, 2014) was previously prepared along with a public notice of its availability.

7.0 REFERENCES

ADEQ, 1996. A Screening Method to Determine Soil Concentrations Protective of Groundwater, September, 1996.

ADEQ, 2014. Feasibility Study Work Plan for the 20th Street and Factor Avenue WQARF Registry Site, Yuma, Arizona. November 24, 2014.

ADEQ, 2016. Project Website. http://www.azdeq.gov/environ/waste/sps/20th_Factor.html, accessed on March 7, 2016.

Britton, P., J. Winter, and R.C. Kroner. 1984. EPA Method Study 12, Cyanide in Water. EPA-600/S4-84-045.

City of Yuma, 2015. Water Conservation Plan. City of Yuma Utilities Department, September, 2015.

Dickinson, J. E., Land, M, Faunt, C.C., Leake, S.A., Reichard, E.G., Fleming, J.B, and D.R. Pool, 2006. Hydrogeologic Framework Refinement, Ground-Water Flow and Storage, Water-Chemistry Analyses, and Water-Budget Components of the Yuma Area, Southwestern Arizona and Southeastern California, United States Geological Survey, Scientific Investigation Report, 2006-5135.

EPA, 2000. A Guide to Developing and Documenting Cost Estimates during the Feasibility Study. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. Washington, D.C. EPA540-R-00-002. July 2000.

GeoTrans, Inc., 2005. Cyanide Compounds Solubility, Leachability and Implications for Groundwater Protection Levels (GPLs), Houston International Facility, 653-655 East 20th Street, 20th and Factor WQARF Site, Yuma, Arizona. June 28, 2005.

GeoTrans, Inc., 2008. Groundwater Modeling Report. 20th and Factor WQARF Site, Yuma, Arizona. June 30, 2008.

Matrix-CALIBRE, 2015a. Basis of Feasibility Study Technical Memorandum, 20th and Factor Water Quality Assurance Revolving Fund (WQARF) Site.

Matrix-CALIBRE, 2015b. Feasibility Study Data Gaps. 20th and Factor WQARF Site, Yuma, Arizona. January 30, 2015.

Olmsted, F.H., Loeltz, O.J., and Irelan, Burdge, 1973, Geohydrology of the Yuma area, Arizona and California: U.S. Geological Survey Professional Paper 486-H, 227 p.

Tetra Tech, 2014. Final Remedial Investigation Report, 20th Street and Factor Avenue WQARF Site, Yuma Arizona, June 27, 2014.

This page left intentionally blank

Tables

Table 2-1 Soil Vapor Screening Levels

Compound	Composite Worker [1]	
	Excess Cancer Risk (1 x 10^{-5})	Hazard Index = 1.0
	Soil vapor concentrations in µg/m^3	
PCE	15,670	6,000
TCE	1,000	293
HCN	NA	117

[1]= The soil vapor screening levels are derived from EPA Regional Screening Levels (RSLs) using an attenuation factor of 0.03. Source: https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016. Composite worker RSLs were used because the portion of the Site where soil vapor has been observed is commercial and industrial.

Table 2-2 Summary Soil and Groundwater Standards for Primary Contaminants of Concern

Compound	AWQS (µg/L)	GPL [(1)] (mg/kg)	Non-residential SRL (mg/kg)
PCE	5	0.80	13
TCE	5	0.76	65
1,1-DCE	7	0.85	410
Cyanide (total)	Not established	290[(2)]	Not established
Cyanide (free)	200	Not established	12,000

AWQS – Aquifer Water Quality Standard (A.A.C. R18-11 Appendix A)
1,1-DCE – 1,1-dichloroethene
GPL – minimum groundwater protection level
PCE – tetrachloroethene
SRL – soil remediation level (A.A.C R18-7 Appendix A)
TCE – trichloroethene
µg/L – micrograms per liter
mg/kg – milligrams per kilogram
Notes:
1. The GPLs for the organic compounds are from ADEQ updates in 2013.
2. The GPL for cyanide is from GeoTrans 2005, as reported by Tetra Tech 2014.

Table 5-1 Summary of Comparison of Reference Remedy and Alternative Remedies

Remedial Alternative	**Will Achieve Site ROs?**	**Is Action Consistent with Water Management Plans?**	**Practicability**	**Risk**	**Costs**	**Benefit**
Reference Remedy: plume treatment with ERD, MNA, cap inspection and maintenance, SVE as a contingency.	Yes	Yes (anticipated)	Yes	Low	Moderate	High
More Aggressive Remedy: plume treatment with ERD, groundwater extraction and treatment (for plume control), cap inspection and maintenance, SVE as a contingency.	Yes	Yes (anticipated)	Yes	Low	High	High
Less Aggressive Remedy: MNA, water supply replacement as contingency, cap inspection and maintenance.	Yes	Yes (anticipated)	Yes	Low to moderate	High	Medium

ERD – enhanced reductive dechlorination
MNA – monitored natural attenuation
SVE – soil vapor extraction

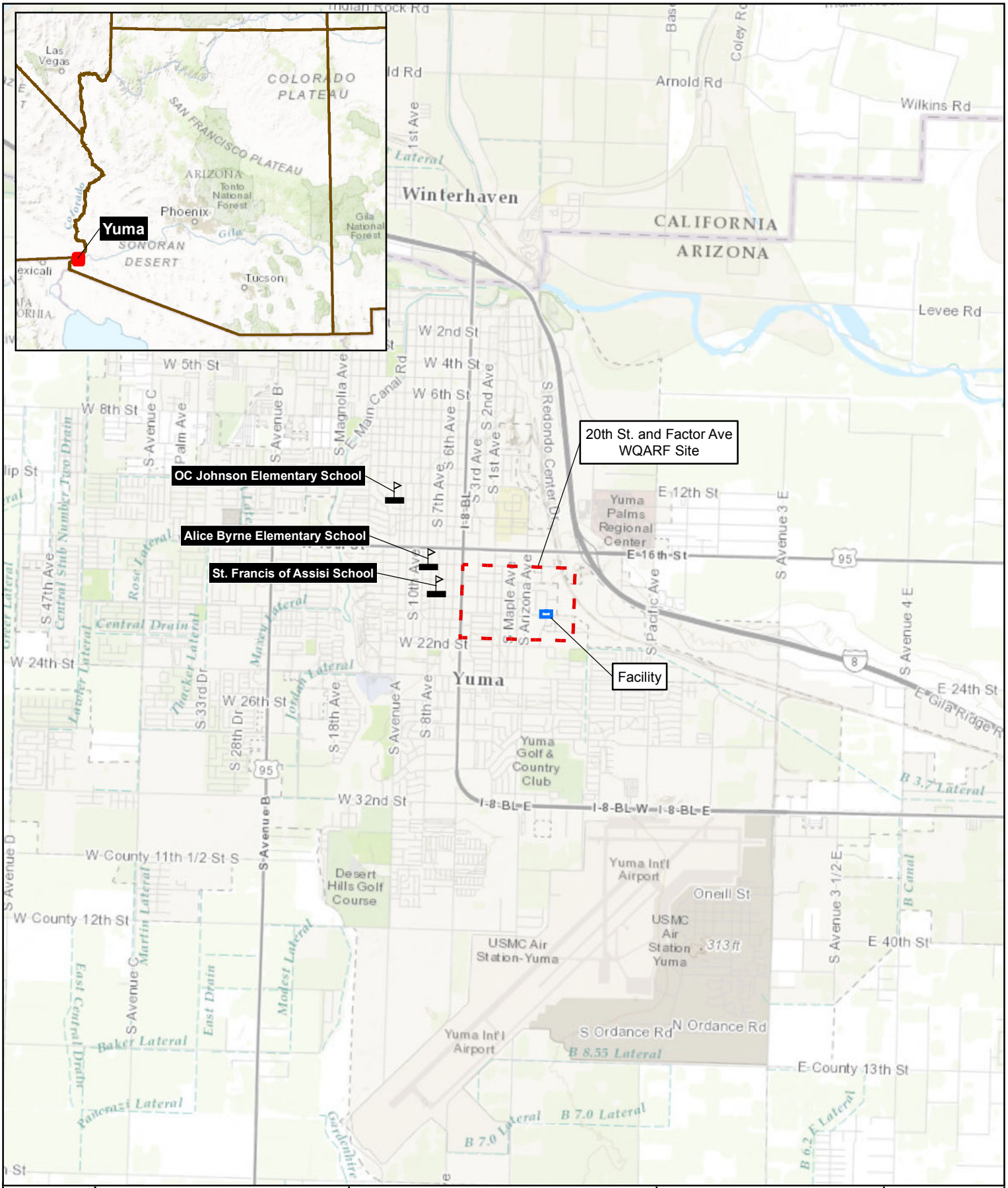
Table 5-2 Summary of Relative Cost Comparisons for Remedial Alternatives

Alternative	**Total Cost [1,2]**	**Projected Restoration Timeframe**	**Costs Presented as Net Present Value [3]**
Less Aggressive Remedial Alternative	$9,400,000	30 Years	$3,800,000
Reference Remedy	$5,400,000	20 Years	$3,800,000
More Aggressive Remedial Alternative	$9,200,000	20 years	$5,900,000

Notes:

1. All costs are estimates and should not be interpreted as final construction, or project bid costs. Costs are in present dollars (2016) and do not include inflation.
2. All costs include a 25% markup for project indirect costs (reporting/design/project oversight). The Reference Remedy and More Aggressive Alternative include a 25% contingency as a FS cost estimate (pre-design). The Less Aggressive Alternative includes a 5% contingency because most of the cost is associated with purchasing water, which should not require a large contingency.
3. The Net Present Value is based on a 7% discount rate.

Figures



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

20th St. and Factor Ave WQARF Site (Approximate Boundary)

Schools

WQARF = Water Quality Assurance Revolving Fund

Site Location Map

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

Matrix DESIGN GROUP

CALIBRE

Figure
1-1

0 0.5 Miles

FILE: G:\gis_projects\ADEQ\activeapps\WVB_Sample_Locs.mxd, 11/13/2014, wilson_wheeler

Drawn By: JKC

QC'd By: JC

7/25/2016

Legend

- Existing Buildings
- Well Location
- Manhole
- Cap Boundary
- Houston International, Ltd Property Boundary
- Concrete Drainage Improvements
- Fence

Facility Layout

Feasibility Study Report
20th & Factor Avenue WQARF Site
Yuma, Arizona

ADEQ Arizona Department of Environmental Quality

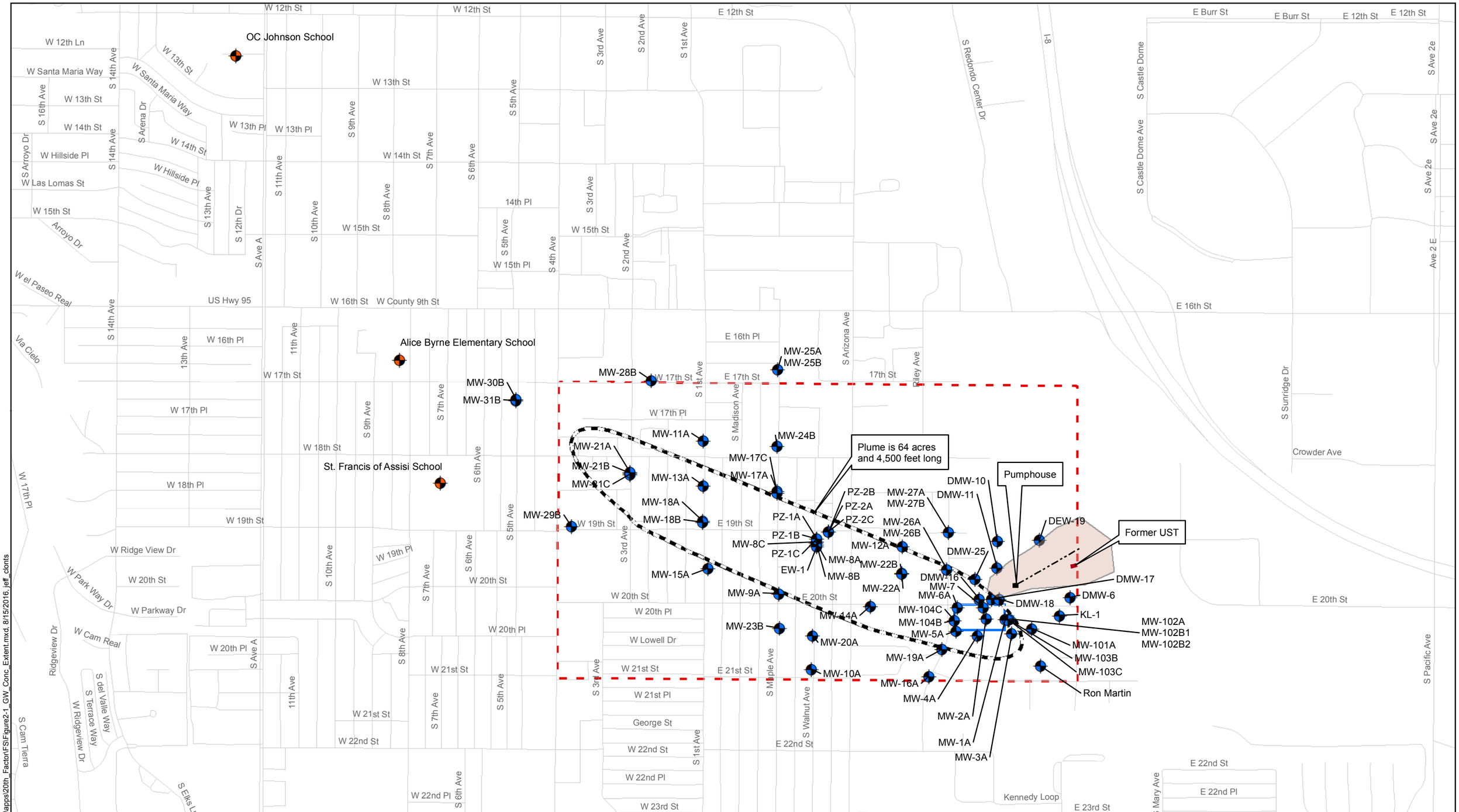
Matrix DESIGN GROUP

CALIBRE

0 25 50 Feet

Figure 1-2

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure1-2_Facility1_layout.mxd, 8/2/2016, jeff_clonts



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Well
- Irrigation Well
- Facility
- Extent of Groundwater Contamination (2016)
- 20th St. and Factor Ave WQARF Site (Approximate Boundary)
- Pumphouse
- Former UST
- 4" Diesel Pipeline
- Approximate Boundary of Dieselville Site
- Streets

WQARF = Water Quality Assurance Revolving Fund

Extent of Groundwater Contamination

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

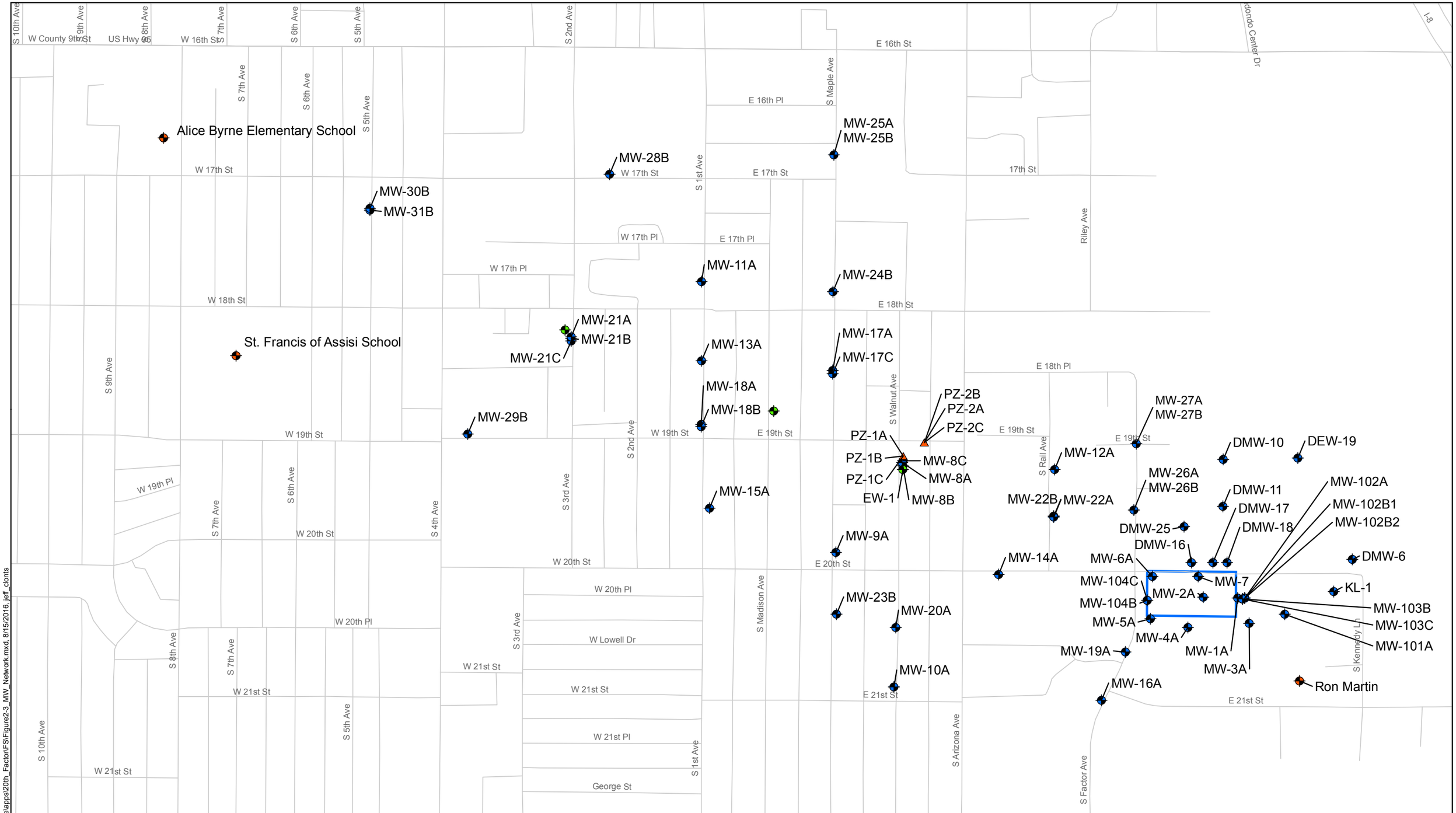
Matrix Design Group

CALIBRE

0 400 800 Feet

Figure 2-1

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-1_GW_Conc_Extent.mxd, 8/15/2016, jeff_clonts



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Well
- Extraction Well
- Irrigation Well
- Piezometer
- Facility
- Streets

WQARF = Water Quality Assurance Revolving Fund

Monitoring Well Network

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

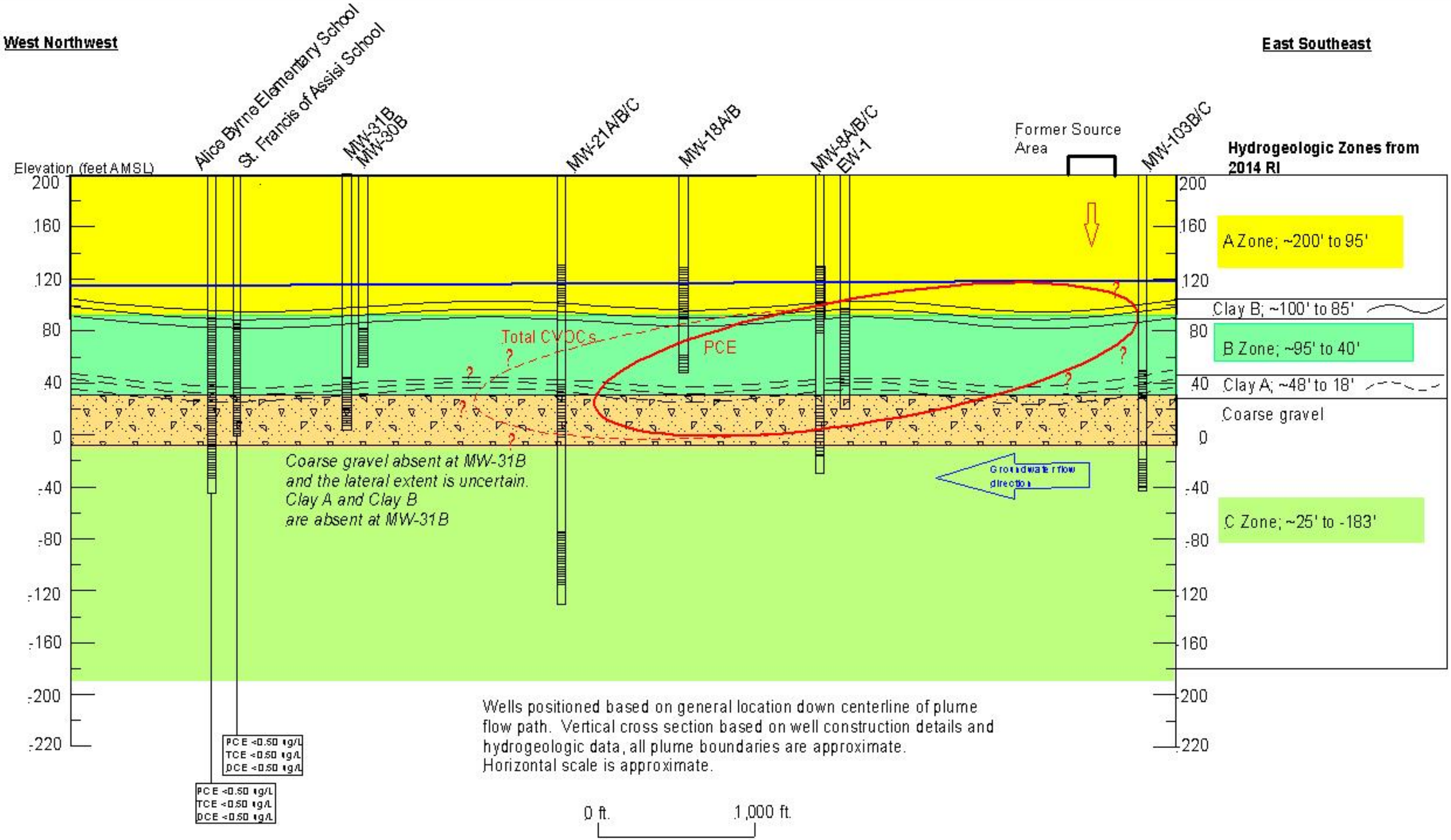
Matrix DESIGN GROUP

CALIBRE

0 225 450 Feet

Figure 2-3

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-3_MW_Network.mxd, 8/15/2016, jeff_clonts



Sample results from February 2016 sampling event.

Drawn By: JKC		**Conceptual Site Model**	ADEQ Arizona Department of Environmental Quality / Matrix Design Group / CALIBRE	Figure
QC'd By: CHW		Feasibility Study Report 20th Street and Factor Avenue WQARF Site	0 150 300 Feet	2-2
Drawing Date: 8/9/2016				

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-2_Conceptual_Site_Model.mxd, 5/17/2016, jeff_clonts

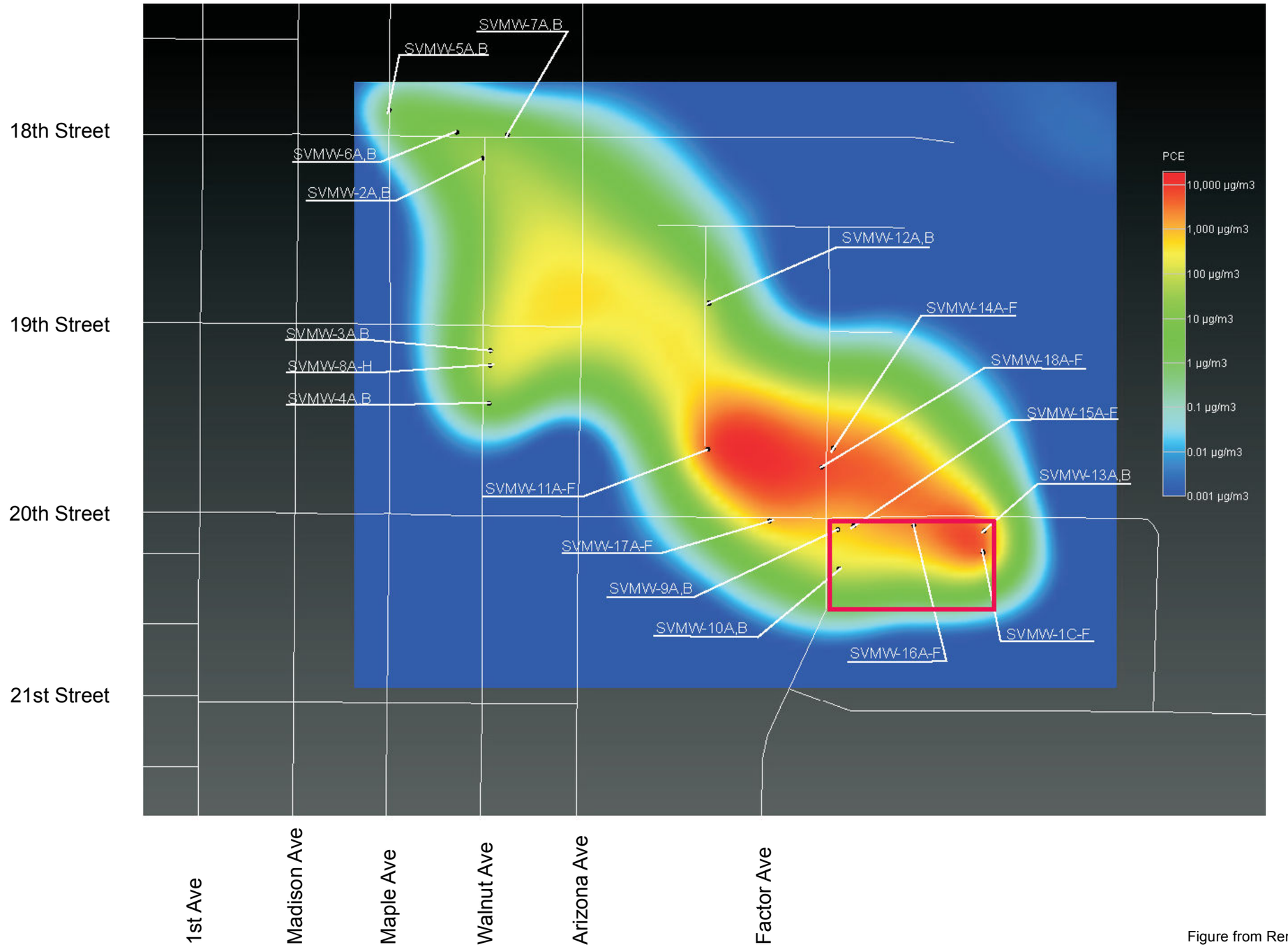
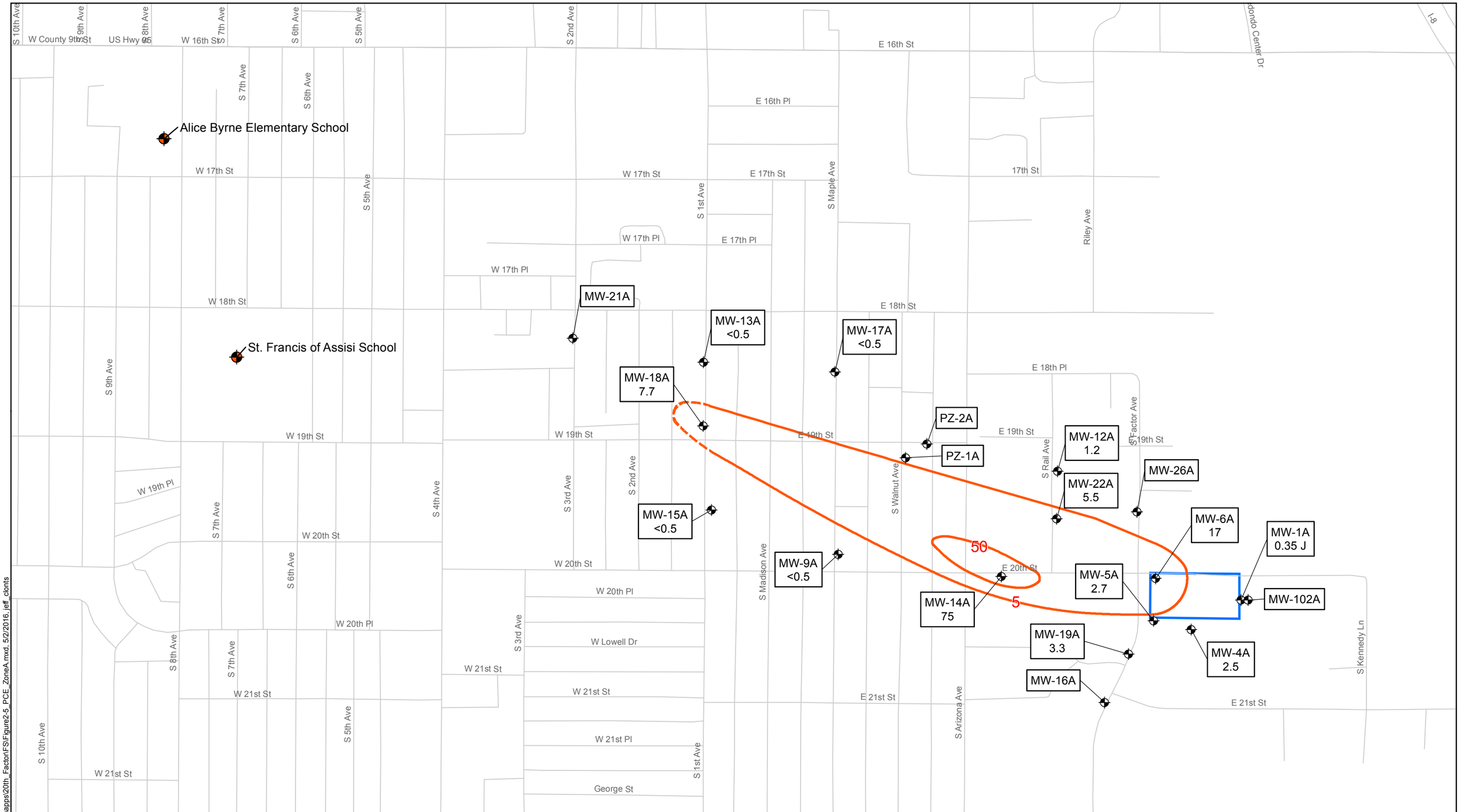


Figure from Remedial Investigation Report, Tetra Tech, 2014

Drawn By: JKC	**Legend** WQARF = Water Quality Assurance Revolving Fund	**PCE Plume in Vadose Zone at 20 feet bgs (January 2011)** Feasibility Study Report 20th Street and Factor Avenue WQARF Site	ADEQ Arizona Department of Environmental Quality Matrix Design Group CALIBRE	0 150 300 Feet	Figure 2-4
QC'd By: CHW					
Drawing Date: 5/2/2016					

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-4_PCE_VadoseZone.mxd, 5/3/2016, jeff_clonts



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Well (Zone A) PCE Concentration (ug/L)
- Irrigation Well
- 5 PCE Concentration (ug/L) (dashed where inferred)
- Facility
- Streets

Notes:
ug/L = micrograms per liter
PCE = Tetrachloroethene
WQARF = Water Quality Assurance Revolving Fund
AWQS = Aquifer Water Quality Standard
AWQS = 5 ug/L
J = estimated concentration

PCE in Zone A (February 2016)

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

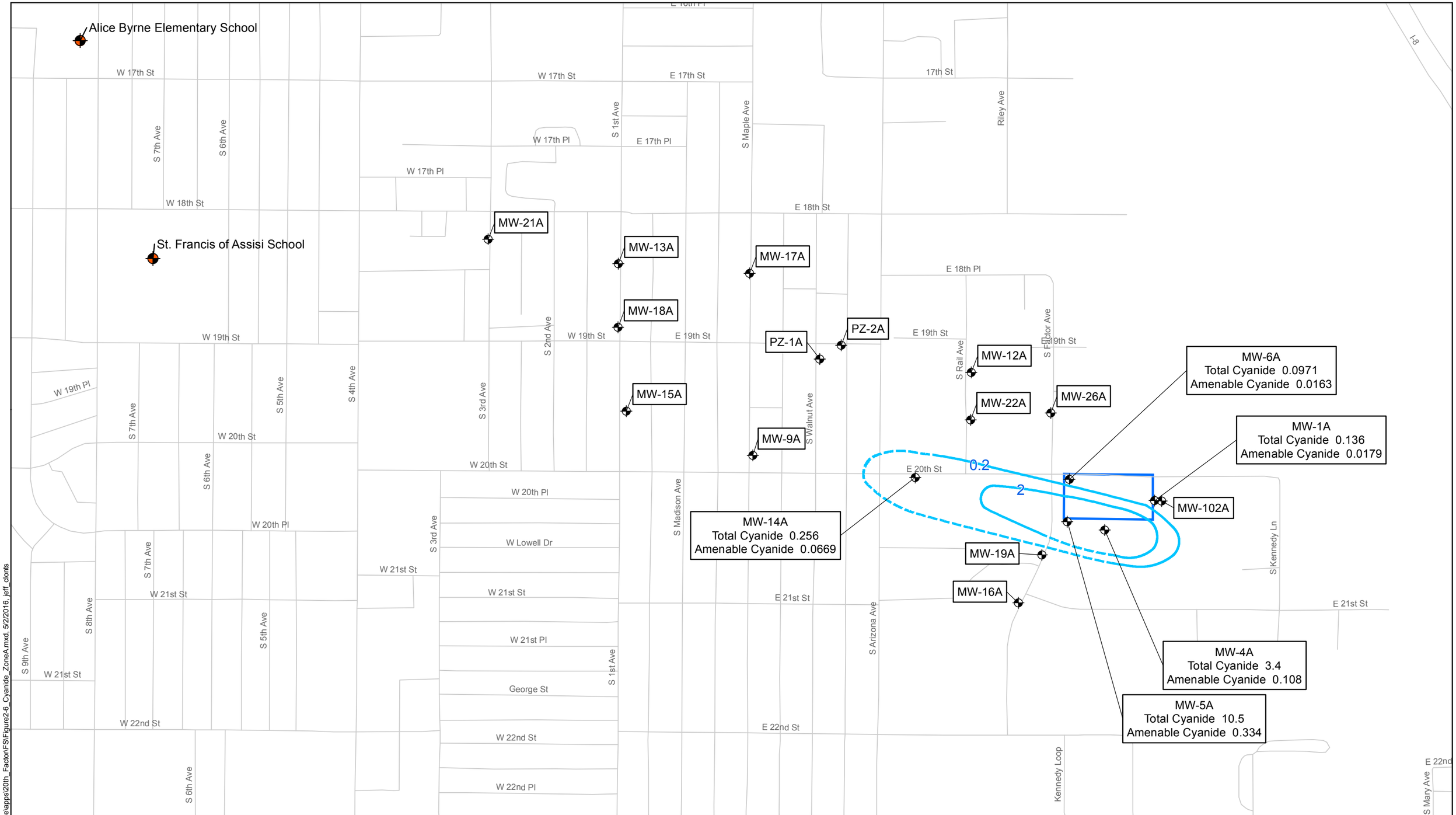
Matrix DESIGN GROUP

CALIBRE

0 200 400 Feet

Figure 2-5

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-5_PCE_ZoneA.mxd, 5/2/2016, jeff_clonts



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Well (Zone A) Cyanide Concentration (mg/L)
- Irrigation Well
- 0.2 Cyanide Concentration (mg/L) (dashed where inferred)
- Facility
- Streets

Notes:
mg/L = milligrams per liter
WQARF = Water Quality Assurance Revolving Fund
AWQS = Aquifer Water Quality Standard
AWQS = 0.20 mg/L (free cyanide)

Cyanide in Zone A (February 2016)

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

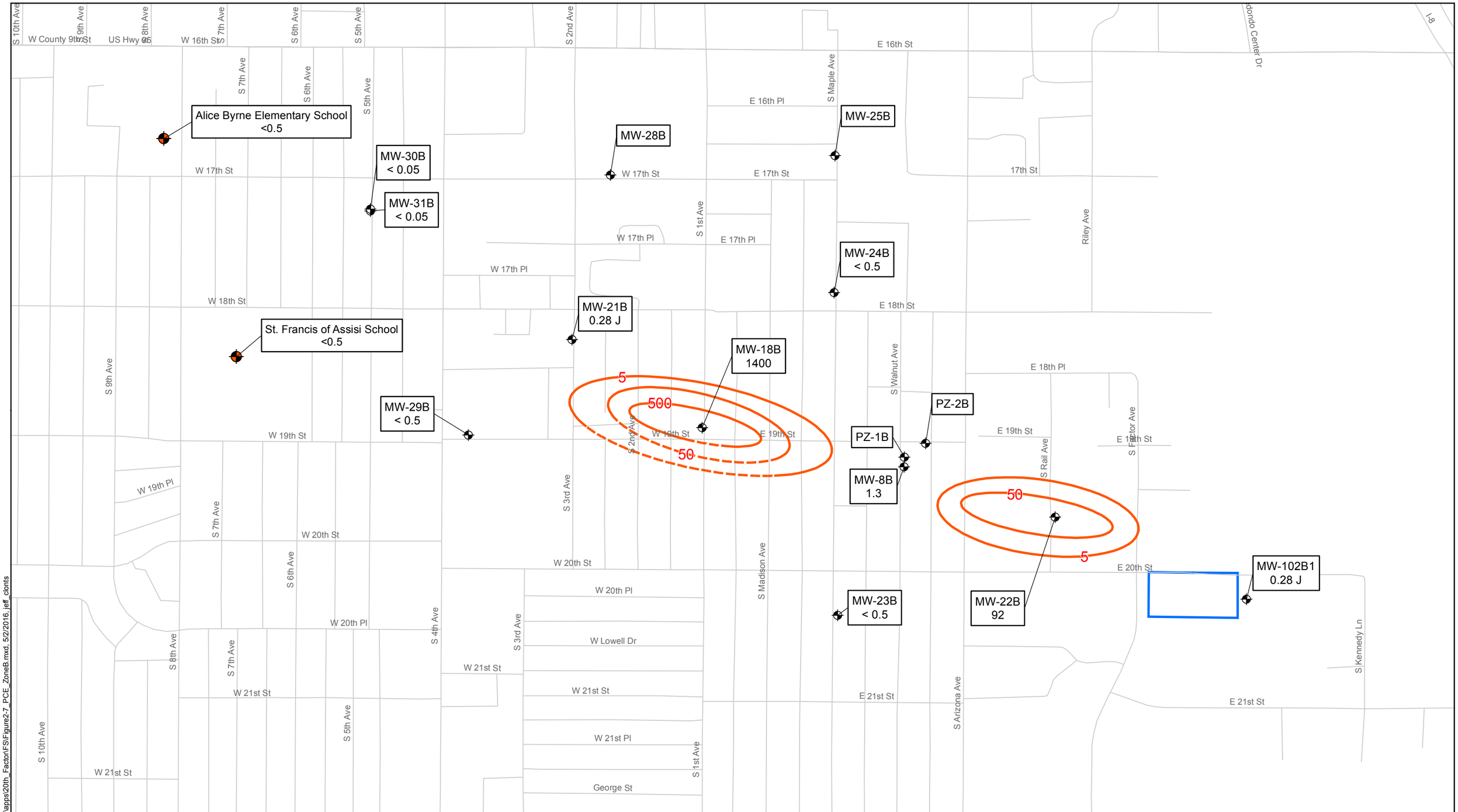
Matrix Design Group

CALIBRE

0 225 450 Feet

Figure 2-6

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-6_Cyanide_ZoneA.mxd, 5/2/2016, jeff_clonts



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Well (Zone B) PCE Concentration (ug/L)
- Irrigation Well
- PCE Concentration (ug/L) (dashed where inferred)
- Facility
- Streets

Notes:
ug/L = micrograms per liter
PCE = Tetrachloroethene
WQARF = Water Quality Assurance Revolving Fund
AWQS = Aquifer Water Quality Standard
AWQS = 5 ug/L
J = estimated concentration

PCE in Zone B (February 2016)

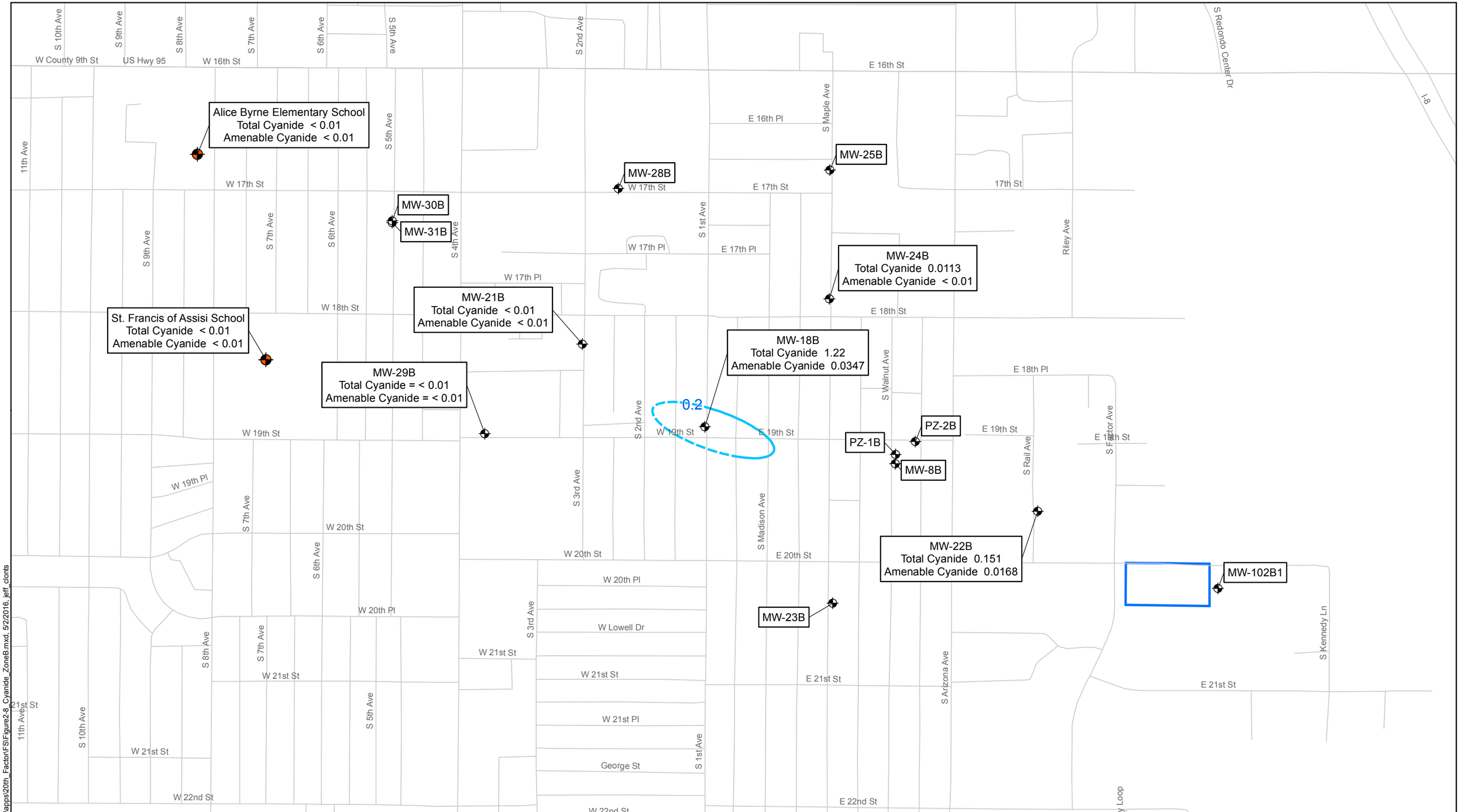
Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality
Matrix Design Group
CALIBRE

0 225 450 Feet

Figure
2-7

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-7_PCE_ZoneB.mxd, 5/2/2016, jeff_clonts



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Well (Zone B) Cyanide Concentration (mg/L)
- Irrigation Well
- 0.2 Cyanide Concentration (mg/L) (dashed where inferred)
- Facility
- Streets

Notes:
mg/L = milligrams per liter
WQARF = Water Quality Assurance Revolving Fund
AWQS = Aquifer Water Quality Standard
AWQS = 0.20 mg/L (free cyanide)

Cyanide in Zone B (February 2016)

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

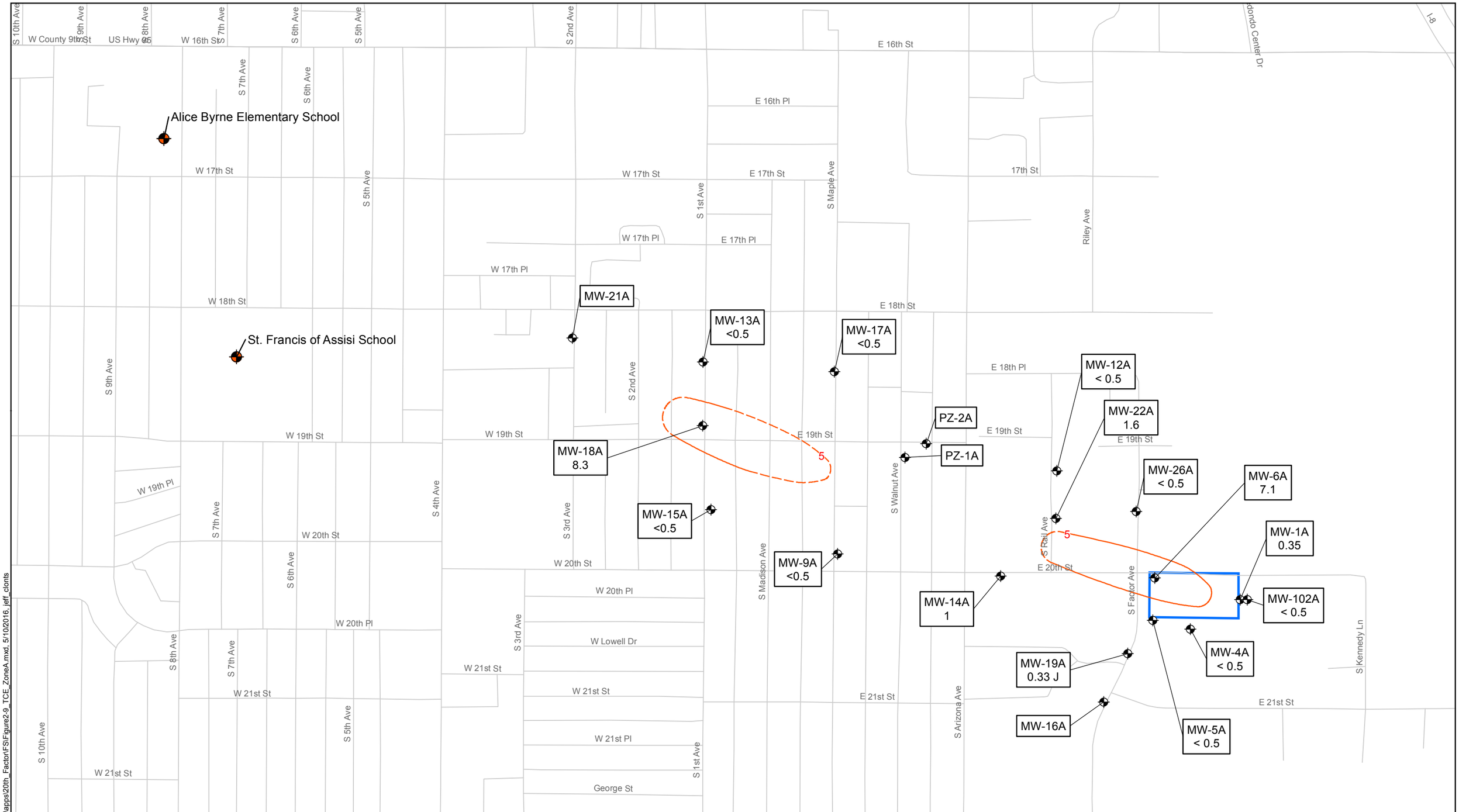
Matrix DESIGN GROUP

CALIBRE

0 200 400 Feet

Figure 2-8

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-8_Cyanide_ZoneB.mxd, 5/2/2016, jeff_clonts



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Well (Zone A) PCE Concentration (ug/L)
- Irrigation Well
- TCE Concentration (ug/L) (dashed where inferred)
- Facility
- Streets

Notes:
ug/L = micrograms per liter
TCE = trichloroethene
WQARF = Water Quality Assurance Revolving Fund
AWQS = Aquifer Water Quality Standard
AWQS = 5 ug/L

TCE in Zone A (February 2016)

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

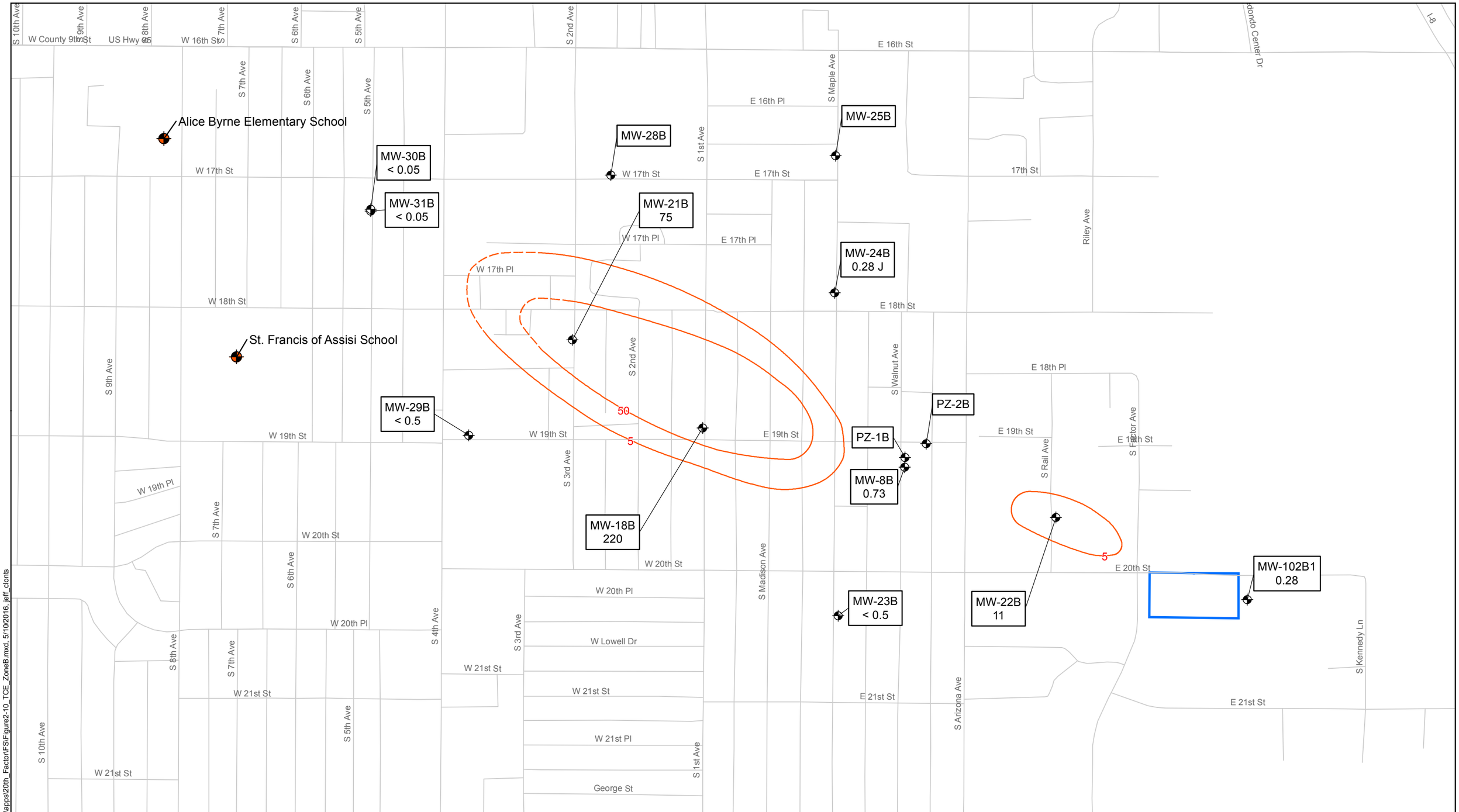
Matrix DESIGN GROUP

CALIBRE

0 225 450 Feet

Figure 2-9

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-9_TCE_ZoneA.mxd, 5/10/2016, jeff_clonts



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Well (Zone B) TCE Concentration (ug/L)
- Irrigation Well
- TCE Concentration (ug/L) (dashed where inferred)
- Facility
- Streets

Notes:
ug/L = micrograms per liter
TCE = trichloroethene
WQARF = Water Quality Assurance Revolving Fund
AWQS = Aquifer Water Quality Standard
AWQS = 5 ug/L

TCE in Zone B (February 2016)

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

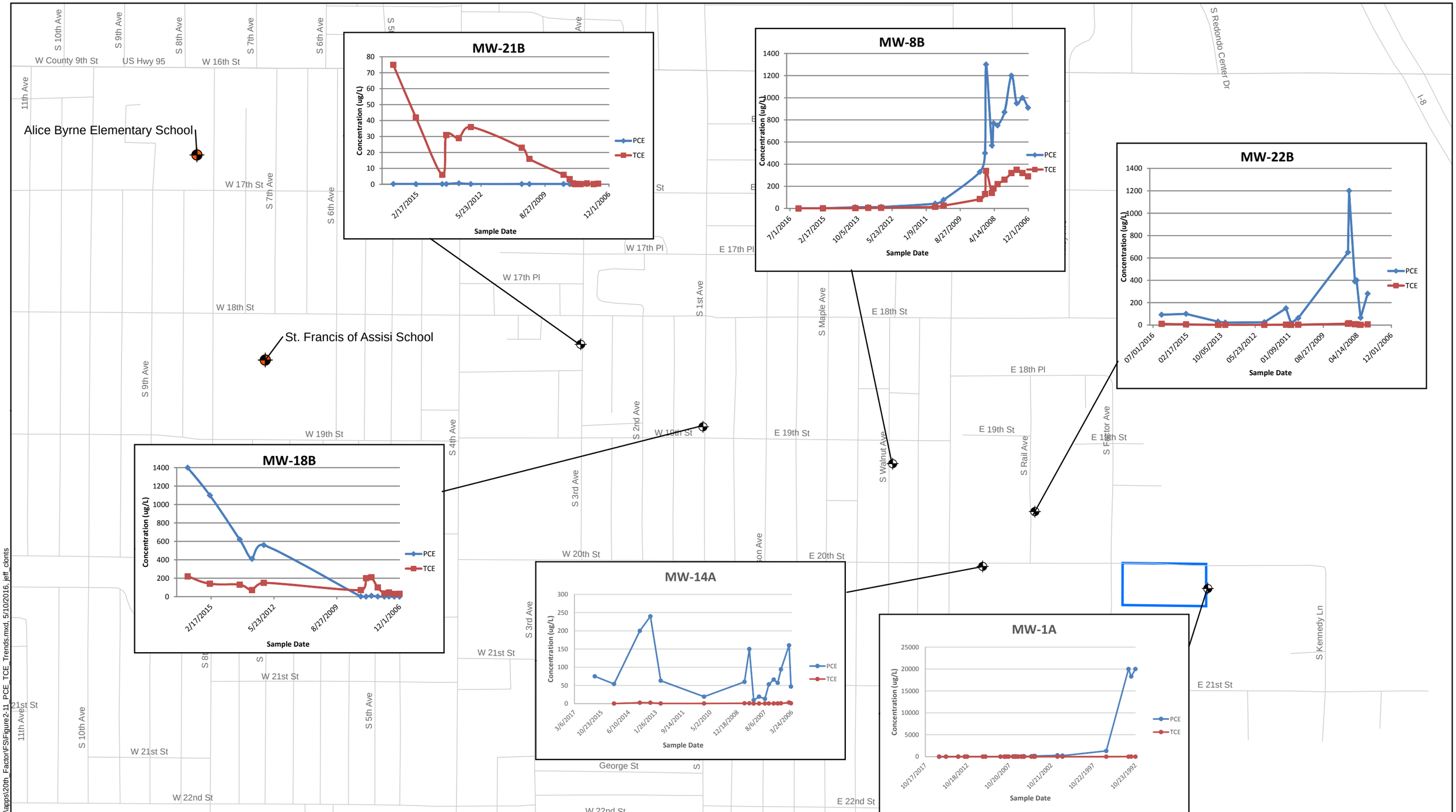
Matrix Design Group

CALIBRE

0 200 400 Feet

Figure
2-10

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-10_TCE_ZoneB.mxd, 5/10/2016, jeff_clonts



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

Monitoring Well

Irrigation Well

Facility

Streets

Notes:
MW-14A - Concentration scale is different on this chart
MW-1A - Concentration and time scales are different on this chart

PCE and TCE trends in selected monitoring wells

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

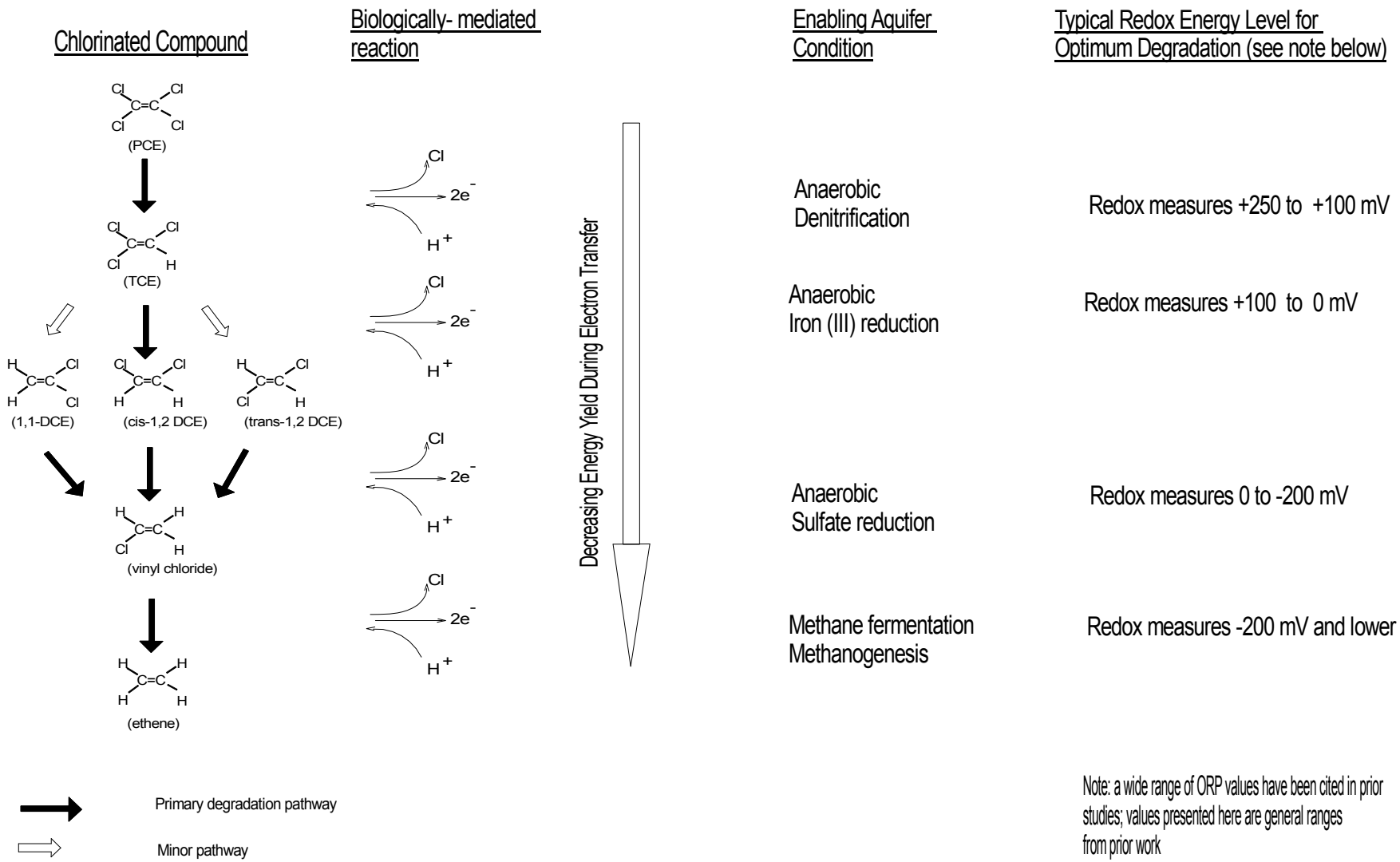
Matrix DESIGN GROUP

CALIBRE

0 200 400 Feet

Figure 2-11

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure2-11_PCE_TCE_Trends.mxd, 5/10/2016, jeff_clonts



ADEQ Arizona Department of Environmental Quality

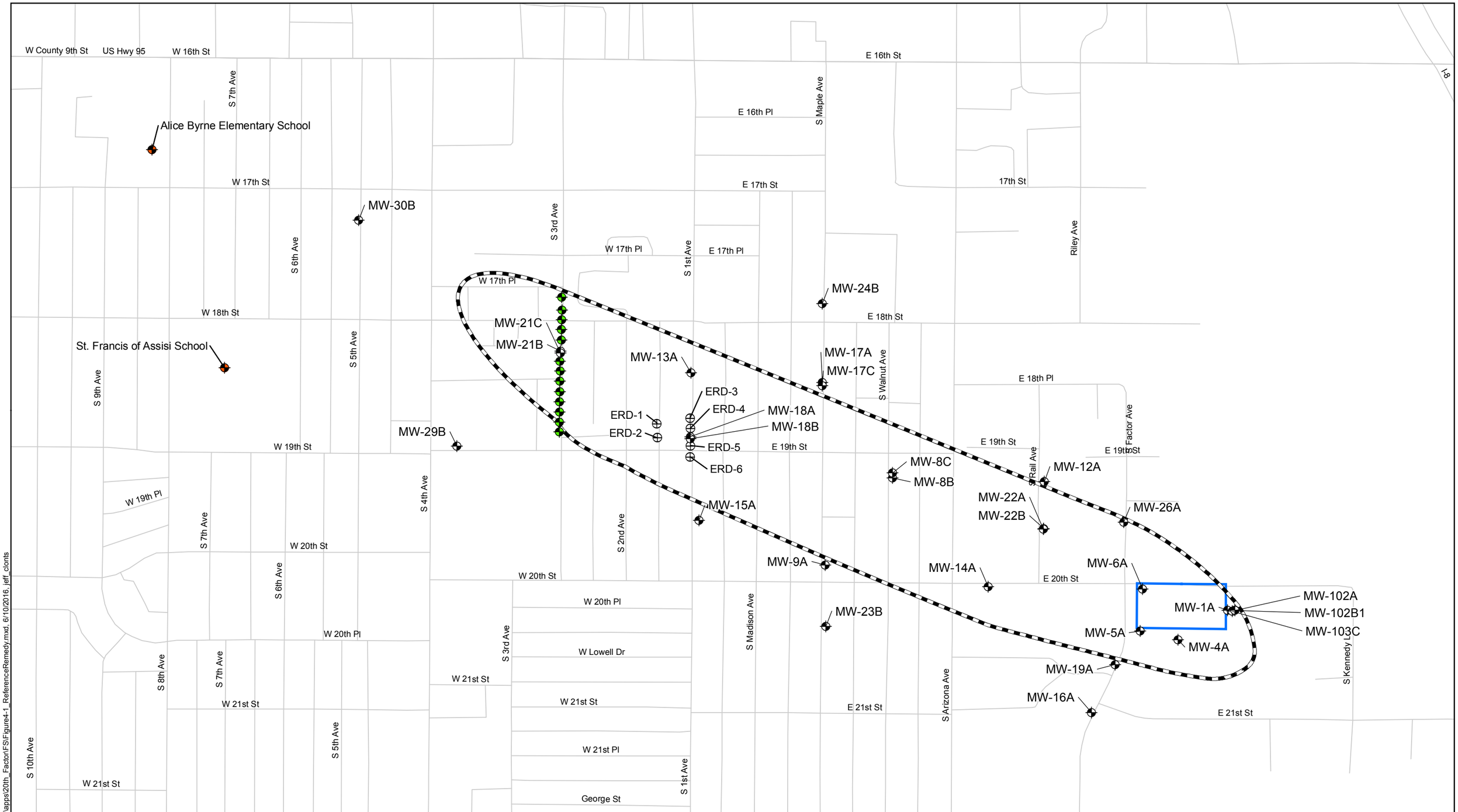
Matrix DESIGN GROUP CALIBRE

Primary Degradation Pathways of Chlorinated Ethenes by Reductive Dechlorination

Feasibility Study Report

20th Street and Factor Avenue WQARF Site

Figure 2- 12



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Wells
- ERD Wells
- Barrier Wells
- Irrigation Well
- Extent of Groundwater Contamination (2016)
- Facility
- Streets

Notes:
WQARF = Water Quality Assurance Revolving Fund

Elements of the Reference Remedy

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

Matrix DESIGN GROUP

CALIBRE

0 225 450 Feet

Figure 4-1

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure4-1_ReferenceRemedy.mxd, 6/10/2016, jeff_clonts

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure4-2_MoreAggressiveRemedy.mxd, 6/10/2016, jeff_clonts

Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Wells
- ERD Wells
- Extraction Well
- Irrigation Well
- Extent of Groundwater Contamination (2016)
- Piping to Treatment Plant
- Treatment Plant
- Streets

WQARF = Water Quality Assurance Revolving Fund

Elements of a More Aggressive Remedy

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

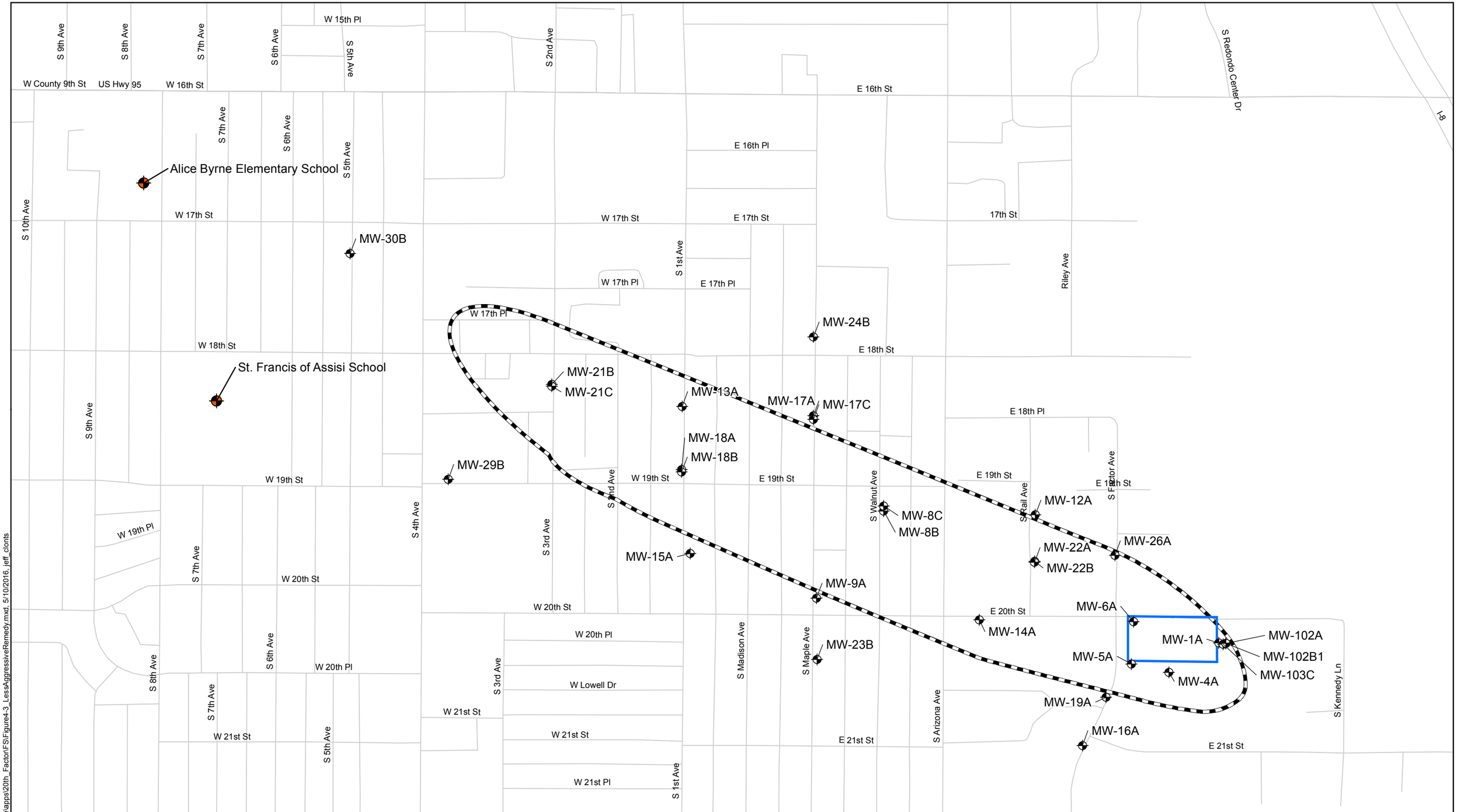
ADEQ Arizona Department of Environmental Quality

Matrix DESIGN GROUP

CALIBRE

0 225 450 Feet

Figure 4-2



Drawn By: JKC

QC'd By: CHW

Drawing Date: 5/2/2016

Legend

- Monitoring Wells
- Irrigation Well
- Extent of Groundwater Contamination (2016)
- Facility

Notes:
WQARF = Water Quality Assurance Revolving Fund to the legend

Elements of a Less Aggressive Remedy

Feasibility Study Report
20th Street and Factor Avenue
WQARF Site

ADEQ Arizona Department of Environmental Quality

Matrix Design Group

CALIBRE

0 225 450 Feet

Figure 4-3

FILE: G:\gis_projects\ADEQ\active\apps\20th_Factor\FS\Figure4-3_LessAggressiveRemedy.mxd, 5/10/2016, jeff_clonts

APPENDIX A

Evaluation of the Need for Soil Vapor Extraction

Introduction

This Appendix presents information intended to help evaluate whether a soil vapor extraction (SVE) system is necessary or appropriate for remedial efforts at the Site. An evaluation of SVE was begun as the FS was developed, but there are existing reports that indicate such a system may not be necessary. The historical reports focus on upward migration of soil vapors in the context of human exposure in structures or excavations and concluded that the risk was at acceptable levels. In contrast, the evaluation described below is focused on soil vapor as a potential ongoing source of contamination to groundwater. The focus of this memorandum is on volatile organic compounds (VOCs), which are amenable to removal and treatment using an SVE system.

The evaluation is based in the characteristics of the contaminant plumes in groundwater and on an estimate of the inventory of VOCs in the vadose zone and in the saturated zone.

Site Background

The 20th and Factor Site includes a mixture of commercial and light industrial businesses, warehouses, residential neighborhoods, and two schools encompassing an area of approximately 64 acres. Releases of VOCs and cyanide are documented at the former Houston Photo Products Facility (Facility). To date, no other sources of VOCs and cyanide have been identified in the area. The Facility is located near the southeast corner of the 20th Street and Factor Avenue intersection. The contaminant plume based on groundwater sampling conducted in February 2016 extends approximately 4,500 feet to the northwest down-gradient from the Facility and is roughly bounded by 17th Street to the north, 21st Street to the south, 3rd Avenue to the west, and Kennedy Lane to the east (see Figure 1-1 of the FS report).

Tetrachloroethene (PCE) is the primary contaminant of concern (COC) identified at the Site; other COCs identified in the 2014 Remedial Investigation (RI) include trichloroethene (TCE), 1,1-dichloroethene (DCE), and cyanide. The COCs have been detected in soil, soil vapor, and groundwater. Based on the areal extent of COCs above the Aquifer Water Quality Standards (AWQSs), groundwater is the most significantly impacted environmental media.

Contaminant Plume Characteristics

Analytical data from Site groundwater sampling in 2016 indicate that PCE and TCE concentrations exceed the AWQS in groundwater in aquifer Zones A and B (Matrix-CALIBRE, 2016). Table A-1 summarizes the maximum detections in 2016 by aquifer unit. The most elevated concentrations are in Zone B. The extent of PCE contamination in groundwater based on 2016 data in Zones A and B are shown in Figures 2-5 and 2-7 in the FS Report. The extent TCE contamination in groundwater based on the 2016 data are shown in Figures 2-9, and 2-10 in the FS Report. Note that on all four figures, the contours are located to the north-northwest of the Facility, in a pattern that suggests the plumes are separated or detached from the Facility. This is an indication that there is not a significant ongoing source of VOC contamination in the vadose zone entering groundwater at the Facility.

Contaminant Mass Calculations

The mass of PCE and TCE in groundwater was calculated from the groundwater data shown on the figures mentioned in the previous paragraph by measuring the areas of each contour and multiplying by the geometric mean of either the two adjacent contours or the contour and the results from the well within the contour (for the inner contour). This result was then multiplied by an assumed porosity (20%) and an estimated thickness of the contaminated zone (40 feet for Zone A and 50 feet for Zone B). Table A-1 summarizes the results of these calculations for groundwater. The total mass of PCE and TCE in groundwater is 56 kilograms or 124 pounds, of which 92 percent is in Zone B. Equilibrium partitioning theory suggests that the total mass in the saturated zone, including PCE and TCE adsorbed to soil particles would be about 2.1 times these values or 383 pounds.

Soil vapor samples were collected most recently in 2011, in support of the RI report, Tetra Tech, 2014. Vapor samples were collected from nested wells screened at several depths between the ground surface and the water table, approximately 70 feet (ft) below ground surface (bgs) at the Facility. Figure 2-4 in the FS Report displays the PCE data from samples collected 20 ft bgs. The pattern and extent of contamination is similar at other depth intervals. The TCE concentrations in soil vapor are negligible compared with PCE and is ignored in the calculation described below.

The mass of PCE in soil vapor was calculated by measuring the area of the 1,000 $\mu g/m^3$ and 100 $\mu g/m^3$ contours and multiplying by the geometric mean concentration of the contour values or the geometric mean of the concentrations at 20 ft (as taken from Table 2-4 of the RI report). This was multiplied by an estimated contaminated thickness of the vadose (70 feet) and an assumed porosity (20%). The mass in soil vapor using this approach is 0.4 kilograms or 0.9 pounds, as shown in Table A-2. Partitioning theory suggests that approximately 65 percent of the mass would be sorbed to soil or contained in soil moisture, so that the total PCE mass in the vadose zone would be 1.2 kilograms or 2.5 pounds.

The total mass of PCE and TCE in the saturated zone, 383 pounds, plus the mass of PCE in the vadose zone, 2.5 pounds is 386 pounds. Therefore, 99 percent of the mass is in groundwater. This supports the statement that there is not a significant ongoing source of contamination entering groundwater at the Facility.

Conclusions

The analysis presented above indicates that there is not an immediate need to include SVE in a remedy for the Site. However, it is possible that conditions at the Site could change in the future. For example, disposal operations ceased at the Site over a decade ago, which decreased (but did not stop) infiltration at the Site. Additionally, the soil removal action included placement of an asphalt cap over the removal area. These factors could delay the impact of contaminant transport from the vadose zone to groundwater. As such, it may be prudent to include SVE in a Site remedy as a contingency, in the event that releases from the vadose zone to groundwater become problematic in the future. Ongoing groundwater monitoring at the Facility could be used to evaluate the need for this type of contingent remedy.

References

Matrix-CALIBRE, 2016. 2016 Groundwater Monitoring Report. 20th and Factor WQARF Site, Yuma, Arizona. June, 2016.

Tetra Tech, 2014. Final Remedial Investigation Report, 20th Street and Factor Avenue WQARF Site, Yuma Arizona, June 27, 2014.

Table A-1. PCE and TCE Inventory in Groundwater, 2016 Data.

Description	Source Figure	Contour Interval	Geometric Mean Concentration (ug/L)	Area (ft^2)	Soil Volume (ft^3)	Pore Volume (ft^3)	Pore Volume (m^3)	Chemical Mass (ug)	Chemical Mass (kg)	Chemical Mass (lb)
PCE Zone A (1)	2-5	50	61.2	70,664	2,826,543	565,309	16,014	980,678,262	0.98	2.16
PCE Zone A (2)	2-5	5	15.8	992,329	39,693,159	7,938,632	224,890	3,555,829,715	3.56	7.82
PCE Zone B (3)	2-7	500	836.7	88,505	4,425,274	885,055	25,072	20,977,054,654	20.98	46.15
PCE Zone B (4)	2-7	50	158.1	347,794	17,389,703	3,477,941	98,525	15,578,206,601	15.58	34.27
PCE Zone B (2)	2-7	5	15.8	336,600	16,830,010	3,366,002	95,354	1,507,681,750	1.51	3.32
TCE Zone A (5)	2-9	5	6.4	89,144	3,565,760	713,152	20,203	130,146,187	0.13	0.29
TCE Zone B (6)	2-10	50	80.1	485,649	24,282,450	4,856,490	137,578	11,025,639,327	11.03	24.26
TCE Zone B (2)	2-10	5	15.8	548,271	27,413,550	5,482,710	155,318	2,455,786,310	2.46	5.40
						Inventory in groundwater (water)			**56**	**124**
						Inventory in groundwater (including sorbed)			**174**	**383**

Notes:

Porosity	0.2	unitless
Zone A thickness	40	ft
Zone B thickness	50	ft
Distribution Coefficient	0.23	L/kg
Bulk density	1.8	g/cc
Retardation factor	3.1	unitless

(1) The geometric mean is of the 50 ug/L contour and 75 ug/L from MW-14A
(2) The geometric mean is of the 5 ug/L contour and the 50 ug/L contour.
(3) The geometric mean is of the 500 ug/L contour and 1,400 ug/L from MW-18B
(4) The geometric mean is of the 50 ug/L contour and the 500 ug/L contour.
(5) The geometric mean is of the 5 ug/L contour and 8.3 ug/L from MW-8A
(6) The geometric mean is of the 50 ug/L contour and the geometric mean of 75 ug/L from MW-21B and 220 from MW-18B

Table A-2. PCE Inventory in the Vadose Zone, 2011 Data.

Description	Source Figure	Contour Interval	Geometric Mean Concentration (ug/m^3)	Area (ft^2)	Soil Volume (ft^3)	Pore Volume (ft^3)	Pore Volume (m^3)	Mass (ug)	Mass (kg)	Mass (lb)
PCE [1]	2-4	1000	2356	307,873	21,551,110	4,310,222	122,103	287,699,125.11	0.29	0.63
PCE [2]	2-4	100	316	929,879	65,091,530	13,018,306	368,791	116,621,808.04	0.12	0.26
							Inventory in vapor phase:		0.40	0.89
							Inventory in soil moisture[3]:		0.15	0.32
							Inventory sorbed to soil [4]:		0.60	1.32
							Total inventory:		1.15	2.54

Notes:

Porosity 0.2 unitless

Vadose Zone thickness 70 ft

(1) The geometric mean is of the 1,000 ug/L contour and 5,553 ug/m^3, which is the geometric mean of the 20 ft vapor samples from SVMW-1, 11, 14, and 18.

(2) The geometric mean is of the 100 ug/m^3 contour and the 1,000 ug/m^3 contour.

(3) Assumes a soil moisture of 10 percent

(4) A distribution coefficient (K_d) of 0.23 is used in this calculation.

APPENDIX B

Backup Details of the Cost Estimates for Each Remedy

Table B-1. Reference Remedy: Bioremediation of Hot Spots, Bio-Barrier Wells for Plume Containment, Cap Inspection and Maintenance, and Soil Vapor Extraction (Contingent).

Source Area Remediation Tasks	Quantity	Unit	Unit Cost [1]	Total Cost [2]	Detail
SITE PREPARATION					
Well Drilling Mobilization/Demobilization	2	LS	$ 4,500	$ 9,000	Includes sonic drill rig and necessary equipment/material.
Well Development Mobilization/Demobilization	2	LS	$ 1,250	$ 2,500	Includes sonic drill rig and necessary equipment/material.
Site Survey/Utility Locate	1	LS	$ 10,000	$ 10,000	Assume this covers both SVE and ERD well locations.
Subtotal:				***$22,000***	
SVE REMEDIATION IN MAIN SOURCE AREA[3]					
SVE Well Installation	10	Well	$ 7,050	$ 70,500	Assumes 80-foot SVE wells. Per well cost from driller.
Field Oversight for SVE Well Install and Development	12	Day	$ 1,500	$ 18,000	Includes 1 FTE for 10 hours per day. 1 day per well install, 2 days travel
IDW Management and Disposal (soil, Subtitle D)	4	Rolloffs	$ 600	$ 2,400	Assume transport and disposal at Subtitle D landfill.
Operate and Maintain SVE System for Vadose Zone, Years 1-2	2	YR	$ 99,000	$ 198,000	Assumes active optimization, operation, and maintenance (including carbon and electricity consumption) for 1-2 years.
Subtotal:				***$289,000***	
ERD REMEDIATION IN PRIMARY HOTSPOT[4]					
Well Installation	10	Well	$ 14,640	$ 147,000	Assumes 4-inch diameter injection wells to be installed to depth of 190 feet; wells are to be screened at multiple depth intervals to allow for injections to be completed throughout the well depth column.
Well Development	10	Well	$ 800	$ 8,000	Based on drillers estimate
Field Oversight Well Install and Development	35	Day	$ 1,500	$ 52,500	Includes 1 FTE for 10 hours per day. 3 days per well installation, development of 2 wells/day.
IDW Management and Disposal (soil, Subtitle D)	6	Rolloffs	$ 600	$ 3,600	Assume rental of roll-off container, transport and disposal at Subtitle D landfill.
IDW Management and Disposal (water)	1	LS	$ 3,000	$ 3,000	Assumes frac tank and carbon treatment system rental, treatment and discharge to sanitary sewer.
Pre-Design Characterization	1	LS	$ 50,000	$ 50,000	Estimate from prior pilot test studies.
Pilot Study	1	LS	$ 50,000	$ 50,000	Assumes 3-well pilot test, with 3 injections per well.
Bioaugmentation , Year 1	1	Event	$ 30,000	$ 30,000	Bioaugmentation, Year 1, one time after all wells are at reducing condition
Perform ERD Injections , Years 1-2	4	Event	$ 35,000	$ 140,000	Substrate injections to be performed semiannually for the 2 years.
Perform ERD Injections , Years 3-5	3	Event	$ 35,000	$ 105,000	Substrate injections to be performed annually as needed, years 3-5.
Perform ERD Injections , Years 6-10	2	Event	$ 35,000	$ 70,000	Focused substrate injections for hot spot treatment(s), years 6-10.
Subtotal:				***$660,000***	
BIO-BARRIER WELLS TO CONTAIN PLUME					
Well Installation	13	Well	$ 14,640	$ 191,000	Assumes 4-inch diameter injection wells to be installed to depth of 190 feet; wells are to be screened at multiple depth intervals to allow for injections to be completed throughout the well depth column.
Well Development	13	Well	$ 800	$ 10,400	Based on drillers estimate
Field Oversight Well Install and Development	46	Day	$ 1,500	$ 69,000	Includes 1 FTE for 10 hours per day. 3 days per well installation, development of 2 wells/day.
IDW Management and Disposal (soil, Subtitle D)	10	Rolloffs	$ 600	$ 6,000	Assume rental of roll-off container, transport and disposal at Subtitle D landfill.
IDW Management and Disposal (water)	1	LS	$ 4,000	$ 4,000	Assumes frac tank and carbon treatment system rental, treatment and discharge to sanitary sewer.
Pre-Design Characterization Wells	5	Well	$ 14,640	$ 73,200	Assumes 4-inch diameter injection wells to be installed to depth of 190 feet.
Well Development	5	Well	$ 800	$ 4,000	Based on drillers estimate
Field Oversight Well Install and Development	18	Day	$ 1,500	$ 27,000	Includes 1 FTE for 10 hours per day. 3 days per well installation, development of 2 wells/day.
Pilot Study for Cyanide Treatment	1	LS	$ 50,000	$ 50,000	Assumes 3-well pilot test, with 3 injections per well.
Bioaugmentation , Year 1	1	Event	$ 39,000	$ 39,000	Bioaugmentation, Year 1, one time after all wells are at reducing condition
Perform ERD Injections , Years 1-2	6	Event	$ 46,000	$ 276,000	Substrate injections to be performed semiannually for the 2 years.
Perform ERD Injections , Years 3-5	4	Event	$ 46,000	$ 184,000	Substrate injections to be performed annually as needed, years 3-5.
Perform ERD Injections , Years 6-10	2	Event	$ 46,000	$ 92,000	Focused substrate injections for hot spot treatment(s), years 6-10.
Subtotal:				***$1,026,000***	
			Remediation Cost	**$1,997,000**	
LONG TERM MONITORING COSTS (MNA+ Cap)					
Monitoring Well Installation	5	Well	$ 14,640	$ 73,200	Assumes 190-foot monitoring wells. Per well cost from vendor.
Monitoring Well Development	5	Well	$ 800	$ 4,000	
Field Oversight for Monitoring Well Install and Development	18	Day	$ 1,500	$ 27,000	Includes 1 FTE for 10 hours per day. 3 days per well install, 2 wells/day development.
IDW Management and Disposal (soil, Subtitle D)	3	Rolloffs	$ 600	$ 1,800	Assume transport and disposal at Subtitle D landfill.
IDW Management and Disposal (water)	1	LS	$ 2,000	$ 2,000	Assumes disposal of well development water and purge water.
ERD Performance Monitoring (Years 1-5)	10	Event	$ 19,100	$ 191,000	Monitoring of 20 wells to be completed semi-annually, years 1-5. Includes labor, equipment, and laboratory analysis.
ERD Performance Monitoring (Years 6-10)	5	Event	$ 19,100	$ 95,500	Monitoring of 20 key wells to be completed semi-annually, years 6-10. Includes labor, equipment, and laboratory analysis.
Annual Key Monitoring Well Sampling (Years 0-10)	10	Event	$ 52,000	$ 520,000	Monitoring of wells (assume 75) to be completed annually, years 0-10. Includes labor, equipment, and laboratory analysis.
Annual Key Monitoring Well Sampling (Years 11-20)	10	Event	$ 26,300	$ 263,000	Monitoring of key wells (assume 30) to be completed annually, years 11-20. Includes labor, equipment, and laboratory analysis.

Cap Inspection	15	Each	$ 6,000	$ 90,000	Assumes every other year for 30 years
Cap Maintenance (crack sealing)	6	Each	$ 2,000	$ 12,000	Assumes every 5 years for 30 years
Cap Replacement 15 years	42740	SF	$ 2.00	$ 85,480	
Cap Replacement 30 years	42740	SF	$ 2.00	$ 85,480	
Subtotal:				***$1,451,000***	
INDIRECT REMEDIATION COSTS					
Permitting/Design/Project Oversight[5]	1	LS	$ 862,000	$ 870,000	Assumes 25% of overall cost for system design, project oversight, management, permits, work plans, confirmational sampling, reporting, regulatory interaction, etc., over the 20-year project period (30 years for the asphalt cap).
Subtotal:				***$870,000***	
Remediation Cost (Plus IDCs and LTM)				**$4,318,000**	
Remediation Contingency (25 Percent) [6]				**$1,080,000**	Appropriate contingency for feasibility-level planning.
TOTAL REMEDIATION COST				**$5,400,000**	

Notes:

1 All cost values are estimates and should not be interpreted as final construction or project costs. Costs are in present dollars and do not include inflation costs.
2 Subtotal costs are rounded up to the nearest $10,000, total cost is rounded to the neared $100,000.
3 SVE system cost estimates are based on experience from past site operations and current estimates for SVE operations.
4 ERD cost estimates are based on experience on similar projects.
5 Anticipated costs for permitting, engineering design, reporting, and construction oversight are assumed as 20% of the estimated remediation cost.
6 Contingency is appropriate for feasibility-level planning and will be reduced during the remedial design phase of the project.

Abbreviations:

ERD Enhanced Reductive Dechlorination
SVE Soil vapor extraction
IDC Indirect Cost
LS Lump Sum
YR Year

Table B-2. More Aggressive Remedy - Bioremediation of Hot Spots, and Groundwater Extraction and Treatment for Plume Containment, Cap Inspection and Maintenance, and Soil Vapor Extraction (Contingent).

SITE PREPARATION					
Well Drilling Mobilization/Demobilization	2	LS	$ 4,500	$ 9,000	Includes sonic drill rig and necessary equipment/material.
Well Development Mobilization/Demobilization	2	LS	$ 1,250	$ 2,500	Includes sonic drill rig and necessary equipment/material.
Site Survey/Utility Locate	1	LS	$ 10,000	$ 10,000	Assume this covers both SVE and ERD well locations.
Subtotal:				***$22,000***	
GW Extraction and Remediation Tasks	**Quantity**	**Unit**	**Unit Cost [1]**	**Total Cost [2]**	**Detail**
Land Purchase Price	1	LS	$ 150,000	$ 150,000	Includes acquisition of property for treatment system.
Capital Costs for Treatment System	1	LS	$ 250,000	$ 250,000	Includes carbon units, electrical drop, and plumbing associated with up to 250 gpm GAC carbon system
Site development and building for treatment system	1	LS	$ 75,000	$ 75,000	Includes site work, small building for controls
Control Systems	1	LS	$ 50,000	$ 50,000	Instrumentation, PLC, Programming, etc.
Installation and Start-up of System	1	LS	$ 25,000	$ 25,000	Includes startup tests, monitoring work plans and reporting
Extraction Well Drilling	2	Well	$ 16,710	$ 34,000	Assumes 6-inch diameter extraction wells to be installed to depth of 200 feet bgs
Well Development	2	Well	$ 800	$ 2,000	Based on drillers estimate
Field Oversight for Injection Well Install and Development	7	Day	$ 1,200	$ 9,000	Includes 1 FTE for 10 hours per day. 3 days per well installation, development of 2 wells/day.
Well vault install	3	EA	$ 6,000	$ 18,000	4 ft by 4 ft, diamond plate, rated for H-20 wheel load
Pump install	3	EA	$ 7,500	$ 23,000	4 Grundfos 3 hp pumps with riser for 190 ft, 10 gauge pump wire
IDW Management and Disposal (soil, Subtitle D)	2	Rolloffs	$ 600	$ 1,200	Assume rental of roll-off container, transport and disposal at Subtitle D landfill.
IDW Management and Disposal (water)	1	LS	$ 2,000	$ 2,000	Assumes frac tank and carbon treatment system rental, treatment and discharge to sanitary sewer.
Power supply to pumps	3	EA	$ 15,000	$ 45,000	
Trenching/conduit for power	250	ft	$ 50	$ 13,000	To each well for power
Trenching/piping for supply to treatment	2000	ft	$ 60	$ 120,000	4 x 1.5 inch lines
Trenching/piping for discharge from treatment	200	ft	$ 80	$ 16,000	1 x 3 inch line
Construction oversight	75	Day	$ 1,200	$ 90,000	
Traffic Control	75	Day	$ 1,200	$ 90,000	
Well Testing/ ROI /Containment verification	1	LS	$ 15,000	$ 15,000	
Equipment Replacement and Maintenance	1	LS	$ 35,000	$ 35,000	Includes periodic replacement costs such as meters, valves, pump, hoses, etc.
Operation and Maintenance, Years 1-10	10	YR	$ 125,000	$ 1,250,000	Assumes routine operation and maintenance (including carbon and electricity consumption) for 10 years after construction.
Operation and Maintenance, Years 11-20	10	YR	$ 93,750	$ 937,500	Assumes routine operation and maintenance (including carbon and electricity consumption) for years 11-20 years after construction.
Subtotal:				**$3,251,000**	
SVE REMEDIATION IN MAIN SOURCE AREA[3]					
SVE Well Installation	10	Well	$ 7,050	$ 70,500	Assumes 80-foot SVE wells. Per well cost from driller.
Field Oversight for SVE Well Install and Development	12	Day	$ 1,500	$ 18,000	Includes 1 FTE for 10 hours per day. 1 day per well install, 2 days travel
IDW Management and Disposal (soil, Subtitle D)	4	Rolloffs	$ 600	$ 2,400	Assume transport and disposal at Subtitle D landfill.
Operate and Maintain SVE System for Vadose Zone, Years 1-2	2	YR	$ 99,000	$ 198,000	Assumes active optimization, operation, and maintenance (including carbon and electricity consumption) for 1-2 years.
Equipment Replacement and Maintenance	1	LS	$ 10,000	$ 10,000	Assumes periodic replacement of SVE components (ie blower replacement, hoses, valves, etc.)
Subtotal:				***$299,000***	
ERD REMEDIATION IN PRIMARY HOTSPOT AREA[4]					
Well Installation	10	Well	$ 14,640	$ 147,000	Assumes 4-inch diameter injection wells to be installed to depth of 190 feet; wells are to be screened at multiple depth intervals to allow for injections to be completed throughout the well depth column.
Well Development	10	Well	$ 800	$ 8,000	Based on drillers estimate
Field Oversight Well Install and Development	35	Day	$ 1,500	$ 52,500	Includes 1 FTE for 10 hours per day. 3 days per well installation, development of 2 wells/day.
IDW Management and Disposal (soil, Subtitle D)	6	Rolloffs	$ 600	$ 3,600	Assume rental of roll-off container, transport and disposal at Subtitle D landfill.
IDW Management and Disposal (water)	1	LS	$ 3,000	$ 3,000	Assumes frac tank and carbon treatment system rental, treatment and discharge to sanitary sewer.
Pre-Design Characterization	1	LS	$ 50,000	$ 50,000	Estimate from prior pilot test studies.
Pilot Study	1	LS	$ 50,000	$ 50,000	Assumes 3-well pilot test, with 3 injections per well.
Bioaugmentation , Year 1	1	Event	$ 30,000	$ 30,000	Bioaugmentation, Year 1, one time after all wells are at reducing condition
Perform ERD Injections , Years 1-2	4	Event	$ 35,000	$ 140,000	Substrate injections to be performed semiannually for the 2 years.
Perform ERD Injections , Years 3-5	3	Event	$ 35,000	$ 105,000	Substrate injections to be performed annually as needed, years 3-5.
Perform ERD Injections , Years 6-10	2	Event	$ 35,000	$ 70,000	Focused substrate injections for hot spot treatment(s), years 6-10.
Subtotal:				***$660,000***	
COMPLIANCE MONITORING COSTS (discharge only)					
Annual Compliance Monitoring, Years 0-20	20	YR	$ 6,000	$ 120,000	Assumes 4 sampling events per year (for 20 years post-construction) for influent, mid-point, and effluent.
Subtotal:				***$120,000***	
Reduced Monitoring from Reference Remedy					
Monitoring Well Installation	5	Well	$ 14,640	$ 73,200	Assumes 190-foot monitoring wells. Per well cost from driller.
Monitoring Well Development	5	Well	$ 800	$ 4,000	Based on drillers estimate

IDW Management and Disposal (soil, Subtitle D)	3	Rolloffs	$ 600	$ 1,800	Assume rental of roll-off container, transport and disposal at Subtitle D landfill.
IDW Management and Disposal (water)	1	LS	$ 2,000	$ 2,000	Assumes frac tank and carbon treatment system rental, treatment and discharge to sanitary sewer.
Field Oversight for Monitoring Well Install and Development	18	Day	$ 1,500	$ 27,000	Includes 1 FTE for 10 hours per day. 3 days per well install, 2 wells/day development.
ERD Performance Monitoring (Years 1-5)	10	Event	$ 28,600	$ 286,000	Monitoring of 20 wells to be completed semi-annually, years 1-5. Includes labor, equipment, and laboratory analysis.
ERD Performance Monitoring (Years 6-10)	5	Event	$ 28,600	$ 143,000	Monitoring of 20 key wells to be completed semi-annually, years 6-10. Includes labor, equipment, and laboratory analysis.
Annual Key Monitoring Well Sampling (Years 0-10)	10	Event	$ 37,000	$ 370,000	Monitoring of key wells (assume 40) to be completed annually, years 0-10. Includes labor, equipment, and laboratory analysis.
Annual Key Monitoring Well Sampling (Years 11-20)	10	Event	$ 34,000	$ 340,000	Monitoring of key wells (assume 20) to be completed annually, years 11-20. Iincludes labor, equipment, and laboratory analysis.
Cap Inspection	15	Each	$ 6,000	$ 90,000	Assumes every other year for 30 years
Cap Maintenance (crack sealing)	6	Each	$ 2,000	$ 12,000	Assumes every 5 years for 30 years
Cap Replacement 15 years	42740	SF	$ 2.00	$ 85,480	
Cap Replacement 30 years	42740	SF	$ 2.00	$ 85,480	
Subtotal:				***$1,520,000***	
			Remediation Cost	**$5,872,000**	
INDIRECT REMEDIATION COSTS					
Reporting/Design/Project Oversight[3]	1	LS	$ 1,468,000	$ 1,470,000	Assumes 25% of overall cost for project oversight, management, permits, work plans, reporting, regulatory interaction, etc.
Subtotal:				***$1,470,000***	
			Remediation Cost (Plus IDCs and LTM)	**$7,342,000**	
			Remediation Contingency (25 Percent)[4]	**$1,840,000**	Appropriate contingency for feasibility-level planning.
			TOTAL REMEDIATION COST	**$9,200,000**	

Notes:
1 All cost values are estimates and should not be interpreted as final construction or project costs. Costs are in present dollar and do not include inflation costs.
2 Subtotal costs are rounded up to the nearest $10,000, total cost is rounded to the neared $100,000.
3 Anticipated indirect costs are assumed as 20% of the estimated remediation cost.
4 Contingency is appropriate for feasibility-level planning and will be reduced during the remedial design phase of the project.

Abbreviations:

GPM Gallons per Minute
IDC Indirect Cost
LS Lump Sum
MO Month
YR Year

Table B-3. Less Aggressive Remedial Alternative—Monitored Natural Attenuation and Replacement of Two Irrigation Wells.

	Quantity	Unit	Unit Cost [1]	Total Cost [2]	Detail
LONG TERM MONITORING COSTS (MNA)					
Well Drilling Mobilization/Demobilization	2	LS	$ 4,500	$ 9,000	Includes sonic drill rig and necessary equipment/material.
Well Development Mobilization/Demobilization	1	LS	$ 1,250	$ 1,250	Includes sonic drill rig and necessary equipment/material.
Site Survey/Utility Locate	1	LS	$ 10,000	$ 10,000	Assume this covers MW well locations.
Monitoring Well Installation	5	Well	$ 14,640	$ 73,200	Assumes 190-foot monitoring wells. Per well cost from driller.
Monitoring Well Development	5	Well	$ 800	$ 4,000	Estimate from driller
Field Oversight for Monitoring Well Install and Development	18	Day	$ 1,500	$ 27,000	Includes 1 FTE for 10 hours per day. 3 days per well install, 2 wells/day development.
IDW Management and Disposal (soil, Subtitle D)	2	Rolloff	$ 600	$ 1,200	Assume transport and disposal at Subtitle D landfill.
IDW Management and Disposal (water)	45	Drum	$ 150	$ 6,750	Assumes disposal of well development water and purge water.
Annual Key Monitoring Well Sampling (Years 0-10)	10	Event	$ 26,300	$ 263,000	Monitoring of 30 key wells to be completed annually. Includes labor, equipment, and laboratory analysis. Assumes 10 year timeframe.
Annual Key Monitoring Well Sampling (Years 11-30)	20	Event	$ 20,000	$ 400,000	Monitoring of 20 key wells to be completed annually. Includes labor, equipment, and laboratory analysis. Assumes 20 year timeframe.
Cap Inspection	15	Each	$ 6,000	$ 90,000	Assumes every other year for 30 years
Cap Maintenance (crack sealing)	6	Each	$ 2,000	$ 12,000	Assumes every 5 years for 30 years
Cap Replacement 15 years	42740	SF	$ 2.00	$ 85,480	
Cap Replacement 30 years	42740	SF	$ 2.00	$ 85,480	
Subtotal:				***$1,068,000***	
REPLACEMENT OF IRRIGATION WELLS					
6" Meter Hook Up Fee	1	LS	$ 216,000	$ 216,000	Base fee for connecting to city water with 6" line.
Construction/Installation	1	LS	$ 50,000	$ 50,000	Includes plumbing, connection, backfill
Annual Cost for Irrigating	27	YR	$ 130,000	$ 3,510,000	Assumes 2% yearly increase
Subtotal:				***$3,776,000***	
Total Replacement Cost for 2 schools[3]				**$7,552,000**	Includes 100% contigency for replacing a well at a second school.
INDIRECT REMEDIATION COSTS					
Reporting/Design/Project Oversight[4]	1	LS	$ 267,000	$ 270,000	Assumes 25% of overall cost for project oversight, management, permits, work plans, reporting, regulatory interaction, etc., over the 30-year project period.
Subtotal:				***$270,000***	
Remediation Cost (Plus IDCs and LTM)				**$8,890,000**	
Remediation Contingency (5 Percent) [5]				**$450,000**	Contigency was lowered from 25% to 5% because most of the costs are associated with irrigation, which should not need a high contigency.
TOTAL REMEDIATION COST				**$9,400,000**	

Notes:
1 All cost values are estimates and should not be interpreted as final construction or project costs. Costs are in present dollars and do not include inflation costs.
2 Subtotal costs are rounded up to the nearest $10,000, total cost is rounded to the neared $100,000.
3 There is a third school (O C Johnson) located approximately 3,000 ft downgradient from Alice Byrne and St Francis that is near the plume's flowpath. The well at O C Johnson could be impacted but the probabilty is considered low.
4 Anticipated indirect costs are assumed as 20% of the estimated long-term monitoring cost.
5 Contingency is appropriate for feasibility-level planning. The contigency for this alternative is lower than the other alternatives because the remedy is a much simpler concept.

Abbreviations:
LS Lump Sum
YR Year

CALIBRE

Matrix DESIGN GROUP