FEASIBILITY STUDY
MILLER VALLEY ROAD AND
HILLSIDE AVENUE WQARF REGISTRY SITE
PRESCOTT, ARIZONA

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TABLE OF CONTENTS

PAGE NO.

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

TABLE OF CONTENTS (CONTINUED)

LIST OF FIGURES

LIST OF TABLES

TABLE OF CONTENTS (CONTINUED)

LIST OF APPENDICES

TABLE OF CONTENTS (CONTINUED)

LIST OF ACRONYMS AND ABBREVIATIONS

A.A.C.	Arizona Administrative Code
A.R.S.	Arizona Revised Statutes
ADEQ	Arizona Department of Environmental Quality
AWQS	Aquifer Water Quality Standard
cells/ml	Cells per Milliliter
COC	Contaminants of Concern
CVOC	Chlorinated Volatile Organic Compound
cis-1,2-DCE	cis-1,2-dichloroethene
DHC	*Dehalococcoides*
DO	Dissolved Oxygen
ERD	Enhanced Reductive Dechlorination
ft bgs	Feet Below Ground Surface
ft/day	Feet per Day
FS	Feasibility Study
GET	Groundwater Extraction and Treatment
LGAC	Liquified Granular Activated Carbon
GPL	Groundwater Protection Level
ISB	*In Situ* Bioremediation
ISCO	*In Situ* Chemical Oxidation
ISCR	*In Situ* Chemical Reduction
ISM	*In Situ* Microcosm
ISTR	*In Situ* Thermal Remediation
$\mu g/m^3$	Micrograms per Cubic Meter
µg/L	Micrograms per Liter
LWUS	Land and Water Use Study
mg/Kg	Milligrams per Kilogram
mg/L	Milligrams per Liter
mV	Millivolts
MNA	Monitored Natural Attenuation
MTBE	Methyl tert-butyl ether
ORP	Oxygen Reduction Potential
PCE	Tetrachloroethene
PI	Preliminary Investigation
RI	Remedial Investigation
RO	Remedial Objective
rSRL	Residential Soil Remediation Level
SRCS	Slow-Release Carbon Substrate
SVSL	Soil Vapor Screening Level
TCE	Trichloroethene
TOC	Total Organic Carbon
UST	Underground Storage Tank
VFA	Volatile Fatty Acids
VOC	Volatile Organic Compound
WQARF	Water Quality Assurance Revolving Fund
ZVI	Zero Valent Iron

1.0 INTRODUCTION

This Feasibility Study (FS) report for the Miller Valley Road and Hillside Avenue Water Quality Assurance Revolving Fund (WQARF) site (the Site) was prepared by the Arizona Department of Environmental Quality (ADEQ) and its consultant Matrix New World Engineering, Land Surveying and Landscape Architecture, PC (Matrix). The Site is located in Prescott, Arizona (**Figure 1**).

1.1 FEASIBILITY STUDY REPORT PURPOSE AND SCOPE

The purpose of the FS report is to:

- Identify and screen possible remedial alternatives in accordance with Arizona Revised Statutes [A.R.S.] §49-287.03(F).
- Develop a reference remedy and alternative remedies that are capable of achieving the Site's Remedial Objectives (ROs) in accordance with Arizona Administrative Code [A.A.C.] (R18-16-407(E)).
- Ensure the remedy alternatives consist of remedial strategies including Plume Remediation, Physical Containment, Controlled Migration, Source Control, Monitoring, and No Action (A.A.C. R18-16-407(E)).
- Ensure all remedies assure protection of the public health, welfare and the environment, allow for the maximum beneficial use of waters of the State, and be reasonable, necessary, cost effective, and technically feasible (A.R.S. §49-282.06).
- Evaluate the consistency of the remedy with water management plans of affected water providers and general land use plans of local governments.
- Evaluate the practicality, risks, costs, and benefits (comparison criteria) of the possible remedies (A.A.C. R18-16-407(H)).

2.0 SITE BACKGROUND

The Site is generally bounded by to the north by the Merritt Street alignment, to the south by Miller Creek, to the east by Division Street, and to the west by Miller Creek and Valley Street (**Figure 2**). The Contaminants of Concern (COCs) are tetrachloroethene (PCE) and PCE breakdown products including trichloroethene (TCE) and *cis*-1,2-dichloroethene (*cis*-1,2-DCE). Petroleum hydrocarbon compounds (benzene, ethylbenzene, toluene) and the fuel additive methyl tert-butyl ether (MTBE) have been reported in the Site vicinity in groundwater samples but are not associated with the Site. The potential source areas are located along Fair Street west of Miller Valley Road (**Figure 2**) and include:

- Former Village Cleaners: Previously addressed at approximately 940-950 Fair Street. Operated from approximately 1965 until 1985. This is the current location of a Fry's Food Store parking lot.
- Current Village Cleaners: Located at 939 Fair Street. Currently operating as a dry cleaner that moved to this location from the north side of Fair Street and began operations in 1987.
- Former Prescott Drive-In Cleaners: Previously addressed at 700 Miller Valley Road. Operated from approximately 1960 to 1970. This location is currently a Fry's Fuel Center.

Two other facilities in the area are the Fry's Fuel Center, a current Underground Storage Tank (UST) facility, and the former The Other Store/Island Store, a former leaking UST facility. These two facilities are regulated under ADEQ's UST program and are not considered part of the Site.

2.1 SITE HISTORY

Chlorinated Volatile Organic Compound (CVOC) groundwater contamination at the Site was first discovered in 2002 through detections of PCE and TCE during a leaking UST investigation for a petroleum hydrocarbon release at The Other Store, also known as The Island Store (**Figure 2**). Concentrations of PCE and TCE were detected above the Aquifer Water Quality Standard (AWQS) of 5 micrograms per liter (µg/L) in the monitoring wells at the UST site. These detections facilitated additional investigations and groundwater sampling to determine the source of the CVOCs.

During the Preliminary Investigation (PI), a passive shallow soil-gas investigation was conducted and found elevated levels of PCE in soil vapor near 940-950 Fair Street and 939 Fair Street, which corresponded with the locations of the former and the current Village Cleaners (**Figure 2**) (MACTEC, 2006). During this investigation, groundwater samples collected from temporary boreholes, private irrigation wells, and monitoring wells in the area identified concentrations of PCE and TCE exceeding AWQS (MACTEC, 2006; ADEQ, 2016). The Site was listed on the WQARF registry on December 12, 2016.

From September 2017 through May 2019, Remedial Investigation (RI) activities were conducted including soil-gas, indoor air, and groundwater investigations to identify the extent of CVOC contamination and potential receptors at the Site.

During the RI, a total of 24 soil borings were drilled and sampled to define the horizontal and vertical extent of CVOC contamination. Based on the sampling results, a total 23 groundwater monitor wells were installed to determine the extent of groundwater contamination and establish groundwater flow directions and hydraulic gradients. The results from groundwater samples collected identified PCE and TCE above the AWQS located in areas near the former Village Cleaners and former Prescott Drive-In Cleaners locations (**Figure 2**). Groundwater samples from monitoring wells installed in the area near the current Village Cleaners location did not contain PCE or TCE at concentrations above their respective AWQS (HGC, 2020). The results of the investigation indicate that the presence of chlorinated Dense No Aqueous Phase Liquid (DNAPL) is unlikely.

2.1.1 Hydrogeology

Three geologic units are present at the Site (Dewitt, 2008). The surface unit or Quaternary Alluvium (Qal) extends to depths of 15 to 30 feet below ground surface (ft bgs). The Qal unit includes unconsolidated, unsorted, poorly bedded clay, silt, sand, pebbles, cobbles, and trace levels of well-rounded boulders. Beneath the Qal are Tertiary Sediments (Ths) which are a mixture of colluvial/alluvial deposits including silty sand, clayey sand, and decomposed granitic material. The Tertiary Sediments extend to depths of 140 to 192 ft bgs with alternating wet and dry zones present. The Ths unit overlies fractured granodiorite bedrock (Xpr). To the east and south of the Site, the depth to the Xpr decreases, and Xpr outcrops are present.

The ephemeral drainage, Miller Creek, flowing from northwest to southeast is present south of the Site. Hydraulic evaluation of the area has indicated that the groundwater at the Site is not connected to Miller Creek.

An intermittent perched groundwater zone at approximately 16 ft bgs is present in some areas. Groundwater below the perched zone has been described as three separate depth intervals (aquifers) based on lithology and hydrogeologic characteristics encountered during drilling: 1) a shallow depth interval from approximately 29 to 50 ft bgs, 2) an intermediate depth interval from approximately 80 to 115 ft bgs, and 3) a deep interval from approximately 165 to 200 ft bgs. A significant undersaturated zone generally extends from about 50 to 80 ft bgs in the area between the shallow and the intermediate depth interval groundwater. Although described as separate groundwater intervals, pumping data and contaminant distribution data indicate hydraulic connectivity exists between the three intervals. All three intervals exhibit confined aquifer characteristics and behaviors. Artesian conditions have also been documented in the area. During the characterization efforts associated with the RI, artesian conditions were noted in soil boring B-1 drilled to 80 ft bgs, and a strong upwelling was observed in soil boring B-11 drilled to 30 ft bgs (HGC, 2020). Neither of these soil borings were completed as monitoring wells.

Based on data collected May 2020, groundwater flow direction in the shallow aquifer is mainly to the east/east-southeast (**Figure 3**). The groundwater flow in the intermediate depth interval trends towards the east-northeast (**Figure 4**), possibly impacted by Xpr outcrops east of the Site. The groundwater flow direction in the deep aquifer is toward the northeast (**Figure 5**). The hydraulic conductivities (K) in all three aquifers are low; K values from the shallow aquifer range from 6.1×10^{-3} feet per day (ft/day) to 4.1 ft/day with a geometric mean of 0.52 ft/day, and K values in the intermediate/deep wells range from 1.8×10^{-4} ft/day to 0.75 ft/day with a geometric mean of 4.3×10^{-2} ft/day. The total porosity and effective porosity are 20% and 10%, for both the shallow and intermediate aquifers, respectively (HGC, 2020).

Average linear groundwater flow velocities in the shallow and intermediate groundwater intervals were estimated using: 1) hydraulic conductivities obtained from the slug test analyses, and 2) hydraulic gradients calculated from the January 2019 groundwater elevation contours and an effective porosity of 20 percent. The calculated average linear velocities based on the geometric mean are in the order of 7.7 feet per year (ft/yr) in the shallow depth interval and, 1.7ft/yr in the intermediate depth interval, and 0.19 ft/yr in the deep interval (HGC, 2020). Estimated travel distances for each groundwater interval were calculated based on an assumed release occurring 59 years ago (circa 1960). Based on this data, the estimated travel distance in the shallow aquifer ranges from 5.9 ft to 4,000 ft with a geometric mean of 500 ft and the estimated travel distance in the intermediate aquifer ranges from 47 ft to 1,000 ft with a geometric mean of 150 ft (HGC, 2020). This is generally consistent with the PCE interpretations shown in **Figure 3** and **Figure 4**.

2.2 CONCEPTUAL SITE MODEL

2.2.1 Sources and Extent of Contamination

Soil-gas concentrations in the area near the Former Village Cleaners showed residual PCE remaining in the soils, although no concentrations exceeded Residential Soil Remediation Levels (rSRLs). The highest soil-gas concentration detected in these areas was from B-21 at a concentration of 16,900 micrograms per cubic meter ($\mu g/m^3$), which when converted to soil-equivalent concentrations using the three-phase partitioning equation is 0.026 milligrams per kilogram (mg/Kg), below the residential rSRL of 0.51 mg/Kg.

Residual PCE was also detected near to the current Village Cleaners location, which showed a maximum soil-gas PCE concentration of 20,480 $\mu g/m^3$, which is equivalent to 0.032 mg/Kg. This is below the residential rSRL, and the minimum Groundwater Protection Level (GPL) for PCE of 1.3 mg/Kg. No CVOCs were identified in soil and no PCE was detected above the AWQS in groundwater at this location, indicating there is likely no source of PCE to groundwater in this location (HGC, 2020). **Table 1** shows the historical CVOC concentrations in groundwater for the Site.

Based on groundwater sample results from August 2022, the extent of PCE above AWQS in the shallow aquifer extends from the area of monitoring well MVH-3 approximately 420 feet to the east/southeast (**Figure 3**). The highest concentration of CVOCs detected in the shallow aquifer in August 2022 sampling event was 632 µg/L PCE in MVH-3. The width of the plume is estimated to be approximately 400 feet and extends to a depth of approximately 40 feet below static water levels. The extent of TCE above AWQS in the shallow aquifer is confined to the area around MVH-3. The highest concentration of TCE in the shallow aquifer in August 2022 was 23.2 µg/L (**Table 1**).

Based on groundwater sample results from August 2022, the extent of PCE in the intermediate aquifer extends from the monitoring well MVH-13 approximately 650 feet to the east (**Figure 4**). The highest concentration detected in the intermediate aquifer in the August 2022 sampling event was 825 µg/L in MVH-9s (**Table 1**). The approximate width of the plume is assumed to be less than 500 feet. The depth of the PCE contamination in the intermediate aquifer extends throughout the thickness of the confined aquifer of to a depth of approximately 135 feet. The extent of TCE in the intermediate aquifer is limited to the area around monitoring well MVH-9s (**Table 1**).

The extent of PCE in the deep aquifer is limited to the area around MVH-13d (**Figure 5**). The most recent groundwater sample collected in August 2022 indicated PCE at a concentration of 20.9 µg/L (**Table 1**). The depth of the PCE contamination in the deep aquifer likely extends through the thickness of the confined aquifer, to a depth of approximately 200 ft bgs. TCE has not been detected above AWQS in the deep aquifer (**Table 1**).

Table 1 shows the CVOC groundwater results for PCE and daughter products in MVH-9s and MVH-3. The concentrations of daughter products of TCE, *cis*-1,2-DCE and vinyl chloride further demonstrate that some minimal reductive dichlorination is occurring at slow rates. The process is likely being limited in part due to the aquifer geochemistry of the aquifers. For example, measured oxidation-reduction potential (ORP) values range from 267 to -288 millivolts (mV) (**Table 2**). These ORP values generally equate to Eh values of 487 to -68 mV, indicating mildly oxidizing to marginally reducing conditions generally consistent with manganese and iron reduction as the dominant terminal electron accepting processes. While there is considerable variation, ORP values generally indicate more reducing conditions in deeper parts of the aquifer at the Site (HGC, 2020). Similarly, groundwater samples collected from MVH-3 and MVH-9s in August 2020 showed ORP levels of -124 mV and -118 mV, respectively **(Table 3).**

Additionally, based on groundwater sample results from MVH-3 and MVH-9s collected in August 2020, the level of total organic carbon (TOC) in the groundwater was low, less than 1 mg/L (**Table 3**). Likewise, groundwater contained very low levels of key nutrient nitrogen (Total Kjeldahl Nitrogen <140 µg/L and ammonia <117 µg/L [**Table 3**]), which may also be limiting the growth of the native microbial population. Dissolved oxygen (DO) concentrations in groundwater have historically been generally low (0.45 mg/L to 0.93 mg/L in the wells containing PCE), however in August 2020, results from wells MVH-3 and MVH-9 were greater than 1 mg/L, indicating aerobic conditions, which would further inhibit reductive dechlorination (**Table 3**). The *Dehalococcoides* and *Dehalogenimonas* concentrations were <0.5 cells/milliliter (cells/mL) and 4.60 cells/mL, respectively, indicating no to low naturally dechlorinating microbes are detectable.

2.2.2 Receptors

According to the RI, the soil vapor results indicated the possibility for vapor intrusion in the area near to the former and current Village Cleaners. The soil vapor results for other locations did not exceed calculated residential SVSLs, indicating potential vapor intrusion is less than *de minimis* levels (HGC, 2020).

The highest PCE concentration in shallow soil gas in the area near the former Village Cleaners was 753 µg/m³, which exceeds the SVSL for residential exposure, but not the SVSL for non-residential exposure. TCE was not present in the sample. Since there is no structure at this location, there are no current indoor air receptors.

The highest PCE concentrations in shallow soil gas collected near the current Village Cleaners was 20,480 µg/m³, which exceeded the SVSL for residential and non-residential exposure. Indoor air sampling results from the residence and business nearest to this SVSL exceedance did not contain PCE or TCE above detection limits. Based on the sample results, there are no current receptors to PCE and TCE from vapor intrusion at the Site (HGC, 2020).

Multiple private water supply wells exist in the vicinity of the Site (**Figure 6**). Of these, only four wells remain in use, with all other wells having no current or future use, as determined in the RI. Two of the private wells still in use, 923 and 925 Fair Street are currently impacted by CVOCs (**Figure 6**). The reported total depth of these wells are 125 ft bgs and 200 ft bgs, respectively, which are in the intermediate and deep units. The reported screen or open hole intervals are unknown (HGC, 2020). The reported current use of these two wells is for landscape irrigation only. The two other wells in the area were reported as being utilized for drinking water use (599 Kildare and 727 Ruth, **Figure 6**). These wells are not currently impacted by the Site contamination. Of these, one well is located hydraulically side-gradient to the Site, and the other downgradient (**Figure 6**).

PCE and TCE concentrations in the 923 Fair Street well have exceeded the AWQS, with PCE concentrations ranging from 418 to 747 µg/L and TCE concentrations ranging from 3.06 to 6.55 µg/L (HGC 2020a). The most recent sample collected in May 2020 indicated PCE at a concentration of 304 µg/L and TCE at a concentration of 5.4 µg/L (**Table 4).**

PCE concentrations in the 925 Fair Street well have exceeded the AWQS with concentrations ranging from 27 to 34.5 µg/L. TCE is present in this well at concentrations below the AWQS ranging from 0.72 to 0.87 µg/L (**Table 4**). The most recent sample collected in December 2019 indicated PCE at a concentration of 16.7 µg/L and TCE at a concentration of 0.5 µg/L (**Table 4).**

Since these two wells are reportedly currently only used for irrigation, there are current irrigation-use receptors. As there are wells with current drinking water use in the area, and the wells currently used for irrigation are still connected to the residences and can be easily switched back to drinking water use, there is also potential future drinking water receptors at this Site. All other private wells sampled indicated CVOC concentrations that were below the AWQS or below laboratory reporting limits, and are not in current use (**Table 4**).

There are no evident points of natural discharge of groundwater to surface water in vicinity of the Site. There is no indication that groundwater contributes to Miller Creek base flow. Water samples from the storm drains discharging to Miller Creek and ponded water in the stream bed did not indicate the presence of any COC related to the Site at concentrations above laboratory reporting limits (HGC, 2020). Therefore, there are no known receptors to surface water.

2.3 RISK EVALUATION SUMMARY

PCE was detected in shallow soil gas at the Site above vapor intrusion screening levels, indicating a potential transport pathway of vapor-phase contaminants to indoor air with subsequent inhalation exposure. However, indoor air sampling results at the Site indicate that vapors above detection levels are not present in buildings in the area (HGC, 2020). Based on the available evidence, soil vapor concentrations in this area are not expected to impact human health. Future conditions are not expected to differ from current conditions based on projected land use.

Consumptive use of groundwater is a potential exposure pathway of concern at the Site through direct ingestion, inhalation, or dermal contact with contaminated groundwater. Several private water supply wells that withdraw groundwater from the deeper portion of the aquifer are located at and adjacent to the Site and are, or have the potential to be, impacted by contaminated groundwater from the Site. While the current exposure pathway is incomplete due to impacted wells not being used for drinking water, potential future use of the groundwater as a drinking water supply could result in possible exposure to contaminated groundwater and is considered a complete potential future exposure pathway for the Site.

With the exception of the private wells located at 923 and 925 Fair Street, the PCE and TCE concentrations in the private wells at the Site are less than AWQS. The 923 and 925 Fair Street wells are currently used for irrigation only, and are less than the full body contact water quality criteria of 2,222 µg/L for PCE and 101 µg/L for TCE, as described in A.A.C. Title 18 Chapter 11, indicating that the potential use of this water from these wells to fill swimming pools or for other recreational activity that causes the human body to come into direct contact with the water should be protective of health concerns (HGC, 2020). This includes complete submergence in the water with contact with skin, eyes, ears, and nose, and includes incidental ingestion during swimming. The absence of any identified ecological receptors precludes any ecological risk existing at the Site.

3.0 FEASIBILITY STUDY SCOPE

The remedial alternatives presented herein were developed within the framework of the current conditions at the Site. Additionally, key elements described in the Conceptual Site Model (CSM) in Section 2.2 have been incorporated into development of the reference remedy and remedial alternatives in order to complete a thorough evaluation and comparison of potential technologies to reduce contaminant mass in groundwater and achieve the established ROs. The section provides an overview of the regulatory requirements presented in statue and rule, delineates the remediation areas and, presents the ROs identified in the RI report.

3.1 REGULATORY REQUIREMENTS

The FS focuses on selection of remedial alternatives that satisfy WQARF remedial action criteria established by ADEQ [A.A.C. R18-16-407] and are consistent with the Groundwater Management Act A.R.S. Title 49, §49-287.03 (F), §49-282.06.

- A.R.S. §49-282.06 states that all remedies must assure protection of the public health and welfare and the environment, allow for the maximum beneficial use of waters of the state, and be reasonable, necessary, cost effective and technically feasible. Therefore, all remedies in the FS must meet these criteria.
- A.R.S. §49-287.03(F) requires the FS to identify and screen possible remedial alternatives and ensure they are consistent with §49-282.06.
- R18-16-407 requires that the FS develop a reference remedy and alternative remedies that are capable of achieving the Site's ROs and are consistent with §49-282.06. At a minimum, at least two alternative remedies shall be developed, where one remedial strategy or combination of strategies is more aggressive than the reference remedy, and the one remedial strategy is less aggressive than the reference remedy. R18-16-407(E) requires that the remedy alternatives consist of remedial strategies listed in R18-16-407(F). These strategies are:
    - Plume Remediation
    - Physical Containment
    - Controlled Migration
    - Source Control
    - Monitoring
    - No Action
- R18-16-407(H) requires that the FS evaluate the consistency of the remedies with water management plans of affected water providers and the general land use plans of local

governments. Additionally, the FS presents the evaluation of the practicality, risks, costs, and benefits (comparison criteria) of the possible remedies.

3.2 DELINEATION AND DESCRIPTION OF REMEDIATION AREAS

Based on groundwater sampling data, impacts of PCE in groundwater above the AWQS are limited to the shallow and intermediate aquifers in the vicinity of monitor wells MVH-3 (678 µg/L) and MW-9s (825 µg/L), respectively **(Table 1, Figure 3** and **Figure 4**). PCE is also present above AWQS in the deep aquifer in the vicinity of MVH-13d (20.9 µg/L) (**Figure 5**). Additionally, PCE has been detected above the AWQS in two private irrigation wells 923 Fair St (304 µg/L) and 925 Fair St (16.7 µg/L). As discussed in Section 2.1.1, the shallow depth interval ranges from approximately 29 to 50 ft bgs and the intermediate depth interval ranges from approximately 80 to 115 ft bgs. The impacts of TCE above the AWQS are limited to the shallow aquifer in vicinity of monitor well MW-9s at a concentration of 16.3 µg/L (**Table 1**).

The PCE contamination is in a developed urbanized area that includes single and multi-family residences, commercial/retail properties and City of Prescott streets and infrastructure. This limits available locations to install remediation wells and a treatment system. As such, the focus of the remedial efforts will be to reduce the high concentrations of PCE (greater than 100 µg/L) in the area near MVH-3 and MVH-9s.

There are no soil or surface water impacts at the Site.

3.3 REMEDIAL OBJECTIVES

The ROs for the Site were developed by ADEQ pursuant to A.A.C. R18-16-406(I) and were described in the RO Report dated February 6, 2020 (ADEQ, 2020) that was contained in Appendix L of the RI Report (HGC, 2020).

The ROs were established for the current and reasonably foreseeable uses of land and waters of the State that have been or are threatened to be affected by a release of a hazardous substance. Pursuant to A.A.C. R18-16-406(D), it is specified that reasonably foreseeable uses of land are those likely to occur at the Site and the reasonably foreseeable uses of water are those likely to occur within one hundred years, unless site-specific information suggests a longer time period is more appropriate. The determination of reasonably foreseeable uses is based on information provided by water providers, well owners, landowners, government agencies, and others for the Land and Water Use Study (LWUS), which was included as Appendix K in the RI Report. The ROs are based on the results of the LWUS and the associated solicitation of proposed ROs during a public meeting held in January 2020. Listed in **Chart 1** are the regulatory limits and associated criteria relating to specific COCs addressing the ROs for the Site.

Chart 1 Regulatory Limits and Criteria

Analyte	AWQS (µg/L)	rSRL - mg.kg	Aquatic Contact (Full Body Contact) (µg/L)
Tetrachloroethylene	5	5.1	2,222
Trichloroethylene	5	30	101
cis-1,2-Dichloroethylene	70	43	1,867

Notes: AWQS = Aquifer Water Quality Standards
µg/L = Micrograms per liter
rSRL = Residential soil remediation level
mg/kg - Milligrams per kilogram

Pursuant to R18-16-406(I)(4), the ROs must be stated in the following terms: 1) protecting against the loss or impairment of each use, 2) restoring, replacing, or otherwise providing for each use, 3) when action is needed to protect or provide for the use, and 4) how long action is needed to protect or provide for the use.

The RO Report indicated that there is no known threat or impacts to soils or surface water from COCs at the Site. Therefore, no ROs were established for the uses of those media. However, PCE and TCE concentrations do exceed the AWQS in groundwater at the Site in aquifers with water used for irrigation and potable water purposes. Thus, the ROs for groundwater use at the Site were established as follows (HGC, 2020).

Irrigation Use

Protect against the threatened loss or impairment of irrigation water due to an exceedance of the Aquifer Water Quality Standards of the contaminants of concern at the Miller Valley Road and Hillside Avenue WQARF Site. Restore, replace, or otherwise provide for irrigation water to the extent it has been or will be lost or impaired due to an exceedance of the Aquifer Water Quality Standards for the contaminants of concern at the Miller Valley Road and Hillside Avenue WQARF Site. The actions will be needed for as long as necessary to ensure that, while the water exists and the resource remains available, the contamination associated with the Miller Valley Road and Hillside Avenue WQARF Site does not prohibit or limit the designated use of groundwater.

Potable Use:

Protect against the threatened loss or impairment of potable water due to an exceedance of the Aquifer Water Quality Standards of the contaminants of concern at the Miller Valley Road and Hillside Avenue WQARF Site. Restore, replace, or otherwise provide for potable water to the extent it has been or will be lost or impaired due to an exceedance of the Aquifer Water Quality Standards for the contaminants of concern at the Miller Valley Road and Hillside Avenue WQARF Site. The actions will be needed for as long as necessary to ensure that, while the water exists and the resource remains available, the contamination associated with the Miller Valley Road and Hillside Avenue WQARF Site does not prohibit or limit the designated use of groundwater.

4.0 IDENTIFICATION AND SCREENING OF REMEDIAL MEASURES AND STRATEGIES

This section presents the evaluation and screening of various remedial measures and strategies related to groundwater contamination in the shallow and intermediate aquifers and lists the technologies that have been retained for further evaluation as part of the reference and alternative less aggressive and more aggressive remedies pursuant to A.A.C. R18-16-407(E) and (F). As previously stated, since there are no known threats or impacts to soils or surface water from COCs at the Site, the remedial strategies focus on groundwater.

4.1 REMEDY SELECTION CRITERIA

The Reference Remedy, Less Aggressive Remedy, and More Aggressive Remedy consist of a package, or combination of remedial strategies and measures in order the meet the ROs established for the Site. In accordance with R18-16-407(F), there are six listed remedial strategies to be developed. These remedial strategies are 1) Plume remediation, 2) Physical containment, 3) Controlled migration, 4) Source control, 5) Monitoring, and 6) No action.

WQARF regulations require the More Aggressive Remedy employ a strategy, or combination of strategies, that is more robust than the Reference Remedy, and a Less Aggressive Remedy that employs one strategy or combination of strategies less robust than the Reference Remedy.

As such, the remedy selection process includes an evaluation of remediation technologies and methodologies based on estimated reduction or removal of contaminants in Site groundwater and the ability to comply with A.R.S. §282.06 and achieve the ROs. Additionally, the remedies were evaluated based on their practicability of implementation, risks and protectiveness, costs, and benefits.

4.2 IDENTIFICATION OF REMEDIAL MEASURES AND STRATEGIES

A summary of the general descriptions of the six remedial strategies required under A.A.C. R18-16-407(F) are presented below in the context of the contaminant concentrations and hydrogeologic conditions at the Site.

4.2.1 Plume Remediation

Plume remediation is a strategy to achieve water quality standards for COCs in Site groundwater. This strategy can involve *ex situ* treatment, such as groundwater extraction and treatment (GET), and *in situ* treatment approaches, such as *In Situ* Chemical Reduction (ISCR), *In Situ* Chemical Oxidation (ISCO), bioremediation, and/or *In Situ* Bioremediation (ISB).

4.2.2 Physical Containment

Physical containment is a strategy to hydraulically contain and control the extent of COCs within the defined boundaries of the plume, such as capping, slurry walls, or GET technologies coupled with the injection of treated water. The containment strategy for groundwater necessitates adequate hydraulic control to prevent migration of COCs beyond the boundaries of the containment zone at concentrations greater than the AWQS. Containment strategies are often combined with plume remediation technologies to expedite cleanup times.

4.2.3 Controlled Migration

Controlled migration is a strategy to control the direction or rate of migration, but not necessarily to contain migration of COCs. This strategy requires some type of hydraulic control or boundary layer to impact the direction of COC movement but does not necessarily contain contaminants and prevent them from migrating past the specified plume boundary. Similar to the physical containment strategy, controlled migration may be combined with plume remediation to affect the groundwater migration patterns via hydraulic control.

4.2.4 Monitoring

Monitoring is a strategy to observe and evaluate contamination at a site through the collection of water level measurements and groundwater samples. This strategy can also be applied as a remedial action in the form of monitored natural attenuation where aquifer conditions are favorable for contaminant reduction through processes such as sorption, dispersion, abiotic degradation and/or biodegradation.

Additionally, an appropriate monitoring program is an important part of every remedial technology to evaluate the effectiveness of the of the chosen remedy and assess trends in COCs concentrations and groundwater flow directions to validate performance and demonstrate that the ROs are being met.

4.2.5 Source Control

Source control is a strategy to eliminate or mitigate a continuing source of contamination to groundwater. As stated in A.A.C. R18-16-407(F) “source control shall be considered as an element of the reference remedy and all alternative remedies, if applicable.” Based on a review of the soil gas and groundwater data, no specific vadose zone source of contamination was identified that is continuing to feed CVOCs in groundwater. However, for purposes of this FS, the source is the groundwater contamination near MVH-3 and MVW-9s in the shallow and intermediate aquifers.

4.2.6 No Action

No Action is a strategy without a remedial technology or monitoring. Based on the data and the ROs, the no action strategy does not ensure the protection of the public health and welfare and the environment due to COC contamination above the AWQSs. In addition, the No Action strategy does not take into consideration the maximum beneficial use of the waters and does not address the potential for impacted and threatened irrigation and domestic water supplies. No Action is inappropriate as a stand-alone strategy because it would not ensure ROs would be met at the Site.

4.3 SCREENING OF REMEDIAL MEASURES AND STRATEGIES

Using each of the applicable remedial strategies discussed in Section 4.2, specific remedial measures were evaluated to address COCs in Site groundwater. The remedial measures were evaluated and screened to develop an appropriate reference remedy and more aggressive and less aggressive remedial alternatives. The approach to selecting an appropriate remedial measure focused on identifying weaknesses with a remedial technology in the context of Site conditions and therefore, that technology would not be retained for further evaluation. Likewise, those technologies that have a demonstrated proven success in similar hydrogeologic environments and conditions were retained and further evaluated as potential remedial alternatives

The detailed evaluation of the remedial measures are shown in **Table 5**, and are summarized on the **Chart 2** below.

Chart 2 Screening Summary of Remedial Measures

Remedial Measure	Comments	Retained
Monitored Natural Attenuation (MNA)	Natural attenuation currently occurring at slow rates. MNA can be used in combination with other remedial strategies to achieve ROs.	Yes
Enhanced Reductive Dechlorination (ERD)	Based on results from the Site, ERD is an appropriate technology for Site groundwater remediation.	Yes
In Situ Chemical Oxidation (ISCO)	Site conditions are more conducive to reductive technologies; ISCO would require more amendment, and Site constraints would prevent the scale of injections needed.	No
In Situ Chemical Reduction (ISCR)	ISCR using nano to micron scale ZVI can be combined with ERD to promote highly anaerobic conditions and abiotic degradation of the CVOCs.	Yes
In Situ Liquid Granular Activated Carbon	Requires multiple injection points and Site constraints and access would be problematic. Radius of influence may be limited.	No
Permeable Reactive Barrier	Not feasible due to depth of contamination and Site constraints and access limitations	No
In Situ Thermal Remediation	Cost prohibitive and not appropriate for low levels of CVOCs observed in the groundwater Site constraints will prevent the installation of a robust well network	No
Groundwater Extraction & Treatment (GET)	Typically used for plume control and mass removal at high concentrations in a source area. Can be used in concert with ERD to promote distribution of ERD biostimulation and bioaugmentation amendments.	Yes
Wellhead Treatment	Would be protective of private wells with use at risk due to COCs in exceedance of AWQS.	Yes
No Action	Not feasible considering the ROs and the protection or irrigation and public water supplies	No

4.4 RETAINED REMEDIAL MEASURES AND STRATEGIES

Based on the screening evaluation, the five remedial technologies retained were 1) MNA, 2) ERD, 3) ISCR, 4) GET, and 5) wellhead treatment (**Table 5**). The retained technologies are discussed below. Each technology are commonly applied approaches to remediate chlorinated solvent contaminated groundwater, specifically PCE. Recent innovative practices for the various technologies are also presented. This evaluation formed the basis for the development of the Reference Remedy and more and less aggressive Alternative Remedies presented in Section 5.0.

4.4.1 Monitored Natural Attenuation

MNA is a remediation approach that involves monitoring the COCs and other parameters in the groundwater to determine which chemical, biological and physical processes are impacting the CVOCs. By understanding the native groundwater chemistry and microbiology conditions, as well as the hydrogeologic characteristics of the aquifer, one can establish which environmental conditions are contributing to the decrease in CVOC concentrations in groundwater. The major mechanisms responsible for the decrease in CVOCs in groundwater typically include dilution, dispersion, adsorption, volatilization, and biodegradation. MNA parameters need to be collected on a periodic basis to demonstrate that dechlorination is continuing to occur at a rate that is consistent with the ROs. MNA may be combined with other appropriate remediation technologies where the source has been significantly depleted or removed. MNA is usually applied to sites where aquifer conditions are favorable to dechlorination processes and the contaminant plume is stable or decreasing.

The progress of MNA can be measured using the following approach:

1. Monitoring to observed changes in CVOC concentrations and changes in groundwater flow fields with time,
2. Use of statistical trend analyses, such as the Mann-Kendall statistical approach to evaluate concentration trends with time, and
3. Evaluation of changes in dissolved phase PCE mass with time.

One-dimensional numerical models, such as BIOCHLOR Natural Attenuation Decision Support System version 2.2, can be also used to develop natural attenuation rates, which are generally used to model biodegradation rates and provide estimates of plume longevity. However, because MNA is not significantly occurring in Site groundwater due to microbial processes, this model cannot currently be applied to establish a natural attenuation rate.

Based on the historical groundwater sampling data, biodegradation is currently not a major mechanism for natural attenuation of CVOCs in Site groundwater. However, the remedial methodology is retained as components required for the MNA approach are observed in some downgradient areas of the plume including plume stability and favorable geochemical parameters that are conducive for MNA and no continuing source.

4.4.2 Enhanced Reductive Dechlorination (ERD)

Biodegradation of CVOCs can occur naturally in anaerobic groundwater environments as discussed in Section 4.4.1. However, natural degradation of these compounds is currently not occurring in Site groundwater. Research has demonstrated that *in situ* biodegradation of CVOCs can be enhanced by the process of biostimulation, which involves the addition of a carbon source, such as sugars, alcohols, lactate, or emulsified vegetable oils and nutrients, that can be degraded by indigenous microbes to provide the electron donor, hydrogen, for the biodegradation of CVOCs. When a carbon source is injected into the groundwater, the native microbes are able to use the amendment for growth and energy, which results in the microbes using up the competing electron acceptors including oxygen, nitrate, iron, manganese and potentially sulfate. The intermediate products from the fermentation of the carbon source are volatile fatty acids (VFAs), which in turn provide the hydrogen that is needed for the dechlorination process. The hydrogen replaces a chlorine atom on the chlorinated compound (the electron acceptor), resulting in the *in situ* dechlorination of the chlorinated compound.

Groundwater sampling results from MVH-9s and MVH-3 showed that the key ethenogenic bacteria (e.g., *Dehalococcoides* or *Dehalogenimonas*) were not present in the Site groundwater at significant concentrations, and therefore, it may be appropriate to inject non-native microbes that are able to biodegrade the CVOCs to non-harmful compounds; this process is referred to as bioaugmentation. Biostimulation alone or in combination with bioaugmentation is used to promote ERD of CVOCs in groundwater.

The shallow aquifer represented by MVH-3 indicates that the groundwater contained elevated levels of the competing electron acceptors, DO (2.83 mg/L) and nitrate (3.23 mg/L), and sulfate at 15.6 mg/L. Whereas the total iron, ferrous iron and manganese levels were quite low (<1 mg/L). The intermediate aquifer as represented by monitor well MVH-9s also showed elevated DO (1.93 mg/L) and even higher nitrate concentration (8.21 mg/L) than the shallow aquifer. In addition, the intermediate aquifer also displayed elevated iron (12.9 mg/L).

An *In Situ* Microcosm (ISM) study was performed at the Site to evaluate the potential for enhanced reductive dechlorination of CVOCs in Site groundwater using various biostimulation and bioaugmentation options. The ISM units deployed into MVH-9s and MVH-3 included two different carbon substrates, EOS PRO and Wilclear Plus and two different microbial consortia, SDC-9 and KB-1. Following a 78-day deployment period, the units were recovered and evaluated for the following parameters: dechlorinating bacteria and key genes responsible for biodegradation of CVOCs, the contaminants of concern, dissolved gases, competing electron acceptors, VFAs, and phospholipid fatty acid (Matrix 2021).

The CVOC results from the ISM units deployed in MVH-3 and MVH9s showed more than a 94 percent reduction in PCE with either carbon substrate and more than a 85% reduction in TCE when Wilclear Plus was the carbon source (Matrix 2021). Cis-1,2-DCE accumulated in the majority of the ISM, with the exception of the Wilclear Plus BioStim unit, which showed a 33.2% reduction (Matrix 2021). The highest levels of ethene and methane were observed in the EOS PRO and SDC-9 ISM unit, which also showed the highest level of VFA production in the ISM units deployed in MVH-9s (Matrix, 2021). The quantitative polymerase chain reaction (qPCR) results showed that the ISMs containing a bioaugmented microbial population increased the *Dehalococcoides* and the key genes tceA Reductase and vinyl chloride reductase by at least two orders of magnitude (Matrix 2021). The SDC-9 increased the *Dehalococcoides* and key genes by three orders of magnitude, which demonstrates the major benefit of bioaugmentation.

As an evaluation of the chemistry, microbiology, key functional genes, CVOCs, VFAs and dissolved gas concentrations demonstrate that an ISB approach would be appropriate to remediate the Site groundwater in both the shallow and intermediate aquifers in the areas upgradient of wells MVH-3 and MVH-9s, this remedial technology is retained.

4.4.3 *In Situ* Chemical Reduction

ISCR is a process that involves injecting chemicals that degrade the COCs by applying a chemical reductant, such as zero-valent iron (ZVI). In addition, a combination of nanoscale and/or microscale ZVI along with an organic carbon substrate can be effective at promoting environmental conditions conducive to ERD. As the use of ZVI promotes highly anaerobic conditions and can abiotically degrade the CVOCs in groundwater that could compliment MNA or ERD technologies, this technology is retained.

4.4.4 Groundwater Extraction and Treatment

A GET system would involve pumping dissolved phase CVOC-contaminated groundwater for treatment through one or more above-ground vessels that contain Liquified Granular Activated Carbon (LGAC), and then ideally reinjecting the treated water to facilitate hydraulic control of the plume and promote pore volume flushing. The treated water could also be discharged to a publicly owned treatment works, water distribution system, surface water body or reinjected back into the aquifer pursuant to appropriate permitting requirements. A modified GET system with LGAC could also be used to compliment other remedial technologies using MNA, ERD, or ISCR to promote amendment distribution. The treated water could also be amended with a carbon source and reinjected into the groundwater to promote ERD. Due to the high utility and complimentary nature of this technology for this Site, GET is retained.

4.4.5 Wellhead Treatment

Wellhead treatment is the installation of LGAC treatment units on already existing production wells. The size and design of the appropriate system is highly dependent on the existing well production capability (e.g. well size, pump capacity, etc.), the concentrations of COCs in the water produced from the well, and the layout of the well site (e.g. location of conveyance pipelines, pressure tanks, etc.). The goal of the wellhead treatment system is to reduce COCs in the water after the treatment system to below AWQS, while ensuring production capacity and delivery pressures are maintained for the well owner/user. As this technology would be the most implementable either at current drinking water wells should they become impacted, or at the impacted wells should their use be switched to drinking water, this technology is retained.

5.0 DEVELOPMENT OF REFERENCE AND ALTERNATIVE REMEDIES

The retained remedial technologies evaluated in Section 4.0 form the basis for the development of the Reference Remedy and alternative Less Aggressive and a More Aggressive remedies to address CVOCs in Site groundwater and achieve the ROs in accordance with R18-16-407. The development of the Reference Remedy, Less Aggressive Remedy, and More Aggressive Remedy include appropriate multiple technologies or contingency strategies to address reasonable uncertainties concerning plume longevity, the achievement of ROs for the current and reasonably foreseeable uses of land as wells as irrigation and domestic water supplies.

5.1 REFERENCE REMEDY

The Reference Remedy will address CVOC concentrations in Site groundwater using a combination of remedial technologies that will focus on source control, plume remediation, plume containment, control migration to remove contaminant mass and achieve ROs, and groundwater monitoring to ensure effectiveness. The chosen technologies to achieve these goals are ERD, GET, an appropriate groundwater monitoring program, and natural attenuation processes. In addition, wellhead treatment systems are included to provide protection of private wells that have been or may in future be impacted by CVOCs. Specifics regarding the Reference Remedy along with general design components are presented below.

5.1.1 Reference Remedy Remedial Measure and Strategies

The remedial strategies for the groundwater Reference Remedy are:

- ERD and MNA to promote ISB and eventual natural attenuation of the CVOCs in the shallow and intermediate aquifers to significantly reduce the CVOC concentrations.
- Use of GET with injection to compliment *in situ* ERD to enhance the distribution of ERD amendments throughout the area with elevated CVOCs and provide hydraulic containment.
- Monitoring to observe and evaluate the changes in contaminant concentrations, groundwater chemistry, and groundwater flow fields. This data will be used to determine an appropriate time to transition to MNA. Two additional monitoring wells will be installed to ensure full monitoring of the plume.
- Installation of wellhead treatment systems on up to two private wells if necessary to provide protection of the water use of the wells.

There are no contingency measures included in the Reference Remedy.

5.1.2 Reference Remedy Remedial Components

The Reference Remedy includes following components:

1. Installation of four paired ERD injection wells, two in the shallow aquifer and two in the intermediate aquifer (Figure 7).
2. A two-phased ERD approach for Site groundwater remediation:
    a. The first phase involves enhanced anaerobic biostimulation to promote conditions that would be conducive to reductive dechlorination of Site CVOCs The process would involve the injection of a quick release carbon substrate (e.g., simple sugar) to promote rapid growth of the indigenous microbes along with a slow-release carbon substrate (SRCS), e.g., emulsified oil substrate, which provides a sustained carbon source for the indigenous and bioaugmented microbial populations and highly-reducing conditions. The injectate solution is assumed to consist of approximately 20,000 gallons of an approximately 4-5% solution of the amendments in each aquifer, injected continuously over a 5-day period. To maintain an optimum pH for the indigenous and bioaugmented microbial populations, an appropriate amount of a buffering agent (i.e., sodium bicarbonate) injected into the groundwater.
    b. The second phase involves bioaugmentation using microbes that are able to biodegrade the chlorinated ethenes to the final end product, ethene. The process would involve the injection of ethenogenic bacteria (produce ethene), such as a microbial consortium containing *Dehalococcoides* (DHC). These types of bacteria promote complete reductive dechlorination of PCE, TCE and other CVOCs to ethene. The injections would occur after anaerobic conditions (DO less than 0.5 mg/L) have been established. The injectate solution would consist of four gallons of undiluted bacterial solution.

    The time frame of injection is assuming an injection flow rate of approximately 3 gpm, which was calculated using the obtainable pumping rate from the extraction well EW-1. Each injection phase would be then followed by approximately 2,000 gallons of anaerobic chase water to aid in preventing biofouling of the injection wells.

    After the initial injections, it is assumed that two additional injections would be required every two years, for a total of three injections, cumulating at year four of the performance monitoring (see below).
3. A GET system consisting of an existing extraction well EW-1 (Figure 7), a small treatment system, and the ERD injection wells to promote further distribution of the amendments in the groundwater. The well, which is screened across the intermediate aquifer, would be pumped at a maximum of 2

gpm, and would only be used to ensure the distribution of ERD injectate occurs in a timely manner due to the extremely low hydraulic conductivity present at the Site. The extracted groundwater would be treated using LGAC to remove CVOCs. The treated groundwater could then be amended with a carbon substrate and microbial population and then reinjected to promote the distribution of amendments and enhance the ISB of the CVOCs in the groundwater. The GET system would then remain in operation only to spread the amendment, and would be terminated if injectate approached the well. The time period of the needed operation of this system is assumed to be two years after injection, based on travel times from the capture analysis of EW-1. The costs assume six years of operation as the well may be cycled back on with each of the additional injection as needed.

4. Up to six years of quarterly ERD performance monitoring of up to five monitoring wells and the extraction well to evaluate changes in groundwater flow fields and the collection of groundwater samples to demonstrate the effectiveness of ERD in reducing CVOC concentrations. After the plume has shown consistent decreasing CVOCs levels in the groundwater, an analysis (e.g. Mann-Kendall) will be performed using CVOC and aquifer parameter data to evaluate when it is appropriate to initiate additional ERD injections or transition to MNA.
5. Six years of annual monitoring of all 16 monitoring wells to occur during the injection time-frame.
6. MNA in up to 16 monitoring wells over the shallow and intermediate aquifers, once aquifer conditions are favorable to demonstrate the continued reductions of CVOC concentrations. MNA is currently projected to be required for 14 years after the determination to transition to MNA. The first five years (remedy years 7 – 11) be semi-annual monitoring, followed by annual monitoring (remedy years 12 – 20).
7. Wellhead treatment on up to two private water supply wells that show Site COCs concentrations that exceed the applicable standard for their selected use. These treatment systems would be appropriately designed LGAC systems that would include an evaluation of the existing pumps installed in each well that will require treatment and conveyance pipelines to properly size the treatment units to ensure production capacity and delivery pressures are maintained. For costing purposes, a maximum flow rate of 10 gpm was assumed, based on the maximum measured flow rate of the private wells in the area. Additionally, the inlet and outlet concentrations of Site COCs will be monitored to ensure treatment requirements are being met and help establish schedules for LGAC change outs to safeguard against breakthroughs that can result in incomplete treatment. The wellhead treatment is projected to be needed to operate for 20 years, out of an abundance of caution due to uncertainties in the current plume remediation time-frame projections.

8. Two additional groundwater monitor wells will be installed to refine the boundaries of the CVOC plume in both the shallow and intermediate aquifers. These wells are included in the above 16 monitoring wells for MNA.

The proposed injection wells will be more than 150 feet cross-gradient to the closest residential well, located at 923 Fair St. The GETs system in combination with reinjection of the carbon substrates and bioaugmentation will increase the ROI in the direction of the plume migration to promote biodegradation of the CVOCs in the area around MVH-3 and MVH-9S. Even with the pumping of the extraction well, the carbon substrate is not anticipated to migrate downgradient to where the substrate would reach the extraction well over a two-year time-frame. In that time, all of the ISB substrates would be expected to be consumed. To evaluate the impact of the carbon substrates, TOC will be measured in the downgradient monitoring wells (MVH-3 and MVH-9s) and the extraction well. The ISB system will not cause potential health impacts or taste and odor issues for the private wells in the area because calculations of travel times show the amendments will not reach the private wells.

5.2 LESS AGGRESSIVE ALTERNATIVE REMEDY

The Less Aggressive Remedy [A.A.C. R18-16-407(E)(3)] will address CVOC concentrations in Site groundwater using a combination of remedial technologies that will focus plume remediation using natural processes within the aquifer to reduce contaminant mass, a groundwater monitoring program, and protection of private wells that have been or may in future be impacted by CVOCs. The chosen technologies to achieve these goals are an appropriate monitoring program and wellhead treatment on select private wells. Specifics regarding the Less Aggressive Remedy along with general design components are presented below.

5.2.1 Less Aggressive Alternative Remedy Remedial Measures and Strategies

The remedial strategies for the Less Aggressive Remedy are:

- Remediation through natural attenuation through biodegradation processes of the CVOCs in the shallow and intermediate aquifers to reduce levels below the AWQS.
- Groundwater monitoring to evaluate the effectiveness of the remedy and evaluate the changes in contaminant concentrations and groundwater flow fields at the Site. For the purposes of this FS, monitoring was projected for 50 years.
- Installation of wellhead treatment systems on up to three private wells if necessary to provide protection of the water use of the wells consistent with the established ROs. For the purposes of this FS, O&M for these systems was projected for 30 years.

- Up to five additional nested groundwater monitor wells may be installed to monitor the boundaries of the CVOC plume in both the shallow and intermediate aquifers over time.

The contingency measures included in the Less Aggressive Remedy are:

- Addition of one round of ISB injections as described in the Reference Remedy should periodic Site reviews indicate that the Site will not obtain ROs within the monitoring timeframe.

5.2.2 Less Aggressive Remedy Remedial Components

The Less Aggressive Remedy includes following components:

1. Monitoring will consist of monitoring 19 monitoring wells, including the current Site wells and five additional monitoring wells to be installed, to monitor the migration path and concentration of COCs in Site groundwater. The wells will be monitored quarterly for years 1 through 5, monitored semiannually for years 5 through 10 years and then annually for years 10 through 30. Some wells may be dropped from the monitoring program on evaluation of data. Groundwater data will continually be evaluated to demonstrate consistent decreasing CVOCs levels in groundwater and stabilization of key aquifer parameters. A Mann-Kendall analysis will be performed to evaluate trends in data and BIOCHLOR will be used to predict plume longevity.
2. Wellhead treatment on up to three private water supply wells, if the well has Site COCs concentrations that exceed the applicable standard for their selected use. These treatment systems would be appropriately designed LGAC systems that would include an evaluation of the existing pumps installed in each well that will require treatment and conveyance pipelines to properly size the treatment units to ensure production capacity and delivery pressures are maintained. For costing purposes, a maximum flow rate of 10 gpm was assumed, based on the maximum measured flow rate of the private wells in the area. Additionally, the inlet and outlet concentrations of Site COCs will be monitored to ensure treatment requirements are being met and help establish schedules for LGAC change outs to safeguard against breakthroughs that can result in incomplete treatment. For costing purposes, based on the age of the wells the length of treatment was assumed to be 30 years.
3. A contingency of one round of ISB injections, triggered during periodic Site reviews should analysis of the data indicate that the Site will not reach ROs within the projected monitoring timeframes. The ISB would be similar to the first round of injections described in the Reference Remedy.

5.3 MORE AGGRESSIVE ALTERNATIVE REMEDY

The More Aggressive Remedy will address CVOC concentrations in Site groundwater using a combination of remedial technologies that will focus on source control, plume remediation, plume containment, control migration to remove contaminant mass and achieve ROs, and groundwater monitoring to ensure effectiveness. The chosen technologies to achieve these goals are ISCR, ERD, GET, an appropriate groundwater monitoring program, natural attenuation processes. In addition, wellhead treatment is included to provide protection of private wells that have been or may in future be impacted by CVOCs. Specifics regarding the More Aggressive Remedy along with general design components are presented below

5.3.1 More Aggressive Remedy Remedial Measures and Strategies

The remedial strategies for the More Aggressive Remedy are:

- ISCR, ERD, and MNA to promote ISB and eventual natural attenuation of the CVOCs in the shallow and intermediate aquifers to reduce the CVOC concentrations.
- Monitoring to observe and evaluate the changes in contaminant concentrations, groundwater chemistry, and groundwater flow fields. This data will be used to determine an appropriate time to transition to MNA.
- GET with injection to compliment ISCR and *In Situ* ERD. The GET system will enhance the distribution of ERD amendments throughout the area with elevated CVOCs.
- Installation of wellhead treatment systems on up to two private wells if necessary to provide protection of the water use of the wells consistent with the established ROs.

There are no contingency measures included in the More Aggressive Remedy.

5.3.2 More Aggressive Remedy Remedial Components

The More Aggressive Remedy includes following components:

1. Installation of six paired ERD injection wells, three in the shallow aquifer and three in the intermediate aquifer (Figure 9).
2. ISCR injections which would involve the use of a chemical compound, such as nano-scale to micron-scale ZVI, to promote abiotic reduction of the CVOCs, and provide the carbon substrate to prepare the aquifer for bioremediation amendments. The ISCR amendments will likely have a smaller radius of influence than the bioremediation amendments and therefore more injection wells than required

for the Reference Remedy are included to effectively distribute the ISCR amendments in the impacted area. The design of the ISB system for the injected ISCR and carbon amendments is based on a 20-foot radius of influence (ROI).

3. Following the ISCR injections, the same two-phased ERD approach as outlined in the Reference Remedy will be used for Site groundwater remediation, namely:
    a. The first phase involves enhanced anaerobic biostimulation to promote conditions that would be conducive to reductive dechlorination of Site CVOCs. The process would involve the injection of a quick release carbon substrate (e.g., sugar syrup) to promote rapid growth of the indigenous microbes along with a SRCS, e.g., emulsified oil substrate, which provides a sustained carbon source for the indigenous and bioaugmented microbial populations and highly-reducing conditions. The injectate solution is assumed to consist of approximately 20,000 gallons of an approximately 4-5% solution of the amendments in each aquifer, injected continuously over a 5-day period. To maintain an optimum pH for the indigenous and bioaugmented microbial populations, an appropriate amount of a buffering agent (i.e., sodium bicarbonate) injected into the groundwater.
    b. The second phase involves bioaugmentation using microbes that are able to biodegrade the chlorinated ethenes to the final end product, ethene. The process would involve the injection of ethenogenic bacteria (produce ethene), such as a microbial consortium containing *Dehalococcoides* (DHC). These types of bacteria promote complete reductive dechlorination of PCE, TCE and other CVOCs to ethene. The injections would occur after anaerobic conditions (DO less than 0.5 mg/L) have been established. The injectate solution would consist of four gallons of undiluted bacterial solution.

As with the Reference Remedy, the time frame of the injections are assuming an injection flow rate of approximately 3 gpm, which was calculated using the obtainable pumping rate from the extraction well EW-1. Each injection phase would be then followed by approximately 2,000 gallons of anaerobic chase water to aid in preventing biofouling of the injection wells.

After the one ISCR injection event and the initial ERD injection, it is assumed that two additional ERD injection events would be required every two years, for a total of one ISCR injection and three ERD injections, cumulating at year seven of the performance monitoring (see below).

4. As with the Reference Remedy, a GET system consisting of an existing extraction well EW-1 (Figure 8), a small treatment system, and the injection wells to promote further distribution of the amendments in the groundwater will be used. The extraction well, which is screened across the intermediate aquifer, would be pumped at a maximum of 2 gpm, and would only be used to ensure

the distribution of ISCR/ERD amendments occurs in a timely manner due to the extremely low hydraulic conductivity present at the Site. The extracted groundwater would be treated using LGAC to remove CVOCs. The treated groundwater could then be amended with an injection substrate and reinjected to promote the distribution of amendments and enhance reduction of the CVOCs in the groundwater. The GET system would then remain in operation only to spread the amendment, and would be terminated if injectate approached the well. The time period of the needed operation of this system is assumed to be two years after each injection, based on travel times from the capture analysis of EW-1. The costs therefore assume eight years of operation as the well may be cycled back on with each additional injection as needed.

5. Eight years of quarterly ISCR/ERD performance monitoring of up to five monitoring wells and the extraction well to evaluate changes in groundwater flow fields and the collection of groundwater samples to demonstrate the effectiveness of ISCR/ERD in reducing CVOC concentrations. After the plume has shown consistent decreasing CVOCs levels in the groundwater, an analysis (e.g. Mann-Kendall) will be performed using CVOC and aquifer parameter data to evaluate when it is appropriate to initiate additional ERD injections or transition to MNA.
6. Eight years of annual monitoring of all 16 monitoring wells during the injection time-frame.
7. MNA in up to 16 monitoring wells over the shallow and intermediate aquifers, once aquifer conditions are favorable to demonstrate the continued reductions of CVOC concentrations. MNA is currently projected to be required for 12 years after the determination to transition to MNA. The first five years of MNA (remedy years 9 - 13) would be semi-annual monitoring, followed by annual monitoring (remedy years 14 – 20).
8. Wellhead treatment on up to two private water supply wells that show Site COCs concentrations that exceed the applicable standard for their selected use. These treatment systems would be appropriately designed LGAC systems that would include an evaluation of the existing pumps installed in each well that will require treatment and conveyance pipelines to properly size the treatment units to ensure production capacity and delivery pressures are maintained. For costing purposes, a maximum flow rate of 10 gpm was assumed, based on the maximum measured flow rate of the private wells in the area. Additionally, the inlet and outlet concentrations of Site COCs will be monitored to ensure treatment requirements are being met and help establish schedules for LGAC change outs to safeguard against breakthroughs that can result in incomplete treatment. The wellhead treatment is projected to be needed to operate for 20 years, out of an abundance of caution due to uncertainties in the current plume remediation time-frame projections.

9. Two additional groundwater monitor wells will be installed to refine the boundaries of the CVOC plume in both the shallow and intermediate aquifers. These wells are included in the above 16 monitoring wells for MNA.

6.0 COMPARISON OF REFERENCE AND ALTERNATIVE REMEDIES

6.1 ACHIEVEMENT OF REMEDIAL OBJECTIVES

The Reference Remedy, the Less Aggressive Remedy, and the More Aggressive Remedy are all capable of achieving the established ROs for the Site in accordance with R18-16-407(H)(1). The Reference Remedy and the More Aggressive Remedy will reduce CVOC concentrations via direct treatment and removal of contaminant mass, and protect water uses in the area via wellhead treatment to meet the established ROs. The proposed Less Aggressive Remedy will achieve the established ROs for the Site by allowing the natural processes to reduce CVOC concentrations as much as practical under the current aquifer conditions. Wellhead treatment installation will protect the water uses in the area to meet the established ROs.

6.2 CONSISTENCY WITH LAND USE AND WATER MANAGEMENT PLANS

The proposed Reference and More Aggressive Remedies is consistent with the water management plans and land use plans for the Site in accordance with R18-16-407(H)(2). The injection approach with GETs is beneficial to the water management plans because it will allow extracted groundwater to be treated and reinjected into the aquifer to promote distribution of the amendments and provide hydraulic containment, preventing further plume movement to downgradient water users while the treatment is ongoing. The implementation of the either remedy will not have a negative impact on land use as the injection and GETS systems are planned to be located in landscaped areas, out of the way of current property uses.

The proposed Less Aggressive Remedy is also consistent with the water management plans and land use plans for the Site in accordance with R18-16-407(H)(2). An MNA approach is beneficial to the water management plans and land use because it does not involve groundwater to be extracted, pumped, and discharged at another location. Likewise, the remedial approach does not have a negative impact on land use.

6.3 COMPARISON CRITERIA

This section compares the Reference Remedy, the Less Aggressive Remedy, and the More Aggressive Remedy to the criteria described in A.A.C R18-16-407(H)(3) to determine the most appropriate path forward to address CVOCs in groundwater. As described above, the three remedies and associated contingencies are all able to achieve the ROs for groundwater and are consistent with general land use and water management plans. The following subsections present the comparison of the practicability and cost benefit analyses for the three evaluated remedies, including the assessment of risk and liability, and reduced COC concentrations and/or volume. **Table 6** shows a detailed evaluation of the comparison criteria that is presented below for the Reference Remedy, Less Aggressive Remedy and More Aggressive Remedy.

Practicability

There are four considerations for determining the practicability of a proposed remedy; 1) Feasibility: the ability to construct and implement the remedy at the Site, 2) Short-term effectiveness: the amount of PCE mass the remedy removes within the first 5 years and the potential for exposure in the short-term, 3) Long-term effectiveness: the success of the remedy in the continuation of PCE mass reduction after the 5-year mark and the potential for exposure in the long-term, and 4) Reliability: the ability of the technology to remove contaminant mass and achieve ROs (**Table 6**).

Cost Benefit Analysis

The cost benefit analysis included the evaluation of each remedy in terms of risk, benefit of remediation and estimated overall costs to implement and operate the remedy. The risk criteria included assessment of the overall protectiveness of public health and the environment in terms of fate and transport of the COCs, current and future land uses, exposure pathways and time periods for potential exposure pathways, changes in risk during remediation and remaining risk at the end of remediation.

The benefit of remediation and overall cost comparison includes capital expenditures, operating and maintenance costs, and life cycle costs. To prepare the overall costs, Matrix used reasonable estimates from subcontractors and vendors based on 2021 pricing. The overall time, materials, operation, and maintenance costs were based on similar projects and level of efforts using 2021 billing rates and presumed a 15 to 30-year remediation time period. The associated cost estimates for each remedy reflect a range between -30% to +30% (**Table 6**). Detailed cost estimates for the Reference Remedy, Less Aggressive Remedy, and More Aggressive Remedy are presented in **Appendix A**.

6.3.1 Reference Remedy

6.3.1.1 Practicability

For the groundwater Reference Remedy, ERD has been shown to be an effective remediation technology for CVOC-contaminated groundwater at numerous sites with similar aquifer conditions. Groundwater sampling confirmed that biostimulation and bioaugmentation would be an effective at degrading the CVOCs in Site groundwater. This technology is highly feasible and requires a relatively small footprint to implement at the Site, where CVOC contamination is elevated. Based on sites with similar CVOC concentrations and similar aquifer properties, it is anticipated for costing purposes that the Reference

Remedy can reduce contaminant mass and achieve the established ROs for the Site over a period of 15 years.

This approach provides moderate to high short- and long-term effectiveness; in the short-term the ERD system provides contaminant destruction in the source area and control over the most contaminated section of the plume. Since groundwater monitoring data do not demonstrate a considerable degree of natural reductive dechlorination, as the TOC is biodegraded, there may be a need for additional ERD injections. In the long-term once a microbial community has been established, ERD is very effective at reducing the size of the plume. The contingency strategy that includes groundwater extraction/injection and treatment could be used to enhance the distribution of amendments and pore volume flushing.

The Reference Remedy is also a reliable remediation approach for the Site groundwater. Groundwater sampling results demonstrated that *in situ* bioremediation would have a high level of success. The construction of the injection wells for the ERD system is very practicable based on Site constraints since the wellheads will be completed in flush-mounted vaults

6.3.1.2 Risk

The Reference Remedy is low risk because it reduces the mobility and level of CVOCs in the groundwater. Within the current plume boundaries, the Reference Remedy will address the area with elevated CVOC concentrations and is protective of human health and the environment.

6.3.1.3 Cost

The Reference Remedy includes technologies that are proven and cost-effective approaches to address CVOCs in groundwater. The estimated cost associated with the implementation of the Reference, is estimated at approximately $5.4M (**Appendix A**).

The implementation costs including ERD install, ERD implementation, and GET system install are estimated at approximately $1.4M, and the costs for monitoring, GET system O&M, and wellhead treatment systems O&M estimated at $4.0M.

There are no contingency costs for the Reference Remedy.

6.3.1.4 Benefit

There are several major benefits to the Reference Remedy including:

- ERD can significantly reduce the CVOCs concentrations in the groundwater as well as contaminants attached to the aquifer sediments.
- ERD can reduce COC concentrations orders of magnitude within a reasonable timeframe.
- ERD, in combination with GET, will enhance mass removal and destruction of COCs.

- This approach will achieve the ROs and is consistent with general land use and water management plans.
- This remedy is not anticipated to have a negative impact on the current or projected future use of the Site.

6.3.2 Less Aggressive Alternative Remedy

6.3.2.1 Practicability

Natural processes decreasing contaminant concentrations can be an effective remediation technology for CVOC-contaminated groundwater. While monitoring as a standalone technology would not be likely to achieve established ROs, wellhead treatment on private wells is included as part of the Less Aggressive Remedy as a practicable solution to allow for continued water use in the area.

This approach provides low short- and long-term effectiveness in reducing CVOC contaminant mass, however the wellhead treatment on private supply wells will provide high short- and long-term reliable effectiveness at protecting water uses.

6.3.2.2 Risk

The Less Aggressive Remedy is moderate risk protective because it does not reduce the mobility and level of CVOCs in the groundwater. The wellhead treatment will provide protection of water supplies. There is a high risk that contingencies would be needed.

6.3.2.3 Cost

The Less Aggressive Remedy includes technologies that are cost effective remedial alternatives. The estimated cost of the Less Aggressive Remedy is estimated to be $9.8M (**Appendix A**).

The implementation costs for the Less Aggressive Remedy, which include installation of additional monitoring wells and private wellhead treatment systems, are estimated to be approximately $0.7M. Monitoring costs and O&M for 30 years are estimated to be $9.1M.

Contingency costs to conduct ISB injections prior to the end of the 30-year MNA timeframe are estimated to be approximately $0.6M.

The total cost for implementation including contingency costs is approximately $10.4M.

6.3.2.4 Benefit

The Less Aggressive Remedy provides moderate benefit as the monitoring provides data to evaluate COCs throughout the plume and will help identify when wellhead treatment is needed. Wellhead treatment provides immediate benefit of allowing for the most beneficial use of the water. In addition, while monitoring as a standalone strategy will not reduce CVOC mass or mobility, over time the plume concentrations may decrease as the plume disperses laterally and migrates advectively with groundwater.

6.3.3 More Aggressive Alternative Remedy

6.3.3.1 Practicability

For the More Aggressive Remedy, ISCR coupled with ERD has been shown to be an effective remediation technology for CVOC-contaminated groundwater at numerous sites with similar aquifer conditions. Groundwater sampling confirmed that biostimulation and bioaugmentation would be an effective at degrading the CVOCs in Site groundwater. The added benefit of ISCR will reduce CVOC mass and condition the aquifer to be more conducive for ERD. This combined *in situ* technology is highly feasible and requires a relatively small footprint to implement at the Site where CVOC contamination is elevated. Based on sites with similar CVOC concentrations and similar aquifer properties, it is anticipated for costing purposes that the More Aggressive Remedy will reduce contaminant mass and achieve the established ROs for the Site over a period of 15 years.

The groundwater extraction/injection and treatment will be used to enhance the distribution of amendments, provide pore volume flushing, and provide hydraulic containment. The GET system provides for mass removal and some plume control and is considered a practicable remedial approach, especially since the treated groundwater would be reinjected into the groundwater. Wellhead treatment will enhance the protection of private wells as needed.

This more aggressive approach provides moderate to high short- and long-term effectiveness; in the short-term the ERD system provides contaminant destruction in the source area and control over the most contaminated section of the plume. The addition of an ISCR amendment would reduce the lag phase identified with the Reference Remedy. In the long-term, once anaerobic aquifer conditions and a microbial community have been established, ISCR and ERD are very effective at reducing the size of the plume.

The More Aggressive Remedy is also a reliable remediation approach for the Site groundwater. Groundwater sampling results demonstrated that *in situ* bioremediation would have a high level of success. The construction of the injection wells for the ISCR and ERD system is very practicable based on Site constraints, since the wellheads will be completed in flush-mounted vaults.

6.3.3.2 Risk

The More Aggressive Remedy is low risk protective because it reduces the mobility and level of CVOCs in the groundwater. Within the current plume boundaries, the More Aggressive Remedy will address the area with elevated CVOC concentrations and is protective of human health and the environment. There is the potential additional risk associated with injecting substances such as ZVI as it can reduce permeability.

6.3.3.3 Cost

The More Aggressive Remedy includes technologies that are proven and cost-effective approaches to address CVOCs in groundwater. The estimated cost for the More Aggressive Remedy is estimated to be approximately $7.1M (**Appendix A**).

The implementation costs for the More Aggressive Remedy, including ISCR and ERD system install, ISCR and ERD implementation, GET system and wellhead treatment system install are estimated to be $2.8M. The costs monitor, to operate the GET system and the wellhead treatment systems are estimated to be $4.3 million.

There are no contingency costs for the More Aggressive Remedy.

6.3.3.4 Benefit

The benefits of the More Aggressive Remedy are similar to the Reference Remedy. This remedy includes technologies that are typically accepted by the public community and will reduce the risk to human and ecological receptors by treating the groundwater prior to being reinjected. This approach will achieve the ROs and is consistent with general land use and water management plans. This remedy is not anticipated to have a negative impact on the current or projected future use of the Site.

6.4 COMPARISON OF REMEDIES

This section presents a discussion of the comparison criteria as required under the Remedy Selection Rule, A.A.C. R18-16-407(H)(3)(e).

6.4.1 Practicability

To address CVOC contaminated groundwater at the Site, the Reference Remedy and the Less Aggressive Remedy are the most technologically feasible, followed by the More Aggressive Remedy. There are no significant technological impediments to the implementation of the ISB system using enhanced reductive dechlorination. The More Aggressive Remedy is slightly less favorable due to the challenges associated with injecting substances like ZVI in already low permeability aquifers.

Long-term effectiveness is provided by the Reference, More Aggressive, and Less Aggressive Remedies.

6.4.2 Risk

The highest level of risk is associated with the Less Aggressive Remedy. In addition to the Less Aggressive Remedy not reducing the mobility and level of CVOCs in the groundwater through active remediation, the Less Aggressive Remedy also has the highest risk of requiring contingencies. The Reference Remedy has a low risk, and the More Aggressive Remedy has the least risk (**Table 6**).

6.4.3 Cost

Appendix A presents a summary of the cost estimates for the groundwater remediation alternatives evaluated. The Reference Remedy has lower costs compared to the Less Aggressive Remedy and More Aggressive Remedies. Since the cost is the least for Reference Remedy, it is the most efficient of the three remedies. Although the implementation cost for the Less Aggressive Remedy is less than the Reference Remedy, the long-term costs are greater for this option, leading to an overall greater cost over time.

6.4.4 Benefits

The major benefits of the Reference Remedy and More Aggressive Remedy compared to the Less Aggressive Remedy include: 1) Significant reduction in contaminant mass in the groundwater, 2) Reduction in the size of the plume, and 3) Shorter time period to remediate the plume. However, the clean-up timeframe for the More Aggressive Remedy and the Reference Remedy are projected to be approximately equivalent, despite the Reference Remedy costing less.

6.5 UNCERTAINTIES

The following uncertainties are present in in the above remedies.

- The actual timeframes for enhanced microbial remediation processes at the Site are not able to be modelled with current Site data. This will be addressed by planned modelling after initial data are obtained during the remedial activities and re-evaluated in periodic Site reviews.

- There are uncertainties associated with the heterogeneity of the aquifer, locations of CVOC mass, and the potential for channeling of the injected amendments that could adversely impact the remedy. These uncertainties will most likely be addressed as injection and monitoring wells are installed, and initial injections/monitoring occur.

- Due to Site constraints and potential access issues, the placement of remedial injection wells and systems may not be able to be located in optimal locations.

7.0 PROPOSED REMEDY

This section presents the proposed remedy as required in A.A.C. R18-16-407(I) and describes how it will achieve the ROs; how the comparison criteria were evaluated, and how the proposed remedy will address the obligations of A.R.S. §49-282.06.

7.1 PROCESS AND REASON FOR SELECTION

The Reference Remedy is recommended for treatment of the CVOC-contaminated groundwater at the Site. This remedy was selected because it showed the highest ranking in accordance with the comparison criteria specified in the Remedy Selection Rule, A.A.C. R18-16-407(H)(3)(e). This recommendation is based on the evaluation of remedial effectiveness, practicability, cost, and benefit for restoration and use of the groundwater resource.

7.2 ACHIEVEMENT OF REMEDIAL OBJECTIVES

The Reference Remedy will achieve ROs by reducing CVOC concentrations via direct treatment and removal of contaminant mass, which will protect against the threatened loss or impairment of water use at the Site. The protection of current and immediate future uses of potable water in the area will be achieved via wellhead treatment of potable use private wells with an exceedances of the AWQS for the Site COCs. The Reference Remedy is currently projected to achieve the ROs in the estimated time frame of 15 years.

7.3 ACHIEVEMENT OF REMEDIAL ACTION CRITERIA

Pursuant to A.R.S. §49-282.06, which 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 substance in order to allow for the maximum beneficial use of waters of the state, and 3) Be reasonable, necessary, cost-effective and technically feasible. The remedial objectives for this Site are to protect groundwater resources for beneficial uses and all three remedies are considered likely to achieve the ROs for the Site. However, the Reference and More Aggressive Remedies may potentially achieve the ROs in a shorter time frame compared to the Less Aggressive Remedy. Based on a comparison of the Reference Remedy with the More Aggressive and Less Aggressive Remedies, it is recommended that the Reference Remedy be implemented because it provides the following:

- Adequate protection of public health and welfare and the environment.
- A thorough and timely option for continued monitoring of the groundwater and assessment of remediation progress.

- Control, management, and cleanup of the COCs in Site groundwater.
- Beneficial use of the groundwater resource.
- Reasonably cost-effective and technically feasible remediation approach.

The major advantages of this approach would include destruction of the CVOCs quickly and likewise, reduce the downgradient migration of CVOCs.

7.3.1 Protectiveness

The Reference Remedy is protective because it reduces the mass and concentration of CVOCs in Site groundwater. The Reference Remedy is protective of human health because it treats groundwater that may be used as a drinking water source.

7.3.2 Maximum Beneficial Use of Water

The Reference Remedy provides for maximum beneficial use of the groundwater since it retains the groundwater source *in situ* and allows for the use of the water as a potable source via wellhead treatment for impacted private wells.

7.3.3 Reasonableness

The Reference Remedy is reasonable because it promotes destruction of the CVOC contaminant mass and reduces the concentrations of CVOCs in groundwater in an acceptable timeframe, while protecting public health.

7.3.4 Cost Effectiveness

The Reference Remedy is a cost-effective approach to reduce CVOC contamination in groundwater in approximately the same estimated time frame as the More Aggressive Remedy, while costing less.

7.3.5 Technical Feasibility

The Reference Remedy is technically feasible remediation approach which has been demonstrated at numerous CVOC contaminated groundwater sites.

7.4 CONSISTENCY WITH CURRENT AND FUTURE LAND AND WATER USE

The Reference Remedy is consistent with water management plans and the current and future land and water uses for the, as it remediates COCs in groundwater with minimal land use in a timely manner.

7.5 CONTINGENCIES

There are no contingencies for the Reference Remedy.

8.0 COMMUNITY INVOLVEMENT

ADEQ will issue a Notice to the Public announcing the availability of the FS on ADEQ's website at www.azdeq.gov. The notice may be mailed to the Public Mailing List for the Site, water providers if appropriate, and any other interested parties. ADEQ may also present a summary of the FS and the remedial alternatives in a public meeting. Interested parties can also review the FS and other Site documents at the ADEQ Main office located at 1110 West Washington St., Phoenix, Arizona. With 24-hour notice, an appointment to review related documentation is available Monday through Friday from 8:30 AM to 4:30 PM at the ADEQ Records Management Center. To schedule an appointment to review documents, call 602-771-4380 or 800-234-5677. Other contact information is presented below:

Name/Title	Phone	Email
Dr. Hazel Cox/ ADEQ Project Manager	520-770-3125	Cox.hazel@azdeq.gov

9.0 REFERENCES

Arizona Department of Environmental Quality (ADEQ), 2016. Preliminary Investigation Report, Miller Valley Road and Hillside Avenue, Prescott, Arizona.

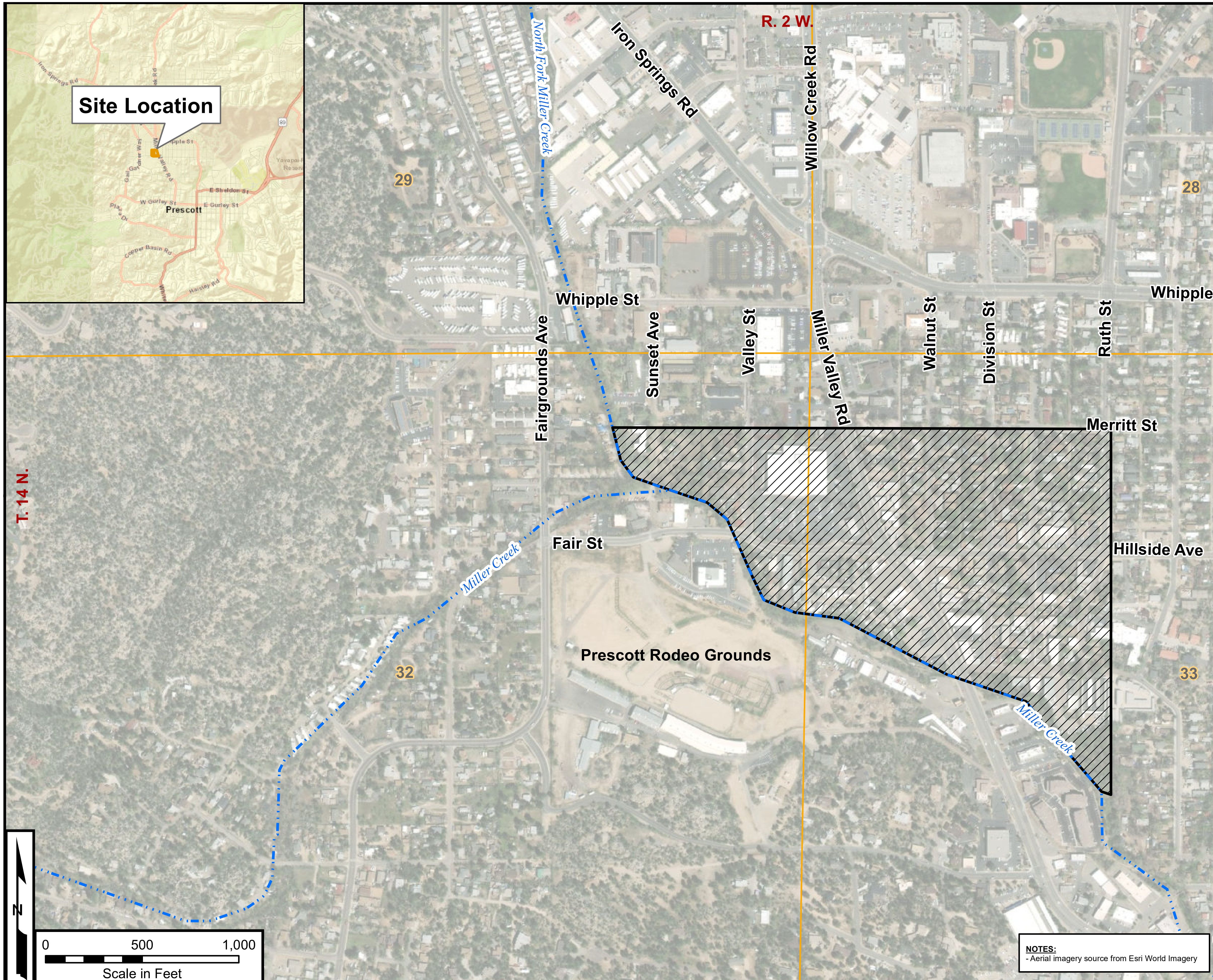
Dewitt, et. al, 2008, Geologic Map of the Prescott National Forest and the Headwaters of the Verde River, Yavapai, and Coconino Counties, Arizona. U.S. Geological Survey

Hydro Geo Chem, Inc. (HGC), 2020. Remedial Investigation Report, Miller Valley Rd and Hillside Ave, Water Quality Assurance Revolving Fund Site, Prescott, Arizona.

MACTEC, 2006. Final Preliminary Investigation Report, Miller Valley Road and Hillside Avenue Site, Prescott, Arizona.

Matrix New World (Matrix), 2021. Evaluation of In Situ Bioremediation Potential for Chlorinated Solvents at Miller Valley Road and Hillside Avenue Water Quality Assurance Revolving Fund Site.

FIGURES



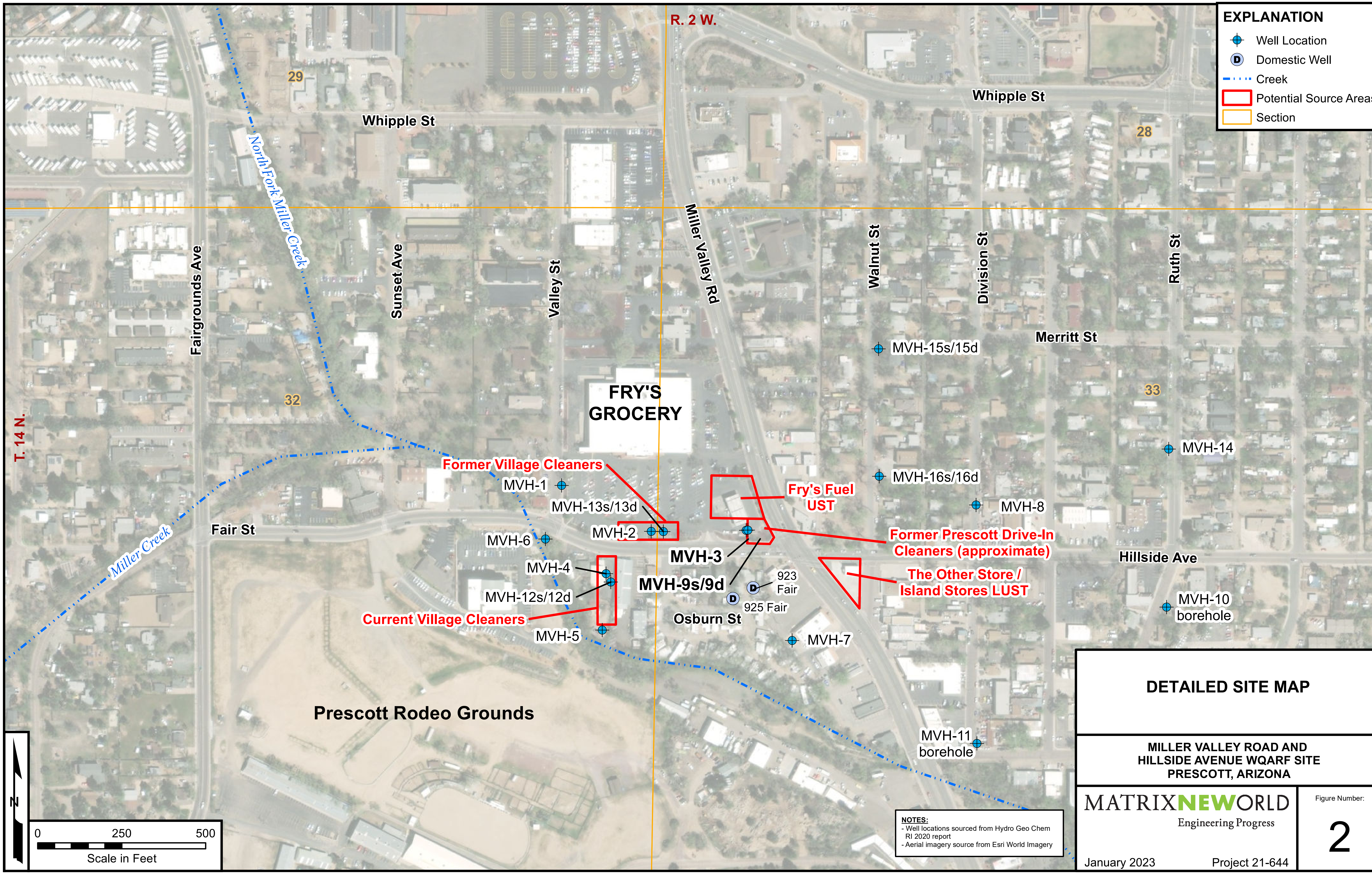
SITE LOCATION MAP

MILLER VALLEY ROAD AND HILLSIDE AVENUE WQARF SITE PRESCOTT, ARIZONA

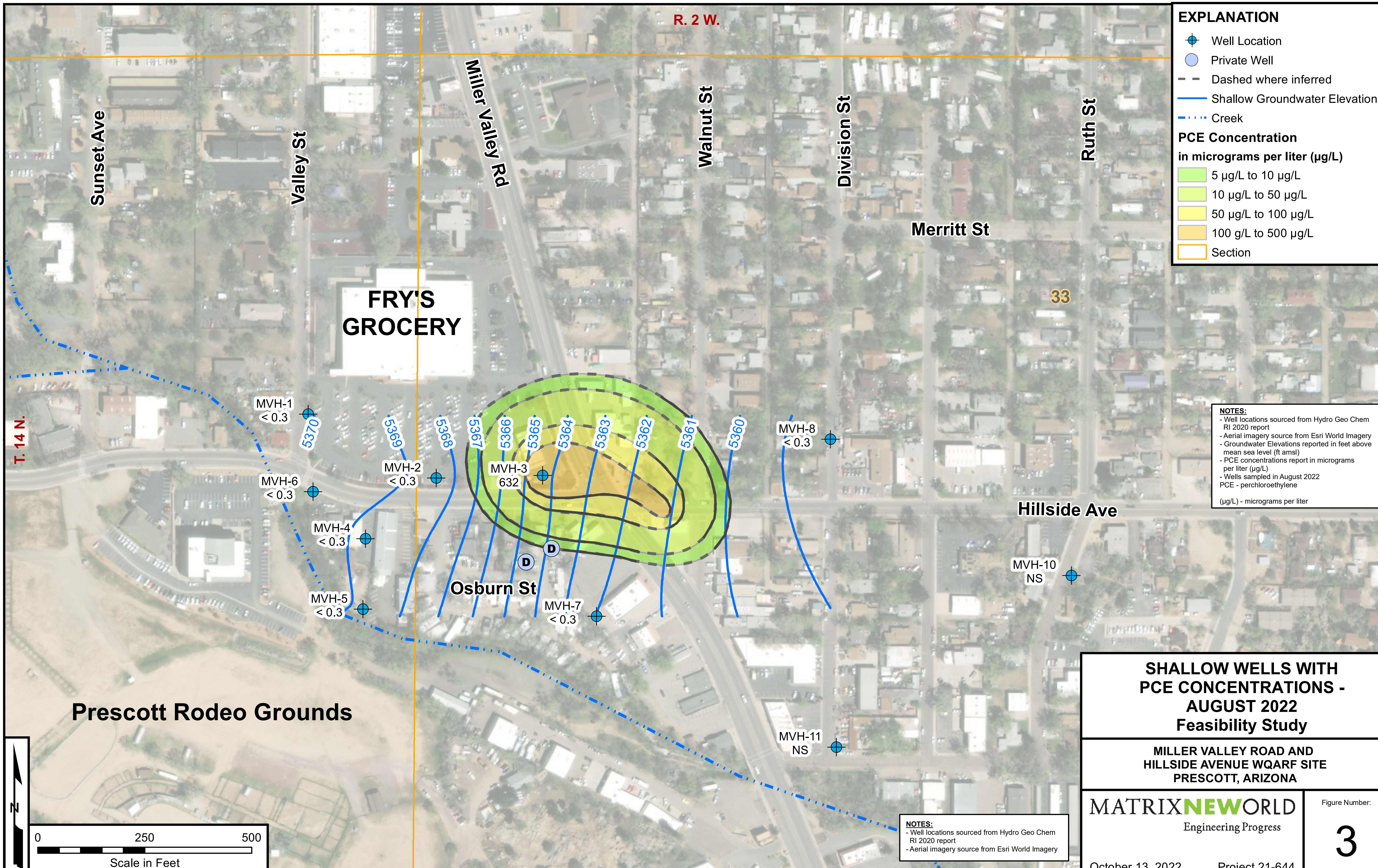
MATRIXNEWORLD
Engineering Progress

January 2023 Project 21-644

Figure Number: 1



EXPLANATION
Well Location
Domestic Well
Creek
Potential Source Areas
Section
R. 2 W.
T. 14 N.
29
28
32
33
Whipple St
Whipple St
North Fork Miller Creek
Miller Creek
Fairgrounds Ave
Sunset Ave
Valley St
Miller Valley Rd
Walnut St
Division St
Ruth St
Merritt St
Fair St
Hillside Ave
Osburn St
FRY'S GROCERY
Former Village Cleaners
Current Village Cleaners
Fry's Fuel UST
Former Prescott Drive-In Cleaners (approximate)
The Other Store / Island Stores LUST
MVH-1
MVH-13s/13d
MVH-2
MVH-6
MVH-4
MVH-12s/12d
MVH-5
MVH-3
MVH-9s/9d
923 Fair
925 Fair
MVH-7
MVH-15s/15d
MVH-16s/16d
MVH-8
MVH-14
MVH-10 borehole
MVH-11 borehole
Prescott Rodeo Grounds
N
0
250
500
Scale in Feet
NOTES:
- Well locations sourced from Hydro Geo Chem RI 2020 report
- Aerial imagery source from Esri World Imagery
DETAILED SITE MAP
MILLER VALLEY ROAD AND HILLSIDE AVENUE WQARF SITE PRESCOTT, ARIZONA
MATRIXNEWORLD
Engineering Progress
January 2023
Project 21-644
Figure Number:
2



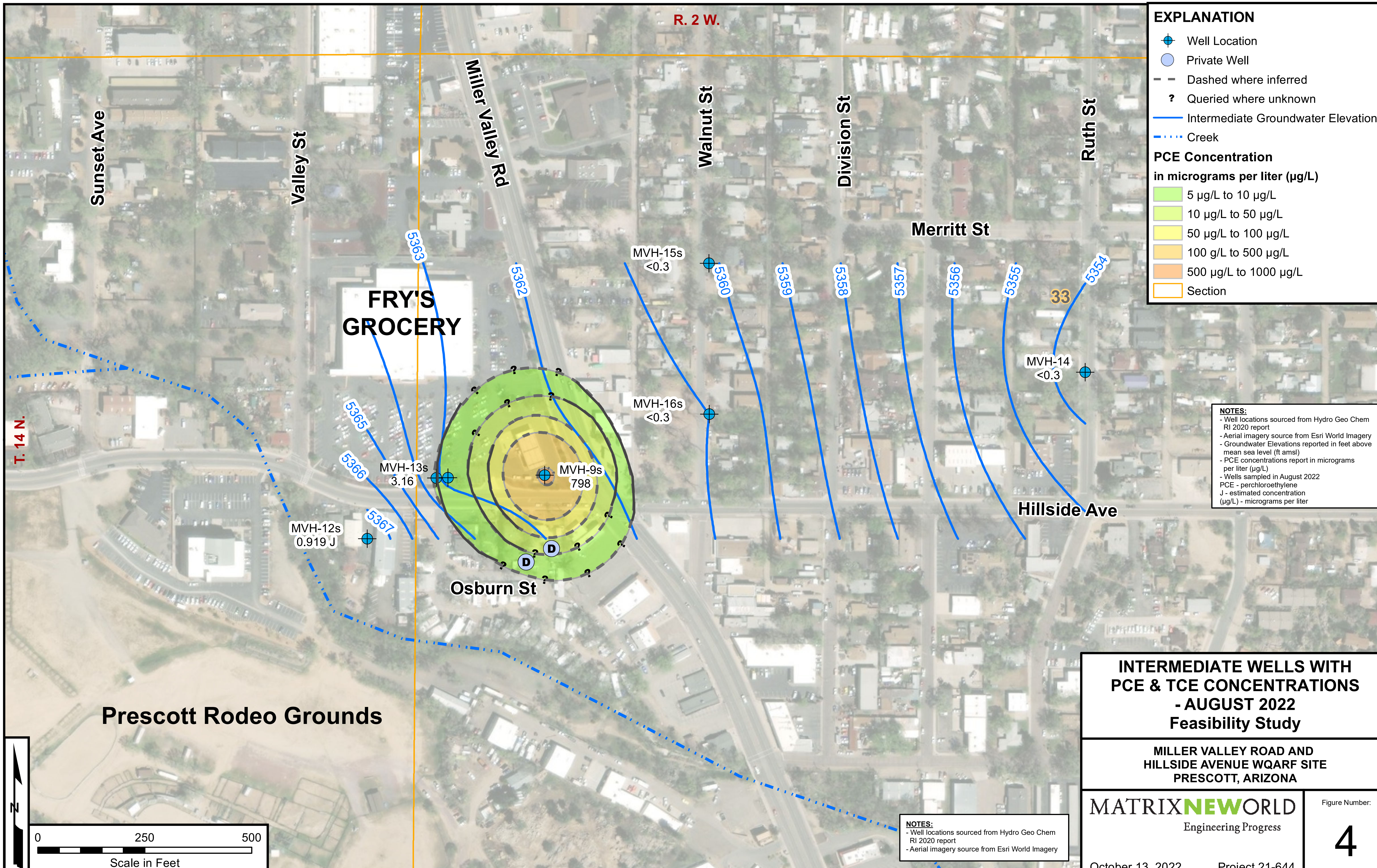
SHALLOW WELLS WITH PCE CONCENTRATIONS - AUGUST 2022
Feasibility Study

MILLER VALLEY ROAD AND HILLSIDE AVENUE WQARF SITE PRESCOTT, ARIZONA

MATRIXNEWORLD
Engineering Progress

October 13, 2022 Project 21-644

Figure Number: 3



EXPLANATION
Well Location
Private Well
Dashed where inferred
? Queried where unknown
Intermediate Groundwater Elevations
Creek
PCE Concentration
in micrograms per liter (µg/L)
5 µg/L to 10 µg/L
10 µg/L to 50 µg/L
50 µg/L to 100 µg/L
100 g/L to 500 µg/L
500 µg/L to 1000 µg/L
Section
R. 2 W.
T. 14 N.
Sunset Ave
Valley St
Miller Valley Rd
Walnut St
Division St
Ruth St
Merritt St
Hillside Ave
Osburn St
FRY'S GROCERY
Prescott Rodeo Grounds
33
MVH-15s
<0.3
MVH-16s
<0.3
MVH-14
<0.3
MVH-13s
3.16
MVH-9s
798
MVH-12s
0.919 J
D
D
5354
5355
5356
5357
5358
5359
5360
5362
5363
5365
5366
5367
NOTES:
- Well locations sourced from Hydro Geo Chem RI 2020 report
- Aerial imagery source from Esri World Imagery
- Groundwater Elevations reported in feet above mean sea level (ft amsl)
- PCE concentrations report in micrograms per liter (µg/L)
- Wells sampled in August 2022
PCE - perchloroethylene
J - estimated concentration
(µg/L) - micrograms per liter
NOTES:
- Well locations sourced from Hydro Geo Chem RI 2020 report
- Aerial imagery source from Esri World Imagery
N
0
250
500
Scale in Feet
INTERMEDIATE WELLS WITH PCE & TCE CONCENTRATIONS - AUGUST 2022
Feasibility Study
MILLER VALLEY ROAD AND HILLSIDE AVENUE WQARF SITE
PRESCOTT, ARIZONA
MATRIXNEWORLD
Engineering Progress
October 13, 2022
Project 21-644
Figure Number:
4

DEEP WELLS WITH PCE & TCE CONCENTRATIONS - AUGUST 2022

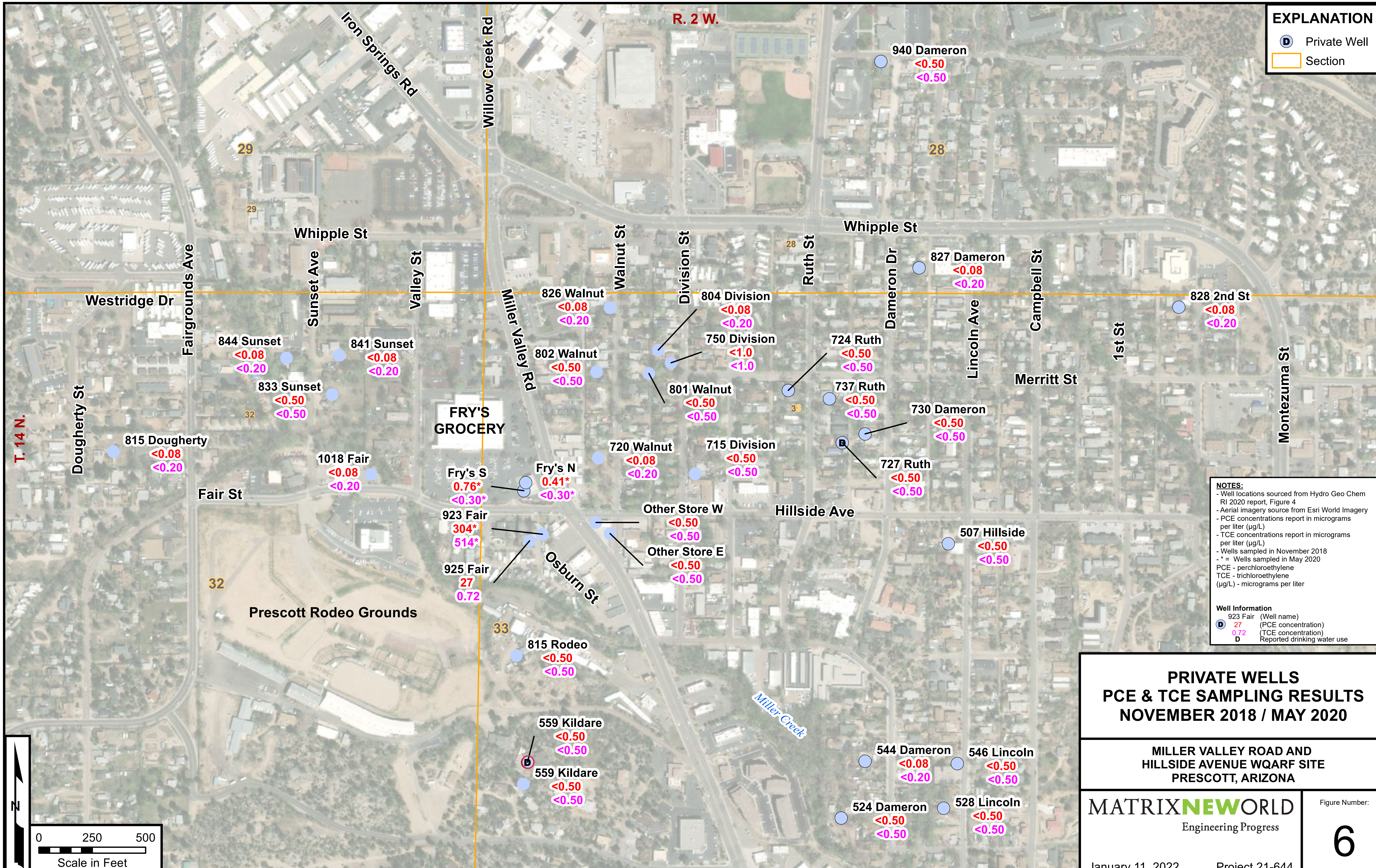
MILLER VALLEY ROAD AND HILLSIDE AVENUE WQARF SITE PRESCOTT, ARIZONA

MATRIX NEW WORLD
Engineering Progress

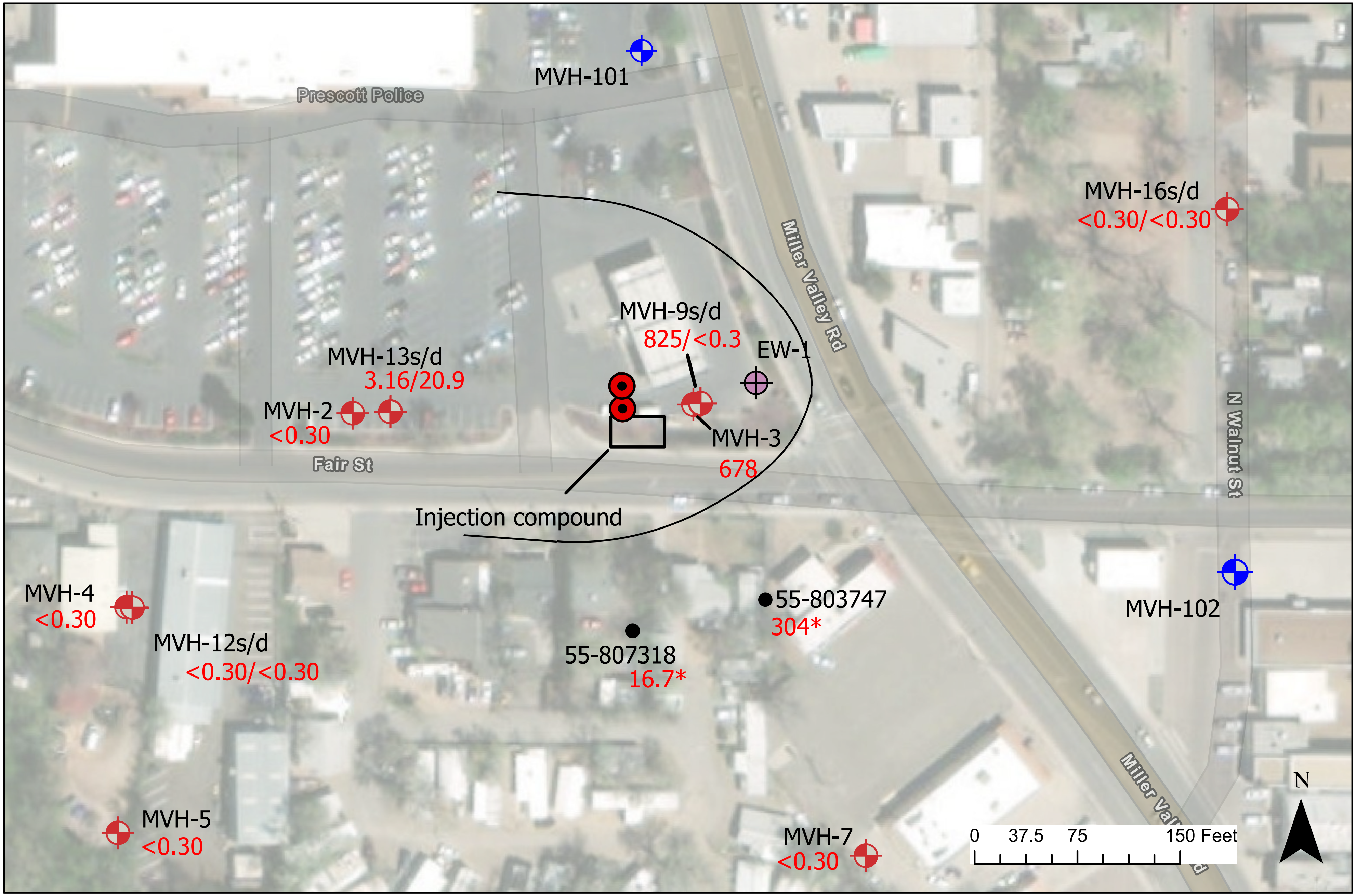
October 13, 2022 Project 21-644

Figure Number: 5

S:\MyDocs\SGCPRJ\2022\22-0855 ADEQ ASRAC MVH_PFAS Sampling\gis\MXDs\Figure1_MVH_Groundwater_deep.mxd



EXPLANATION
Private Well
Section
R. 2 W.
T. 14 N.
29
28
32
33
Iron Springs Rd
Willow Creek Rd
Whipple St
Westridge Dr
Fairgrounds Ave
Sunset Ave
Valley St
Miller Valley Rd
Walnut St
Division St
Ruth St
Dameron Dr
Lincoln Ave
Campbell St
1st St
Montezuma St
Merritt St
Dougherty St
Fair St
Hillside Ave
Osburn St
Miller Creek
FRY'S GROCERY
Prescott Rodeo Grounds
940 Dameron <0.50 <0.50
827 Dameron <0.08 <0.20
828 2nd St <0.08 <0.20
826 Walnut <0.08 <0.20
804 Division <0.08 <0.20
750 Division <1.0 <1.0
724 Ruth <0.50 <0.50
844 Sunset <0.08 <0.20
841 Sunset <0.08 <0.20
802 Walnut <0.50 <0.50
833 Sunset <0.50 <0.50
801 Walnut <0.50 <0.50
737 Ruth <0.50 <0.50
730 Dameron <0.50 <0.50
815 Dougherty <0.08 <0.20
720 Walnut <0.08 <0.20
715 Division <0.50 <0.50
727 Ruth <0.50 <0.50
1018 Fair <0.08 <0.20
Fry's S 0.76* <0.30*
Fry's N 0.41* <0.30*
923 Fair 304* 514*
Other Store W <0.50 <0.50
Other Store E <0.50 <0.50
925 Fair 27 0.72
507 Hillside <0.50 <0.50
815 Rodeo <0.50 <0.50
559 Kildare <0.50 <0.50
559 Kildare <0.50 <0.50
544 Dameron <0.08 <0.20
546 Lincoln <0.50 <0.50
524 Dameron <0.50 <0.50
528 Lincoln <0.50 <0.50
NOTES:
- Well locations sourced from Hydro Geo Chem RI 2020 report, Figure 4
- Aerial imagery source from Esri World Imagery
- PCE concentrations report in micrograms per liter (µg/L)
- TCE concentrations report in micrograms per liter (µg/L)
- Wells sampled in November 2018
- * = Wells sampled in May 2020
PCE - perchloroethylene
TCE - trichloroethylene
(µg/L) - micrograms per liter
Well Information
923 Fair (Well name)
27 (PCE concentration)
0.72 (TCE concentration)
D Reported drinking water use
0 250 500
Scale in Feet
N
PRIVATE WELLS
PCE & TCE SAMPLING RESULTS
NOVEMBER 2018 / MAY 2020
MILLER VALLEY ROAD AND
HILLSIDE AVENUE WQARF SITE
PRESCOTT, ARIZONA
MATRIXNEWORLD
Engineering Progress
Figure Number:
6
January 11, 2022
Project 21-644



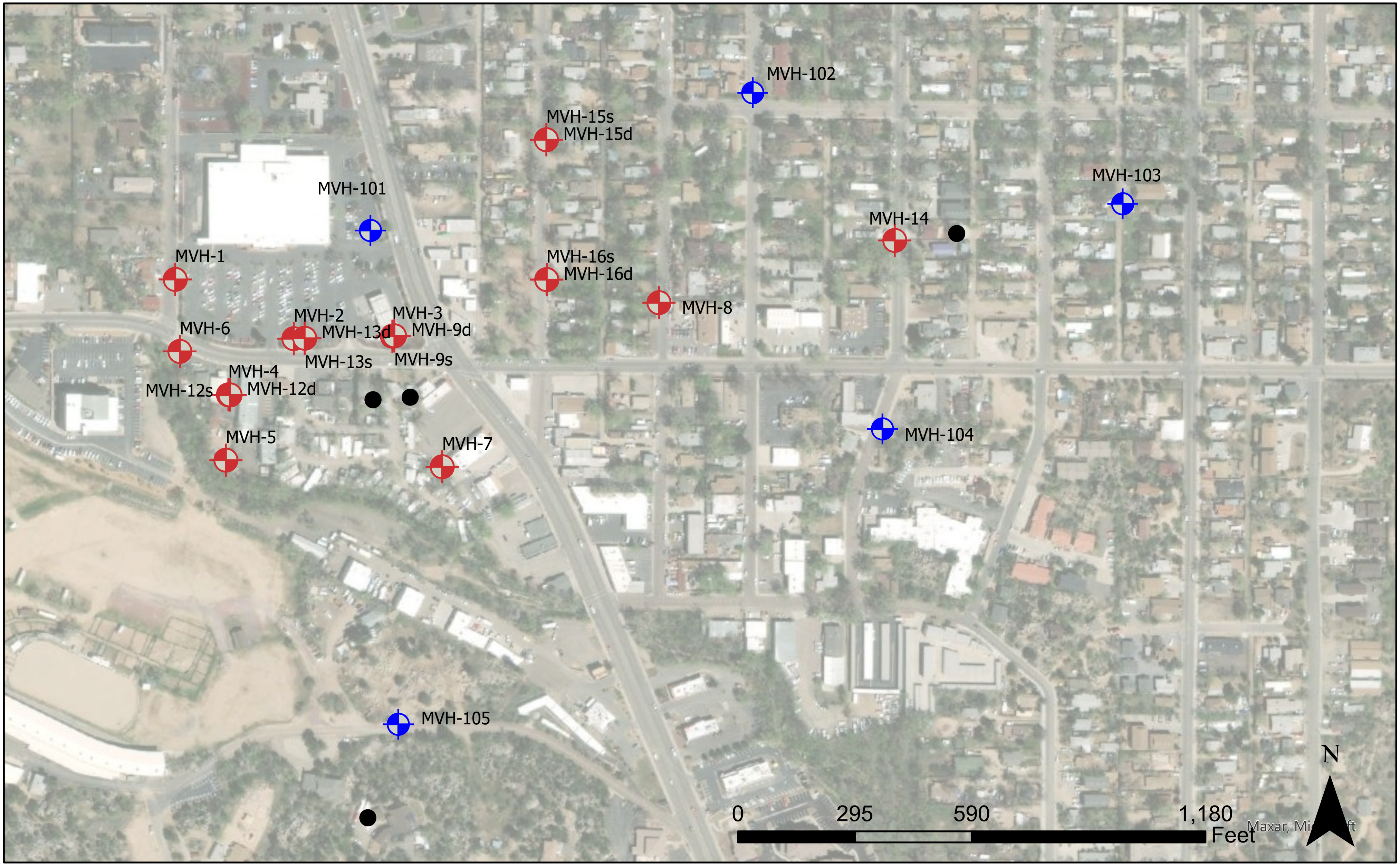
Legend

- Existing Monitoring Wells
- Existing Extraction Well
- Private Wells
- 211 2022 PCE Result
- Conceptual Paired Injection Wells
- Example Remedy Monitoring Wells
- Calculated EW-1 Capture Zone

ADEQ Arizona Department of Environmental Quality

Notes:
All results in µg/L
*PCE result from 2020

Figure 7
Reference Remedy Conceptual Design
Feasibility Study
Miller Valley Rd. and Hillside Ave. WQARF Site



Legend

- Existing Monitoring Well
- Example Less Aggressive Remedy Monitoring Well
- Private wells with known water use

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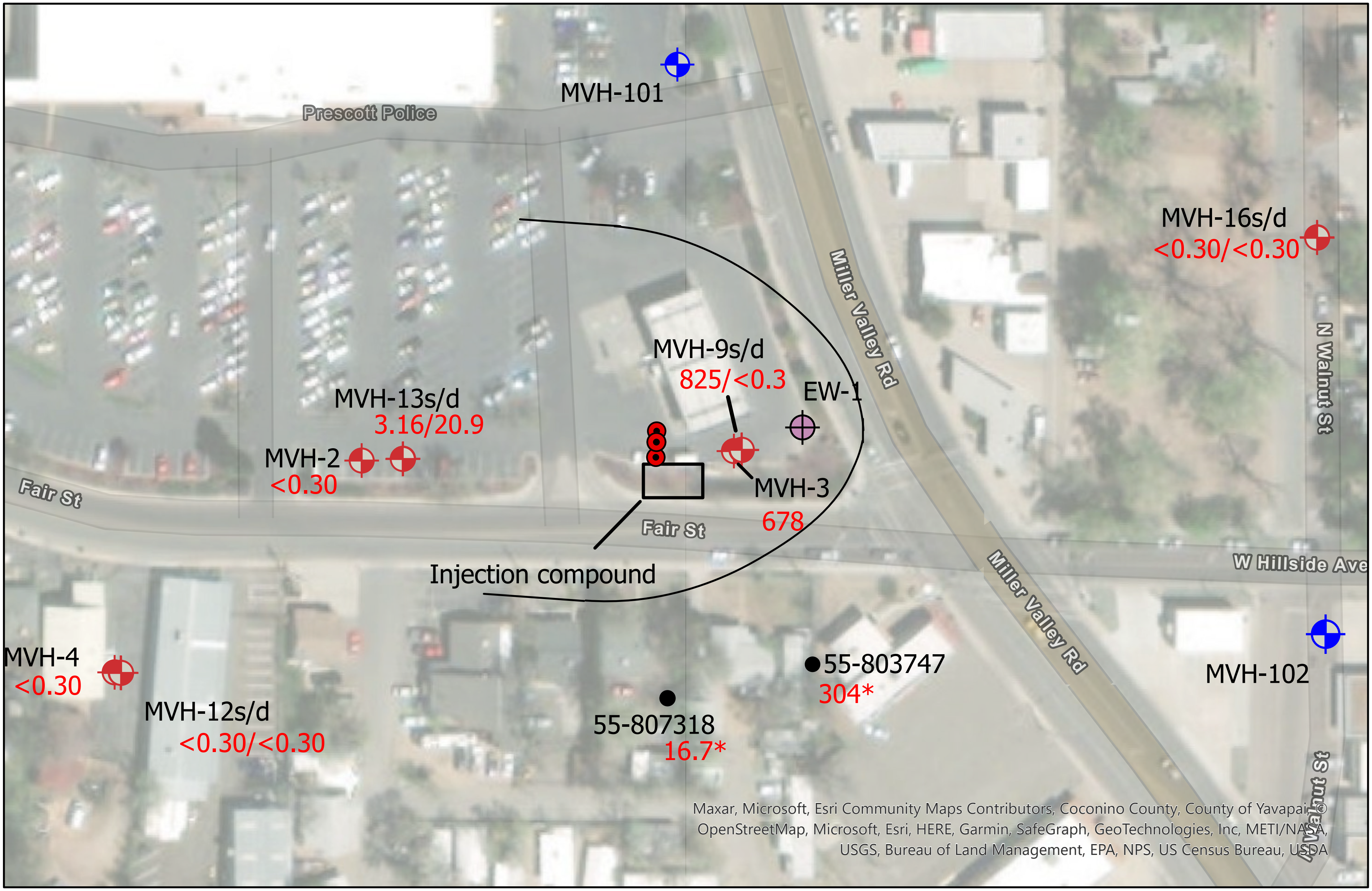
Arizona Department of Environmental Quality

Figure 8
Less Aggressive Remedy Conceptual Design
Feasibility Study
Miller Valley Rd. and Hillside Ave. WQARF Site



Legend

- Existing Monitoring Wells
- Existing Extraction Well
- Private Wells
- 211 — 2022 PCE Result
- Conceptual Paired Injection Wells
- Example Remedy Monitoring Wells
- Calculated EW-1 Capture Zone

ADEQ
Arizona Department of Environmental Quality

Notes:
All results in µg/L
*PCE result from 2020

Figure 9
More Aggressive Remedy Conceptual Design
Feasibility Study
Miller Valley Rd. and Hillside Ave. WQARF Site

TABLES

Table 1: Groundwater VOC Sampling Results
Feasibility Study, Miller Valley Rd and Hillside Ave WQARF Site

Well ID	Date	Tetrachloroethene	Trichloroethene	cis-1,2-DCE	Vinyl Chloride
		µg/L	µg/L	µg/L	µg/L
MVH-1	3/19/2018	<0.50	<0.50	<0.50	<0.50
	10/15/2018	<0.50	<0.50	<0.50	<0.50
	2/26/2019	<0.50	<0.50	<0.50	<0.50
	12/3/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/30/2022	<0.30	<0.19	<0.126	<0.149
MVH-2	3/19/2018	<0.50	<0.50	<0.50	<0.50
	10/11/2018	**0.60**	<0.50	<0.50	<0.50
	2/26/2019	**1.2**	<0.50	<0.50	<0.50
	12/3/2019	<0.37	<0.41	<0.42	<0.33
	5/6/2020	**0.56**	<0.36	<0.39	<0.30
	8/29/2022	<0.30	<0.19	<0.126	<0.149
MVH-3	3/19/2018	**3.1**	<0.50	**0.99**	<0.50
	10/11/2018	**120**	**4.8**	**2.0**	<0.50
	2/26/2019	**76**	**2.7**	**0.65**	<0.50
	12/3/2019	**82.8**	**8.7**	**5.5**	<0.33
	12/3/2019 (du)	**80.5**	**9.7**	**5.4**	<0.33
	5/6/2020	**211**	**10**	**4.2**	<0.30
	5/6/2020 (du)	**159**	**10.1**	**4.4**	<0.30
	8/26/2020	**273**	**8.7**	**5.1**	<2.34
	8/30/2022	**678**	**23.2**	**12.6**	**0.222 J**
MVH-4	3/19/2018	<0.50	<0.50	<0.50	<0.50
	10/8/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/3/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/29/2022	<0.30	<0.19	<0.126	<0.149
MVH-5	3/19/2018	<0.50	<0.50	<0.50	<0.50
	10/7/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/3/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/29/2022	<0.30	<0.19	<0.126	<0.149
MVH-6	3/19/2018	<0.50	<0.50	<0.50	<0.50
	10/15/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/3/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/29/2022	<0.30	<0.19	<0.126	<0.149
MVH-7	3/19/2018	<0.50	<0.50	<0.50	<0.50
	10/15/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/2/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/29/2022	<0.30	<0.19	<0.126	<0.149
MVH-8	3/19/2018	<0.50	<0.50	<0.50	<0.50
	10/14/2018	<0.50	<0.50	<0.50	<0.50
	2/26/2019	<0.50	<0.50	<0.50	<0.50
	12/2/2019	<0.37	<0.41	<0.42	<0.33
	5/6/2020	<0.30	<0.36	<0.39	<0.30
	8/29/2022	<0.30	<0.19	<0.126	<0.149
MVH-9s	10/11/2018	**560**	**7.1**	<0.50	<0.50
	2/26/2019	**740**	**6.4**	**11**	<0.50
	12/3/2019	**194**	**6.8**	**12.8**	<0.33
	12/3/2019 (du)	**238**	**6.7**	**11.9**	<0.33
	5/6/2020	**705**	**8.5**	**12.2**	<0.30
	8/26/2020	**670**	**<4.75**	**6.5**	<5.85
	8/30/2022	**825**	**16.3**	**27.5**	**0.192 J**
MVH-9d	10/10/2018	**3.7**	<0.50	<0.50	<0.50
	2/26/2019	**3.0**	<0.50	<0.50	<0.50
	12/3/2019	**0.47 J**	**2.1**	**0.72**	<0.33
	5/6/2020	**1.2**	**2.1**	**0.50**	<0.30
	8/30/2022	**<0.3**	**0.8**	**1.41**	<0.149
MVH-10d	10/16/2018	<0.50	<0.50	<0.50	<0.50
MVH-12s	10/8/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/3/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/29/2022	0.919	<0.19	<0.126	<0.149
MVH-12d	10/7/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/3/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	5/5/2020 (du)	<0.30	<0.36	<0.39	<0.30
	8/29/2022	<0.30	<0.19	<0.126	<0.149
MVH-13s	10/10/2018	**3.0**	<0.50	<0.50	<0.50
	2/26/2019	**3.0**	<0.50	<0.50	<0.50
	12/3/2019	**2.3**	<0.41	<0.42	<0.33
	5/6/2020	**6.8**	<0.36	<0.39	<0.30
	8/29/2022	**3.2**	**0.203 J**	0.175	<0.149
MVH-13d	10/10/2018	**1.1**	<0.50	<0.50	<0.50
	2/26/2019	**3.8**	<0.50	<0.50	<0.50
	12/3/2019	**4.3**	<0.41	**0.47 J**	<0.33
	5/6/2020	**13.5**	<0.36	<0.39	<0.30
	8/29/2022	**20.9**	**0.466 J**	<0.126	<0.149
MVH-14	8/15/2018	<0.50	<0.50	<0.50	<0.50
	10/16/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/2/2019	<0.37	<0.41	<0.42	<0.33
	5/6/2020	<0.30	<0.36	<0.39	<0.30
	8/22/2022	<0.30	<0.19	<0.126	<0.149

Table 1: Groundwater VOC Sampling Results
Feasibility Study, Miller Valley Rd and Hillside Ave WQARF Site

Well ID	Date	Tetrachloroethene	Trichloroethene	cis-1,2-DCE	Vinyl Chloride
		µg/L	µg/L	µg/L	µg/L
MVH-15s	8/15/2018	<0.50	<0.50	<0.50	<0.50
	10/16/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/2/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/29/2022	<0.30	<0.19	<0.126	<0.149
MVH-15d	8/15/2018	<0.50	<0.50	<0.50	<0.50
	10/9/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/2/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/30/2022	<0.30	<0.19	<0.126	<0.149
MVH-16s	8/15/2018	<0.50	<0.50	<0.50	<0.50
	10/17/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/2/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/30/2022	<0.30	<0.19	<0.126	<0.149
MVH-16d	8/15/2018	<0.50	<0.50	<0.50	<0.50
	10/9/2018	<0.50	<0.50	<0.50	<0.50
	2/27/2019	<0.50	<0.50	<0.50	<0.50
	12/2/2019	<0.37	<0.41	<0.42	<0.33
	5/5/2020	<0.30	<0.36	<0.39	<0.30
	8/30/2022	<0.30	<0.19	<0.126	<0.149

J - Estimated value below Method Reporting Limit

Bold - Compound detected

Highlight - Over Aquifer Water Quality Standard

Parameter	AWQS	MVH-1 10/15/2018	MVH-2 10/11/2018	MVH-3 10/11/2018	MVH-4 10/8/2018	MVH-5 10/7/2018	MVH-6 10/15/2018	MVH-7 10/15/2018	MVH-8 10/14/2018	MVH-9s 10/11/2018	MVH-9d 10/10/2018	MVH-10d 10/16/2018	MVH-12s 10/8/2018	MVH-12d 10/7/2018	MVH-13s 10/10/2018	MVH-13d 10/10/2018	MVH-14 10/16/2018	MVH-15s 10/16/2018	MVH-15d 10/9/2018	MVH-16s 10/17/2018	MVH-16d 10/9/2018
Purge Parameters																					
Temperature (°C)	NE	16.4	19.3	18.4	18.1	15.4	19.4	15.9	15.6	18.1	18.0	16.0	18.2	16.5	18.4	20.4	14.0	15.7	18.2	16.0	15.9
Conductivity (µS/cm)	NE	654	869	288.8	861	955	1323	675	292.2	493.2	281.4	613	681	1111	579	273.3	588.2	332.6	262.7	1641.0	384.9
pH	NE	6.72	6.75	7.24	6.66	6.62	6.96	6.98	7.21	7.25	8.52	6.92	6.97	11.62	11.19	8.09	7.22	10.19	8.42	11.35	7.88
Oxidation Reduction Potential (mV)	NE	92.9	36.9	47.4	174.8	266.6	85.2	86.9	44.8	-72.9	-244.6	62.6	248.3	80.7	-89.9	-243.3	-183.5	-287.6	-213.6	-98.8	-162.2
Dissolved Oxygen (mg/L)	NE	1.90	0.17	0.93	3.63	3.66	1.38	2.57	0.95	0.85	0.48	0.34	4.11	0.85	0.54	0.45	0.18	0.31	0.51	1.99	0.41
Field Parameters (mg/L)																					
Nitrate	NE	**10.0**	**5.2**	**2.9**	**6.8**	**9.7**	**4.2**	**10.1**	**>30**	**>30**	**2.7**	**3.0**	**10.9**	**0.8**	**1.7**	**8.4**	**9.8**	<0.3	**>30**	**1.6**	**0.2**
Sulfide	NE	**0.09**	**0.04**	**0.12**	**0.64**	<0.005	**0.47**	**0.37**	**0.69**	**0.75**	**3.15 ***	**0.16**	**0.13**	<0.005	**0.26**	**3.5 ***	**2.25 ***	**0.13**	**>0.8**	<0.005	**0.53**
Ferrous Iron	NE	<0.02	<0.02	**0.02**	<0.02	<0.02	**0.03**	**0.07**	<0.02	**0.25**	**0.02**	<0.02	<0.02	<0.02	**0.02**	<0.02	**0.77**	**0.25**	**0.14**	**0.95**	**0.10**
Manganese	NE	<0.1	**0.2**	<0.1	<0.1	<0.1	**0.3**	<0.1	<0.1	**0.1**	**0.4**	<0.1	**0.2**	<0.1	<0.1	**0.4**	**1.6**	**0.5**	<0.1	<0.1	**0.8**
Dissolved Gases by RSK-175 (mg/L)																					
Ethene	NE	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028	<0.0028
Ethane	NE	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	**0.0057**	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	<0.0020	**0.0033**	**0.0026**	<0.0020	**0.0024**
Methane	NE	<0.00099	<0.00099	<0.00099	<0.00099	<0.00099	<0.00099	<0.00099	<0.00099	<0.00099	**0.012**	<0.00099	<0.00099	<0.00099	**0.0023**	**0.0013**	**0.0013**	**0.0043**	**0.0039**	<0.00099	**0.0044**
Anions, Ion Chromatography by 300.0 (mg/L)																					
Chloride	NE	**67**	**64**	**15**	**100**	**130**	**190**	**58**	**17**	**46**	**10**	**43**	**76**	**38**	**52**	**12**	**57**	**8.5**	**10**	**7.6**	**35**
Sulfate	NE	**46**	**40**	**9.3**	**44**	**56**	**95**	**37**	**19**	**21**	<2.0	**45**	**40**	**110**	**42**	<2.0	**56**	**31**	**3.0**	**6.2**	**22**
Metals by 200.8 (µg/L)																					
Chromium (dissolved)	100	NA	NA	NA	**2.5**	<1.0	NA	NA	NA	NA	NA	NA	<1.0	**3.9**	NA	NA	NA	NA	NA	NA	NA
Hexavalent Chromium by SM 3500 CR B (mg/L)																					
Hexavalent Chromium	NE	NA	NA	NA	<0.0050	<0.0050	NA	NA	NA	NA	NA	NA	<0.0050	<0.0050	NA	NA	NA	NA	NA	NA	NA
General Chemistry by SM 2320B (mg/L)																					
Alkalinity as CaCO3	NE	**130**	**320**	**110**	**200**	**170**	**310**	**180**	**100**	**140**	**130**	**200**	**140**	**190**	**56**	**120**	**170**	**95**	**110**	**290**	**110**
Bicarbonate (HCO3-)	NE	**158.6**	**390.4**	**134.2**	**244**	**207.4**	**378.2**	**219.6**	**122**	**170.8**	**158.6**	**244**	**170.8**	<6.0	<6.0	**146.4**	**207.4**	<6.0	**134.2**	<6.0	**134.2**
Carbonate (CO32-)	NE	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	**59.4**	**16.2**	<6.0	<6.0	**24**	<6.0	**43.8**	<6.0
Alkalinity, Phenolphthalein	NE	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	**140**	**43**	<6.0	<6.0	**75**	<6.0	**260**	<6.0
Hydroxide (OH-)	NE	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	**32.3**	**9.86**	<6.0	<6.0	**18.7**	<6.0	**74.8**	<6.0
General Chemistry- Dissolved by SM5310B (mg/L)																					
Dissolved Organic Carbon	NE	<1.0	**1.6**	<1.0	<1.0	<1.0	**1.2**	<1.0	<1.0	<1.0	**3.0**	**1.5**	<1.0	**15**	**2.9**	**1.0**	**1.2**	**6.0**	**1.9**	<1.0	**1.8**

Notes:

AWQS = Aquifer Water Quality Standards (A.A.C. R18-11 Article 4)

Bold values indicate concentration above the reporting limit.

°C = degress Celcius

µS/cm = microSiemens per centimeter

mV = millivolts

mg/L = milligrams per liter

µg/L = micrograms per liter

* Sample required dilution due to high concentration of analyte; reported value based on 5-fold dilution factor

Alkalinities converted to species concentrations using the following conversion factors: HCO_3^- 1.22; CO_3^{2-} 0.6; OH^- 0.34

NE = not established

NA = not anlayzed

Source: Hydro Geo Chem, April 2020

Groundwater Geochemistry Results
October 2018

Miller Valley Rd and Hillside Ave WQARF Site
Feasibility Study

MATRIXNEWORLD
Engineering Progress

January 11, 2022 Project 21-644

TABLE NUMBER:
2

Analyte	Sample Date	Well MVH-3 @ 40 ft btoc	Well MVH-9s @ 100 ft btoc	Units
Inorganic Chemistry				
Alkalinity (CaCO3)	8/26/2020	119	128	mg/L
Nitrate (N)	8/26/2020	3.23	8.21	mg/L
Sulfate	8/26/2020	15.6	19.8	mg/L
Total Metals				
Iron	8/26/2020	0.688	12.9	mg/L
Manganese	8/26/2020	0.0226	0.717	mg/L
Nutrients				
Total Organic Carbon (TOC)	8/26/2020	0.847	0.582	mg/L
Total Kjeldahl Nitrogen (TKN)	8/26/2020	<140	<140	µg/L
Ammonia	8/26/2020	<117	<117	µg/L
Phosphorus	8/26/2020	82.3	328	µg/L
Chlorinated Volatile Organic Compounds (CVOCs)				
Tetrachloroethene (PCE)	8/26/2020	273	670	µg/L
Trichloroethene (TCE)	8/26/2020	8.74	<4.75	µg/L
cis-1,2-dichloroethene (*cis*-1,2-DCE)	8/26/2020	5.09	6.53	µg/L
Vinyl Chloride (VC)	8/26/2020	<2.34	5.85 J3	µg/L
Field Parameters				
Temperature	8/26/2020	24.38	21.81	°C
Ferrous Iron	8/26/2020	0.07	0.21	mg/L
Electrical Conductivity (EC)	8/26/2020	316	428	µS/cm
pH	8/26/2020	6.81	6.99	SU
Oxidation Reduction Potential (ORP)	8/26/2020	-124	-118	mV
Dissolved Oxygen (DO)	8/26/2020	2.83	1.93	mg/L

Notes:

ft btoc = Feet below top of casing
mg/L = Milligrams per liter
µg/L = Micrograms per liter
ppm Parts per million
°C = Degrees Celsius
µS/cm = Microsiemens per centimeter
SU = Standard units
mV = millivolts
NA = Not analyzed
< = Less than. The number shown is the analytical limit of detection for that consituent.
J3 = The associated batch QC was outside the established quality control range for precision.

Groundwater Sampling Results
August 2020

Miller Valley Rd and Hillside Ave WQARF Site
Feasibility Study

MATRIXNEWORLD
Engineering Progress

January 11, 2023 Project 21-644

TABLE NUMBER:
3

Sample Name	Sample Date	1,2-DCP	2-Butanone	Acetone	Benzene	Chloroform	*cis*-1,2-DCE	Ethyl benzene	MTBE	PCE	Toluene	TCE
		ug/L										
Private Wells Sampled in 2018												
730 Dameron	8/21/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
727 Ruth	8/21/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
559 Kildare (Steinbrink-1)[b]	8/22/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
833 Sunset / 836 Valley	8/23/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
737 Ruth	8/23/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	**5.7**	<0.50
923 Fair	8/29/2018	<0.50	<5.0	<10	<0.50	<0.50	**2.5**	<0.50	<0.50	**430**	<0.50	**3.2**
815 Rodeo	10/31/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
925 Fair	11/1/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	**27**	<0.50	**0.72**
507 Hillside	11/1/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
528 Lincoln	11/12/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Fry's S (702 Miller Valley Rd)	10/11/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	**0.58**	**7.0**	<0.50	<0.50
Fry's N (702 Miller Valley Rd)	10/11/2018	<0.50	<5.0	<10	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Private Wells Sampled in 2019												
940 Dameron	1/29/2019	<0.50	-	**80**	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Fry's S (702 Miller Valley Rd)	12/3/2019	<0.38	-	<10	<0.40	<0.39	<0.42	<0.41	<0.37	**1.8**	<0.42	<0.36
Fry's N (702 Miller Valley Rd)	12/3/2019	<0.38	-	<10	<0.40	<0.39	<0.42	<0.41	<0.37	<0.37	<0.42	<0.36
925 Fair St	12/3/2019	<0.38	-	<10	<0.40	<0.39	<0.42	<0.41	<0.37	**16.7**	<0.42	**0.5**
Private Wells Sampled in 2020												
Fry's S (702 Miller Valley Rd)	5/6/2020	<0.34	-	<10	<0.30	<0.35	<0.39	<0.38	<0.72	**0.76**	<0.30	<0.36
Fry's N (702 Miller Valley Rd)	5/6/2020	<0.34	-	<10	<0.30	<0.35	<0.39	<0.38	<0.72	**0.41**	<0.30	<0.36
923 Fair St	5/5/2020	<0.34	-	<10	<0.30	<0.35	**4.1**	<0.38	<0.72	**304**	<0.30	**5.4**
AWQS		5	NE	NE	5	NE	70	700	NE	5	1,000	5

Notes:

AWQS = Aquifer Water Quality Standards (A.A.C. R18-11 Article 4)

This table presents an abridged list of EPA Method 8260B. Compounds not included in this table were below reporting limits for all samples.

2015 results are from the MVH Preliminary Investigation and were reported previously (ADEQ, 2016).

SGS Accutest performed laboratory analysis for samples collected by ADEQ on 5/16/2017. Xenco Laboratories performed all other 2017 laboratory analyses.

TestAmerica, Inc. performed laboratory analysis in 2018 and 2019.

***Bold** values indicate detection above the reporting limit. **Highlighted** values indicate an exceedance of the AWQS.*

NE = Not Established

ug/L = micrograms per Liter

[a] 841 Sunset field duplicate was labeled with blind field ID Sunset 888

[b] labeled incorrectly as 539 Kildare on analytical report

TCE = trichloroethene; PCE = tetrachloroethene; cis-1,2-DCE = cis-1,2-dichloroethene; 1,2-DCP = 1,2-dichloropropane

Acetone was detected in all trip blanks submitted to Xenco Laboratories in 2017. No trip blank was available for SGS analyses. Acetone was not detected in trip blanks for 2018 or 2019.

Source: Hydro Geo Chem, June 2020

PRIVATE WELL ANALYTICAL RESULTS
2018, 2019, 2020

Miller Valley Rd and Hillside Ave WQARF Site
Feasibility Study

MATRIXNEWORLD
Engineering Progress

January 11, 2023 Project 21-644

TABLE NUMBER:
4

Table 5
Summary of Remedial Technology Screening Criteria
Miller Valley Rd and Hillside Ave WQARF Site
Feasibility Study

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Technology	Treatment Effectiveness	Constructability/Flexibility/Expandability	Operation & Maintenance Requirements	Operational Hazards	Cost Effectiveness	Overall Feasibility for Site	Retained	Reason for Elimination
Monitored Natural Attenuation (MNA)	Can be effective for CVOCs in groundwater depending on aquifer chemistry.	No barriers to constructability and no barriers to expansion.	None	No special hazard considerations	Cost effective if natural processes can be established.	Historical data show that natural processes are slow at reducing COCs in groundwater. However, MNA can be used in combination with other remedial strategies to achieve ROs.	Yes	
Enhanced Reductive Dechlorination (ERD)	Effective for CVOCs in groundwater.	Due to site constraints that are present there is limited access to the entire footprint of the CVOC plume.	None. Although, additional injections may be needed.	No special hazard considerations	Cost effective for medium to high CVOCs in groundwater.	Based on the results from the Site, ERD is an appropriate technology for site groundwater remediation.	Yes	
In Situ Chemical Oxidation (ISCO)	Effective for CVOCs in groundwater.	Due to site constraints that are present there is limited access to the entire footprint of the CVOC plume.	None. Although, additional injections may be needed.	Chemical oxidizers required safe handling precautions.	Cost effective for very high concentrations of CVOCs in groundwater.	Can be effective as a source mitigation technology. Typically requires multiple injection points. May require additional injections over time.	No	Not feasible as a stand alone treatment technology for the site. ISCO would require more amendment, and site constraints would prevent the scale of injections needed.
In Situ Chemical Reduction (ISCR)	Effective for CVOCs in groundwater.	Due to site constraints that are present there is limited access to the entire footprint of the CVOC plume.	None. Although, additional injections may be needed.	Chemical reductants require safe handling precautions.	Cost effective for very high concentrations of CVOCs in groundwater.	Can be effective as a source mitigation technology. Typically requires multiple injection points. May require additional injections over time. ISCR using nano to micron scale ZVI can be combined with ERD to promote highly anaerobic conditions and abiotic degradation of the CVOCs.	Yes	
In Situ Liquid Granular Activated Carbon	Effective for CVOCs in groundwater.	Due to site constraints that are present there is limited access to the entire footprint of the CVOC plume.	None. Although, additional injections may be needed.	No special hazard considerations.	Not cost effective given the site constraints and depth of contamination.	Can be effective for source control and/or controlled migration. Requires multiple injection points and site constraints and access would be problematic. Radius of influence may be limited.	No	Not as cost effective as other in situ treatment approaches. The depth of contamination are problematic if trenching is used. Site constraints will prevent the installation of a robust injection well network to adequately distribute the amendment if injection wells are used.
Permeable Reactive Barrier	Effective for CVOCs in groundwater.	Due to site constraints that are present there is limited access to the entire footprint of the CVOC plume. Additionally, trenching is not practical to due depth of contamination.	None	Potential hazards with injecting under high pressure.	Not cost effective given the site constraints and depth of contamination.	Not feasible due to depth of contamination and site constraints and access limitations.	No	Not as cost effective as other in situ treatment approaches. The depth of contamination is problematic if trenching is used. Site constraints will prevent the installation of a robust injection well network to adequately distribute the amendment if injection wells are needed.
In Situ Thermal Remediation	Effective for CVOCs in groundwater.	Due to site constraints that are present there is limited access to the entire footprint of the CVOC plume. Additionally, depth of contamination limits implementation.	Short and long term operation and maintenance costs. If SVE wells are employed to ensure pneumatic control for volatilized CVOCs , this will increase O&M efforts.	High voltage requirement to generate in situ heat Could damage existing utility infrastructure.	Not cost effective given the site constraints and depth of contamination.	Very aggressive remediation approach, which is appropriate to address high concentrations of CVOCs in vadose zone and groundwater.	No	Can be cost prohibitive and not appropriate for the levels of CVOCs observed in the groundwater Site constraints will prevent the installation of a robust well network to adequately cover the horizontal and vertical distribution of contaminants.
Groundwater Extraction & Treatment (GET)	Effective for CVOC in groundwater. Facilitates hydraulic containment and to control plume migration. Pore volume flushing benefits.	Due to site constraints that are present there is limited access to the entire footprint of the CVOC plume. May be difficult to locate wells that are hydraulically optimal.	Long term operation and maintenance on well equipment, treatment system equipment, that will include well rehabilitation and carbon change outs.	No special hazard considerations.	Cost effective to implement. Long term operation and maintenance costs can be problematic.	Typically used for plume control and mass removal at high concentrations in a source area. Can be used in concert with ERD to promote distribution of ERD biostimulation and bioaugmentation amendments.	Yes	
Wellhead Treatment	Effective for CVOCs in groundwater.	Need to ask well owners permission to install and operate.	Monthly and annual operational checks and sampling to monitor effectiveness of treatment.	No special hazard considerations.	Cost effective to protect well owners.	Can be feasible to protect well owners.	Yes	
No Action	Not effective for CVOCs in groundwater.	No barriers to constructability and no barriers to expansion.	None	None	Very cost effective.	Not feasible considering the ROs and the protection or irrigation and public water supplies.	No	Will not reduce CVOC mass in groundwater. Irrigation and public water supplies will remain at risk.

Table 6
Comparison of Reference, Less Aggressive, and More Aggressive Remedies
Miller Valley Rd and Hillside Ave WQARF Site
Feasibility Study

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Criteria		Reference Remedy	Less Aggressive Remedy	More Aggressive Remedy
THRESHOLD REQUIREMENTS	**Remedial Strategies**	Enhanced Reductive Dechlorination (ERD) via *In Situ* Bioremediation (ISB) using biostimulation in combination with bioaugmentation. Groundwater extraction and injection system to promote the distribution of ERD amendments and provide hydraulic containment. Wellhead treatment using GAC for two private wells. Performance and groundwater monitoring Two additional monitor wells to refine the extent of CVOC contamination	Monitored Natural Attenuation. Groundwater Monitoring Wellhead treatment using GAC for three private wells Five additional monitor wells to refine the extent of CVOC contamination	*In Situ* Chemical Reduction (ISCR) ERD Groundwater extraction/injection and Treatment (GET) Wellhead treatment using GAC for domestic wells Groundwater and Performance monitoring Two additional monitor wells to refine the extent of CVOC contamination
	Contingency Strategies	None	ERD biostimulation/bioaugmentation injection	None
	Achievement of Remedial Objectives	Yes Remedial approach reduces CVOCs in groundwater and is consistent with achieving ROs described in Appendix L in the RI Report.	Yes Due to the current aquifer chemistry, natural degradation of CVOCs in groundwater is not occurring at appreciable rates. Wellhead treatment is needed to achieve ROs described in Appendix L in the RI Report	Yes Remedial approach reduces CVOCs in groundwater and is consistent with achieving ROs described in Appendix L in the RI Report
	Consistency with General Land Use	Yes. Each remedy is consistent with land use plans described Appendix K in RI Report.	Yes. Each remedy is consistent with land use plans described Appendix K in RI Report.	Yes. Each remedy is consistent with land use plans described Appendix K in RI Report.
	Consistency with Water Management Plans	Yes. Improves water quality and does not affect the quantity of groundwater available for pumping.	Possibly - Minimal positive impact on water quality and does not affect the quantity of groundwater available for pumping	Yes. Improves water quality and does not affect the quantity of groundwater available for pumping
PRACTICALITY	**Feasibility**	**Moderate to High:** Comparable implementations at similar sites using ISB have been successful. Site presents challenges in locating extraction wells, injection wells and treatment systems. Groundwater sampling results demonstrated that the ISB technology is appropriate for CVOC-contaminated groundwater at the site.	**High**: Monitoring can be readily implemented at the site. Needs additional monitoring wells to refine plume extents and evaluate water quality and demonstrate remedial effectiveness.	**Moderate to High:** GET systems, ISB and ISCR are demonstrated technologies for CVOC-contaminated groundwater that can be readily implemented at the site. Site presents challenges in locating extraction wells, injection wells and treatment systems.
	Short Term Effectiveness	**Moderate**: Groundwater monitoring data do not demonstrate a considerable degree of natural reductive dechlorination, which could lead to a lag phase that may require additional injections.	**Low - Medium:** Monitoring of the contaminants has no short-term effectiveness. Wellhead treatment has high short-term effectiveness and achieves ROs	**Moderate to High**: Anaerobic aquifer conditions using ISCR injections coupled with groundwater extraction will take time to establish.
	Long Term Effectiveness	**Moderate to High**: Once a microbial community has been established, ERD is very effective in the long term. Groundwater extraction/injection and treatment will be used promote the distribution of amendments and pore volume flushing. Wellhead treatment will provide additional protection to affected private supply wells as needed	**Low - Medium** : Long term effectiveness will depend on the ability of the aquifer to naturally degrade CVOCs. Continued wellhead treatment is needed in order to maintain ROs	**High**: ISCR can be used to quickly removed CVOC contaminant mass and establish aquifer conditions that are conducive for ERD. Once a microbial community has been established, ERD is very effective in the long term. The GET system will establish flow paths to promote the distribution of amendments and pore volume flushing Wellhead treatment will provide additional protection to affected private supply wells as needed
	Reliability	**High**: Groundwater sampling results demonstrated that in situ bioremediation would have a high level of success. This technology has been used in similar hydrogeological conditions and is considered reliable.	**Low-Medium:** Natural abiotic processes can be reliable but may not occurring at a significant rate within the aquifer, but wellhead treatment is highly reliable technology	**High**: ISCR coupled with ISB Technology has been used in similar hydrogeological conditions and is considered reliable. GET systems are reliable technology to plume containment, promote the distribution of amendments and pore volume flushing. Wellhead treatment is a reliable technology to protect domestic water supplies

Table 6 cont.
Comparison of Reference, Less Aggressive, and More Aggressive Remedies
Miller Valley Rd and Hillside Ave WQARF Site
Feasibility Study

MATRIXNEWORLD Engineering Progress

Criteria		Reference Remedy	Less Aggressive Remedy	More Aggressive Remedy
COST BENEFIT ANALYSIS	Risk	**Low:** ISB reduces the mass of CVOCs in groundwater and the mobility of contaminants. Treatment addresses the area with elevated CVOC concentrations. Will not pose a significant threat to the community, workers, or the environment.	**High:** Due to aquifer conditions, elevated CVOCs in source area may not decreasing in site groundwater at a fast rate. MNA as a standalone treatment technology does not address the area with elevated CVOC concentrations. Will not pose a significant threat to the community, workers, or the environment	**Low:** ISB and ISCR along with GET will reduce the mass of CVOCs in groundwater. Treatment addresses the area with elevated CVOC concentrations Will not pose a significant threat to the community, workers, or the environment
	Benefit of Remediation	**High:** ISB will reduce the mass and decrease the mobility of COVCs in groundwater, and reduce time frame to reach ROs. Estimated time for remediation is 15 -20 years The GET system will help promote amendment distribution, provide hydraulic containment. The GET system will also accelerate aquifer restoration time frames. Wellhead treatment will protect private supply wells as needed	**Moderate**: Monitoring provides data to evaluate COCs throughout plume and identify trends in data to estimate plume longevity Wellhead treatment will protect private supply wells as needed Estimated time for remediation is 30+ years	**High**: ISB in combination with ISCR will reduce the mass and decrease the mobility of CVOCs in groundwater, and reduce time frame to reach ROs.. Estimated time for remediation is 15 -20 years The GET system will help promote amendment distribution, provide hydraulic control, and accelerate aquifer restoration time frames. Wellhead treatment will protect private supply wells as needed
	Cost	**High:** Capital Cost to Implement: **$ 998K to $1.9M** Total Monitoring Cost: **$820K to $1.5M** O&M Costs: GET System; **$371k to $690k** Wellhead Treatment; **$1.6M to $3.0M** **Total Remedy Costs: $3.8M to $7.0M** **No Contingency costs** **Total Costs: $3.8M to $7.0M**	**Moderate to High:** Capital Cost to Implement: **$ 523K to $971K** Total Monitoring Cost: **$2.3M to $4.2M** O&M Costs; Wellhead Treatment; **$4.1M to $7.5M** **Total Remedy Costs; $6.9M to $12.8M** **Contingency costs for ERD injections $393k to $731M** **Total Costs Incl. Contingency: 7.3M - 13.5M**	**High:** Capital Cost to Implement: **$1.9M to $3.6M** Annual Monitoring cost: **$911K to $1.7M** O&M Costs: GET System; **$510K to $948K** Wellhead Treatment; **$2.3M to $2.9M** **Total Remedy Costs: $4.9M - $9.1M** **No contingency costs** **Total Costs: $4.9M - $9.1M**

APPENDIX A

Detailed Cost Estimate

REFERENCE REMEDY COST ESTIMATE			
ERD system	**Costs**	**Minus 30%**	**Plus 30%**
Remedial System Design and Coordination	$ 65,000	$ 45,500	$ 84,500
ERD System Construction (piping, trenching, plumbing etc.)	$ 120,000	$ 84,000	$ 156,000
Injection Well Installation (assuming four wells)	$ 200,000	$ 140,000	$ 260,000
Reporting	$ 40,000	$ 28,000	$ 52,000
Subtotal ERD System	**$ 425,000**	**$ 297,500**	**$ 552,500**
ERD injections and Performance Monitoring	**Costs**	**Minus 30%**	**Plus 30%**
Biostimulation/Bioaugmentation Injections (Incl. 20,000 gallons ERD Substrate)			
Year 1 Injection	$ 87,000	$ 60,900	$ 113,100
Year 3 Injection (Includes 3% Annual Inflation)	$ 92,298	$ 64,609	$ 119,988
Year 5 Injection (Includes 3% Annual Inflation)	$ 97,919	$ 68,543	$ 127,295
ERD Injections Subtotal	**$ 277,218**	**$ 194,052**	**$ 360,383**
Performance Monitoring			
Year 1	$ 25,000	$ 17,500	$ 32,500
Year 2	$ 25,750	$ 18,025	$ 33,475
Year 3	$ 26,523	$ 18,566	$ 34,479
Year 4	$ 27,318	$ 19,123	$ 35,514
Year 5	$ 28,138	$ 19,696	$ 36,579
Year 6	$ 28,982	$ 20,287	$ 37,676
Performance Monitoring Subtotal	**$ 161,710**	**$ 113,197**	**$ 210,223**
Annual Reporting for 6 years	**$ 180,000**	**$ 126,000**	**$ 234,000**
Subtotal ERD Injections and Performance Monitoring	**$ 618,928**	**$ 433,249**	**$ 804,606**
Total ERD System, Injections, and Monitoring Costs	**$ 1,043,928**	**$ 730,749**	**$ 1,357,106**
Annual monitoring and MNA	**Costs**	**Minus 30%**	**Plus 30%**
Annual Monitoring Per Year	$ 25,000	$ 17,500	$ 32,500
Year 1-6 Subtotal (Includes 3% Annual Inflation)	**$ 161,710**	**$ 113,197**	**$ 210,223**
Semi-Annual MNA Per Year	$ 50,000	$ 35,000	$ 65,000
Year 7 - 11 Subtotal (Includes 3% Annual Inflation)	**$ 316,969**	**$ 221,879**	**$ 412,060**
Annual MNA Per Year	$ 25,000	$ 17,500	$ 32,500
Year 12-20 Subtotal (Includes 3% Annual Inflation)	**$ 351,564**	**$ 246,095**	**$ 457,034**
Total Site Monitoring and MNA Costs	**$ 830,244**	**$ 581,171**	**$ 1,079,317**
Groundwater Extraction and Treatment system	**Costs**	**Minus 30%**	**Plus 30%**
System Design and permitting	$ 40,000	$ 28,000	$ 52,000
System componants (including pump, electrical, etc)	$ 200,000	$ 140,000	$ 260,000
Trenching/piping for treated groundwater (assuming 700 ft @ $90/ft)	$ 65,000	$ 45,500	$ 84,500
Installation of GETS system (including oversight, equipment rental, expendables)	$ 50,000	$ 35,000	$ 65,000
Subtotal	**$ 355,000**	**$ 248,500**	**$ 461,500**
Annual Operation and Maintenance (includes one carbon changeout)	$ 82,000	$ 57,400	$ 106,600
Subtotal GETS O&M for 6 yrs (assuming 3% inflation)	**$ 530,410**	$ 371,287	$ 689,532
Total GETS System and O&M Costs	**$ 885,410**	**$ 619,787**	**$ 1,151,032**
Two Wellhead Treatment System	**Costs**	**Minus 30%**	**Plus 30%**
Design and Installation of LGAC systems	$ 128,000	$ 89,600	$ 166,400
Design and Construction Documents	$ 50,000	$ 35,000	$ 65,000
Subtotal Wellhead Treatment Installation	**$ 178,000**	**$ 124,600**	**$ 231,400**
Annual O&M including carbon changeouts	$ 84,000	$ 58,800	$ 109,200
Subtotal LGAC Changeouts (20 years, assuming 3% inflation)	**$ 2,257,111**	**$ 1,579,978**	**$ 2,934,245**
Total Wellhead Treatment Systems Cost	**$ 2,435,111**	**$ 1,704,578**	**$ 3,165,645**
Monitoring Well Installation	**Costs**	**Minus 30%**	**Plus 30%**
Total Monitor Well Drilling/installation/development (2 Nested Wells)	**$ 190,000**	**$ 133,000**	**$ 247,000**
COST SUMMARY			
SUMMARY OF COSTS TO IMPLEMENT	**Costs**	**Total Minus 30%**	**Total Plus 30%**
ERD System Design and Install	$ 425,000	$ 297,500	$ 552,500
ERD Injections	$ 277,218	$ 194,052	$ 360,383
GETS System Design and Install	$ 355,000	$ 248,500	$ 461,500
Wellhead Treatment Systems Design and Install	$ 178,000	$ 124,600	$ 231,400
Monitoing Well Installation	$ 190,000	$ 133,000	$ 247,000
Total	**$ 1,425,218**	**$ 997,652**	**$ 1,852,783**
SUMMARY OF COSTS FOR MONITORING, OPERATION AND MAINTENANCE	**Costs**	**Total Minus 30%**	**Total Plus 30%**
ERD Performance Monitoring and Reporting	$ 341,710	$ 239,197	$ 444,223
Annual monitoring and MNA (20 years)	$ 830,244	$ 581,171	$ 1,079,317
GETS O&M (6 years)	$ 530,410	$ 371,287	$ 689,532
Wellhead Treatment O&M (20 years)	$ 2,257,111	$ 1,579,978	$ 2,934,245
Total	**$ 3,959,475**	**$ 2,771,633**	**$ 5,147,318**
	TOTAL	**Total Minus 30%**	**Total Plus 30%**
TOTAL REMEDY COSTS	**$ 5,384,693**	**$ 3,769,285**	**$ 7,000,101**
TOTAL CONTINGENCY COSTS	**$ -**	**$ -**	**$ -**
TOTAL COSTS (ERD, 15 YEARS OF MONITORING AND O&M, CONTINGENCY INJECTIONS)	**$ 5,384,693**	**$ 3,769,285**	**$ 7,000,101**

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LESS AGGRESSIVE REMEDY COST ESTIMATE			
MNA Construction Activities	**Costs**	**Minus 30%**	**Plus 30%**
Monitor Well Installation (5 Nested Wells)	$ 475,000	$ 332,500	$ 617,500
Subtotal Monitoring Well Installation	**$ 475,000**	**$ 332,500**	**$ 617,500**
Groundwater Monitoring and Sampling	**Costs**	**Minus 30%**	**Plus 30%**
Quarterly Monitoring Per Year, Years 1 through 5	$ 80,000	$ 56,000	$ 104,000
Year 1-5 Subtotal (Includes 3% Annual Inflation)	**$ 424,731**	**$ 297,312**	**$ 552,150**
Semi-Annual Monitoring Per Year, Years 6 through 10	$ 50,000	$ 35,000	$ 65,000
Year 6 - 10 Subtotal (Includes 3% Annual Inflation)	**$ 307,737**	**$ 215,416**	**$ 400,058**
Annual Monitoring Per Year, Years 11 through 50	$ 25,000	$ 17,500	$ 32,500
Year 11-50 Subtotal (Includes 3% Annual Inflation)	**$ 2,533,325**	**$ 1,773,327**	**$ 3,293,322**
Subtotal MNA Costs	**$ 3,265,793**	**$ 2,286,055**	**$ 4,245,531**
Three Wellhead Treatment Systems	**Quantity**	**Unit**	**Unit Cost**
Design and Installation of LGAC systems	$ 192,000	$ 134,400	$ 249,600
Design and Construction Documents	$ 80,000	$ 56,000	$ 104,000
Subtotal Wellhead Treatment Installation	**$ 272,000**	**$ 190,400**	**$ 353,600**
Annual LGAC Changeout	$ 122,000	$ 85,400	$ 158,600
Subtotal LGAC Changeouts (30 years, assuming 3% inflation)	**$ 5,804,201**	**$ 4,062,941**	**$ 7,545,461**
Subtotal Wellhead Treatment Systems	**$ 6,076,201**	**$ 4,253,341**	**$ 7,899,061**
CONTINGENCIES			
ERD system	**Costs**	**Minus 30%**	**Plus 30%**
Remedial System Design and Coordination	$ 65,000	$ 45,500	$ 84,500
ERD System Construction (piping, trenching, plumbing etc.)	$ 120,000	$ 84,000	$ 156,000
Injection Well Installation (assuming four wells)	$ 200,000	$ 140,000	$ 260,000
Reporting	$ 40,000	$ 28,000	$ 52,000
Subtotal ERD System Design and Install	**$ 425,000**	**$ 297,500**	**$ 552,500**
Biostimulation/Bioaugmentation Injections (Incl. 20,000 gallons ERD Substrate)	$ 87,000	$ 60,900	$ 113,100
Performance monitoring (2 years)	$ 50,000	$ 35,000	$ 65,000
Subtotal Injections and Monitoring	**$ 137,000**	**$ 95,900**	**$ 178,100**
Subtotal Contingency ERD System and Injections	**$ 562,000**	**$ 393,400**	**$ 730,600**
COST SUMMARY			
SUMMARY OF COSTS TO IMPLEMENT	**Costs**	**Total Minus 30%**	**Total Plus 30%**
Monitor Well Installation and Development (5 wells)	$ 475,000	$ 332,500	$ 617,500
Wellhead Treatment Systems Installation	$ 272,000	$ 190,400	$ 353,600
Total	**$ 747,000**	**$ 522,900**	**$ 971,100**
SUMMARY OF MONITORING, OPERATION AND MAINTENANCE			
Groundwater Monitoring	$ 3,265,793	$ 2,286,055	$ 4,245,531
Wellhead Treatment O&M	$ 5,804,201	$ 4,062,941	$ 7,545,461
Total	**$ 9,069,993**	**$ 6,348,995**	**$ 11,790,991**
COST FOR CONTINGENCIES			
Contingency ERD Design and Install	$ 425,000	$ 297,500	$ 552,500
Contingency Injections and Performance Monitoring	$ 137,000	$ 95,900	$ 178,100
Total	**$ 562,000**	**$ 393,400**	**$ 730,600**
	TOTAL	**Total Minus 30%**	**Total Plus 30%**
TOTAL REMEDY COSTS	**$ 9,816,993**	**$ 6,871,895**	**$ 12,762,091**
TOTAL CONTINGENCY COSTS	**$ 562,000**	**$ 393,400**	**$ 730,600**
TOTAL COSTS (30 YEARS OF MONITORING AND O&M, CONTINGENCY WELLHEAD TREATMENT)	**$ 10,378,993**	**$ 7,265,295**	**$ 13,492,691**

MORE AGRESSIVE REMEDY COST ESTIMATE			
ISCR/ERD Remediation Systems	**Quantity**	**Unit**	**Unit Cost**
Remedial System Design and Coordination	$ 120,000	$ 84,000	$ 156,000
Injection Well Installation (assuming six wells)	$ 300,000	$ 210,000	$ 390,000
ISCR Remediation System Construction (tanks, piping, trenching, plumbing etc.)	$ 1,200,000	$ 840,000	$ 1,560,000
ERD Remediation System Construction (tanks, plumbing)	$ 45,000	$ 31,500	$ 58,500
Subtotal	**$ 1,665,000**	**$ 1,165,500**	**$ 2,164,500**
ISCR/ERD Injections and Performance Monitoring	**Costs**	**Minus 30%**	**Plus 30%**
ISCR and ERD Injections (Incl. 20,000 gallons ISCR and ERD Substrate Each)			
Year 1 ISCR Injection (Includes 3% Annual Inflation)	$ 89,000	$ 62,300	$ 115,700
Year 3 ERD Injection (Includes 3% Annual Inflation)	$ 92,298	$ 64,609	$ 119,988
Year 5 ERD Injection (Includes 3% Annual Inflation)	$ 97,919	$ 68,543	$ 127,295
Year 7 ERD Injection (Includes 3% Annual Inflation)	$ 103,883	$ 72,718	$ 135,047
ISCR and 'ERD Injections Subtotal	**$ 383,100**	**$ 268,170**	**$ 498,030**
Performance Monitoring			
Year 1	$ 25,000	$ 17,500	$ 32,500
Year 2	$ 25,750	$ 18,025	$ 33,475
Year 3	$ 26,523	$ 18,566	$ 34,479
Year 4	$ 27,318	$ 19,123	$ 35,514
Year 5	$ 28,138	$ 19,696	$ 36,579
Year 6	$ 28,982	$ 20,287	$ 37,676
Year 7	$ 29,851	$ 20,896	$ 38,807
Year 8	$ 30,747	$ 21,523	$ 39,971
Performance Monitoring Subtotal	**$ 222,308**	**$ 155,616**	**$ 289,001**
Annual Reporting for 8 years	**$ 240,000**	**$ 168,000**	**$ 312,000**
Subtotal ISCR/ERD Injections and Performance Monitoring	**$ 845,409**	**$ 591,786**	**$ 1,099,031**
Total ISCR/ERD System, Injections, and Monitoring Costs	**$ 2,510,409**	**$ 1,757,286**	**$ 3,263,531**
ISCR/ERD Monitoring and MNA	**Costs**	**Minus 30%**	**Plus 30%**
Annual Monitoring Per Year	$ 25,000	$ 17,500	$ 32,500
Year 1-8 Subtotal (Includes 3% Annual Inflation)	**$ 222,308**	**$ 155,616**	**$ 289,001**
Semi-Annual MNA Per Year	$ 50,000	$ 35,000	$ 65,000
Year 9 - 13 Subtotal (Includes 3% Annual Inflation)	**$ 336,273**	**$ 235,391**	**$ 437,155**
Annual MNA Per Year	$ 25,000	$ 17,500	$ 32,500
Year 14 - 20 Subtotal (Includes 3% Annual Inflation)	**$ 281,315**	**$ 196,920**	**$ 365,709**
Total Site Monitoring and MNA Costs	**$ 839,896**	**$ 587,927**	**$ 1,091,864**
Groundwater Extraction and Treatment system	**Costs**	**Minus 30%**	**Plus 30%**
System Design and permitting	$ 40,000	$ 28,000	$ 52,000
System componants (including pump, electrical, etc)	$ 200,000	$ 140,000	$ 260,000
Trenching/piping for treated groundwater (assuming 700 ft @ $90/ft)	$ 65,000	$ 45,500	$ 84,500
Installation of GETS system (including oversight, equipment rental, expendables)	$ 50,000	$ 35,000	$ 65,000
Subtotal	**$ 355,000**	**$ 248,500**	**$ 461,500**
Annual Operation and Maintenance (includes one carbon changeout)	$ 82,000	$ 57,400	$ 106,600
Subtotal GETS O&M for 8 yrs (assuming 3% inflation)	**$ 729,172**	**$ 510,420**	**$ 947,923**
Total GETS System and O&M Costs	**$ 1,084,172**	**$ 758,920**	**$ 1,409,423**
Two Wellhead Treatment System	**Costs**	**Minus 30%**	**Plus 30%**
Design and Installation of LGAC systems	$ 128,000	$ 89,600	$ 166,400
Design and Construction Documents	$ 50,000	$ 35,000	$ 65,000
Subtotal Wellhead Treatment Installation	**$ 178,000**	**$ 124,600**	**$ 231,400**
Annual O&M including carbon changeouts	$ 84,000	$ 58,800	$ 109,200
Subtotal LGAC Changeouts (20 years, assuming 3% inflation)	**$ 2,257,111**	**$ 1,579,978**	**$ 2,934,245**
Total Wellhead Treatment Systems Cost	**$ 2,435,111**	**$ 1,704,578**	**$ 3,165,645**
Monitoring Well Installation	**Costs**	**Minus 30%**	**Plus 30%**
Total Monitor Well Drilling/installation/development (2 Nested Wells)	**$ 190,000**	**$ 133,000**	**$ 247,000**
COST SUMMARY			
SUMMARY OF COSTS TO IMPLEMENT	**Costs**	**Total Minus 30%**	**Total Plus 30%**
ISCR/ERD System Design and Install	$ 1,665,000	$ 1,165,500	$ 2,164,500
ISCR/ERD Injections	$ 383,100	$ 268,170	$ 498,030
GETS System Design and Install	$ 355,000	$ 248,500	$ 461,500
Wellhead Treatment Systems Design and Install	$ 178,000	$ 124,600	$ 231,400
Monitoing Well Installation	$ 190,000	$ 133,000	$ 247,000
Total	**$ 2,771,100**	**$ 1,939,770**	**$ 3,602,430**
SUMMARY OF COSTS FOR MONITORING, OPERATION AND MAINTENANCE	**Costs**	**Total Minus 30%**	**Total Plus 30%**
ISCR/ERD Performance Monitoring and Reporting	$ 462,308	$ 323,616	$ 601,001
Annual monitoring and MNA (20 years)	$ 839,896	$ 587,927	$ 1,091,864
GETS O&M (6 years)	$ 729,172	$ 510,420	$ 947,923
Wellhead Treatment O&M (20 years)	$ 2,257,111	$ 1,579,978	$ 2,934,245
Total	**$ 4,288,487**	**$ 3,001,941**	**$ 5,575,033**
	TOTAL	Total Minus 30%	Total Plus 30%
TOTAL REMEDY COSTS	$ 7,059,587	$ 4,941,711	$ 9,177,463
TOTAL CONTINGENCY COSTS	$ -	$ -	$ -
TOTAL COSTS (15 YEARS OF MONITORING AND O&M, CONTINGENCY INJECTIONS)	$ 7,059,587	$ 4,941,711	$ 9,177,463