

CORRECTIVE MEASURES STUDY REPORT

FORMER PLYMOUTH TUBE COMPANY FACILITY
6573 WEST WILLIS ROAD
CHANDLER, ARIZONA

DATED: JANUARY 29, 2016

PREPARED FOR:



Plymouth Tube Company
29W150 Warrenville Road
Warrenville, IL 60555

PREPARED BY:



1 WEST DEER VALLEY ROAD, BLDG 2, STE 305, PHOENIX, AZ 85027
PHONE: 623-374-6637

NV5 PROJECT No. 444215-08300.01/010

**CORRECTIVE MEASURES STUDY REPORT
FORMER PLYMOUTH TUBE COMPANY FACILITY
CHANDLER, ARIZONA**

This report was prepared by the staff of NV5 under the supervision of the Geologist whose seal and signature appear hereon.

The findings, recommendations, specifications, or professional opinions are presented within the limits described by the client, in accordance with generally accepted professional engineering and geologic practice. No expressed warranty is given or implied.



Michelle Oakley
Sr. Project Manager



Bruce C. Travers
Arizona Registered Geologist No. 26776

TABLE OF CONTENTS

EXECUTIVE SUMMARY

ES 1.0 INTRODUCTION.....	1
ES 1.1 BACKGROUND	1
ES 2.0 CORRECTIVE MEASURES STUDY.....	2
ES 2.1 PRELIMINARY SCREENING OF CORRECTIVE MEASURE ALTERNATIVES	3
ES 2.2 EXPANDED EVALUATION OF RETAINED CORRECTIVE MEASURE ALTERNATIVES	5
ES 2.3 DETAILED SCREENING OF CORRECTIVE MEASURE ALTERNATIVES	7
PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	8
ES 2.4 PREFERRED CORRECTIVE MEASURE ALTERNATIVE	11

CORRECTIVE MEASURES STUDY REPORT

1.0 INTRODUCTION.....	1
1.1 REPORT ORGANIZATION.....	1
1.2 PURPOSE OF THE CMS REPORT	1
1.3 BACKGROUND	1
1.4 SITE DESCRIPTION AND PROPERTY HISTORY	3
1.5 CONCEPTUAL SITE MODEL.....	4
1.5.1 SOIL	4
1.5.2 SOIL GAS	4
1.5.3 INDOOR AIR QUALITY	4
1.5.4 PERCHED WATER	5
1.5.5 GROUNDWATER.....	5
1.6 SUMMARY OF INTERIM CORRECTIVE MEASURES.....	6
1.6.1 SVE SYSTEM SUMMARY	6
1.6.2 LGWP&T SYSTEM SUMMARY.....	7
2.0 HUMAN HEALTH RISK ASSESSMENT AND MEDIA SPECIFIC CLEANUP OBJECTIVES SUMMARY.....	7
2.1 GROUNDWATER TARGET CLEANUP STANDARD.....	10
2.2 SOIL GAS TARGET CLEANUP STANDARD	10
3.0 CORRECTIVE MEASURES STUDY.....	10
3.1 PRELIMINARY SCREENING CRITERIA	11
3.1.1 SHORT TERM EFFECTIVENESS.....	11
3.1.2 IMPLEMENTABILITY	12
3.1.3 RELATIVE COST	12
3.2 PRELIMINARY SCREENING OF CORRECTIVE MEASURE ALTERNATIVES	12
3.2.1 NO ACTION.....	12
3.2.2 MONITORED NATURAL ATTENUATION	13
3.2.3 FOCUSED IN-SITU CHEMICAL OXIDATION (ISCO) AT LB-7/LB-7R SOURCE AREA ...	14
3.2.4 REGIONAL ISCO APPLICATION	16
3.2.5 AIR SPARGING/SVE	17
3.2.6 GROUNDWATER PUMP AND TREAT.....	17
4.0 EXPANDED EVALUATION OF RETAINED CORRECTIVE MEASURE ALTERNATIVES	18
4.1 CORRECTIVE MEASURE ALTERNATIVE 1: MONITORED NATURAL ATTENUATION (MNA) .	18

4.2	CORRECTIVE MEASURE ALTERNATIVE 2: FOCUSED IN-SITU CHEMICAL OXIDATION	21
4.2.1	CATALYZED HYDROGEN PEROXIDE (CHP) – MODIFIED FENTON’S REAGENT (MFR).....	21
4.2.2	POTASSIUM / SODIUM PERMANGANATE	23
4.2.3	ACTIVATED SODIUM PERSULFATE	24
4.3	FOCUSED ISCO CORRECTIVE MEASURE ALTERNATIVE.....	27
5.0	DETAILED SCREENING OF CORRECTIVE MEASURE ALTERNATIVES	31
5.1	PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT.....	32
5.2	ATTAINMENT OF CLEANUP OBJECTIVES	32
5.3	SOURCE CONTROL	33
5.4	LONG-TERM EFFECTIVENESS	33
5.5	REDUCTION IN TOXICITY, MOBILITY OR VOLUME OF WASTE.....	33
5.6	SHORT-TERM EFFECTIVENESS	34
5.7	IMPLEMENTABILITY	35
5.8	COST	35
6.0	PREFERRED CORRECTIVE MEASURE ALTERNATIVE	36
7.0	REFERENCES	38

TABLES

Table 1	Groundwater Interim Cleanup Goals and Final Cleanup Goals
Table 2	Soil Gas Interim Cleanup Goals and Final Cleanup Goals
Table 3	Plymouth Tube Groundwater Quality
Table 4	Selected Gila River Indian Community Groundwater Quality
Table 5	Preliminary Screening Evaluation
Table 6	Detailed Screening Evaluation

FIGURES

Figure 1	Site Location Map
Figure 2	Site Plan
Figure 3	Conceptual Site Model
Figure 4	Approximate Lateral Distribution of Dissolved Phase TCE, August 2015
Figure 5	Site Vicinity Map
Figure 6	Approximate Lateral Distribution of Dissolved Phase TCE, August 2012

CORRECTIVE MEASURES STUDY

EXECUTIVE SUMMARY

ES 1.0 INTRODUCTION

NV5, on behalf of the Plymouth Tube Company (Plymouth Tube), has prepared this *Corrective Measures Study Report* (CMS Report) for the Former Plymouth Tube Company Facility (now operated by Kaiser Aluminum [Kaiser]), located at 6573 West Willis Road, Chandler, Arizona (Site). This CMS Report has been prepared pursuant to the December 28, 2007 Unilateral Administrative Order, United States Environmental Protection Agency (EPA) Docket No. RCRA-7003-09-2008-0002 (Order) and the written request dated October 13, 2015 from Mr. John Moody of the EPA Region IX to Scott Morling, Vice President, Plymouth Tube Company regarding the Unilateral Administrative Order, Docket No. RCRA-7003-09-2008-0002. The October 13, 2015 EPA letter requested final documents related to the Order and the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Work Plan.

ES 1.1 Background

The Gila River Indian Community (GRIC) Department of Environmental Quality (DEQ) Water Quality Program (WQP) has been conducting an ongoing remedial investigation of groundwater impacts by trichloroethene (TCE), other volatile organic compounds (VOCs) and perchlorate in the vicinity of Lone Butte Industrial Park (Lone Butte) since January 2000. The North Central Aquifer Cleanup Project was initiated when GRIC DEQ installed monitor well GFW (Gila Floodway) in January 2000 and groundwater results from this monitor well detected TCE at concentrations ranged from 8.4 to 25 micrograms per liter (µg/L). Based on these results, GRIC DEQ initiated a series of investigations to locate the source(s) of contamination and mitigate further impacts to groundwater. As part of the GRIC investigations, numerous monitor wells have been installed and GRIC has been conducting routine groundwater monitoring to define the nature and extent of groundwater contamination. The activities and result of the GRIC investigations and monitoring have been documented in numerous reports for the North Central Aquifer Cleanup Project.

Pursuant to EPA's Order, Plymouth Tube has undertaken, with EPA and GRIC oversight, multiple investigations including monitoring and sampling activities at and around the Former Plymouth Tube Company Facility. Results from these investigations have delineated the horizontal, vertical and lateral extent of soil, soil vapor, perched water and groundwater impacted by VOCs related to the activities at the Former Plymouth Tube Company Facility. The chemicals of concern (COCs) include TCE, 1,1-dichloroethene (1,1-DCE) and 1,4-dioxane, and, to a lesser extent, tetrachloroethene (PCE). Historical monitoring data have indicated that TCE, 1,1-DCE and PCE have been detected in groundwater above their respective EPA Maximum

Contaminant Levels (MCLs) of 5 µg/L, 7 µg/L and 5 µg/L. 1,4-Dioxane does not currently have an MCL. TCE has been the most detected VOC and at the greatest concentration. The lateral, vertical and horizontal extent of the VOC plume has been defined. Continued groundwater monitoring of the shallow aquifer water quality data confirms that: 1) the VOC plume is not migrating; 2) VOC concentrations are declining over time; 3) and the overall footprint of the VOC plume is shrinking.

Results from these Site investigations and the continued monitoring programs indicate that there are no significant undefined VOC sources in the vadose zone or groundwater. The two interim corrective measures (ICMs) (the soil vapor extraction [SVE] system and the limited groundwater pump and treat [LGWP&T] system) which have been conducted by Plymouth Tube, have addressed the sources of contamination identified in the vadose zone. The only remaining area of elevated VOC concentrations (TCE >10,000 µg/L) in groundwater is in the vicinity of the former GRIC monitor well LB-7. Based upon the results of the recent water quality data collected during the Reduced Pumping Investigation, the footprint of the elevated VOC concentrations (referred to as the Site Area of Interest [AOI]) is small and is being addressed in this CMS report.

Potential exposure to VOCs in soil does not pose a risk as the detected concentrations are below established risk based remediation levels. Potential exposure to soil vapor at the Former Plymouth Tube Company Facility has been addressed by the on-Site SVE system. There is no current exposure to impacted groundwater, as there are no identified potable drinking water wells within the footprint of the VOC plume. Lone Butte Development Corporation (LBDC) and GRIC have stated they would enforce a risk management control that will prevent future installation of supply wells in the shallow water-bearing zone, resulting in no future exposure pathways for groundwater. Off gassing from the impacted groundwater does not pose an adverse non-cancer or cancer risk to indoor air or outdoor air. There is also the presence of the competent clay unit (a continuous confining unit) above the water table.

The RFI Report dated December 29, 2015, presents a detailed presentation and discussion of the RFI activities and results, along with an updated Conceptual Site Model, a presentation of the Interim Corrective Measures conducted, the results of the Human Health Risk Assessment (HHRA) and calculations of the media cleanup objectives, and an evaluation of the environmental indicators. The reader is referred to the RFI Report and Appendices for additional information on these topics.

ES 2.0 CORRECTIVE MEASURES STUDY

A streamlined CMS was conducted to identify, develop and evaluate various corrective measure alternatives to address the residual VOC impacts at the Site. The RFI has determined the following: 1) the sources of historical impacts to soil and groundwater have been addressed

through the proper abandonment of the conduit monitor well LB-7, and the design and implementation of two ICMs; the SVE system and the LGWP&T system; 2) there are no current human exposures to the residual contamination as presented in the HHRA; and, 3) the corrective measures to address the VOCs in groundwater are generally understood.

The EPA has identified three threshold criteria that potential corrective measure must achieve the following: 1) be protective of human health and the environment; 2) attain the media cleanup objectives; and 3) control the source.

The HHRA has demonstrated that there is no current risk to human health and the environment. Potential corrective measures will not alter the HHRA conclusions.

Evaluation of the water quality data indicates that VOC concentrations are trending downward and the VOC plume is not migrating and is shrinking expanding. Attenuation, dispersion and dilution processes will continue to reduce the groundwater VOC concentrations towards the groundwater cleanup objectives. Soil VOC concentrations are below regulatory standards. The HHRA determined that there is no adverse non-cancer risk from soil gas to outdoor air. With the exception of the cancer risk at one location (SVE well location AASG-3), the soil gas to indoor air exposure pathway does not pose an adverse human health risk. The cancer risk at AASG-3 (2E-06) is just above the *de minimus* level of 1E-06 and at the low end of EPA's risk management range of 1E-06 to 1E-04.

The sources from the historical releases have been addressed though the proper abandonment of the conduit monitor well LB-7, and the design and implementation of the SVE system and the LGWP&T system.

ES 2.1 Preliminary Screening of Corrective Measure Alternatives

NV5 identified six corrective measures related to VOCs in groundwater (including the No Action alternative) based on literature review and experience. The preliminary screening of the No Action, Monitored Natural Attenuation (MNA), Focused In-Situ Chemical Oxidation (ISCO), Regional ISCO Application, Air Sparging/SVE, and Groundwater Pump and Treat (P&T) Corrective Measure Alternatives are presented below. These identified corrective measure alternatives are evaluated using the preliminary screening criteria (Short Term Effectiveness, Implementability and Relative Costs).

Based upon the preliminary screening criteria, the No Action, the Regional ISCO Application, the Air Sparging/SVE, and the Groundwater Pump and Treat Corrective Measure Alternatives were not considered for further evaluation. The MNA Corrective Measure Alternative and the Focused ISCO at LB-7/LB-7R Source Area Corrective Measure Alternative were considered for

further evaluation. The preliminary screening of these two Corrective Measure Alternatives are summarized below:

The proposed **MNA Corrective Measure Alternative** consists of ongoing groundwater monitoring and sampling to verify that attenuation is continuing to occur over time. The preliminary screening results are summarized below.

- Short Term Effectiveness: **Ranked High** - There is no current completed exposure routes, potential future exposure routes are being addressed through institutional controls by GRIC and LBDC, and the VOC groundwater plume is shrinking and VOC concentrations in groundwater are declining.
- Implementability: **Ranked High** - An appropriate groundwater monitoring network to verify future VOC reduction is currently in place.
- Relative Cost: **Ranked High** - No additional capital costs since an appropriate groundwater monitoring network current exists. The MNA groundwater monitoring operation and maintenance (O&M) costs are low.
- Retained for Further Analysis: **Yes**.

The proposed **Focused ISCO at LB-7/LB-7R Source Area Corrective Measure Alternative** consists of a Focused ISCO application in the area of elevated COCs around monitor wells LB-7/LB-7R (Site AOI). The preliminary screening results are summarized below.

- Short Term Effectiveness: **Ranked Moderate to High** - would reduce the volume of the COCs via desorption and degradation. The end products of the selected ISCO oxidant reaction with the COCs need to be evaluated prior to selection of an appropriate oxidant.
- Implementability: **Ranked Low to Moderate** - Most ISCO oxidants can be readily mixed at the surface using appropriate tanks and mixers prior to injection into the subsurface. Installation of an injection system is not technologically difficult. No known regulatory framework exists for application of ISCO on GRIC lands, which may complicate any applicable regulatory implementability. A low ranking is provided due to the uncertainty of the regulatory requirements and acceptance of the Focused ISCO Corrective Measure Alternative. However, it may be noted that this technology has been approved by several state regulatory agencies throughout the United States and abroad over the last two decades.
- Relative Cost: **Ranked High to Moderate** - Low to moderate capital costs for the acquisition of the oxidant and rental of the necessary mixing tanks and equipment. Low to moderate costs associated with providing pathway (injection wells) for groundwater treatment. No additional capital costs for monitoring since an appropriate groundwater

monitoring network currently exists. Low O&M costs are associated with groundwater monitoring.

- Retained for Further Analysis: **Yes** - EPA and GRIC DEQ have expressed interest in further evaluation of this Corrective Measure Alternative.

ES 2.2 Expanded Evaluation of Retained Corrective Measure Alternatives

Two corrective measure alternatives retained from the preliminary screening were further defined and evaluated.

Corrective Measure Alternative 1: Monitored Natural Attenuation (MNA)

MNA using the current Plymouth Tube groundwater monitoring network along with selected GRIC monitor wells comprises Corrective Measure Alternative 1. The MNA alternative consists of quarterly groundwater monitoring and quarterly reporting for one year after EPA approval of the CMS. After the one year of quarterly monitoring and reporting has been completed, the MNA alternative would switch to semi-annual groundwater monitoring and semi-annual reporting for four additional years.

Groundwater sampling and analysis would be conducted using the same protocols as has been conducted during historic quarterly groundwater monitoring events. A monitoring and sampling report would be prepared and submitted to EPA and GRIC DEQ for each event.

Sampling of an individual monitor well may be discontinued if VOC concentrations are below their respective MCLs for two consecutive sampling events, and EPA and GRIC DEQ agree with the request to stop sampling.

The following present the updated evaluation using the preliminary screening criteria:

- Short Term Effectiveness: **Ranked High** - There is no current completed exposure routes to the shallow impacted groundwater. No supply wells are known to exist within the footprint of the defined VOC plume. Potential future exposure routes to groundwater are being addressed through institutional controls by GRIC and LBDC. The historical water quality data shows that the VOC groundwater plume is not migrating, and in fact is shrinking and that the VOC concentrations in groundwater are declining. The existing Plymouth Tube groundwater monitoring network would be used to collect data to verify continued plume reduction.
- Implementability: **Ranked High** - An appropriate groundwater monitoring network to verify future VOC reduction is currently in place so Corrective Measure Alternative 1 can be implemented without delay. Plymouth Tube already has a contract in place with GRIC

DEQ to provide access to the selected GRIC monitor wells that would be a part of the MNA monitoring network.

- Relative Cost: **Ranked High** - No additional capital costs would be incurred as the MNA groundwater monitoring network current exists. The MNA monitoring network wells do not have dedicated pumps so there would be no costs for in-well pump replacement or repair. Overall the O&M costs for MNA groundwater monitoring is low.
- Retained for Further Analysis: **Yes**.

Corrective Measure Alternative 2: Focused In-Situ Chemical Oxidation (ISCO)

ISCO involves delivery of an oxidant into the subsurface to abiotically destroy the chemicals of concern into non-toxic byproducts. ISCO is considered for an approximate 40 feet by 30 feet hot-spot area referred to as the Site AOI surrounding monitor wells LB-7/LB-7R.

The following ISCO technologies (oxidants) were evaluated for stability, precipitation, treatment of COCs, desorption, radial distribution, matrix treatment, treatment costs, free radical chemistry, reaction off gassing during injection, and reaction pH based on the known Site conditions:

- Catalyzed Hydrogen Peroxide (CHP) – Modified Fenton's Reagent (MFR)
- Traditional Fenton's Reagent
- Potassium / Sodium Permanganate
- Activated Sodium Persulfate

Based upon the referenced comparative analysis, the Focused ISCO Corrective Measure Alternative best suited for the reduction of the COCs at the Site AOI is CHP consisting of the delivery of MFR at a concentration of 5% to 12% and injected into the aquifer at one or more locations within the Site AOI. The rationale for selection of MFR is based on the following considerations:

- Subsurface matrix
- Target Contaminants
- Reagent contact with contaminates

The typical ISCO project approach would consist of starting in the laboratory and scaling-up to field application. First, a laboratory treatability study (i.e., Bench Test) is performed to test several dosages of the selected oxidant (i.e. MFR) on saturated soil and groundwater samples obtained from the Site to obtain the optimal dosage for field application. Next, a field pilot program is designed to evaluate not only the efficiency of the reagent, but also the distribution of the reagent within the impacted media. The data generated during the pilot program can be used to design a full-scale remediation program. The field pilot treatment program would also serve as the full scale treatment program due to the relatively smaller target treatment area.

Field injections are typically conducted in a sequential manner over 1 to 2 applications to allow for maximum desorption and oxidation of sorbed contaminants and thereby enhance treatment efficiency per unit volume of reagent injected. The treatment approach works via the in-situ oxidation of contaminants.

- **Short-term effectiveness** – is considered to have **moderate to high** effectiveness in the short-term because it would reduce the volume of the COCs via desorption and degradation. The end products of the MFR reaction with the COCs are benign and include carbon dioxide, water and chloride (for chlorinated contaminants). The temporary increases in dissolved oxygen and iron concentrations are short term effects and are not anticipated to remain over long term. One of the primary differences between Fenton's and other oxidants (i.e. permanganate, persulfate) is the fact that gas formation occurs only during Fenton's application due to eventual breakdown of hydrogen peroxide to oxygen and water vapor. The presence of gas creates significant agitation within the subsurface matrix resulting in better overall contact of the oxidant with the contamination. Besides the superior oxidation potential of hydroxyl radicals, the agitation caused by gas formation is believed to be one of the reasons why only Fenton's is capable of oxidizing contaminants not present in dissolved phase.
- **Implementability – Low to moderate.** MFR can be readily mixed at the surface using appropriate tanks and mixers prior to injection into the subsurface through one or more newly installed injection wells located within the Site AOI. No regulatory framework exists for application of ISCO on GRIC lands, which may complicate any applicable regulatory implementability. A low ranking is provided due to the uncertainty of the regulatory requirements and acceptance of the Focused ISCO Corrective Measure Alternative. However, it may be noted that this technology has been approved by several state regulatory agencies throughout the United States and abroad over the last two decades.
- **Cost – High to moderate.** Low to moderate capital costs for the acquisition of the oxidant and rental of the necessary mixing tanks and equipment and installation of one or more newly installed injection wells. Low O&M costs associated with groundwater monitoring.
- **Retained for further analysis – Yes.**

ES 2.3 Detailed Screening of Corrective Measure Alternatives

Two corrective measure alternatives were retained and modified from the preliminary screening of corrective measure alternatives and are evaluated further. Corrective Measure Alternative 1 consists of MNA only. Corrective Measure Alternative 2 consists of the Focused ISCO with the addition of MNA as presented in Corrective Measure Alternative 1.

The two retained corrective measure alternatives were evaluated using the following criteria:

- Protection of Human Health and the Environment.
- Attainment of Corrective Measure Objective of reduction of specific COCs in the groundwater.
- Source Control.
- Long-Term effectiveness.
- Reduction in Toxicity, Mobility of Volume of Waste.
- Short-Term Effectiveness.
- Implementability.
- Cost.

The Corrective Measure Alternatives 1 and 2 are summarized below:

Corrective Measure Alternative 1 is Monitored Natural Attenuation. This MNA alternative consist of quarterly groundwater monitoring and quarterly reporting for one year after EPA approval of the CMS. After the one year of quarterly monitoring and reporting has been completed, the MNA alternative would switch to semi-annual groundwater monitoring and semi-annual reporting for four additional years.

Corrective Measure Alternative 2 is Focused ISCO as a supplement to MNA. The Focused ISCO Remedial Alternative consists of injection of MFR, consisting of stabilized hydrogen peroxide and chelated iron catalyst, into the aquifer through one or more newly installed injection wells located within the Site AOI. For the purposes of this evaluation, it is assumed that 1 to 2 MFR injection events into the subsurface would take place to achieve the remedial goal of reducing COC concentrations in the groundwater. Groundwater monitoring would be continued under Corrective Measure Alternative 2 utilizing the same program as described in Corrective Measure Alternative 1.

Protection of Human Health and the Environment

Corrective Measure Alternative 1 (MNA) is considered to be protective of human health and the environment. There are no current or anticipated future exposure pathways to impacted groundwater. Attenuation is observed to be occurring with a retreating VOC plume and decreasing COC concentrations.

Corrective Measure Alternative 2 (Focused ISCO with MNA) is considered to be protective of human health and the environment. ISCO has been demonstrated to treat each of the identified COCs and the application of this Corrective Measure Alternative (i.e., MFR) would reduce the concentrations of each of the COCs at and downgradient of the Site with MNA processes continuing in the remaining portion of the plume. Use of MFR can result in production of off gases including oxygen and carbon dioxide, which should readily disperse within the TTZ. Although the reaction is somewhat exothermic, the temperature increases are typically less than

10° C. The end products of the reaction are benign and mainly consist of carbon dioxide and water vapor.

Attainment of Cleanup Objectives

Corrective Measure Alternative 1 (MNA) is expected to achieve the specified cleanup objectives at the Site (i.e., reduction of COCs concentrations in the groundwater). MNA processes would continue to reduce COC concentrations in the plume to achieve the cleanup objectives over time.

Corrective Measure Alternative 2 (Focused ISCO with MNA) is expected to obtain the specified cleanup objectives at the Site (i.e., reduction of COCs concentrations in the groundwater). It is anticipated that focused application of ISCO would reduce the concentrations of COCs at Site AOI via desorption and degradation of COCs. MNA processes would continue to reduce COC concentrations in that area and the remainder of the plume to achieve the cleanup objectives over time. By reducing COC concentrations at the Site AOI, a reduction of COC concentrations downgradient are expected to occur earlier in comparison to Corrective Measure Alternative 1. Elevated dissolved oxygen concentrations and iron concentrations may be present over several weeks following MFR application but would eventually return to background levels.

Source Control

This criterion is an assessment of how the corrective measure alternative addresses sources of contamination. There are no continuing sources of groundwater contamination associated with the subject contaminant plume at the Former Plymouth Tube Company Site. Therefore, since there are no sources, both Corrective Measure Alternative 1 (MNA) and Corrective Measure Alternative 2 (Focused ISCO with MNA) meet the source control criterion.

Long-Term Effectiveness

Corrective Measure Alternative 1 (MNA) the long-term effectiveness of this Corrective Measure Alternative is considered to be effective and reliable. Historical monitoring data has shown that attenuation is occurring at the Site. The MNA monitoring would provide the data needed to verify that attenuation is continuing at the Site. Should different or unexpected conditions be encountered, modifications to the Corrective Measure Alternative could be identified and proposed as part of this on-going reporting requirements.

Corrective Measure Alternative 2 (Focused ISCO with MNA) is considered to be effective and reliable at reducing concentrations in and near the application site and coupled with MNA, throughout the identified plume area. Desorption and degradation of submerged soil-bound COCs mass would mean greater potential exists for long term groundwater plume shrinkage with this Corrective Measure Alternative. The end products of the MFR reaction with the COCs are benign and include carbon dioxide, water and chloride (for chlorinated contaminants). The temporary increases in dissolved oxygen and iron concentrations are short-term effects, and are not anticipated to remain over the long-term.

Reduction in Toxicity, Mobility or Volume of Waste

Corrective Measure Alternative 1 (MNA) would reduce the overall volume of COCs in groundwater through dilution, dispersion, degradation, and volatilization. The mobility of COCs would be reduced through sorption of the COCs. These reductions in toxicity, mobility or volume would occur over a longer time period than Corrective Measure Alternative 2.

Corrective Measure Alternative 2 (Focused ISCO with MNA) would reduce the volume of the COCs more quickly than Corrective Measure Alternative 1. The co-existing redox reactions associated with a modified Fenton's process promote enhanced desorption and degradation of recalcitrant compounds. Hydroxyl radicals would oxidize nearly all contaminants with carbon/carbon double bonds (e.g. TCE, 1,1-DCE, PCE) and single bonded contaminants with extractable hydrogen. The end products of the reaction are typically innocuous such as carbon dioxide and water, and chloride ions when chlorinated compounds are being treated. The end products of the MFR reaction with COCs are benign and include carbon dioxide, water and chloride (for chlorinated contaminants). The temporary increases in dissolved oxygen and iron concentrations are short-term effects and are not anticipated to remain over long-term.

Short-Term Effectiveness

Corrective Measure Alternative 1 (MNA) is considered to be effective in the short-term. Following proper field procedures and Standard Operating Procedures (SOPs) human health risks during groundwater monitoring activities would result in little to no risk to human health and the environment.

Corrective Measure Alternative 2 (Focused ISCO with MNA) is considered to have moderate to high effectiveness in the short-term because it would reduce the volume of the COCs via desorption and degradation. The end products of the MFR reaction with the COCs are benign and include carbon dioxide, water and chloride (for chlorinated contaminants). The temporary increases in dissolved oxygen and iron concentrations are short-term effects and are not anticipated to remain over long-term.

Implementability

Corrective Measure Alternative 1 (MNA) is the easiest corrective measure alternative to implement. The monitoring well network and groundwater monitoring and reporting program already exist.

Corrective Measure Alternative 2 (Focused ISCO with MNA) may have regulatory/administrative considerations that could adversely impact the implementation of this corrective measure alternative. For the purposes of this evaluation, it is assumed that one or more ISCO treatment areas would be implemented. An injection test has not been conducted; however, a bench study is recommended to determine the proper site-specific dose of the MFR treatment. The target treatment area below the competent clay layer consists of gravels, sand and some clay which is optimal for the aquifer formation to accept the oxidant. One potential factor that could

complicate implementation would be that there is no regulatory framework governing injection of an oxidant into the subsurface on GRIC lands which could prevent or delay this Corrective Measure Alternative. However, this oxidant has been approved for in situ use by several state regulatory agencies and extensively used over the last two decades throughout the United States and abroad.

Cost

Cost is the assessment of the total cost, capital (or construction) costs and long-term operation and maintenance costs of the Corrective Measure Alternative. For the purposes of this CMS, Corrective Measure Alternative 1 and Corrective Measure Alternative 2 are assumed to have the same MNA groundwater monitoring and reporting program.

Total costs for Corrective Measure Alternative 2 would include costs of the bench test and one-time ISCO MFR application event in addition to MNA groundwater monitoring costs.

To be conservative, cumulative present value costs were calculated assuming an annual inflation rate of 3% and a discount factor of 7%.

Corrective Measure Alternative 1 (MNA) has no capital (construction) costs and the lowest overall cost of the two Corrective Measure Alternatives. Total costs in 2016 dollars for Corrective Measure Alternative 1 (MNA) are estimated to be \$254,232. Cumulative present net value costs are estimated to be \$217,680.

Corrective Measure Alternative 2 (Focused ISCO with MNA) has the higher capital (construction) costs and equivalent monitoring costs. The cost for the MNA portion of this alternative is \$254,232. Total capital costs are estimated to be approximately \$8,000 to \$10,000 for the bench test study. Total capital costs range for the ISCO injection wells, ISCO application(s) and monitoring is between \$100,000 to \$300,000 depending on the final number of newly installed injection wells and the number of planned injections. Total costs in 2016 dollars for Corrective Measure Alternative 2 (Focused ISCO with MNA) are estimated to range from \$362,232 to \$564,232. Cumulative present net value costs range from \$315,862 to \$499,499.

ES 2.4 Preferred Corrective Measure Alternative

Corrective Measure Alternative 2: Focused ISCO with MNA is the preferred Corrective Measure Alternative as detailed below:

- Is protective of human health and the environment.
- Is able to achieve the media clean up objectives in a reasonable time period. ISCO has been demonstrated to treat all of the identified COCs and the application of this Corrective Measure Alternative (i.e., MFR) would reduce the concentrations of all of the

COCs on and downgradient of the Site with MNA processes continuing in the remaining portion of the plume.

- Meets the source control criteria, due to the remediation of the source. There are no continuing sources of groundwater contamination associated with the subject contaminant plume at the Former Plymouth Tube Company Facility Site.
- Is reliable and effective for the long-term. Effective and reliable at reducing concentrations in and near the application site and coupled with MNA, throughout the identified plume area.
- Reduces the mobility and toxicity of COCs in groundwater. The end products of the MFR reaction with the COCs are benign and include carbon dioxide, water and chloride (for chlorinated contaminants).
- Is effective in the short-term because it would reduce the volume of the COCs via desorption and degradation.
- Has proven technologies which are easily implemented. One potential factor that could complicate implementation of the ISCO component would be that there is no regulatory framework governing injection of an oxidant into the subsurface on GRIC lands which could prevent or delay this Corrective Measure Alternative. However, this oxidant has been approved for *in-situ* use by several state regulatory agencies and extensively used over the last two decades throughout the United States and abroad.
- Although the ISCO application increases the overall costs, there is an increase benefit associated with the increased mass reduction of COCs over a shorter time period as compared to MNA alone.

CORRECTIVE MEASURES STUDY REPORT FORMER PLYMOUTH TUBE COMPANY FACILITY CHANDLER, ARIZONA

1.0 INTRODUCTION

NV5, on behalf of the Plymouth Tube Company (Plymouth Tube), has prepared this *Corrective Measures Study Report* (CMS Report) for the Former Plymouth Tube Company Facility (now operated by Kaiser Aluminum [Kaiser]), located at 6573 West Willis Road, Chandler, Arizona (Site) (Figure 1). This CMS Report has been prepared pursuant to the December 28, 2007 Unilateral Administrative Order, United States Environmental Protection Agency (EPA) Docket No. RCRA-7003-09-2008-0002 (Order) (U.S. EPA, 2007) and the written request dated October 13, 2015 from Mr. John Moody of the EPA Region IX to Scott Morling, Vice President, Plymouth Tube Company regarding the Unilateral Administrative Order, Docket No. RCRA-7003-09-2008-0002 (U.S. EPA, 2015). The October 13, 2015 EPA letter requested final documents related to the Order and the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Work Plan (Geosyntec, 2013).

1.1 Report Organization

This CMS Report is organized into the following sections: Introduction; Human Health Risk Assessment and Media Specific Cleanup Objectives Summary; Corrective Measures Study; Expanded Evaluation of Retained Corrective Measure Alternatives; Detailed Screening of Corrective Measures Alternatives; Preferred Corrective Measure Alternative; and References.

1.2 Purpose of the CMS Report

The purpose of this CMS Report is to identify, develop and evaluate the various corrective measure alternative(s) that will achieve the media cleanup objectives for the groundwater and soil gas impacts as identified in the RFI Report (NV5, 2015c), and to recommend the corrective measure(s) be taken so that risks to human health and the environment are eliminated, reduced, or controlled.

1.3 Background

The Gila River Indian Community (GRIC) Department of Environmental Quality (DEQ) Water Quality Program (WQP) has been conducting an ongoing remedial investigation of groundwater impacts by trichloroethene (TCE), other volatile organic compounds (VOCs) and perchlorate in the vicinity of Lone Butte Industrial Park (Lone Butte) since January 2000. The North Central Aquifer Cleanup Project was initiated when GRIC DEQ installed monitor well GFW (Gila

Floodway) in January 2000 and groundwater results from this monitor well detected TCE at concentrations ranging from 8.4 to 25 micrograms per liter (µg/L). Based on these results, GRIC DEQ initiated a series of investigations to locate the source(s) of contamination and mitigate further impacts to groundwater. As part of the GRIC investigations, numerous monitor wells have been installed and GRIC has been conducting routine groundwater monitoring to define the nature and extent of groundwater contamination. The activities and result of the GRIC investigations and monitoring have been documented in numerous reports for the North Central Aquifer Cleanup Project.

Pursuant to EPAs Order, Plymouth Tube has undertaken, with EPA and GRIC oversight, multiple investigations including monitoring and sampling activities at and around the Former Plymouth Tube Company Facility. Results from these investigations have delineated the horizontal, vertical and lateral extent of soil, soil vapor, perched water and groundwater impacted by VOCs related to the activities at the Former Plymouth Tube Company Facility. The chemicals of concern (COCs) include TCE, 1,1-dichloroethene (1,1-DCE) and 1,4-dioxane, and, to a lesser extent, tetrachloroethene (PCE). Historical monitoring data have indicated that TCE, 1,1-DCE and PCE have been detected in groundwater above their respective EPA Maximum Contaminant Levels (MCLs) of 5 µg/L, 7 µg/L and 5 µg/L. 1,4-Dioxane does not currently have an MCL. TCE has been the most detected VOC and at the greatest concentration. The lateral, vertical and horizontal extent of the VOC plume has been defined. Continued groundwater monitoring of the shallow aquifer water quality data confirms that; 1) the VOC plume is not migrating; 2) VOC concentrations are declining over time; and 3) the overall footprint of the VOC plume is shrinking (NV5, 2015c).

Results from these Site investigations and the continued monitoring programs indicate that there are no significant undefined VOC sources in the vadose zone or groundwater. Further, as presented below, the two interim corrective measures (ICMs) (the soil vapor extraction [SVE] system and the limited groundwater pump and treat [LGWP&T] system) which have been conducted by Plymouth Tube, have addressed the sources of contamination identified in the vadose zone (Appendix A and B to the RFI Report; NV5, 2015c). The only remaining area of elevated VOC concentrations (TCE >10,000 µg/L) (Figure 2) in groundwater is in the vicinity of the former GRIC monitor well LB-7 (NV5, 2015a). Based upon the results of the recent water quality data collected during the Reduced Pumping Investigation (NV5, 2015a), the footprint of the elevated VOC concentrations (referred to as the Site Area of Interest [AOI]) is small and is being addressed in this CMS report.

Potential exposure to VOCs in soil does not pose a risk as the detected concentrations are below established risk based remediation levels. Potential exposure to soil vapor at the Former

Plymouth Tube Company Facility has been addressed by the on-Site SVE system. There is no current exposure to impacted groundwater, as there are no identified potable drinking water wells within the footprint of the VOC plume. Lone Butte Development Corporation (LBDC) and GRIC have stated they would enforce a risk management control that will prevent future installation of supply wells in the shallow water-bearing zone, resulting in no future exposure pathways for groundwater. Off gassing from the impacted groundwater does not pose an adverse non-cancer or cancer risk to indoor air or outdoor air. There is also the presence of the competent clay unit (a continuous confining unit) above the water table.

1.4 Site Description and Property History

The Site is located at Lone Butte on the GRIC Reservation. Development of Lone Butte began in 1966. The Site is located on Tract 14C (Tract 14C previously included Tract 21D) with a street address of 6573 West Willis Road, Chandler, Arizona (Figure 2). The Site is within the NE ¼, NE ¼, SW ¼ of Section 4, Township 2 South, Range 4 East of the Gila River and Salt River Baseline and Meridian, Maricopa County, Arizona.

The Site is located on 15.154 acres of land zoned for industrial occupancy (Figure 2). Only the northern portion of the property has historically been used by the various tenants. The northern portion of the property is almost completely covered by either production/administration buildings and concrete or asphalt paving. A lined evaporation pond is located south of the building/paving. The land is leased from GRIC through the LBDC (formerly known as Lone Butte Industrial Development Corporation).

Prior to 1970, the Site consisted of undeveloped desert land. The Site was originally developed through GRIC by Metalware in 1973. Metalware produced aluminum bats, but reportedly due to quality control issues, the business failed. In 1975, Plymouth Tube took over the plant after purchasing certain assets previously owned by Metalware. Plymouth Tube operated at this location as an aluminum tube extruder company with a Standard Industrial Code (SIC) of 3356. The building was expanded considerably from 1984 through early 1986, when the area of the horizontal heat treat was enclosed, and the building was expanded to the south. Immediately following this expansion, the building was expanded to the north, and a new office area was added on the east side of the building. The vertical heat treat tower was added in 1994. No significant additions were made from that date until Kaiser purchased the business.

Plymouth Tube sold the business and facility assets to Kaiser in May 2000. Since that time, Kaiser has continued the manufacturing of aluminum tubing. Kaiser is the current lessee of the underlying real estate, and recently constructed a 35,000 square-foot facility expansion at the Site west of their current operations building.

1.5 Conceptual Site Model

The following sections summarized the Conceptual Site Model (CSM) by media (Appendix A to the RFI Report; NV5, 2015c).

1.5.1 Soil

Extensive soil sampling at the Site has been conducted and the soil sampling results indicated that the detected VOC concentrations in soils are well below the Arizona Department of Environmental Quality (ADEQ) non-residential soil remediation levels (NR-SRLs) of 65 milligrams per kilogram (mg/kg) for TCE, 410 mg/kg for 1,1-DCE, and 13 mg/kg for PCE. No further remedial assessment of soils is warranted.

1.5.2 Soil Gas

The soil gas at the Site has been extensively investigated and elevated concentrations were detected. As a result the Site has been under active remediation via an extensive SVE system since February 2009 reducing the VOC content in the unsaturated zone. The SVE system had removed approximately 3,151 pounds (lbs) of VOCs as of October 31, 2015.

The RFI Human Health Risk Assessment (HHRA) as presented as Appendix C to the RFI Report (NV5, 2015c) has evaluated potential risk from soil gas to outdoor air and to indoor air. The HHRA determined that there is no adverse non-cancer risk from soil gas to outdoor air. With the exception of the cancer risk at one location (SVE well location AASG-3) (Figure 2), the soil gas to indoor air exposure pathway does not pose an adverse human health risk. The cancer risk at AASG-3 (2E-06) is just above the *de minimus* level of 1E-06 and at the low end of EPA's risk management range of 1E-06 to 1E-04 (Appendix C to the RFI Report; NV5, 2015c). Continued operation of the SVE remedial system is no longer necessary as the risk levels determined during the HHRA fall within the EPA's risk management range.

1.5.3 Indoor Air Quality

Potential exposure routes of VOC via indoor air quality were independently investigated by Kaiser prior to the startup of the SVE system (Workplace Safety Specialists, 2008). Kaiser collected indoor air quality samples as a result of the background soil gas samples collected by Plymouth Tube during the soil and soil gas investigation. Kaiser's report was submitted and approved by EPA. The conclusion of the Kaiser indoor air quality sampling was that VOC concentration detected in the indoor air quality samples was not a risk to their workers. The active SVE system has recovered tremendous volumes of VOCs and also has continued to produce a negative pressure environment below the Kaiser Facility foundation.

1.5.4 Perched Water

During the drilling activities at borings VASG-3 and VASG-7 perched water zones were encountered at approximately 50 feet below ground surface (bgs) at VASG-3, and at approximately 66 feet bgs at VASG-7 (Figure 2). Geomatrix also encountered thin saturated zones at angle borings AASG-5 at approximately 60 vertical feet bgs, and at AASG-4 and AASG-3 at approximately 65 vertical feet bgs (Figure 2). The encountered perched water was identified on or above the top of the competent clay unit (Geomatrix, 2006). Samples of the perched water were collected from two boreholes and were found to contain elevated VOC concentrations.

The SVE system has encompassed (as evidenced by the radius of influence [ROI] testing conducted) the areas of observed perched water, including the area in the vicinity of monitor well LB-7, and it is highly likely the SVE system has remediated perched water by evaporating the water. Ongoing rebound testing of the SVE system demonstrates that soil gas concentrations have stabilized at low HHRA *de minimis* exemption thresholds indicating that the perched water has either been removed and/or no longer serves as a source that could result in higher soil gas concentrations in the future (Appendix C to the RFI Report; NV5, 2015c). No further remedial assessment for the perched water is warranted.

1.5.5 Groundwater

The upgradient, lateral and vertical extent of VOC contamination in groundwater has been defined. There is no known current risk to human health through exposure to groundwater. LBDC and GRIC have stated they would enforce a risk management control that will prevent future installation of supply wells in the shallow water-bearing zone, resulting in no future exposure pathways for groundwater.

The HHRA has evaluated potential risk from VOC off gassing from groundwater and has determined there is no adverse non-cancer or cancer risk from groundwater to indoor air or groundwater to outdoor air (Appendix C to the RFI Report; NV5, 2015c).

The water quality data collected to date has indicated the VOCs in groundwater above their respective MCLs are located in the upper most portion of the saturated Upper Alluvial Unit (UAU). Investigations conducted by EPA, GRIC, and others have not identified any domestic or public supply wells located within the plume boundaries that are completed in this portion of the UAU. The Lone Butte production well and the three GRIC production wells (WHP-1, WHP-2 and WHP-3) located by Whirlwind Golf Course are completed much deeper in the Lower Alluvial Unit (LAU) aquifer and outside the footprint of the VOC plume. VOC concentrations across the Site are declining. Future monitoring of the VOC plume is being addressed in this CMS Report.

The only remaining area of elevated VOC concentrations (TCE >10,000 µg/L) (Figure 2) in groundwater is in the vicinity of the former GRIC monitor well LB-7 (NV5, 2015a). Based upon the results of the recent water quality data collected during the Reduced Pumping Investigation (NV5, 2015a), the footprint of this elevated VOC AOI is small and is being addressed in this CMS Report.

1.6 Summary of Interim Corrective Measures

The following is a summary of the two ICMs conducted by Plymouth Tube (Appendix B to the RFI Report; NV5, 2015c).

1.6.1 SVE System Summary

The SVE system consists of twelve extraction wells, underground lateral piping, an aboveground polyvinyl chloride (PVC) manifold, an SVE skid mounted blower, and two 3,000 lb vapor phase granular activated carbon (VGAC) filled vessels.

The SVE system began operation in February 2009. During the continued monitoring of the SVE system, several shut down/rebound tests were conducted on the system. The rebound testing did not indicate any high concentration VOC sources remained in the vadose zone. Based upon an engineering evaluation of those rebound tests, adjustments were made regarding which SVE wells were actively pulled from. Subsequent analytical results for the 2012 and 2013 SVE system influent samples indicated that the uncontrolled influent concentrations of detected constituents had decreased to mass loading rates less than GRIC *de minimis* exemption thresholds. The VGAC filled vessels were bypassed starting on February 5, 2014. The two 3,000-lb VGAC filled vessels were subsequently demobilized from the Site on February 7, 2014. Following which, the SVE system extraction flow rate was reduced to continue the focused extraction of soil vapor from a limited number of SVE wells that still yield low levels of VOCs.

From February 2009 to October 31, 2015, the SVE system operated for approximately 42,325 hours. Approximately 3,150 pounds of VOCs were removed during this period of operation. The SVE system is currently operating from five SVE wells (VASG-5, -6 and -11, and AAGS-2 and -3) at an extraction rate of approximately 187 cubic feet per minute (cfm). Continued operation of the SVE remedial system is no longer necessary, as the risk levels determined during the HHRA fall within the EPA's risk management range.

Upon EPA's approval of the RFI Report and Appendices, and the CMS Report, Plymouth Tube would discontinued the operation of the SVE system. Above grade structures, equipment, piping, vapor extraction wells and appurtenances would be removed at the discretion of Plymouth Tube.

1.6.2 LGWP&T System Summary

The LGWP&T system consisted of two extraction wells (LB-7R and PT-2S), equipped with two submersible Grundfos pumps rated to provide 30 gallons per minute (gpm) with 90 feet of vertical head, underground lateral piping, an aboveground PVC manifold, and two 2,000-lb liquid phase granular activated carbon (LGAC) filled vessels which treated the groundwater for VOCs. A TrojanUVPhox™ system (an advanced oxidation system that uses hydrogen peroxide and ultraviolet light to treat 1,4-dioxane) is located downstream of the two 2,000-lb LGAC filled vessels. The system was designed to discharge the effluent into the City of Chandler sanitary sewer under the City of Chandler Industrial User Permit No. 79.

The LGWP&T was initially brought on line on August 23, 2010. With the discovery of 1,4-dioxane and the addition of the TrojanUVPhox™ system, commissioning activities began on August 22, 2011. Operation of the LGWP&T system resumed on September 14, 2011 after receiving approval from the City of Chandler to discharge the treated groundwater to the sanitary sewer system.

Based on the flow meter measurements, a total of approximately 75,611,000 gallons of groundwater were extracted and treated by the LGWP&T system and then discharged to the City of Chandler sanitary sewer during the operational period of August 23, 2010 to May 15, 2015. A total of approximately 110 pounds (less than 10 gallons) of VOCs were removed during this period.

The LGWP&T system was shut down on May 15, 2015 as part of the Reduced Pumping and Temporary Shutdown of the LGWP&T System Investigation. That investigation indicated that large volumes of clean water were being extracted and run through the LGWP&T system. The data from that study indicates that extremely low levels of VOCs were being removed from the groundwater, and therefore continued operation of the LGWP&T system was neither technically appropriate, nor cost effective.

Above grade structures, equipment, piping, and appurtenances would be removed at the discretion of Plymouth Tube. Abandonment of the discharge line to the City of Chandler sewer line would be coordinated with Lone Butte. The subsurface lateral piping will be capped and left in place. The extraction/monitor wells would be left in place.

2.0 HUMAN HEALTH RISK ASSESSMENT AND MEDIA SPECIFIC CLEANUP OBJECTIVES SUMMARY

An HHRA and Media Specific Cleanup Objectives Report has been prepared for the Former Plymouth Tube Company Facility as presented in the RFI Report, Appendix C (NV5, 2015c). The

objective of the HHRA was to propose interim cleanup goals (ICGs) and final cleanup goals (FCGs) for hazardous waste constituents detected in groundwater, soil gas, and soil as follows:

Media	Interim Cleanup Goals (ICGs)	Final Cleanup Goals (FCGs)
Groundwater	Risk-based (indoor and outdoor air vapor volatilization pathways)	EPA MCLs (drinking water ingestion pathway)
Soil Gas	Risk-based (indoor and outdoor air volatilization pathways)	Risk-based (indoor and outdoor air volatilization pathways)
Soil	Risk-based EPA Screening Levels (SLs) (incidental ingestion and volatilization to outdoor air pathway)	Risk-based (incidental ingestion and volatilization to outdoor air pathway)

The cleanup goals consider both cancer and non-cancer effects; therefore, in addition to establishing these human health risk-based cleanup goals, the HHRA also presented incremental lifetime cancer risk (ILCR) and hazard index (HI) (non-cancer) values based on current data.

The HHRA also evaluated potential exposure to soil. The HHRA evaluated a default future commercial/industrial land use scenario, as this scenario – with its inherently conservative assumptions regarding exposure time, exposure duration, exposure frequency, and building air exchange rate (for the indoor receptors) – is the most conservative basis for risk management decisions.

Neither residential nor ecological receptors, nor leaching-to-groundwater or groundwater exposure were considered in the HHRA. Furthermore, the LBDC and GRIC have stated that they would enforce a risk management control that will prevent future installation of supply wells in the shallow water-bearing zone; therefore, there are no exposure pathways for groundwater.

The HHRA identified the exposure pathways, environmental media of interest (i.e., exposure points), and compounds of potential concern (COPCs) (Appendix C to the RFI Report; NV5, 2015c). The site-specific CSM on which the HHRA was based identified the following (Figure 3):

- A source and mechanism for chemical release;
- An environmental transport medium (e.g., groundwater, air, soil);
- A point of potential human contact with the medium; and

- A route of exposure (e.g., ingestion, dermal contact, inhalation).

As such the CSM identified the following receptors:

- Outdoor commercial/industrial worker receptor (long-term worker); and
- Indoor commercial/industrial worker receptor (long-term worker).

The HHRA evaluated a default future commercial/industrial scenario, as this is the most conservative scenario that will be used as the basis for Site closure decisions. Neither residential nor ecological receptors, were considered in the HHRA. Leaching-to-groundwater, which is being addressed through ongoing quarterly monitoring was also not considered in the HHRA. Water for drinking, bathing, and commercial uses is supplied by the Lone Butte water system. No supply wells have been located or reported in the area screened within the VOC-impacted shallow water-bearing zone that is the subject of the ongoing quarterly monitoring. Furthermore, LBDC and GRIC have stated that they would enforce a control that prevents future installation of supply wells in this shallow water-bearing zone; therefore, there is no exposure to groundwater.

The HHRA evaluated the following potential routes of exposure (Figure 3):

- Inhalation of VOC vapors in ambient (outdoor) air;
- Inhalation of VOC vapors in indoor air; and
- Incidental ingestion of VOC-impacted soil.

Neither dermal absorption nor particulate inhalation of VOCs in soil was considered in the HHRA. The rationale for this was that VOCs tend to be volatilized from the soil on skin and are accounted for via inhalation.

Based upon the calculated ICGs and FCGs, the HHRA concluded the following:

- Groundwater-to-indoor air: no adverse non-cancer or cancer effects.
- Groundwater-to-outdoor air: no adverse non-cancer or cancer effects.

- Soil gas-to-indoor air: With the exception of cancer risk at one location (AASG-3), the soil gas-to-indoor air exposure pathway does not pose an adverse risk. The cancer risk at AASG-3 is just above the low end of EPA's risk management range of 1E-06 to 1E-04.
- Soil gas-to-outdoor air: no adverse non-cancer or cancer effects.
- Soil: no adverse non-cancer or cancer effects.

Ongoing rebound testing of the SVE system demonstrates that soil gas concentrations have stabilized at low *de minimis* exemption thresholds indicating that the perched water has either been removed and/or no longer serves as a source that could result in higher soil gas concentrations in the future. Given the low risk values associated with the soil gas-to-indoor air and outdoor air exposure pathways, there is no health-based reason to continue to operate the SVE system.

2.1 Groundwater Target Cleanup Standard

The groundwater ICGs and FCGs determined by the HHRA are presented in Table 1.

2.2 Soil Gas Target Cleanup Standard

The soil gas ICGs and FCGs determined by the HHRA are presented in Table 2.

3.0 CORRECTIVE MEASURES STUDY

This section presents a streamlined CMS to identify, develop and evaluate various corrective measure alternatives that are designed to address the residual VOC impacts at the Site. The RFI has determined the following: 1) the sources of historical impacts to soil and groundwater have been addressed through the proper abandonment of the conduit monitor well LB-7, and the design and implementation of two ICMs; the SVE system and the LGWP&T system; 2) there are no current human exposures to the residual contamination as presented in the HHRA; and, 3) the corrective measures to address the VOCs in groundwater are generally understood. The available VOC groundwater quality data from the 3rd Quarter 2015 monitoring event are presented in Tables 3 and 4, and Figure 4 (NV5, 2015b).

The EPA has identified three threshold criteria that potential corrective measure must achieve. These threshold criteria include the following: 1) be protective of human health and the environment; 2) attain the media cleanup objectives; and 3) control the source.

The HHRA as presented as Appendix C to the RFI Report has demonstrated that there is no current risk to human health and the environment. Potential corrective measures will not alter the HHRA conclusions.

Evaluation of the water quality data as presented in the Updated Conceptual Site Model (Appendix A to the RFI Report; NV5, 2015c) indicates that VOC concentrations are trending downward and the VOC plume is not migrating and is shrinking expanding. Attenuation, dispersion and dilution processes will continue to reduce the groundwater VOC concentrations towards the groundwater cleanup objectives. Soil VOC concentrations are below regulatory standards. The HHRA determined that there is no adverse non-cancer risk from soil gas to outdoor air. With the exception of the cancer risk at one location (SVE well location AASG-3) (Figure 2), the soil gas to indoor air exposure pathway does not pose an adverse human health risk. The cancer risk at AASG-3 ($2\text{E}-06$) is just above the *de minimus* level of $1\text{E}-06$ and at the low end of EPA's risk management range of $1\text{E}-06$ to $1\text{E}-04$ (Appendix C to the RFI Report; NV5, 2015c).

As noted above, the sources from the historical releases have been addressed through the proper abandonment of the conduit monitor well LB-7, and the design and implementation of the SVE system and the LGWP&T system.

NV5 has identified a number of corrective measure alternatives to address the residual VOCs in groundwater that meet the two remaining EPA threshold criteria. These identified corrective measure alternatives are evaluated using the preliminary screening criteria (Short Term Effectiveness, Implementability and Relative Costs) presented below.

3.1 Preliminary Screening Criteria

The following describes the three preliminary screening criteria that will be used to evaluate the initial Corrective Measure Alternatives.

3.1.1 Short Term Effectiveness

Short term effectiveness is an assessment of the effectiveness of the corrective measure alternative in protecting human health and the environment during construction and implementation of the corrective measure alternative and prior to the attainment of media cleanup objectives. Short-term effectiveness may address factors such as magnitude of reduction of existing risk, and time until full protection is achieved. It also addresses risks that might be posed to community, workers, or the environment during implementation (U.S. EPA, Undated).

3.1.2 Implementability

Implementability is an assessment of the technical and regulatory/administrative feasibility of implementing the corrective measure alternative. Implementability will often be a determining variable in shaping remedies. For example, some technologies will require State or local permits prior to construction, which may increase the time needed to implement the remedy. Also, the evaluation should include an assessment as to whether the remedy is implementable with respect to future land use (U.S. EPA, Undated).

3.1.3 Relative Cost

Relative cost is an assessment of the total cost which includes the estimated capital cost for bench and/or field testing, construction costs and the costs for long term operation and maintenance of the corrective measure alternative, including associated monitoring and inspection costs. During the preliminary screening of corrective measure alternatives, an assessment of the relative costs (as low, moderate or high) was conducted rather than performing a more detailed costing evaluation. An inverse ranking of the various corrective measure alternatives was conducted which assigned a corrective measure alternative with relative high costs a low overall priority ranking.

3.2 Preliminary Screening of Corrective Measure Alternatives

NV5 identified six corrective measures (including the No Action alternative) based on literature review and our experience with remedy's related to VOCs in groundwater. The preliminary screening of the No Action, Monitored Natural Attenuation, Focused In-Situ Chemical Oxidation (ISCO), Regional ISCO Application, Air Sparging/SVE, and Groundwater Pump and Treat (P&T) Corrective Measure Alternatives are presented below.

3.2.1 No Action

A No Action Corrective Measure Alternative was considered for use as a baseline when comparing other corrective measure alternatives. A No Action Corrective Measure Alternative would discontinue ongoing corrective measures, refrain from implementation of any new corrective measures, and end the groundwater monitoring program. The RFI has determined that the VOC groundwater plume has been defined, the VOC groundwater plume is not migrating, VOC concentrations in groundwater are decline, and the VOC groundwater plume is shrinking. No supply wells have been located or reported in the area that are screened within the VOC-impacted shallow water-bearing zone that is the subject of the ongoing quarterly monitoring. Furthermore, LBDC and GRIC have stated that they would enforce a control that prevents future installation of supply wells in this shallow water-bearing zone; therefore, there is no exposure to groundwater.

Based upon the calculated ICGs and FCGs, the HHRA concluded the following:

- Groundwater-to-indoor air: no adverse non-cancer or cancer effects.
- Groundwater-to-outdoor air: no adverse non-cancer or cancer effects.
- Soil gas-to-indoor air: With the exception of cancer risk at one location (AASG-3), the soil gas-to-indoor air exposure pathway does not pose an adverse risk. The cancer risk at AASG-3 is just above the low end of EPA's risk management range of 1E-06 to 1E-04.
- Soil gas-to-outdoor air: no adverse non-cancer or cancer effects.
- Soil: no adverse non-cancer or cancer effects.

The No Action Corrective Measure Alternative is not considered to be protective of human health and the environment, one of RCRA's threshold criteria, because no mechanism would be in place to detect adverse changes in Site conditions prior to attainment of the media cleanup objectives.

The No Action Corrective Measure Alternative is therefore **not considered for further evaluation** in this CMS (Table 5).

3.2.2 Monitored Natural Attenuation

Monitored natural attenuation (MNA) uses natural process to decrease or attenuate contaminant concentrations in soil and groundwater. Monitoring of these conditions typically involves the collection and analysis of media specific samples to verify and quantify the presence of contaminants and their rates of attenuation.

The RFI has determined that the VOC sources have been identified and addressed, the remaining soil vapor concentrations do not pose an adverse risk to human health or the environment, the VOC groundwater plume has been defined. The VOC concentrations in groundwater are in decline, there is no ongoing migrating of the plume, and the VOC groundwater plume is shrinking. No supply wells have been located or reported in the area that are screened within the VOC-impacted shallow water-bearing zone that is the subject of the ongoing quarterly monitoring. Furthermore, LBDC and GRIC have stated that they would enforce a control that prevents future installation of supply wells in this shallow water-bearing zone; therefore, there is no exposure to groundwater.

MNA remedies are appropriate at sites such as the Former Plymouth Tube Company Facility where not only have the sources of contamination been addressed and the plume appropriately defined, but the contaminant concentrations are declining and the plume is shrinking. Plymouth Tube has established a groundwater monitoring network (Figure 5) which has defined the plume laterally, horizontally and vertically. The associated data collection and monitoring activities have confirmed that VOC concentrations in groundwater are declining and the plume is shrinking. A visual comparison of Figures 4 and 6 shows the large reduction in the TCE plume size and concentrations between August 2012 and August 2015. There are no data which would indicate that this trend would not continue over time.

The proposed MNA Corrective Measure Alternative consists of ongoing groundwater monitoring and sampling to verify that attenuation is continuing to occur over time. The preliminary screening results for the MNA Corrective Measure Alternative are presented on Table 5 and summarized below.

- Short Term Effectiveness: **Ranked High** - There is no current completed exposure routes, potential future exposure routes are being addressed through institutional controls by GRIC and LBDC, and the VOC groundwater plume is shrinking and VOC concentrations in groundwater are declining.
- Implementability: **Ranked High** - An appropriate groundwater monitoring network to verify future VOC reduction is currently in place.
- Relative Cost: **Ranked High** - No additional capital costs since an appropriate groundwater monitoring network current exists. The MNA groundwater monitoring operation and maintenance (O&M) costs are low.
- Retained for Further Analysis: **Yes**.

3.2.3 Focused In-Situ Chemical Oxidation (ISCO) at LB-7/LB-7R Source Area

The remediation of groundwater contamination using ISCO involves injecting oxidants directly into the subsurface at the area of concern to destroy the COCs. The series byproducts created during the destruction of the COCs depends on the selected oxidant. The primary advantages of using ISCO over other treatment technologies are a short implementation time and limited or negligible quantity of generated waste material.

Groundwater samples near the western property line have been collected from groundwater monitor wells LB-7 and LB-7R. Elevated concentrations of VOCs (up to 53,000 µg/L of TCE)

were detected in depth specific groundwater samples collected from monitor well LB-7 by ATC (Cardno, 2015). VOC concentrations detected in the depth specific groundwater samples from this monitor well reduced with depth (ATC, 2011). Due to the concerns that this well was acting as a conduit well, and with the discovery of perched groundwater onsite with elevated VOCs, Plymouth Tube abandoned GRIC monitor well LB-7 and constructed a replacement monitor well LB-7R.

Recent sampling of monitor well LB-7R using traditional purge and sampling protocols detected VOCs, specifically TCE, in the range of 10,000 µg/L. Depth specific samples from this well using the depth specific low flow sampling protocol used during the Joint Groundwater Sampling Effort (Geomatrix, 2007) indicated a TCE concentration (8,400 µg/L in the upper most sampling interval) and TCE and other detected VOC concentrations reduced with depth (1,400 µg/L in the lowest sample). The results from the two different sampling methods may indicate that the detected VOC results are a remnant of possible migration of VOCs through the annular seal or perforated casing at monitor well LB-7, since the two wells are within approximately 15 feet of each other. The dramatic drop in VOC concentrations during the standard purge and sample event while the well was pumping as part of the LGWP&T system likely indicates the hydraulic capturing of uncontaminated or lower contaminated water close to the well. The totality of the groundwater quality data (both pumping and non-pumping and vertical profiling) strongly indicates that there remains a small footprint of highly impacted groundwater just west of monitor well LB-7R, most likely in the vicinity of the former monitor well LB-7.

This proposed Corrective Measure Alternative consists of a Focused ISCO application in the area of elevated COCs around monitor wells LB-7/LB-7R (Site AOI). The preliminary screening results for the Focused ISCO Corrective Measure Alternative are presented on Table 5 and summarized below.

- Short Term Effectiveness: **Ranked Moderate to High** - Would reduce the volume of the COCs (i.e., TCE, 1,1-DCE, and 1,4-dioxane) via desorption and degradation. The end products of the selected ISCO oxidant reaction with TCE, 1,1-DCE, 1,4-dioxane and PCE need to be evaluated prior to selection of an appropriate oxidant.
- Implementability: **Ranked Low to Moderate** - Most ISCO oxidants can be readily mixed at the surface using appropriate tanks and mixers prior to injection into the subsurface. Installation of an injection system is not technologically difficult. No known regulatory framework exists for application of ISCO on GRIC lands, which may complicate any applicable regulatory implementability. A low ranking is provided due to the uncertainty of

the regulatory requirements and acceptance of the Focused ISCO Corrective Measure Alternative. However, it may be noted that this technology has been approved by several state regulatory agencies throughout the United States and abroad over the last two decades.

- Relative Cost: **Ranked High to Moderate** - Low to moderate capital costs for the acquisition of the oxidant and rental of the necessary mixing tanks and equipment. Low to moderate costs associated with providing pathway (injection wells) for groundwater treatment. No additional capital costs for monitoring since an appropriate groundwater monitoring network currently exists. Low O&M costs are associated with groundwater monitoring.
- Retained for Further Analysis: **Yes** - EPA and GRIC DEQ have expressed interest in further evaluation of this Corrective Measure Alternative.

3.2.4 Regional ISCO Application

The upgradient, lateral and vertical extent of VOC contamination in groundwater has been defined. There is no known current risk to human health through exposure to groundwater. LBDC and GRIC have stated they would enforce a risk management control that will prevent future installation of supply wells in the shallow water-bearing zone, resulting in no future exposure pathways for groundwater. The HHRA has evaluated potential risk from VOC off gassing and determined that there is no adverse health risk.

The water quality data collected to date has indicated the VOCs in groundwater above their respective MCLs are located in the upper most portion of the saturated UAU. Investigations conducted by EPA, GRIC, and others have not identified any domestic or public supply wells located within the plume boundaries and that are completed in this portion of the UAU. The Lone Butte production well and the three GRIC production wells (WHP-1, WHP-2 and WHP-3) located by Whirlwind Golf Course are completed much deeper in the LAU aquifer and outside the footprint of the VOC plume. VOC concentrations in groundwater across the Site are declining and the VOC plume is not migrating.

Analysis of the water quality data collected from the Plymouth Tube monitoring network indicates that there is a declining trend in VOC concentrations. Comparison of the August 2012 and August 2015 contoured TCE concentrations in shallow groundwater show dramatic shrinking of the TCE plume (Figures 4 and 6).

ISCO is most typically applied in areas with elevated concentrations of VOC such as source areas. While somewhat feasible in low VOC concentrations areas, it may not be cost-effective remedial approach (ITRC, 2005). As noted above, the VOC plume is shrinking and the overall concentrations have and continue to decrease over time. There remains only one area of elevated VOC concentrations (as presented in 2.2.3) where ISCO is appropriate. As such, the regional application of ISCO as a corrective measure alternative is therefore **not considered for further evaluation** in this CMS (Table 5).

3.2.5 *Air Sparging/SVE*

Air sparging of VOCs in groundwater consists of the injection of air, typically by one or more injection wells, into the impacted groundwater. The injection of air into groundwater promotes the volatilization of VOCs from the dissolved phase into the vapor phase. The injected air, now containing VOCs in the vapor phase, migrates upward into the vadose zone where VOCs in the soil vapor can now be removed and treated by the installation and operation of an SVE system. The extracted soil vapor containing VOCs is typically treated by passing the soil vapor through one or more vessels containing VGAC.

Because of the regional Site hydrostratigraphy, an air sparging system cannot be implemented due to the presence of the competent clay unit which is located above the water table. The geotechnical characteristics of the competent clay unit will not allow the injected air to migrate upward into the vadose zone. Also due to the tightness of the competent clay unit, soil vapor cannot be pulled from within the competent clay unit. As such, air sparging of the impacted groundwater is not considered to be able to meet the implementability criteria and therefore is **not considered for further evaluation** in this CMS (Table 5).

3.2.6 *Groundwater Pump and Treat*

Groundwater Pump and Treat involves the installation and operation of a groundwater extraction well network within the footprint of the VOC plume. The extraction wells would need to be piped back to a common groundwater treatment system which would include a LGAC treatment system to remediate the VOC s followed by a UV/Phox type treatment system to remediate the 1,4-dioxane which cannot be effectively treated by the LGAC system. Treated water would then need to be put to a beneficial end used. Beneficial end uses may include reinjection into a deeper portion of the aquifer, piping to the Gila Ditch for agriculture application, transmission to a Lone Butte business that is willing to accept the treated water, or disposal of the treated groundwater to the City of Chandler sanitary sewer system. The LGAC vessels would require regular carbon change outs. The UV/Phox type system would require O&M including replacement of the UV

bulbs and the use of large quantities of hydrogen peroxide. The preliminary screening results for the Groundwater Pump and Treat Corrective Measure Alternative are shown on Table 5.

- Short Term Effectiveness: **Ranked Moderate to High** – Would need numerous extraction wells to capture the current VOC plume. Corrective measure technology is proven for the remediation of VOCs and 1,4-dioxane.
- Implementability: **Ranked Low** – Relatively low concentration VOC plume located along an appropriate 2.5-mile long VOC plume. Would require substantial property access for the extraction wells as well as for the piping back to a centralized treatment system. After treatment may require substantial access for piping to the disposal point or beneficial end use. If treated groundwater were not reinjected or reused, the City of Chandler may not allow disposal of a large volume of water into their sanitary sewer system. Piping for discharge to the Gila Drain may not be practicable. No know facility was identified that would accept the treated water. No other beneficial end use for the water has been identified.
- Relative Cost: **Ranked Low** - High costs for the extraction well installations, and piping from the extraction wells to a centralized treatment system. High capital costs for the design and construction of both a LGAC treatment system (for VOCs) and a UV/Phox type treatment system (for 1,4-dioxane). High O&M costs including power, LGAC replacement, hydrogen peroxide usage, and replacement parts (UV bulbs) for the UV/Phox system.
- Retained for Further Analysis: **No**.

4.0 EXPANDED EVALUATION OF RETAINED CORRECTIVE MEASURE ALTERNATIVES

Two corrective measure alternatives were retained from the preliminary screening of corrective measure alternatives. These two remedial alternatives are further evaluated below.

4.1 Corrective Measure Alternative 1: Monitored Natural Attenuation (MNA)

MNA using the current Plymouth Tube groundwater monitoring network along with selected GRIC monitor wells comprises Corrective Measure Alternative 1. This MNA alternative consists of quarterly groundwater monitoring and quarterly reporting for one year after EPA approval of the CMS. After the one year of quarterly monitoring and reporting has been completed, the MNA alternative would switch to semi-annual groundwater monitoring and semi-annual reporting for four additional years.

Groundwater sampling and analysis would be conducted using the same protocols as has been conducted during historic quarterly groundwater monitoring events (Geosyntec, 2013, NV5, 2015b and 2015c). The depth to groundwater would be measured in the Plymouth Tube groundwater monitor wells PT-1S, PT-1D, LB-7R, PT-2S, PT-2D, PT-3, PT-3D, PT-4, PT-4D, and PT-5 and selected GRIC monitor wells LB-1, LB-13, LB-17, and PT-6D using a calibrated and decontaminated electric water level sounder. The depth to groundwater would be measured from the top of the well casing (north side) to the nearest 0.01 foot.

A low-flow sampling method would be implemented at monitor wells in order to collect groundwater samples from the Plymouth Tube monitor wells and select GRIC monitor wells (Geomatrix, 2005). The low-flow sampling method involves the use of a QED Sample Pro[®] micropurge bladder pump (pump), QED MP-10 control box and compressed gas (carbon dioxide [CO₂]) cylinders. Groundwater samples would be collected approximately at the mid-point of the saturated screen interval. Prior to submerging the decontaminated pump at each monitor well, the water level would be measured using an electric water level sounder to verify the depth to water.

The pump would be slowly lowered into the well to minimize disturbance to the water column until the intake port has reached the desired sample collection depth. Groundwater would be purged from each monitor well at an approximate rate of 200 milliliters per minute (mL/min). Following purging, a groundwater sample would be collected at an approximate pumping rate of 100 mL/min.

For all monitor wells sampled, a water quality data instrument (YSI 556 MPS) with a flow-through cell would be used to continuously measure the field water quality parameters: pH, temperature, dissolved oxygen (DO), reduction/oxidation potential (Redox), and specific electrical conductance every three to five minutes. Pre-sample purging would be continued until water quality parameters have stabilized for three successive readings collected at every three- to five- minute interval which is the approximate time required to fill the flow-through cell. Pre-sample purging would be continued until water quality standards stabilized within approximately 5 percent (%) of the previous three readings, and positive/negative (+/-) 0.1 standard units for pH, +/- 4 degrees Fahrenheit for temperature, +/- 3% of last reading for specific electrical conductance, +/- 10 millivolt (mV) for Redox, +/- 10% for DO, and until the water appeared clear and free of sediment. These data would be recorded on a Well Sampling Record for each monitor well.

Upon stabilization of the water quality parameters, the flow-through cell would be disconnected, and the groundwater sample would be collected from the outlet tubing. New polyethylene tubing

would be used in each monitor well to transmit the water from the pump to the surface for collection. Groundwater samples would be collected into the following laboratory-certified sample containers:

➤ Plymouth Tube & Selected GRIC Groundwater Monitor Wells

○ VOCs

EPA Test Method 8260B

Three 40-milliliter (mL) volatile organic analysis (VOA) vials preserved with hydrochloric acid

○ 1,4-Dioxane

EPA Test Method 8260B SIM

Three 40-mL VOA vials preserved with hydrochloric acid

Each set of VOA vials would be labeled and enclosed in bubble wrap and placed in a cooler with wet ice for transport to an Arizona Department of Health Services certified laboratory, under standard chain-of-custody protocol.

The depth to water would again be measured at the conclusion of sampling. These measurements would be performed to ensure that minimal water level drawdown is maintained throughout the sampling effort.

A monitoring and sampling report would be prepared and submitted to EPA and GRIC DEQ for each event. The report would document the monitoring and sampling activities, and present the laboratory results in tabular and graphic form. The data would undergo data verification which would be presented in the report.

Sampling of an individual monitor well may be discontinued if VOC concentrations are below their respective MCLs for two consecutive sampling events, and EPA and GRIC DEQ agree with the request to stop sampling.

- Short Term Effectiveness: Ranked High - There is no current completed exposure routes to the shallow impacted groundwater. No supply wells are known to exist within the footprint of the defined VOC plume. Potential future exposure routes to groundwater are being addressed through institutional controls by GRIC and LBDC. The historical water quality data shows that the VOC groundwater plume is not migrating, and in fact is shrinking and that the VOC concentrations in groundwater are declining. The existing

Plymouth Tube groundwater monitoring network would be used to collect data to verify continued plume reduction.

- **Implementability: Ranked High** - An appropriate groundwater monitoring network to verify future VOC reduction is currently in place so Corrective Measure Alternative 1 can be implemented without delay. Plymouth Tube already has a contract in place with GRIC DEQ to provide access to the selected GRIC monitor wells that would be a part of the MNA monitoring network.
- **Relative Cost: Ranked High** - No additional capital costs would be incurred as the MNA groundwater monitoring network current exists. The MNA monitoring network wells do not have dedicated pumps so there would be no costs for in-well pump replacement or repair. Overall the O&M costs for MNA groundwater monitoring is low.
- **Retained for Further Analysis: Yes.**

4.2 Corrective Measure Alternative 2: Focused In-Situ Chemical Oxidation

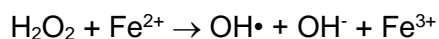
ISCO involves delivery of an oxidant into the subsurface to abiotically destroy the chemicals of concern into non-toxic byproducts. Oxidants commonly used include hydrogen peroxide, ozone, permanganate and persulfate. The ISCO technologies evaluated for the Former Plymouth Tube Company Facility Site include catalyzed hydrogen peroxide (CHP), activated sodium persulfate (ASP) and potassium/sodium permanganate.

ISCO is considered for an approximate 40 feet by 30 feet hot-spot area referred to as the Site AOI surrounding monitor wells LB-7/LB-7R located to the west of the facility (Figure 5). The primary COCs at the Site include TCE, 1,1,-DCE, 1,4-dioxane and limited PCE. Site lithology consists of gravels, sands, silts and clay. A competent clay layer exists at approximately 60 to 70 feet bgs and the target treatment zone appears to exist under confined/semi-confined conditions underneath the clay layer. Groundwater was encountered at approximately 60 feet bgs and flows in the westerly direction.

4.2.1 Catalyzed Hydrogen Peroxide (CHP) – Modified Fenton's Reagent (MFR)

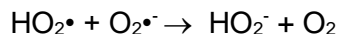
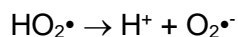
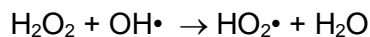
The proposed catalyzed hydrogen peroxide (CHP) evaluated for the Former Plymouth Tube Company Facility is Modified Fenton's Reagent (MFR). The modified Fenton's process incorporates the fundamental goal of enhancing *in-situ* treatment of soil and groundwater contamination using Fenton's chemistry while mitigating the negatives associated with application of Fenton's reagent in its conventional form. As compared to conventional Fenton's Reagent, which requires acidic conditions ($\text{pH} \leq 3$), the modified Fenton's process is effective over a wide

pH range (i.e. pH 2-10) including neutral (pH \cong 7) conditions. The modified Fenton's process combines proprietary chelated iron complex catalysts¹, mobility control agents, oxidizers, and stabilizers in an optimal, chemical formulation, and employs site-specific delivery systems to achieve destruction of the targeted COCs. Unlike conventional applications, the oxidant (i.e. hydrogen peroxide) is mixed with proprietary stabilizers to control its rate of decomposition and injected in a diluted form (typically <12.5%) to minimize temperature increase due to exothermic reaction. The oxidant compounds are injected through a site-specific delivery system providing sufficient distribution to treat the contaminants in the Site AOI. The process generates powerful free radicals when the catalyst reacts with hydrogen peroxide to promote co-existing oxidation-reduction (redox) conditions. The principal chemical reaction associated with the modified Fenton's process is provided below.



H₂O₂ = Hydrogen Peroxide; Fe²⁺ = Ferrous Ion; Fe³⁺ = Ferric Ion; OH[•] = Hydroxyl Radicals; and OH⁻ = Hydroxide ion.

In addition to the initiation reaction described above that produces hydroxyl radical oxidants, the modified Fenton's process also produces superoxide radical and hydroperoxide anion reductants by additional chain propagation reactions described below, which provides a secondary remediation pathway.



H₂O₂ = Hydrogen Peroxide; OH[•] = Hydroxyl Radicals; O₂^{•-} = Superoxide Radicals; HO₂⁻ = Hydroperoxide Anion; HO₂[•] = Perhydroxyl Radical; H⁺ = Hydrogen ion; and O₂ = Oxygen

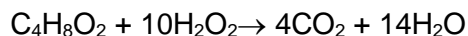
The co-existing redox reactions associated with a modified Fenton's process promote enhanced desorption and degradation of recalcitrant compounds. These include compounds such as carbon tetrachloride and chloroform, which were previously considered untreatable by Fenton's chemistry.

The modified Fenton's process is effective on a wide range of contaminants including hard to treat recalcitrant compounds such as petroleum hydrocarbons, gasoline additives including MTBE,

¹ The catalysts consist of proprietary chelated iron complexes, which remain soluble under a range of pH conditions including neutral pH.

chlorinated solvents and pesticides. Hydroxyl radicals will oxidize nearly all contaminants with carbon/carbon double bonds (e.g. TCE, 1,1-DCE, PCE) and single bonded contaminants with extractable hydrogen. The end products of the reaction are typically innocuous such as carbon dioxide and water, and chloride ions when chlorinated compounds are being treated.

As an example, the chemical reaction associated with target COCs breakdown at the Former Plymouth Tube Company Facility Site (i.e. 1,4-dioxane and TCE) is provided below.



Where

H_2O_2 = Hydrogen Peroxide; $\text{C}_4\text{H}_8\text{O}_2$ = 1,4-Dioxane; CO_2 = Carbon Dioxide; and H_2O = Water



$\text{C}_2\text{Cl}_3\text{H}$ = Trichloroethene (TCE); Cl^- = Chloride; H^+ = Hydrogen ion.

As can be seen from the above reactions, the end products of the MFR reaction are benign and include carbon dioxide, water and chloride (for chlorinated contaminants).

4.2.2 Potassium / Sodium Permanganate

The permanganate process uses either potassium permanganate or sodium permanganate as the oxidant. Unlike the CHP or activated persulfate process, catalyst/activator addition is not required using permanganate as the oxidant. Similar to CHP, the oxidant compounds are injected through a site-specific delivery system providing sufficient distribution to treat the contaminants in the Site AOI. Unlike CHP and persulfate, the permanganate process does not generate free radicals; however, the permanganate anion is a strong oxidant, which is self-activated and does not require addition of external catalysts or amendments. The half reactions associated with TCE oxidation and permanganate reduction are as follows.



C_2HCl_3 = Trichloroethene (TCE), MnO_4^- = Permanganate (Sodium or Potassium), CO_2 = Carbon dioxide, Cl^- = Chloride ion, H^+ = Hydrogen ion, e^- = Electrons, MnO_2 = Manganese Dioxide, and H_2O = Water

When combined, the oxidation of TCE by permanganate requires two moles of permanganate per mole of TCE.



C_2HCl_3 = Trichloroethene (TCE), MnO_4^- = Permanganate (Sodium or Potassium), CO_2 = Carbon dioxide, Cl^- = Chloride ion, H^+ = Hydrogen ion, and MnO_2 = Manganese Dioxide

The end products of the permanganate reaction are carbon dioxide, chloride (for chlorinated contaminants) and black manganese dioxide precipitate.

The selection of sodium permanganate or potassium permanganate reagents should be based on the following fundamental differences between the two permanganates. Please note that the primary differences are in the solubility and in the cost of each permanganate with the contaminant treatment effectiveness similar for both permanganates when delivered at the same dosage on a 100% basis.

- Under field conditions, the practical solubility of potassium permanganate is limited to 3% or less whereas the practical solubility of sodium permanganate is 40% or greater. However, health and safety considerations limit usage percentage of sodium permanganate to a maximum of approximately 10%. At 10% concentration, the volume of permanganate can be reduced to a third of the volume compared to 3% potassium permanganate significantly reducing time and labor costs.
- On a 100% basis, sodium permanganate costs 4-5 times more than potassium permanganate.

4.2.3 Activated Sodium Persulfate

The activated sodium persulfate process utilizes sodium persulfate ($\text{Na}_2\text{S}_2\text{O}_8$) oxidant activated using various methods to produce sulfate free radicals. The activators include chelated iron catalyst, alkali (e.g. sodium hydroxide $[\text{NaOH}]$), heat or hydrogen peroxide. Persulfate reagents are designed for both solo use or in combination with other reagents (e.g. CHP/MFR, Permanganate reagent). Similar to CHP and permanganate, the oxidant compounds are injected through a site-specific delivery system providing sufficient distribution to treat the contaminants in the Site AOI. The reaction mechanism associated with the activated sodium persulfate process is shown below.

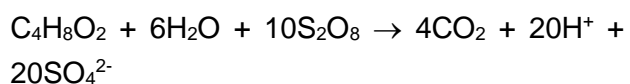


$\text{S}_2\text{O}_8^{2-}$ = Sodium persulfate

$\text{SO}_4^{\bullet-}$ = Sulfate free radical

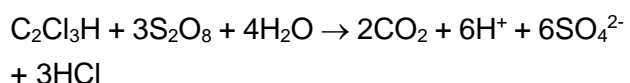
Activator = Chelated Iron catalyst or Hydrogen Peroxide

For example, the chemical reaction associated with 1,4-dioxane and TCE breakdown, which are target COCs at the Site, using sodium persulfate is provided below.



Where

$\text{C}_4\text{H}_8\text{O}_2$ = 1,4-dioxane; CO_2 = Carbon Dioxide; S_2O_8 = Persulfate; HCl = Hydrochloric acid; and H_2O = Water



$\text{C}_2\text{Cl}_3\text{H}$ = Trichloroethene (TCE); Cl^- = Chloride; H^+ = Hydrogen ion; SO_4^{2-} = Sulfate

The end products of the reaction are carbon dioxide, chloride (for chlorinated contaminants) and sulfate/ sulfuric acid.

A comparison of the various oxidants is provided below.

Comparison of Oxidants

Property	Permanganate	Sodium Persulfate	Modified Fenton's Reagent (MFR)	Traditional Fenton's
Stability	Half-life in days	Half-life in hours to days	Half-life in hours	Half-life in minutes to hours
Precipitation	Will form black MnO_2 precipitate, which may reduce subsurface permeability.	Slight precipitation of iron, when iron activated persulfate is used, which will be adsorbed by soil matrix. Permeability is not significantly affected.	Slight precipitation of iron, which will be adsorbed by soil matrix. Permeability is not significantly affected.	Will precipitate excess dark brown iron hydroxide, which may cause iron fouling and reduce subsurface permeability.

Property	Permanganate	Sodium Persulfate	Modified Fenton's Reagent (MFR)	Traditional Fenton's
Treatment of COCs	Can treat chlorinated alkenes such as TCE, 1,1-DCE, PCE effectively but is ineffective with chlorinated alkanes such as TCA. Also, ineffective with benzene and chlorobenzene. Not effective towards 1,4-dioxane	Can treat chlorinated alkenes such as TCE, 1,1-DCE, PCE effectively. Moderately effective with chlorinated alkanes. Persulfate may be combined with MFR for carbon tetrachloride & chloroform treatment. Effective towards 1,4-dioxane	Can treat both chlorinated alkenes such as TCE, 1,1-DCE, PCE and alkanes effectively. Also effective with a wide range of petroleum hydrocarbons, carbon tetrachloride and chloroform. Effective towards 1,4-dioxane	Can treat both chlorinated alkenes such as TCE, 1,1-DCE, PCE and alkanes effectively. Also effective with a wide range of petroleum hydrocarbons. Not effective with carbon tetrachloride and chloroform. Effective towards 1,4-dioxane
Desorption Ability	Limited	Limited	Very effective at desorbing soil-bound contaminants.	Limited due to poor generation of superoxide radical.
Radial Distribution	Good	Good for chelated iron activation. Poor for alkaline activation due to immediate pH buffering by native soils.	Good due to stabilized peroxide and chelated iron catalysts.	Poor due to immediate buffering of acidic pH by native soils and iron precipitation.
Matrix Treatment	Effective in GW phase but has limited effectiveness towards soil-bound contaminant treatment due to inability to desorb contaminants. This may result in subsequent rebound in GW concentrations after purple/pink color disappears.	Effective in GW phase but has limited effectiveness with soil-bound contaminant treatment due to inability to desorb contaminants. This may result in subsequent rebound in GW concentrations after residual persulfate is consumed.	Effective for aqueous phase contaminants. Also, effective in the treatment of soil-bound contaminants because of the ability to desorb and destroy contaminants.	Effective in GW phase, but has limited effectiveness with soil-bound contaminant treatment due to limited ability to desorb contaminants. This may result in subsequent rebound in GW concentrations.
Treatment Cost	Similar or more expensive when compared with MFR, if used as KMnO_4 depending on the NOD. More expensive used as NaMnO_4 .	More expensive compared to Fenton's reagent or KMnO_4 , but less expensive compared to NaMnO_4 .	Similar to cheaper than KMnO_4 and persulfate depending on the NOD.	Similar to MFR. Similar to cheaper than KMnO_4 and persulfate depending on the NOD.

Property	Permanganate	Sodium Persulfate	Modified Fenton's Reagent (MFR)	Traditional Fenton's
Free Radical Chemistry	None. Contaminant destruction occurs via direct oxidation.	Sulfate free radicals are produced.	Free radicals including hydroxyl and superoxide radicals are produced.	Hydroxyl radicals are produced.
Reaction off gases during injections	None noticeable.	None noticeable.	Gas formation occurs in the form of O ₂ , CO ₂ , and H ₂ O.	More aggressive gas formation occurs as O ₂ , CO ₂ , & H ₂ O, which can result in explosive conditions.
Reaction pH	Effective at natural subsurface pH (i.e. pH 5-8).	Native subsurface pH is lowered by persulfate. At high pH (i.e. pH > 10.5), alkaline activation may occur.	Modified Fenton's can function over a broad pH range (i.e. pH 2-10).	Requires acidic pH (i.e. pH ≤ 3.5). Addition of acid in the subsurface often results in an exothermic reaction.

4.3 Focused ISCO Corrective Measure Alternative

After review of the above referenced comparative analysis, the Focused ISCO Corrective Measure Alternative best suited for the reduction of the COCs (i.e., TCE, 1,1-DCE, 1,4-dioxane, PCE) at the Site AOI is CHP consisting of the delivery of MFR at a concentration of 5% to 12% and injected into the aquifer at one or more locations within the Site AOI. The objective is to treat the COCs in groundwater and the soil in the target treatment area(s). The rationale for selection of MFR is based on the following considerations.

- Subsurface Matrix:** The lithology at the Former Plymouth Tube Company Facility consists of gravels, sands, and some clay within the target treatment zone (TTZ). A competent clay layer is present right above the TTZ, which can potentially contain adsorbed soil bound mass at the interface with the more permeable sands and gravel. In areas with soil-bound contamination (such as source areas), it is imperative to use modified Fenton's reagent since this is the only oxidant that can effectively desorb soil-bound mass. Gravelly and sandy soils present in the TTZ are the most conducive for ISCO applications due to their low organic demand, high permeability and greatest potential for accepting the calculated volume of reagents. Therefore, any of the oxidants can be used within this TTZ; however, due to the potential for adsorbed mass that would need to be desorbed and treated, CHP/MFR has the greatest chance of success. Both permanganate and persulfate technologies are effective in plumes consisting of dissolved phase contamination only since the soil-bound contamination is limited. With permanganate oxidant, the formation of black manganese dioxide (MnO₂) precipitate occurs, which is an

important consideration as well screen clogging and/or aquifer permeability reduction is possible. Using sodium persulfate, significant sulfate is produced (~0.8 lbs for each 1 lb of sodium persulfate injected), which may be undesirable when other greener remedial alternatives such as modified Fenton's are available. The sulfate/sulfuric acid produced would increase the acidity of the subsurface increasing aquifer corrosivity as well as the potential for metals leaching. Although iron precipitation occurs with catalyst activated persulfate and modified Fenton's reagent, the use of chelated catalysts helps disperse the catalyst significantly before slow precipitation of iron occurs. Most of this iron gets adsorbed to the native soils and makes a negligible difference in the subsurface permeability because low concentrations are typically used and precipitation occurs after dispersion.

- **Target Contaminants:** The chemical structure, phase, and distribution of target contaminants is an important consideration since the oxidation occurs either via addition reaction or hydrogen abstraction by free radicals (in Fenton's or persulfate) or by direct oxidation (permanganate). The target COCs at the Former Plymouth Tube Company Facility include TCE, 1,1-DCE, 1,4-dioxane and PCE. Most contaminants with double bonds are amenable to both free radical chemistry and direct oxidation and are relatively straight forward to treat using chemical oxidation. These include TCE, 1,1-DCE and PCE. For 1,4-dioxane, both MFR and persulfate have been demonstrated to be effective under laboratory and field conditions; however, permanganate has not been demonstrated to be effective towards this contaminant. Within the TTZ, it is likely that a significant portion of the COCs are present in both soils and groundwater and the groundwater concentrations only represent a small portion of the overall COC mass. Since free radicals are non-selective, it is impossible to only target groundwater phase contamination. Use of permanganate or activated persulfate oxidants would result in reduction of groundwater concentrations as long as the oxidant is active but over time, rebound may occur since soil-bound contamination/ NAPL contamination is not desorbed. In modified Fenton's chemistry, superoxide radicals are produced along with hydroxyl radicals, which have been documented to promote desorption of soil-bound contaminants. This may sometimes cause a spike in the groundwater concentrations after the initial injections (although the overall mass reduced) but would decrease sharply after subsequent injections.
- **Reagent Contact with Contaminants:** Most ISCO applications involve injection of the selected reagent via a series of permanent injection wells or temporary direct push points screened through the target treatment interval. For the Former Plymouth Tube Company

Facility Site, the selected injection pathway would likely be newly installed permanent injection wells since direct push technology most likely would encounter refusal issues. One of the primary differences between Fenton's and other oxidants (i.e. permanganate, persulfate) is the fact that gas formation occurs only during Fenton's application due to eventual breakdown of hydrogen peroxide to oxygen and water vapor. The presence of gas creates significant agitation within the subsurface matrix resulting in better overall contact of the oxidant with the contamination. Besides the superior oxidation potential of hydroxyl radicals, the agitation caused by gas formation is believed to be one of the reasons why only Fenton's is capable of oxidizing contaminants not present in dissolved phase (which explains why Fenton's is much more effective compared to permanganate or persulfate in treatment of soil-bound contamination and Non-Aqueous Phase Liquids [NAPLs]). This feature of MFR can be of significant benefit at the Site AOI where potential for significant submerged soil-bound contamination exists based on groundwater TCE concentrations of 10,400 µg/L.

The typical ISCO project approach would consist of starting in the laboratory and scaling-up to field application, to ensure that ISCO is optimized for the Site. First, a laboratory treatability study (i.e., Bench Test) is performed. This step would test several dosages of the selected oxidant (i.e. MFR) on saturated soil and groundwater samples obtained from the Site to obtain the optimal dosage for field application. Following the treatability study, a field pilot program is designed to evaluate not only the efficiency of the reagent, but also the distribution of the reagent within the impacted media. The data generated during the pilot program can be used to design a full-scale remediation program that would be the most effective in meeting the remedial objectives at the Site. For the Former Plymouth Tube Company Facility, the field pilot treatment program would also serve as the full scale treatment program due to the relatively smaller target treatment area. Typical field treatment program consists of a series of injection pathways installed in a grid fashion to achieve overlapping radial effects.

The following factors would be evaluated during the field treatment program.

- ISCO reagent volume intake in the injection well before refusal due to excess back pressure buildup from reaction off gases, or limited permeability.
- Actual ISCO reagent volume injected into the injection well to attain influence in the monitor wells. The ROI would be evaluated based on fluctuations in the monitored parameters and the COC reduction noted. The greater the fluctuation in the measured parameters, the greater is the ROI.

- Pre- versus post-treatment effectiveness attained for the injection point spacing used, and volume and concentration of reagents injected during the preceding event.

Field injections are typically conducted in a sequential manner over 1 to 2 applications to allow for maximum desorption and oxidation of sorbed contaminants and thereby enhance treatment efficiency per unit volume of reagent injected. The treatment approach works via the in-situ oxidation of contaminants, while creating minimal disturbance to site operations.

- **Short-term effectiveness** – is considered to have **moderate to high** effectiveness in the short-term because it would reduce the volume of the COCs (i.e., TCE, 1,1-DCE, and 1,4-dioxane) via desorption and degradation. The end products of the MFR reaction with TCE, 1,1-DCE, 1,4-dioxane and PCE are benign and include carbon dioxide, water and chloride (for chlorinated contaminants). The temporary increases in dissolved oxygen and iron concentrations are short term effects and are not anticipated to remain over long term. One of the primary differences between Fenton's and other oxidants (i.e. permanganate, persulfate) is the fact that gas formation occurs only during Fenton's application due to eventual breakdown of hydrogen peroxide to oxygen and water vapor. The presence of gas creates significant agitation within the subsurface matrix resulting in better overall contact of the oxidant with the contamination. Besides the superior oxidation potential of hydroxyl radicals, the agitation caused by gas formation is believed to be one of the reasons why only Fenton's is capable of oxidizing contaminants not present in dissolved phase (which explains why Fenton's is much more effective compared to permanganate or persulfate in treatment of soil-bound contamination and NAPLs).
- **Implementability – Low to moderate.** MFR can be readily mixed at the surface using appropriate tanks and mixers prior to injection into the subsurface through one or more newly installed injection wells located within the Site AOI. No regulatory framework exists for application of ISCO on GRIC lands, which may complicate any applicable regulatory implementability. A low ranking is provided due to the uncertainty of the regulatory requirements and acceptance of the Focused ISCO Corrective Measure Alternative. However, it may be noted that this technology has been approved by several state regulatory agencies throughout the United States and abroad over the last two decades.
- **Cost – High to moderate.** Low to moderate capital costs for the acquisition of the oxidant and rental of the necessary mixing tanks and equipment and installation of one or more newly installed injection wells. Low O&M costs associated with groundwater monitoring.

- Retained for further analysis – Yes.

5.0 DETAILED SCREENING OF CORRECTIVE MEASURE ALTERNATIVES

Two corrective measure alternatives were retained and modified from the preliminary screening of corrective measure alternatives and are evaluated further (Table 6). Corrective Measure Alternative 1 consists of MNA only. Corrective Measure Alternative 2 consists of the Focused ISCO with the addition of MNA as presented in Corrective Measure Alternative 1.

Corrective Measure Alternative 1 is Monitored Natural Attenuation. The MNA alternative consist of quarterly groundwater monitoring and quarterly reporting for one year after EPA approval of the CMS as outlined in Section 3.1 above. After the one year of quarterly monitoring and reporting has been completed, the MNA alternative would switch to semi-annual groundwater monitoring and semi-annual reporting for four additional years.

Corrective Measure Alternative 2 is Focused ISCO as a supplement to MNA. The Focused ISCO Remedial Alternative consists of injection of MFR, consisting of stabilized hydrogen peroxide and chelated iron catalyst into the aquifer through one or more newly installed injection wells located within the Site AOI. For the purposes of this evaluation, it is assumed that 1 to 2 MFR injection events into the subsurface would take place to achieve the remedial goal of reducing COC concentrations in the groundwater. Groundwater monitoring would be continued under Corrective Measure Alternative 2 utilizing the same program as described in Corrective Measure Alternative 1.

Each retained Corrective Measure Alternative was evaluated using the following criteria (Table 6):

1. Protection of Human Health and the Environment.
2. Attainment of Corrective Measure Objective of reduction of specific COCs in the groundwater.
3. Source Control.
4. Long-Term effectiveness.
5. Reduction in Toxicity, Mobility of Volume of Waste.
6. Short-Term Effectiveness.

7. Implementability.

8. Cost.

5.1 Protection of Human Health and the Environment

This criterion is an assessment of how the corrective measure alternative, as a whole, is protective of human health and the environment (Table 6).

Corrective Measure Alternative 1 (MNA) is considered to be protective of human health and the environment. There are no current or anticipated future exposure pathways to impacted groundwater. Attenuation is observed to be occurring with a retreating VOC plume and decreasing COC concentrations.

Corrective Measure Alternative 2 (Focused ISCO with MNA) is considered to be protective of human health and the environment. ISCO has been demonstrated to treat each of the identified COCs and the application of this Corrective Measure Alternative (i.e., MFR) would reduce the concentrations of each of the COCs at and downgradient of the Site with MNA processes continuing in the remaining portion of the plume. Use of MFR can result in production of off gases including oxygen and carbon dioxide, which should readily disperse within the TTZ. Although the reaction is somewhat exothermic, the temperature increases are typically less than 10° C. The end products of the reaction are benign and mainly consist of carbon dioxide and water vapor.

5.2 Attainment of Cleanup Objectives

This criterion describes how the corrective measure alternative would attain the overall cleanup objective of reduction of TCE, 1,1-DCE, 1,4-dioxane and PCE concentrations in the groundwater at the Site and the estimated time frame by which the objective would be met (Table 6).

Corrective Measure Alternative 1 (MNA) is expected to achieve the specified cleanup objectives at the Site (i.e., reduction of TCE, 1,1-DCE, 1,4-dioxane and PCE concentrations in the groundwater). MNA processes would continue to reduce COC concentrations in the plume to achieve the cleanup objectives over time.

Corrective Measure Alternative 2 (Focused ISCO with MNA) is expected to obtain the specified cleanup objectives at the Site (i.e., reduction of TCE, 1,1-DCE, 1,4-dioxane and PCE concentrations in the groundwater). It is anticipated that focused application of ISCO would reduce the concentrations of COCs at Site AOI via desorption and degradation of COCs. MNA processes would continue to reduce COC concentrations in that area and the remainder of the plume to achieve the cleanup objectives over time. By reducing COC concentrations at the Site

AOI, a reduction of COC concentrations downgradient are expected to occur earlier in comparison to Corrective Measure Alternative 1. Elevated dissolved oxygen concentrations and iron concentrations may be present over several weeks following MFR application but would eventually return to background levels.

5.3 Source Control

This criterion is an assessment of how the corrective measure alternative addresses sources of contamination. There are no continuing sources of groundwater contamination associated with the subject contaminant plume at the Former Plymouth Tube Company Site. Therefore, since there are no sources, both Corrective Measure Alternative 1 (MNA) and Corrective Measure Alternative 2 (Focused ISCO with MNA) meet the source control criterion (Table 6).

5.4 Long-Term Effectiveness

This criterion is an assessment of the long-term effectiveness and reliability of the corrective measure alternative (Table 6).

Corrective Measure Alternative 1 (MNA) the long-term effectiveness of this Corrective Measure Alternative is considered to be effective and reliable. Historical monitoring data has shown that attenuation is occurring at the Site. The MNA monitoring would provide the data needed to verify that attenuation is continuing at the Site. Should different or unexpected conditions be encountered, modifications to the Corrective Measure Alternative could be identified and proposed as part of this on-going reporting requirements.

Corrective Measure Alternative 2 (Focused ISCO with MNA) is considered to be effective and reliable at reducing concentrations in and near the application site and coupled with MNA, throughout the identified plume area. Desorption and degradation of submerged soil-bound COCs mass would mean greater potential exists for long term groundwater plume shrinkage with this Corrective Measure Alternative. The end products of the MFR reaction with TCE, 1,1-DCE, 1,4-dioxane and PCE are benign and include carbon dioxide, water and chloride (for chlorinated contaminants). The temporary increases in dissolved oxygen and iron concentrations are short-term effects, and are not anticipated to remain over the long-term.

5.5 Reduction in Toxicity, Mobility or Volume of Waste

This criterion provides an assessment of how the corrective measure alternative reduces the toxicity, mobility or volume of waste by evaluating, to the extent practicable, the current conditions with the anticipated future conditions after implementing the corrective measure alternative (Table 6).

Corrective Measure Alternative 1 (MNA) would reduce the overall volume of COCs in groundwater through dilution, dispersion, degradation, and volatilization. The mobility of COCs would be reduced through sorption of the COCs. These reductions in toxicity, mobility or volume would occur over a longer time period than Remedial Alternative 2.

Corrective Measure Alternative 2 (Focused ISCO with MNA) would reduce the volume of the COCs (i.e., TCE, 1,1-DCE, 1,4-dioxane, and PCE) more quickly than Corrective Measure Alternative 1. The co-existing redox reactions associated with a modified Fenton's process promote enhanced desorption and degradation of recalcitrant compounds. Hydroxyl radicals would oxidize nearly all contaminants with carbon/carbon double bonds (e.g. TCE, 1,1-DCE, PCE) and single bonded contaminants with extractable hydrogen. The end products of the reaction are typically innocuous such as carbon dioxide and water, and chloride ions when chlorinated compounds are being treated. The end products of the MFR reaction with TCE, 1,1-DCE, 1,4-dioxane and PCE are benign and include carbon dioxide, water and chloride (for chlorinated contaminants). The temporary increases in dissolved oxygen and iron concentrations are short-term effects and are not anticipated to remain over long-term.

5.6 Short-Term Effectiveness

Short-term effectiveness is an assessment of the effectiveness of the corrective measure alternative in protecting human health and the environment during construction and implementation of the corrective measure alternative and prior to the attainment of the cleanup objectives (Table 6).

Corrective Measure Alternative 1 (MNA) is considered to be effective in the short-term. Following proper field procedures and Standard Operating Procedures (SOPs) human health risks during groundwater monitoring activities would result in little to no risk to human health and the environment.

Corrective Measure Alternative 2 (Focused ISCO with MNA) is considered to have moderate to high effectiveness in the short-term because it would reduce the volume of the COCs (i.e., TCE, 1,1-DCE, 1,4-dioxane and PCE) via desorption and degradation. The end products of the MFR reaction with TCE, 1,1-DCE, 1,4-dioxane and PCE are benign and include carbon dioxide, water and chloride (for chlorinated contaminants). The temporary increases in dissolved oxygen and iron concentrations are short-term effects and are not anticipated to remain over long-term. One of the primary differences between Fenton's and other oxidants (i.e. permanganate, persulfate) is the fact that gas formation occurs only during Fenton's application due to eventual breakdown of hydrogen peroxide to oxygen and water vapor. The presence of gas creates significant agitation within the subsurface matrix resulting in better overall contact of the oxidant with the

contamination. Besides the superior oxidation potential of hydroxyl radicals, the agitation caused by gas formation is believed to be one of the reasons why only Fenton's is capable of oxidizing contaminants not present in dissolved phase (which explains why Fenton's is much more effective compared to permanganate or persulfate in treatment of soil-bound contamination and NAPLs).

5.7 Implementability

Implementability is an assessment of the technical and regulatory/feasibility of implementing the corrective measure alternative (Table 6).

Corrective Measure Alternative 1 (MNA) is the easiest corrective measure alternative to implement. The monitoring well network and groundwater monitoring and reporting program already exist.

Corrective Measure Alternative 2 (Focused ISCO with MNA) may have regulatory/administrative considerations that could adversely impact the implementation of this corrective measure alternative. For the purposes of this evaluation, it is assumed that one or more ISCO treatment areas (injection application just west of the former LB-7 monitor well location) would be implemented. An injection test has not been conducted; however, a bench study (conducted on both representative site soil and groundwater samples) is recommended to determine the proper site-specific dose of the MFR treatment. It is also documented via well construction logs that the target treatment area below the competent clay layer consists of gravels, sand and some clay which is optimal for the aquifer formation to accept the oxidant. One potential factor that could complicate implementation would be that there is no regulatory framework governing injection of an oxidant into the subsurface on GRIC lands which could prevent or delay this Corrective Measure Alternative. However, this oxidant has been approved for in situ use by several state regulatory agencies and extensively used over the last two decades throughout the United States and abroad.

5.8 Cost

Cost is the assessment of the total cost, capital (or construction) costs and long-term operation and maintenance costs of the Corrective Measure Alternative (Table 6). For the purposes of this CMS, Corrective Measure Alternative 1 and Corrective Measure Alternative 2 are assumed to have the same MNA groundwater monitoring and reporting program. It is assumed that the MNA groundwater monitoring and reporting would consist of quarterly groundwater monitoring and quarterly reporting for one year after approval of the CMS. After the one year of quarterly monitoring and reporting has been completed, the MNA alternative would switch to semi-annual groundwater monitoring and semi-annual reporting for four additional years. The depth to groundwater would be measured and groundwater samples would be collected from the Plymouth

Tube groundwater monitor wells PT-1S, PT-1D, LB-7R, PT-2S, PT-2D, PT-3, PT-3D, PT-4, PT-4D, and PT-5 and selected GRIC monitor wells LB-1, LB-13, LB-17, and PT-6D. Groundwater samples would be analyzed by an ADHS certified laboratory for VOCs following EPA Test Method 8260B and 1,4-dioxane by EPA Test Method 8260B SIM. A monitoring and sampling report would be prepared and submitted to EPA and GRIC DEQ for each event. The report would document the monitoring and sampling activities, and present the laboratory results in tabular and graphic form. The data would undergo a data verification which would be presented in the report.

Total costs for Corrective Measure Alternative 2 would include costs of the bench test and one-time ISCO MFR application event in addition to MNA groundwater monitoring costs.

To be conservative, cumulative present value costs were calculated assuming an annual inflation rate of 3% and a discount factor of 7% as prescribed by Office of Solid Waste and Emergency Response (OSWER) Directive 9355.3-20.

Corrective Measure Alternative 1 (MNA) has no capital (construction) costs and the lowest overall cost of the two Corrective Measure Alternatives. Total costs in 2016 dollars for Corrective Measure Alternative 1 (MNA) are estimated to be \$254,232. Cumulative present net value costs are estimated to be \$217,680.

Corrective Measure Alternative 2 (Focused ISCO with MNA) has the higher capital (construction) costs and equivalent monitoring costs. The cost for the MNA portion of this alternative is \$254,232. Total capital costs are estimated to be approximately \$8,000 to \$10,000 for the bench test study. Total capital costs range for the ISCO injection wells, ISCO application(s) and monitoring is between \$100,000 to \$300,000 depending on the final number of newly installed injection wells and the number of planned injections. Total costs in 2016 dollars for Corrective Measure Alternative 2 (Focused ISCO with MNA) are estimated to range from \$362,232 to \$564,232. Cumulative present net value costs range from \$315,862 to \$499,499.

6.0 PREFERRED CORRECTIVE MEASURE ALTERNATIVE

Corrective Measure Alternative 2: Focused ISCO with MNA is the preferred Corrective Measure Alternative as detailed below:

- Is protective of human health and the environment.
- Is able to achieve the media clean up objectives in a reasonable time period. ISCO has been demonstrated to treat all of the identified COCs and the application of this Corrective Measure Alternative (i.e., MFR) would reduce the concentrations of all of the COCs on

and downgradient of the Site with MNA processes continuing in the remaining portion of the plume.

- Meets the source control criteria, due to the remediation of the source. There are no continuing sources of groundwater contamination associated with the subject contaminant plume at the Former Plymouth Tube Company Facility Site.
- Is reliable and effective for the long-term. Effective and reliable at reducing concentrations in and near the application site and coupled with MNA, throughout the identified plume area.
- Reduces the mobility and toxicity of COCs in groundwater. The end products of the MFR reaction with TCE, 1,1-DCE, 1,4-dioxane and PCE are benign and include carbon dioxide, water and chloride (for chlorinated contaminants).
- Is effective in the short-term because it would reduce the volume of the COCs (i.e., TCE, 1,1-DCE, 1,4-dioxane and PCE) via desorption and degradation.
- Has proven technologies which are easily implemented. One potential factor that could complicate implementation of the ISCO component would be that there is no regulatory framework governing injection of an oxidant into the subsurface on GRIC lands which could prevent or delay this Corrective Measure Alternative. However, this oxidant has been approved for *in-situ* use by several state regulatory agencies and extensively used over the last two decades throughout the United States and abroad.
- Although the ISCO application increases the overall costs, there is an increase benefit associated with the increased mass reduction of COCs over a shorter time period as compared to MNA alone.

Following EPA's review and approval of the Corrective Measures Study for the Former Plymouth Tube Company Facility in Chandler, Arizona, EPA will prepare a Statement of Basis. The purpose of the Statement of Basis is to summarize the information contained in the RFI Report and the CMS Report and document EPA's rationale for identifying EPA's proposed remedy for the Site. Plymouth Tube Company will support the community involvement activities conducted by EPA and/or GRIC DEQ as required during the selection and implantation of the selected corrective measure for the Former Plymouth Tube Company Facility.

7.0 REFERENCES

- ATC Associates, Inc., 2011. *North Central Aquifer Cleanup Project—Phase VIII Groundwater Investigation Report. Gila River Indian Community Arizona*. Submitted to Gila River Indian Community, Department of Environmental Quality, Water Quality Program, Sacaton, Arizona 85247, September 30.
- Cardno, 2015. North Central Aquifer Cleanup Project-Phase XII Groundwater Investigation, Report for Gila River Indian Community, Department of Environmental Quality, Water Quality Program, Sacaton, Arizona. September 8.
- Geomatrix Consultants, Inc., 2005. Phased Remedial Investigation Quality Assurance Project Plan for the Former Plymouth Tube Company, Chandler, Arizona. August 25.
- Geomatrix Consultants, Inc., 2006. Initial Site Characterization Report, Former Plymouth Tube Company Facility, 6573 West Willis Road, Chandler, Arizona, July 10.
- Geomatrix Consultants, Inc., 2007. Findings Report – Joint Groundwater Sampling Effort, Gila River Indian Community North Central Project Chandler, Arizona, October 31.
- Geosyntec Consultants, Inc., 2013. DRAFT RCRA Facility Investigation (RFI) Work Plan Former Plymouth Tube Company Facility, Chandler, Arizona. February 19.
- Interstate Technology Regulatory Council (ITRC), 2005. Technical and Regulatory Guidance for In Situ Chemical Oxidation of Contaminated Soil and Groundwater, Second Edition. January.
- NV5, 2015a. Summary Report --Groundwater Sampling Results During the Reduced Pumping and Temporary Shutdown of the Limited Groundwater Pump & Treat System--Former Plymouth Tube Company Facility, Chandler, Arizona. March 27.
- NV5, 2015b. Groundwater Monitoring Report—3rd Quarter 2015, Former Plymouth Tube Company Facility, Chandler, Arizona. October 5.
- NV5, 2015c. Resource Conservation and Recovery Act (RCRA) Facility Investigation Report – Including: Updated Conceptual Site Model Report (Appendix A), Interim Corrective Measures Report (Appendix B), Human Health Risk Assessment and Media Cleanup

Objectives (Appendix C), Environmental Indicators Report (Appendix D), Former Plymouth Tube Company Facility, Chandler, Arizona. December 29.

United States, Environmental Protection Agency, Undated. Final Remedy Selection Presentation, http://www3.epa.gov/epawaste/hazard/correctiveaction/pdfs/workshop/frs_slides.pdf.

United States, Environmental Protection Agency, Region IX, 2007. Unilateral Administrative Order, U.S. EPA Docket No. RCRA-7003-09-2008-0002, Proceeding Under Section 7003(a) of the Resource Conservation and Recovery Act, as amended, 42 U.S.C. §6973(a), effective date December 28, 2007.

United States, Environmental Protection Agency, 2015. Letter to Scott Morling, Vice President, Plymouth Tube Company from John R. Moody, Project Manager, USEAP Region IX, Re: Unilateral Administrative Order, Docket No. RCRA-7003-09-2008-0002. October 13.

Workplace Safety Specialists, 2008. *Chandler Manufacturing Facility Airborne Chlorinated Ethylenes*, Prepared for Kaiser Aluminum Fabricated Products, LLC, June 17.

TABLES

Table 1
Groundwater Interim Cleanup Goals and Final
Cleanup Goals (ICGs and FCGs, in µg/L)

COPC	ICG and FCG (ug/L)	Exposure Medium	Endpoint	Alternative FCG (MCL) (ug/L)
TCE	9.15E+03	Indoor Air	Cancer	5
MC	4.62E+06	Indoor Air	Cancer	5
1,1-DCE	1.50E+06	Indoor Air	Non-cancer	7
1,4-DIOX	2.86E+05	Indoor Air	Cancer	No value
PCE	1.33E+05	Indoor Air	Cancer	5
CF	2.31E+03	Indoor Air	Cancer	80*
CT	4.40E+03	Indoor Air	Cancer	5
1,1-DCA	2.69E+04	Indoor Air	Cancer	No value
1,2-DCA	3.11E+03	Indoor Air	Cancer	5
c-1,2-DCE	1.33E+05	Indoor Air	Non-cancer	70
1,1,1,2-PCA	1.14E+04	Indoor Air	Cancer	No value
1,1,2-TCA	6.67E+03	Indoor Air	Cancer	5

NC - non-carcinogenic

* - value shown is for total trihalomethanes (TTHMs)

Table 2
Soil Gas Interim Cleanup Goals and
Final Cleanup Goals (ICGs and FCGs, in $\mu\text{g}/\text{m}^3$)

COPC	ICG ($\mu\text{g}/\text{m}^3$)	Exposure Medium	Endpoint	FCG ($\mu\text{g}/\text{m}^3$)*	Exposure Medium	Endpoint
TCE	7.03E+03	Indoor Air	Cancer	2.97E+04	Indoor Air	Cancer
1,1-DCE	1.78E+06	Indoor Air	Non-cancer	7.06E+06	Indoor Air	Non-cancer
PCE	1.37E+05	Indoor Air	Cancer	6.23E+05	Indoor Air	Cancer
TCTFA (Freon 113)	4.76E+08	Indoor Air	Non-cancer	2.30E+09	Indoor Air	Non-cancer

NC - non-carcinogenic

* - Lowest average value derived for location-specific sources (see **Table J-3e**).

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoe)	Constituent	Sample Date	Concentration (µg/L)	MCL
PT-1S	90	Trichloroethene	09/23/08	46	5
			04/08/09	100	
			06/15/09	60	
			09/01/09	50	
			01/28/10	25	
			07/10/10	23	
			11/15/11	5.5	
			02/23/12	3.0	
			05/30/12	3.3	
			08/29/12	2.5	
			12/05/12	3.3	
			02/18/13	3.7	
			05/22/13	4.3	
			08/19/13	7.9	
			11/20/13	22.3	
			02/17/14	29.8	
			05/27/14	74.2	
			08/17/14	92.2	
			11/13/14	50.3	
			02/23/15	49.8	
			05/28/15	71.4*	
			08/28/15	64.0	
		1,1-Dichloroethene	09/23/08	12	7
			04/08/09	26	
			06/15/09	24	
			09/01/09	22	
			01/28/10	9.4	
			07/10/10	7.3	
			11/15/11	ND (<2.0)	
			02/23/12	ND (<2.0)	
			05/30/12	0.71	
			08/29/12	0.39 (J)	
			12/05/12	0.72	
			02/18/13	0.83	
			05/22/13	0.95	
			08/19/13	2.3	
			11/20/13	5.7	
			02/17/14	8.1	
			05/27/14	18.8	
			08/17/14	24.2	
			11/13/14	16.6	
			02/23/15	17.3	
			05/28/15	18.1*	
			08/28/15	20.3	
		Tetrachloroethene	09/23/08	ND (<0.5)	5
			04/08/09	0.93	
			06/15/09	ND (<0.50)	
			09/01/09	ND (<0.50)	
			01/28/10	ND (<0.50)	
			07/10/10	ND (<0.50)	
			11/15/11	ND (<1.0)	
			02/23/12	ND (<1.0)	
			05/30/12	ND (<0.50)	
			08/29/12	ND (<0.50)	
			12/05/12	ND (<0.50)	
			02/18/13	ND (<0.50)	
			05/22/13	ND (<0.50)	
			08/19/13	ND (<0.50)	
			11/20/13	ND (<0.50)	
			02/17/14	ND (<0.50)	
			05/27/14	0.56	
			08/17/14	0.44 (J)	
			11/13/14	ND (<0.50)	
			02/23/15	ND (<0.50)	
			05/28/15	0.34 (J) *	
			08/28/15	0.38 (J)	
		1,4-Dioxane	09/24/08	1.5	N/A
			11/15/11	1.2	
			02/23/12	ND (<2.0)	
			05/30/12	ND (<2.0)	
			08/29/12	ND (<2.0)	
			12/05/12	0.67 (J)	
			02/18/13	0.67 (J)	
			05/22/13	0.94 (J)	
			08/19/13	1.5 (J)	
			11/20/13	4.6	
			02/17/14	5.0	
			05/27/14	10.5	
			08/17/14	18.2	
			11/13/14	8.4	
			02/23/15	12.7	
			05/28/15	7.9 *	
			08/28/15	11.9	

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Constituent	Sample Date	Concentration (µg/L)	MCL
PT-1D	120	Trichloroethene	09/24/08	ND (<0.50)	5
			04/07/09	ND (<0.50)	
			06/15/09	ND (<0.50)	
			08/31/09	ND (<0.50)	
			01/28/10	ND (<0.50)	
			07/10/10	ND (<0.50)	
			11/15/11	ND (<1.0)	
			02/23/12	ND (<1.0)	
			05/30/12	ND (<0.50)	
			08/29/12	ND (<0.50)	
			12/05/12	ND (<0.50)	
			02/18/13	ND (<0.50)	
			05/22/13	ND (<0.50)	
			08/19/13	ND (<0.50)	
			11/20/13	ND (<0.50)	
			02/17/14	ND (<0.50)	
			05/27/14	ND (<0.50)	
			08/17/14	ND (<0.50)	
			11/13/14	ND (<0.50)	
			02/23/15	ND (<0.50)	
			05/26/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		1,1-Dichloroethene	09/24/08	ND (<0.50)	7
			04/07/09	ND (<0.50)	
			06/15/09	ND (<0.50)	
			08/31/09	ND (<0.50)	
			01/28/10	ND (<0.50)	
			07/10/10	ND (<0.50)	
			11/15/11	ND (<2.0)	
			02/23/12	ND (<2.0)	
			05/30/12	ND (<0.50)	
			08/29/12	ND (<0.50)	
			12/05/12	ND (<0.50)	
			02/18/13	ND (<0.50)	
			05/22/13	ND (<0.50)	
			08/19/13	ND (<0.50)	
			11/20/13	ND (<0.50)	
			02/17/14	ND (<0.50)	
			05/27/14	ND (<0.50)	
			08/17/14	ND (<0.50)	
			11/13/14	ND (<0.50)	
			02/23/15	ND (<0.50)	
			05/26/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		Tetrachloroethene	09/24/08	ND (<0.50)	5
			04/07/09	ND (<0.50)	
			06/15/09	ND (<0.50)	
			08/31/09	ND (<0.50)	
			01/28/10	ND (<0.50)	
			07/10/10	ND (<0.50)	
			11/15/11	ND (<1.0)	
			02/23/12	ND (<1.0)	
			05/30/12	ND (<0.50)	
			08/29/12	ND (<0.50)	
			12/05/12	ND (<0.50)	
			02/18/13	ND (<0.50)	
			05/22/13	ND (<0.50)	
			08/19/13	ND (<0.50)	
			11/20/13	ND (<0.50)	
			02/17/14	ND (<0.50)	
			05/27/14	ND (<0.50)	
			08/17/14	ND (<0.50)	
			11/13/14	ND (<0.50)	
			02/23/15	ND (<0.50)	
			05/26/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		1,4-Dioxane	11/15/2011	ND (<2.0)	N/A
			02/23/12	ND (<2.0)	
			05/30/12	ND (<2.0)	
			08/29/12	ND (<2.0)	
			12/05/12	0.72 (J)	
			02/18/13	ND (<2.0)	
			05/22/13	ND (<2.0)	
			08/19/13	ND (<2.0)	
			11/20/13	ND (<2.0)	
			02/17/14	0.62 (J)	
			05/27/14	ND (<2.0)	
			08/17/14	ND (<2.0)	
			11/13/14	ND (<2.0)	
			02/23/15	ND (<2.0)	
			05/26/15	ND (<2.0)	
			08/26/15	ND (<2.0)	

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Constituent	Sample Date	Concentration (µg/L)	MCL
LB-7R	90	Trichloroethene	08/29/07	3400	5
			04/09/09	1300	
			06/16/09	1300	
			09/01/09	870	
			01/28/10	950	
			07/10/10	770	
			11/16/11	230	
			02/23/12	130	
			05/31/12	150	
			08/29/12	139	
			12/06/12	109	
			02/18/13	141	
			05/08/13	157 ⁽¹⁾	
			05/23/13	97.3	
			08/19/13	136 ⁽²⁾	
			11/21/13	142	
			02/18/14	103	
			05/28/14	113	
			08/19/14	167 ⁽³⁾	
			11/13/14	155	
			02/23/15	NS ⁽⁴⁾	
		1,1-Dichloroethene	05/29/15	6910 ⁽⁵⁾ *	7
			08/28/15	10400 ⁽⁵⁾	
			08/29/07	230	
			04/09/09	120	
			06/16/09	120	
			09/01/09	100	
			01/28/10	140	
			07/10/10	110	
			11/16/11	22	
			02/23/12	19	
			05/31/12	23	
			08/29/12	17.2	
			12/06/12	18.8	
			02/18/13	20	
			05/08/13	13.1 ⁽¹⁾	
			05/23/13	13.7	
			08/19/13	17.0 ⁽²⁾	
			11/21/13	17.7	
			02/18/14	13.5	
			05/28/14	15.6	
			08/19/14	17.2 ⁽³⁾	
			11/13/14	20.9	
			02/23/15	NS ⁽⁴⁾	
			05/29/15	386 ⁽⁵⁾ *	
			08/28/15	576 ⁽⁵⁾	
		Tetrachloroethene	08/29/07	2.5	5
			04/09/09	0.71	
			06/16/09	0.51	
			09/01/09	ND (<0.50)	
			01/28/10	0.55	
			07/10/10	ND (<5.0)	
			11/16/11	ND (<1.0)	
			02/23/12	ND (<1.0)	
			05/31/12	ND (<1.3)	
			08/29/12	ND (<1.0)	
			12/06/12	ND (<1.0)	
			02/18/13	ND (<1.0)	
			05/08/13	ND (<1.0) ⁽¹⁾	
			05/23/13	ND (<1.0)	
			08/19/13	ND (<1.0) ⁽²⁾	
			11/21/13	ND (<1.0)	
			02/18/14	ND (<1.0)	
			05/28/14	ND (<1.0)	
			08/19/14	ND (<1.3) ⁽³⁾	
			11/13/14	ND (<1.0)	
			02/23/15	NS ⁽⁴⁾	
			05/29/15	5.2 *	
			08/28/15	12.0	
		1,4-Dioxane	11/16/11	9.3	N/A
			02/23/12	9.2	
			05/31/12	6.6	
			08/29/12	6.8	
			12/06/12	5.7	
			02/18/13	6.0	
			05/08/13	7.3 ⁽¹⁾	
			05/23/13	4.7	
			08/19/13	5.5 ⁽²⁾	
			11/21/13	7.2	
			02/18/14	6.0	
			05/28/14	5.2	
			08/19/14	10.6 ⁽³⁾	
			11/13/14	9.2	
			02/23/15	NS ⁽⁴⁾	
			05/29/15	604 *	
			08/28/15	1570	

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Constituent	Sample Date	Concentration (µg/L)	MCL
PT-2S	90	Trichloroethene	09/23/08	920	5
			04/09/09	1100	
			06/16/09	950	
			09/01/09	950	
			01/28/10	1500	
			07/10/10	1400	
			11/16/11	520	
			02/23/12	150	
			05/31/12	143	
			08/29/12	115	
			12/06/12	99.7	
			02/18/13	101	
			05/08/13	588 ⁽¹⁾	
			05/23/13	116	
			08/19/13	123 ⁽²⁾	
			11/21/13	105	
			02/18/14	91.5	
			05/28/14	88.7	
			08/19/14	90.9 ⁽³⁾	
			11/13/14	88.9	
			02/23/15	73.1	
			05/29/15	267 ^{(3) *}	
			08/28/15	247 ⁽³⁾	
		1,1-Dichloroethene	09/23/08	100	7
			04/09/09	150	
			06/16/09	140	
			09/01/09	170	
			01/28/10	230	
			07/10/10	180	
			11/16/11	78	
			02/23/12	22	
			05/31/12	21	
			08/29/12	16.4	
			12/06/12	16.4	
			02/18/13	12.6	
			05/08/13	77.2 ⁽¹⁾	
			05/23/13	15.7	
			08/19/13	18.7 ⁽²⁾	
			11/21/13	14.7	
			02/18/14	12.8	
			05/28/14	11.2	
			08/19/14	11.3 ⁽³⁾	
			11/13/14	11.1	
			02/23/15	12.9	
			05/29/15	47.4 *	
			08/28/15	46.5	
		Tetrachloroethene	09/23/08	1.0	5
			04/09/09	0.96	
			06/16/09	0.62	
			09/01/09	0.88	
			01/28/10	0.90	
			07/10/10	ND (<1.0)	
			11/16/11	1.0	
			02/23/12	ND (<1.0)	
			05/31/12	ND (<1.3)	
			08/29/12	ND (<1.0)	
			12/06/12	ND (<1.0)	
			02/18/13	ND (<1.0)	
			05/08/13	ND (<5.0) ⁽¹⁾	
			05/23/13	ND (<1.0)	
			08/19/13	ND (<1.0) ⁽²⁾	
			11/21/13	ND (<1.0)	
			02/18/14	ND (<0.50)	
			05/28/14	ND (<0.50)	
			08/19/14	ND (<1.0) ⁽³⁾	
			11/13/14	ND (<1.0)	
			02/23/15	ND (<0.50)	
			05/29/15	0.32 (J)	
			08/28/15	0.42 (J)	
		1,4-Dioxane	09/23/08	21	N/A
			11/16/11	28	
			02/23/12	9.1	
			05/31/12	6.6	
			08/29/12	5.6	
			12/06/12	6.5	
			02/18/13	4.7	
			05/08/13	31.4 ⁽¹⁾	
			05/23/13	4.1	
			08/19/13	5.7 ⁽²⁾	
			11/21/13	4.6	
			02/18/14	4.6	
			05/28/14	3.6	
			08/19/14	4.6 ⁽³⁾	
			11/13/14	3.3	
			02/23/15	2.7	
			05/29/15	14.4*	
			08/28/15	18.8	

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btec)	Constituent	Sample Date	Concentration (µg/L)	MCL
PT-2D	120	Trichloroethene	09/23/08	23	5
			04/08/09	53	
			06/15/09	26	
			08/31/09	19	
			01/28/10	19	
			07/10/10	12	
			11/15/11	2.5	
			02/23/12	ND (<1.0)	
			05/30/12	0.23 (J)	
			08/29/12	ND (<0.50)	
			12/05/12	0.26 (J)	
			02/18/13	0.25 (J)	
			05/23/13	ND (<0.50)	
			08/19/13	0.69	
			11/20/13	ND (<0.50)	
			02/19/14	0.44 (J)	
			05/27/14	ND (<0.50)	
			08/19/14	ND (<0.50)	
			11/12/14	ND (<0.50)	
			02/23/15	ND (<0.50)	
			05/26/15	1.1	
			08/26/15	1.9	
		1,1-Dichloroethene	09/23/08	3.2	7
			04/08/09	12	
			06/15/09	5.8	
			08/31/09	2.2	
			01/28/10	2.2	
			07/10/10	3.4	
			11/15/11	ND (<2.0)	
			02/23/12	ND (<2.0)	
			05/30/12	ND (<0.50)	
			08/29/12	ND (<0.50)	
			12/05/12	ND (<0.50)	
			02/18/13	ND (<0.50)	
			05/23/13	ND (<0.50)	
			08/19/13	ND (<0.50)	
			11/20/13	ND (<0.50)	
			02/19/14	ND (<0.50)	
			05/27/14	ND (<0.50)	
			08/19/14	ND (<0.50)	
			11/12/14	ND (<0.50)	
			02/23/15	ND (<0.50)	
			05/26/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		Tetrachloroethene	09/23/08	ND (<0.50)	5
			04/08/09	ND (<0.50)	
			06/15/09	ND (<0.50)	
			08/31/09	ND (<0.50)	
			01/28/10	ND (<0.50)	
			07/10/10	ND (<0.50)	
			11/15/11	ND (<1.0)	
			02/23/12	ND (<1.0)	
			05/30/12	ND (<0.50)	
			08/29/12	ND (<0.50)	
			12/05/12	ND (<0.50)	
			02/18/13	ND (<0.50)	
			05/23/13	ND (<0.50)	
			08/19/13	ND (<0.50)	
			11/20/13	ND (<0.50)	
			02/19/14	ND (<0.50)	
			05/27/14	ND (<0.50)	
			08/19/14	ND (<0.50)	
			11/12/14	ND (<0.50)	
			02/23/15	ND (<0.50)	
			05/26/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		1,4-Dioxane	11/15/11	ND (<2.0)	N/A
			02/23/12	ND (<2.0)	
			05/30/12	ND (<2.0)	
			08/29/12	ND (<2.0)	
			12/05/12	ND (<2.0)	
			02/18/13	ND (<2.0)	
			05/23/13	ND (<2.0)	
			08/19/13	ND (<2.0)	
			11/20/13	ND (<2.0)	
			02/19/14	ND (<2.0)	
			05/27/14	ND (<2.0)	
			08/19/14	ND (<2.0)	
			11/12/14	ND (<2.0)	
			02/23/15	ND (<2.0)	
			05/26/15	ND (<2.0)	
			08/26/15	ND (<2.0)	

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Constituent	Sample Date	Concentration (µg/L)	MCL
PT-3	90	Trichloroethene	11/16/11	230	5
			02/24/12	160	
			05/31/12	143	
			08/30/12	96.8	
			12/06/12	89.4	
			02/19/13	99.1	
			05/23/13	93.7	
			08/20/13	96.7	
			11/21/13	108	
			02/19/14	89.3	
			05/28/14	52.2	
			08/17/14	92.0	
			11/13/14	73.5	
			02/26/15	72.7	
			05/28/15	73.2*	
			08/28/15	98.3	
		1,1-Dichloroethene	11/16/11	36	7
			02/24/12	19	
			05/31/12	16.7	
			08/30/12	12.6	
			12/06/12	10.1	
			02/19/13	11.1	
			05/23/13	11.2	
			08/20/13	10.8	
			11/21/13	10	
			02/19/14	9.4	
			05/28/14	2.7	
			08/17/14	8.4	
			11/13/14	7.2	
			02/26/15	10.1	
			05/28/15	11.0*	
			08/28/15	10.8	
		Tetrachloroethene	11/16/11	ND (<1.0)	5
			02/24/12	ND (<1.0)	
			05/31/12	ND (<1.3)	
			08/30/12	ND (<1.0)	
			12/06/12	ND (<1.0)	
			02/19/13	ND (<0.50)	
			05/23/13	ND (<0.50)	
			08/20/13	ND (<0.50)	
			11/21/13	ND (<1.0)	
			02/19/14	ND (<0.50)	
			05/28/14	ND (<0.50)	
			08/17/14	ND (<2.5)	
			11/13/14	ND (<1.0)	
			02/26/15	ND (<0.50)	
			05/28/15	ND (<0.50)*	
			08/28/15	ND (<0.50)	
		1,4-Dioxane	11/16/11	12	N/A
			02/24/12	16	
			05/31/12	9.0	
			08/30/12	6.3	
			12/06/12	7.0	
			02/19/13	5.7	
			05/23/13	5.0	
			08/20/13	5.1	
			11/21/13	4.8	
			02/19/14	4.6	
			05/28/14	4.1	
			08/17/14	5.2	
			11/13/14	3.4	
			02/26/15	3.7	
			05/28/15	3.8*	
			08/28/15	4.7	

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Constituent	Sample Date	Concentration (µg/L)	MCL
PT-3D	126	Trichloroethene	04/26/12	ND (<0.50)	5
			05/31/12	ND (<0.50)	
			08/30/12	ND (<0.50)	
			12/06/12	ND (<0.50)	
			02/19/13	ND (<0.50)	
			05/23/13	ND (<0.50)	
			08/20/13	ND (<0.50)	
			11/21/13	ND (<0.50)	
			02/19/14	ND (<0.50)	
			05/28/14	ND (<0.50)	
			08/17/14	ND (<0.50)	
			11/13/14	ND (<0.50)	
			02/26/15	ND (<0.50)	
			05/27/15	ND (<0.50)	
			08/26/15	0.64	
		1,1-Dichloroethene	04/26/12	ND (<0.50)	7
			05/31/12	ND (<0.50)	
			08/30/12	ND (<0.50)	
			12/06/12	ND (<0.50)	
			02/19/13	ND (<0.50)	
			05/23/13	ND (<0.50)	
			08/20/13	ND (<0.50)	
			11/21/13	ND (<0.50)	
			02/19/14	ND (<0.50)	
			05/28/14	ND (<0.50)	
			08/17/14	ND (<0.50)	
			11/13/14	ND (<0.50)	
			02/26/15	ND (<0.50)	
			05/27/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		Tetrachloroethene	04/26/12	ND (<0.50)	5
			05/31/12	ND (<0.50)	
			08/30/12	ND (<0.50)	
			12/06/12	ND (<0.50)	
			02/19/13	ND (<0.50)	
			05/23/13	ND (<0.50)	
			08/20/13	ND (<0.50)	
			11/21/13	ND (<0.50)	
			02/19/14	ND (<0.50)	
			05/28/14	ND (<0.50)	
			08/17/14	ND (<0.50)	
			11/13/14	ND (<0.50)	
			02/26/15	ND (<0.50)	
			05/27/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		1,4-Dioxane	04/26/12	ND (<2.0)	N/A
			05/31/12	ND (<2.0)	
			08/30/12	ND (<2.0)	
			12/06/12	0.64 (J)	
			02/19/13	ND (<2.0)	
			05/23/13	ND (<2.0)	
			08/20/13	ND (<2.0)	
			11/21/13	ND (<2.0)	
			02/19/14	ND (<2.0)	
			05/28/14	ND (<2.0)	
			08/17/14	ND (<2.0)	
			11/13/14	ND (<2.0)	
			02/26/15	ND (<2.0)	
			05/27/15	ND (<2.0)	
			08/26/15	ND (<2.0)	

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Constituent	Sample Date	Concentration (µg/L)	MCL
PT-4	90	Trichloroethene	11/16/11	44	5
			02/24/12	53	
			05/31/12	57.2	
			08/30/12	48.5	
			12/06/12	39.2	
			02/19/13	49	
			05/23/13	43.3	
			08/20/13	38.9	
			11/21/13	40.4	
			02/17/14	35.8	
			05/28/14	14.7	
			08/19/14	43.6	
			11/12/14	45.5	
			02/26/15	28.0	
			05/26/15	36.2	
			08/26/15	32.0	
		1,1-Dichloroethene	11/16/11	2.8	7
			02/24/12	8.7	
			05/31/12	8.0	
			08/30/12	7.4	
			12/06/12	5.9	
			02/19/13	5.6	
			05/23/13	5.6	
			08/20/13	5.4	
			11/21/13	5.6	
			02/17/14	4.3	
			05/28/14	0.60	
			08/19/14	5.5	
			11/12/14	6.0	
			02/26/15	3.8	
			05/26/15	5.0	
			08/26/15	4.2	
		Tetrachloroethene	11/16/11	ND (<1.0)	5
			02/24/12	ND (<1.0)	
			05/31/12	ND (<0.50)	
			08/30/12	ND (<0.50)	
			12/06/12	ND (<0.50)	
			02/19/13	ND (<0.50)	
			05/23/13	ND (<0.50)	
			08/20/13	ND (<0.50)	
			11/21/13	ND (<0.50)	
			02/17/14	ND (<0.50)	
			05/28/14	ND (<0.50)	
			08/19/14	ND (<0.50)	
			11/12/14	ND (<0.50)	
			02/26/15	ND (<0.50)	
			05/26/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		1,4-Dioxane	11/16/11	4.3	N/A
			02/24/12	5.3	
			05/31/12	3.4	
			08/30/12	2.8	
			12/06/12	2.6	
			02/19/13	3.1	
			05/23/13	2.4	
			08/20/13	2.8	
			11/21/13	2.9	
			02/17/14	1.9 (J)	
			05/28/14	2.1	
			08/19/14	2.9	
			11/12/14	2.4	
			02/26/15	1.9 (J)	
			05/26/15	1.7 (J)	
			08/26/15	2.1	

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Constituent	Sample Date	Concentration (µg/L)	MCL
PT-4D	126	Trichloroethene	04/26/12	3.8	5
			05/31/12	3.9	
			08/30/12	3.7	
			12/06/12	2.3	
			02/19/13	1.7	
			05/23/13	1.3	
			08/20/13	1.2	
			11/21/13	1.1	
			02/17/14	0.83	
			05/28/14	0.61	
			08/19/14	0.49 (J)	
			11/12/14	0.69	
			02/26/15	0.67	
			05/26/15	0.48 (J)	
			08/26/15	0.49 (J)	
		1,1-Dichloroethene	04/26/12	0.59	7
			05/31/12	0.55	
			08/30/12	0.69	
			12/06/12	ND (<0.50)	
			02/19/13	0.27 (J)	
			05/23/13	0.20 (J)	
			08/20/13	0.21 (J)	
			11/21/13	ND (<0.50)	
			02/17/14	ND (<0.50)	
			05/28/14	ND (<0.50)	
			08/19/14	ND (<0.50)	
			11/12/14	ND (<0.50)	
			02/26/15	ND (<0.50)	
			05/26/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		Tetrachloroethene	04/26/12	ND (<0.50)	5
			05/31/12	ND (<0.50)	
			08/30/12	ND (<0.50)	
			12/06/12	ND (<0.50)	
			02/19/13	ND (<0.50)	
			05/23/13	ND (<0.50)	
			08/20/13	ND (<0.50)	
			11/21/13	ND (<0.50)	
			02/17/14	ND (<0.50)	
			05/28/14	ND (<0.50)	
			08/19/14	ND (<0.50)	
			11/12/14	ND (<0.50)	
			02/26/15	ND (<0.50)	
			05/26/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		1,4-Dioxane	04/26/12	ND (<2.0)	N/A
			05/31/12	ND (<2.0)	
			08/30/12	ND (<2.0)	
			12/06/12	ND (<2.0)	
			02/19/13	ND (<2.0)	
			05/23/13	ND (<2.0)	
			08/20/13	ND (<2.0)	
			11/21/13	ND (<2.0)	
			02/17/14	ND (<2.0)	
			05/28/14	ND (<2.0)	
			08/19/14	ND (<2.0)	
			11/12/14	ND (<2.0)	
			02/26/15	ND (<2.0)	
			05/26/15	ND (<2.0)	
			08/26/15	ND (<2.0)	

TABLE 3
PLYMOUTH TUBE GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Constituent	Sample Date	Concentration (µg/L)	MCL
PT-5	90	Trichloroethene	11/15/11	11	5
			02/24/12	9.0	
			05/30/12	9.0	
			08/29/12	10.4	
			12/05/12	8.7	
			02/18/13	8.1	
			05/23/13	5.0	
			08/20/13	3.6	
			11/20/13	3.1	
			02/17/14	2.5	
			05/27/14	2.1	
			08/19/14	1.3	
			11/12/14	1.8	
			02/23/15	1.7	
			05/26/15	1.2	
			08/26/15	0.86	
		1,1-Dichloroethene	11/15/11	ND (<2.0)	7
			02/24/12	ND (<2.0)	
			05/30/12	0.59	
			08/29/12	1.1	
			12/05/12	1.2	
			02/18/13	1.1	
			05/23/13	0.70	
			08/20/13	0.58	
			11/20/13	0.42 (J)	
			02/17/14	0.33 (J)	
			05/27/14	0.31 (J)	
			08/19/14	ND (<0.50)	
			11/12/14	0.26 (J)	
			02/23/15	0.24 (J)	
			05/26/15	0.23 (J)	
			08/26/15	ND (<0.50)	
		Tetrachloroethene	11/15/11	ND (<1.0)	5
			02/24/12	ND (<1.0)	
			05/30/12	ND (<0.50)	
			08/29/12	ND (<0.50)	
			12/05/12	ND (<0.50)	
			02/18/13	ND (<0.50)	
			05/23/13	ND (<0.50)	
			08/20/13	ND (<0.50)	
			11/20/13	ND (<0.50)	
			02/17/14	ND (<0.50)	
			05/27/14	ND (<0.50)	
			08/19/14	ND (<0.50)	
			11/12/14	ND (<0.50)	
			02/23/15	ND (<0.50)	
			05/26/15	ND (<0.50)	
			08/26/15	ND (<0.50)	
		1,4-Dioxane	11/15/11	ND (<2.0)	N/A
			02/24/12	ND (<2.0)	
			05/30/12	ND (<2.0)	
			08/29/12	ND (<2.0)	
			12/05/12	1.2 (J)	
			02/18/13	ND (<2.0)	
			05/23/13	ND (<2.0)	
			08/20/13	ND (<2.0)	
			11/20/13	ND (<2.0)	
			02/17/14	ND (<2.0)	
			05/27/14	ND (<2.0)	
			08/19/14	ND (<2.0)	
			11/12/14	ND (<2.0)	
			02/23/15	ND (<2.0)	
			05/26/15	ND (<2.0)	
			08/26/15	ND (<2.0)	

Abbreviations:

ID = Identification

feet btoc = feet below top of the casing

MCL = EPA Maximum Contaminant Level

Notes:

J= Concentration estimated. Analyte was detected below laboratory minimum reporting limit.

< = Less than, analyte not detected at concentration greater than the reporting limit shown

ND= Analyte Not Detected at or above the reporting limit

NS= Not Sampled

Bold values indicate detects

Red Highlighted values indicate detection exceeding MCL

Blue Highlighted values indicates a detection but below MCL

Detected 1,4-Dioxane value (N/A: No current MCL)

⁽¹⁾ Groundwater sample collected 41 days after Limited Groundwater Pump & Treat (LGWP&T) System was shut off.

⁽²⁾ The LGWP&T System was shut down for 30 days from 7/17/13 through 8/15/13 for maintenance. The monitor well was operational for approximately 4 days prior to sampling.

⁽³⁾ The LGWP&T Sytem was shut down for 7 days from 8/12/14 through 8/18/14 possibly due to a storm event.

The monitor well was operational for approximately 15 hours prior to sampling.

⁽⁴⁾ Pump was non-operable at time of sampling event and was replaced on March 5, 2015

⁽⁵⁾ Result is from Run #2 of analysis.

Pumps in wells LB-7R and PT-2S were removed on May 19, 2015

* - Data presented were collected as part of vertical profiling sampling event. Data from wells PT-1S and PT-3 were collected at 90 feet btoc. Data from wells LB-7Rand PT-2S were collected at 85 and 95 feet btoc, respectively.

TABLE 4
SELECTED GILA RIVER INDIAN COMMUNITY GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Compounds	Sample Date	Results	MCL
LB-1	88	Trichloroethene	05/22/13	36.4	5
			11/20/13	33.9	
			02/18/14	23.1	
			08/18/14	25.1	
			11/11/14	21.6	
			02/25/15	22.7	
			05/27/15	18.0	
			08/27/15	18.5	
		1,1-Dichloroethene	05/22/13	4.4	7
			11/20/13	4.62	
			02/18/14	2.8	
			08/18/14	1.4	
			11/11/14	2.4	
			02/25/15	1.9	
			05/27/15	2.2	
			08/27/15	2.2	
		Tetrachloroethene	05/22/13	ND (<0.50)	5
			11/20/13	ND (<0.50)	
			02/18/14	ND (<0.50)	
			08/18/14	ND (<0.50)	
			11/11/14	ND (<0.50)	
			02/25/15	ND (<0.50)	
			05/27/15	ND (<0.50)	
			08/27/15	ND (<0.50)	
		1,4-Dioxane	05/22/13	2.4	N/A
			11/20/13	NS	
			02/18/14	1.8 (J)	
			08/18/14	2.0	
			11/11/14	1.6 (J)	
			02/25/15	1.8 (J)	
			05/27/15	1.3 (J)	
			08/27/15	ND (<2.0)	
LB-13	124	Trichloroethene	05/22/13	12.5	5
			11/20/13	17.5	
			02/18/14	13.0	
			08/18/14	15.3	
			11/11/14	10.8	
			02/25/15	10.0	
			05/27/15	9.7	
			08/27/15	9.4	
		1,1-Dichloroethene	05/22/13	2.3	7
			11/20/13	1.77	
			02/18/14	2.2	
			08/18/14	2.2	
			11/11/14	1.8	
			02/25/15	1.8	
			05/27/15	1.8	
			08/27/15	1.6	
		Tetrachloroethene	05/22/13	ND (<0.50)	5
			11/20/13	ND (<0.50)	
			02/18/14	ND (<0.50)	
			08/18/14	ND (<0.50)	
			11/11/14	ND (<0.50)	
			02/25/15	ND (<0.50)	
			05/27/15	ND (<0.50)	
			08/27/15	ND (<0.50)	
		1,4-Dioxane	05/22/13	1.5 (J)	N/A
			11/20/13	NS	
			02/18/14	1.1 (J)	
			08/18/14	1.4 (J)	
			11/11/14	1.2 (J)	
			02/25/15	1.1(J)	
			05/27/15	1.1(J)	
			08/27/15	1.1(J)	

TABLE 4
SELECTED GILA RIVER INDIAN COMMUNITY GROUNDWATER QUALITY
Former Plymouth Tube Company
Chandler, Arizona

Concentrations are presented in micrograms per liter (µg/L)

Monitor Well ID	Sample Depth (feet btoc)	Compounds	Sample Date	Results	MCL
LB-17	138	Trichloroethene	05/22/13	9.2	5
			11/20/13	10.8	
			02/18/14	8.2	
			08/18/14	9.0	
			11/11/14	7.9	
			02/25/15	7.5	
			05/27/15	7.0	
			08/27/15	6.3	
		1,1-Dichloroethene	05/22/13	2.3	7
			11/20/13	1.08	
			02/18/14	2.0	
			08/18/14	2.1	
			11/11/14	2.3	
			02/25/15	2.1	
			05/27/15	1.9	
			08/27/15	1.6	
		Tetrachloroethene	05/22/13	1.2	5
			11/20/13	2.57	
			02/18/14	1.7	
			08/18/14	1.7	
			11/11/14	1.3	
			02/25/15	2.2	
			05/27/15	1.4	
			08/27/15	1.7	
		1,4-Dioxane	05/22/13	0.98 (J)	N/A
			11/20/13	NS	
			02/18/14	0.73 (J)	
			08/18/14	1.2 (J)	
			11/11/14	ND (<2.0)	
			02/25/15	ND (<2.0)	
			05/27/15	0.67 (J)	
			08/27/15	ND (<2.0)	
PT-6D	165	Trichloroethene	11/11/14	12.3	5
			02/25/15	5.6	
			05/27/15	5.3	
			08/27/15	4.4	
		1,1-Dichloroethene	11/11/14	1.8	7
			02/25/15	1.0	
			05/27/15	1.0	
			08/27/15	0.49 (J)	
		Tetrachloroethene	11/11/14	ND (<0.50)	5
			02/25/15	ND (<0.50)	
			05/27/15	ND (<0.50)	
			08/27/15	ND (<0.50)	
		1,4-Dioxane	11/11/14	0.83 (J)	N/A
			02/25/15	ND (<2.0)	
			05/27/15	0.56 (J)	
			08/27/15	ND (<2.0)	

Abbreviations:

ID = Identification

feet btoc = feet below top of the casing

MCL = EPA Maximum Contaminant Level

NS= Not Submitted for this compound

Notes:

J= Concentration estimated. Analyte was detected below laboratory minimum reporting limit.

< = Less than, analyte not detected at concentration greater than the reporting limit shown

ND= Analyte Not Detected at or above the reporting limit

Bold values indicate detects

Red Highlighted values indicate detection exceeding MCL

Blue Highlighted values indicates a detection but below MCL

Detected 1,4-Dioxane value (N/A: No current MCL)

TABLE 5

Preliminary Screening Evaluation - Former Plymouth Tube Company Facility, Chandler, Arizona

Corrective Measure Alternative	Short Term Effectiveness	Implementability	Relative Cost	Retained For Further Analysis
No Action	Not Applicable	Not Applicable	Not Applicable	No
Monitored Natural Attenuation	High: There is no current completed exposure routes. Potential future exposure routes are being addressed through institutional controls by GRIC and LBDC. VOC groundwater plume is shrinking and VOC concentrations in groundwater are declining.	High: VOC plume is defined horizontally and vertically. Monitor well network already in place.	High: No capital costs with low O&M costs for groundwater MNA monitoring.	Yes: MNA is retained for further analysis.
Focused In-Situ Chemical Oxidation at Site AOI (LB-7/LB-7R)	Moderate to High: Would reduce the volume of the COCs (i.e., TCE, 1,1-DCE, and 1,4-dioxane) via desorption and degradation. The end products of the selected ISCO oxidant reaction with TCE, 1,1-DCE, 1,4-dioxane and PCE need to be evaluated prior to selection of an appropriate oxidant.	Low to Moderate: Oxidants have been applied at numerous sites. Can be readily mixed at the surface using appropriate tanks and mixers to inject into the subsurface. No known regulatory framework exists for applications of ISCO on GRIC land may complicate regulatory implementability.	High to Moderate: Low to moderate capital costs depending on need for and number of injection wells. Low O&M costs include potential additional doses of oxidants and groundwater monitoring costs.	Yes: EPA and GRIC have requested further evaluation of this alternative. Focused ISCO application combined with MNA is retained for further analysis.
Regional ISCO Application	Not Applicable	Not Applicable	Not Applicable	No
Air Sparging / Soil Vapor Extraction	Not Applicable	Not Applicable A	Not Applicable	No

TABLE 5

Preliminary Screening Evaluation - Former Plymouth Tube Company Facility, Chandler, Arizona

Corrective Measure Alternative	Short Term Effectiveness	Implementability	Relative Cost	Retained For Further Analysis
Groundwater Pump and Treat	Moderate to High: Would need numerous extraction wells to capture the current VOC plume. Corrective measure technology is proven for the remediation of VOCs and 1,4-dioxane.	Low: Relatively low concentration VOC plume located along an appropriate 2 mile long VOC plume. Would require substantial property access for the extraction wells as well as for the piping back to a centralized treatment system. After treatment may require substantial access for piping to the disposal point or beneficial end use. If treated groundwater not reinjected or reused, the City of Chandler may not allow disposal of a large volume of water into their sanitary sewer system. Piping for discharge to the Gila Drain may not be practicable. No know facility was identified that would accept the treated water. No other beneficial end use for the water has been identified.	Low: High costs for the extraction well network installations, and piping from the extraction well network to a centralized treatment system. High capital costs for the design and construction of both a LGAC treatment system (for VOCs) and a UV/Phox type treatment system (for 1,4-dioxane). High O&M costs including power, LGAC replacement, hydrogen peroxide usage, and replacement parts (UV bulbs) for the UV/Phox system.	No

TABLE 6

Detailed Screening Evaluation - Former Plymouth Tube Company Facility, Chandler, AZ

Corrective Measure Alternative	Technical Approach	Protection of Human Health and Environment	Attainment of Remedial Objectives	Source Control	Long-Term Effectiveness	Reduction in Toxicity, Mobility, or Volume of Wastes	Short-Term Effectiveness	Implementability	Estimated Costs
Corrective Measure Alternative 1: Monitored Natural Attenuation (MNA)	Continued groundwater monitoring of the Plymouth Tube Monitor Well Network including selected GRIC monitor wells to track attenuation of COCs over time	Is considered to be protective of human health and the environment. There are no current or anticipated future completed exposure pathways. Attenuation is occurring, plume is shrinking and COC concentrations are declining.	Is expected to obtain the specified cleanup objectives at the Site (i.e., reduction of TCE, 1,1-DCE, 1,4-dioxane and PCE concentrations in the groundwater).	Meets the criterion as there are no continuing sources of groundwater contamination.	Considered to be effective and reliable at reducing concentrations throughout the plume. Longer term needed to substantially reduce the COC concentrations in the area near Site AOI (LB-7/LB-7R) elevated COC area	Would reduce the overall COC volume through dispersion, degradation and dilution. These reductions would occur over a longer time frame if not coupled with ISCO.	Considered to be effective in the short-term.	Easy to implement as the groundwater monitoring network and sampling program is already established.	<u>2016 Costs</u> Capital: \$0 O&M: \$254,232 Total: \$254,232 <u>Present Value Costs</u> Capital: \$0 O&M: \$217,680 Total: \$217,680
Corrective Measure Alternative 2: Focused In-Situ Chemical Oxidation with MNA Preferred Alternative	Same groundwater monitoring program as Remedial Alternative 1 plus a MFR ISCO application event in the Site AOI area (LB-7/LB-7R) with elevated COCs.	Is considered to be protective of human health and the environment. There are no current or anticipated future completed exposure pathways. Attenuation is occurring, plume is shrinking and COC	Is expected to obtain the specified cleanup objectives at the Site (i.e., reduction of TCE, 1,1-DCE, 1,4-dioxane and PCE concentrations in the groundwater).	Meets the criterion as there are no continuing sources of groundwater contamination.	Considered to be effective and reliable at reducing concentrations in and near the application site and, coupled with MNA, throughout the identified plume.	Would reduce the volume of COCs, and lead to groundwater plume shrinkage by reducing/eliminating elevated COCs in the Site AOI area (LB-7/LB-7R).	Considered to have moderate to high effectiveness due to desorption and degradation of COCs with relatively benign end products.	Same groundwater monitoring program as Remedial Alternative 1. MFR application is technically feasible. However, regulatory uncertainty may delay or prevent implementation.	<u>2016 Costs</u> MNA: \$254,232 ISCO Bench Test: \$8-\$10K ISCO Injection Program: \$100-\$300K Total: \$362,232-\$564,232

TABLE 6

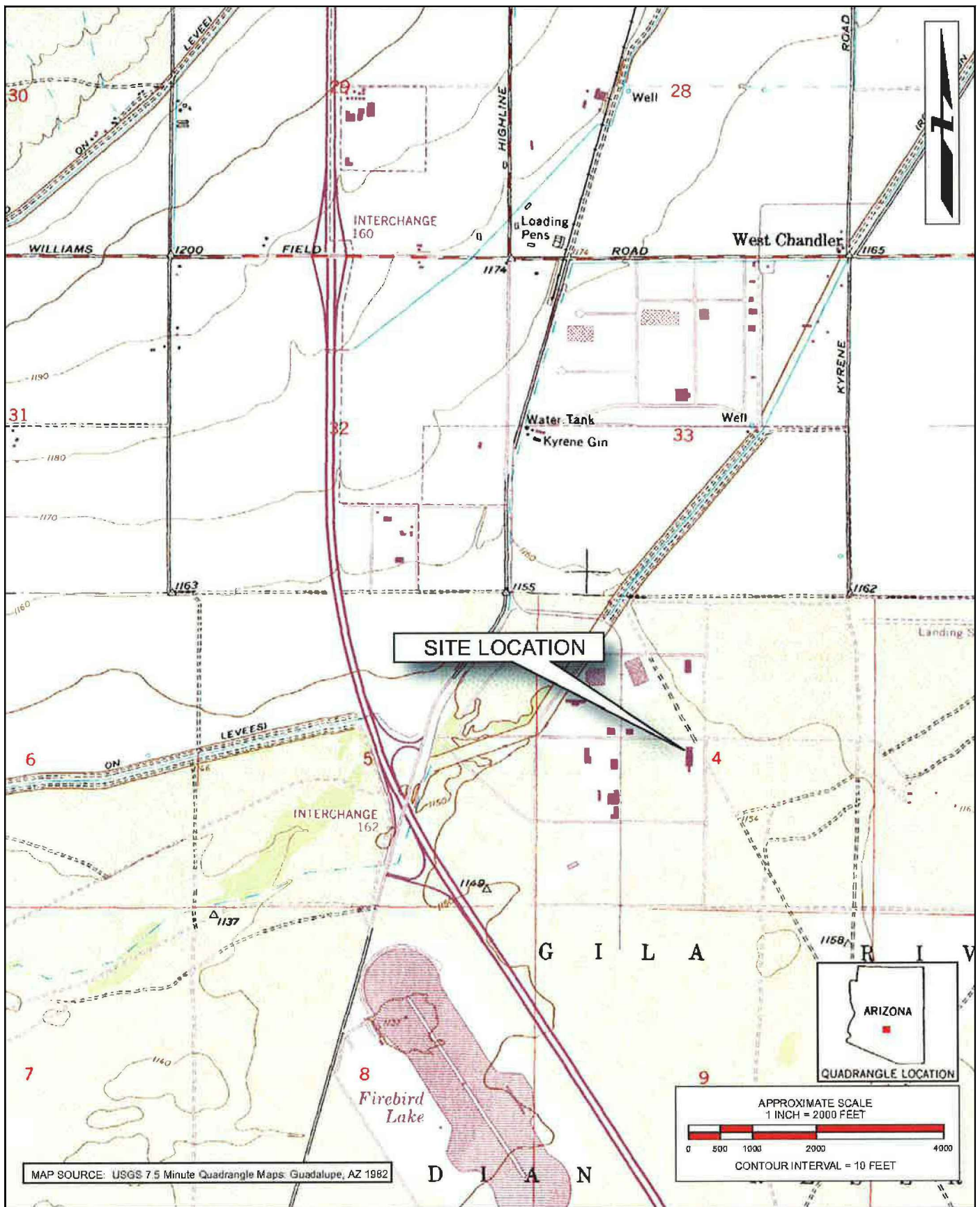
Detailed Screening Evaluation - Former Plymouth Tube Company Facility, Chandler, AZ

		concentrations are declining. Relatively benign end products.								<u>Present</u> <u>Value Costs</u> \$317,680 to \$499,499
--	--	---	--	--	--	--	--	--	--	---

Notes:

- Inflation Rate of 3% and discount rate of 7% used to calculate present valve costs
- MNA Quarterly groundwater monitoring and reporting for Year 1.
- MNA Semi-annual groundwater monitoring and reporting for Years 2 through 5.

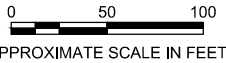
FIGURES





EXPLANATIONS

- LB-7R Monitor Well Location
- ◆ PT-3 Monitor Well Location
- ⊙ SB-13 Arcadis, 2006 Soil Boring Locations
- ⊙ SB-1 Geraghty & Miller, 1995 Soil Boring Locations
- ▽ VASG-4 Groundwater Monitoring Well
- ▽ VASG-1 Abandoned Groundwater Monitoring Well
- ▽ AASG-2 Angle Vapor Monitoring Well
- ▽ AASG-1 Abandoned Angle Soil/Soil Gas Boring
- △ SASG-1 Shallow Soil/Soil Gas Sampling Location
- ▽ VASG-4 Vertical Vapor Monitor Well
- HHRA Site Boundary
- Assumed Area of TCE Concentration > 10,000 µg/L




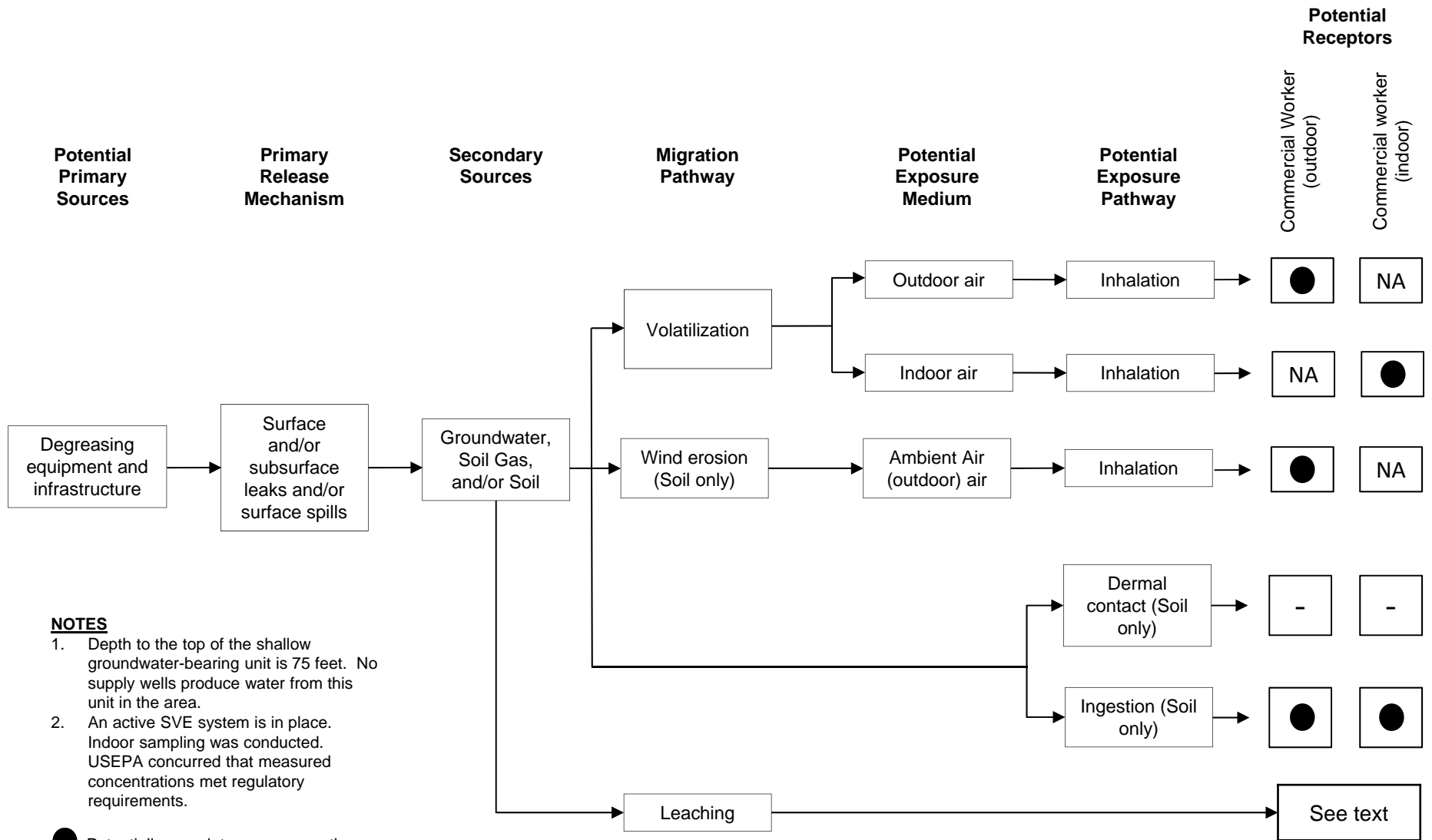
SITE PLAN		
Former Plymouth Tube Company Chandler, Arizona		
 <div>www.NV5.com 1 W. Deer Valley Road, Bldg. 2, Suite 305 Phoenix, AZ 85027 P:623.374.6637</div>	Figure: 2	
	Phoenix, AZ	16 Novemeber 2015

Figure 3 Conceptual Site Model



NOTES

1. Depth to the top of the shallow groundwater-bearing unit is 75 feet. No supply wells produce water from this unit in the area.
2. An active SVE system is in place. Indoor sampling was conducted. USEPA concurred that measured concentrations met regulatory requirements.



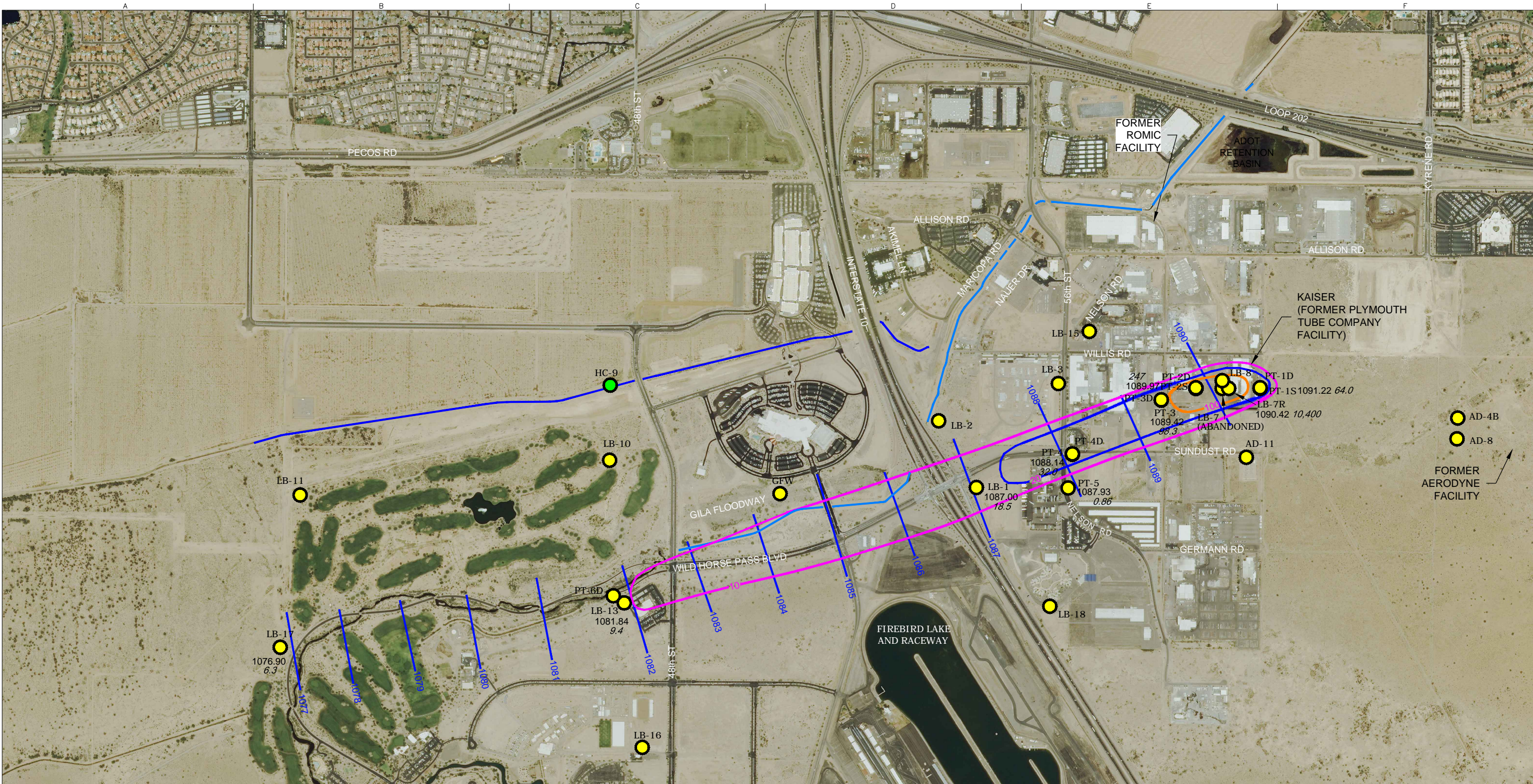
Potentially complete exposure pathway



Incomplete exposure pathway for VOCs (USEPA, 2004a)

NA Pathway not applicable

N:\NV5\PLYMOUTH TUBE\2015 GROUNDWATER MONITORING\PLYMOUTH GW MONITORING 3RD QTR 2015 EXHIBIT



GILA RIVER INDIAN COMMUNITY GROUNDWATER ELEVATION MEASUREMENT AND TCE CONCENTRATIONS IN SHALLOW MONITOR WELLS. PERIMETER LB-MONITOR WELLS NOT MEASURED OR SAMPLED DURING THIS QUARTERLY EVENT
August 27, 2015

PLYMOUTH TUBE GROUNDWATER ELEVATION MEASUREMENT AND TCE CONCENTRATIONS IN SHALLOW MONITOR WELLS
August 26, 27 and 28, 2015

EXPLANATION

	10	Trichloroethene (TCE) Concentration Contour
	10	TCE Concentration in Micrograms Per Liter (µg/L)
	1079.65	Groundwater Elevations (in feet above mean sea level, [AMSL])
	1080	Groundwater Elevation Contours, AMSL

	LB-1	Monitor Well
	HC-9	Agricultural Well
		Gila Drain
		Unlined Irrigation Canal

0 650 1,300
APPROXIMATE SCALE IN FEET

2013 AERIAL IMAGE FROM USDA: GEOSPATIAL GATEWAY

APPROXIMATE LATERAL DISTRIBUTION OF DISSOLVED PHASE TCE
AUGUST 2015
Former Plymouth Tube Company
Chandler, Arizona



www.NV5.com
1 W. Deer Valley Road, Bldg. 2, Suite 305
Phoenix, AZ 85027
P:623.374.6637

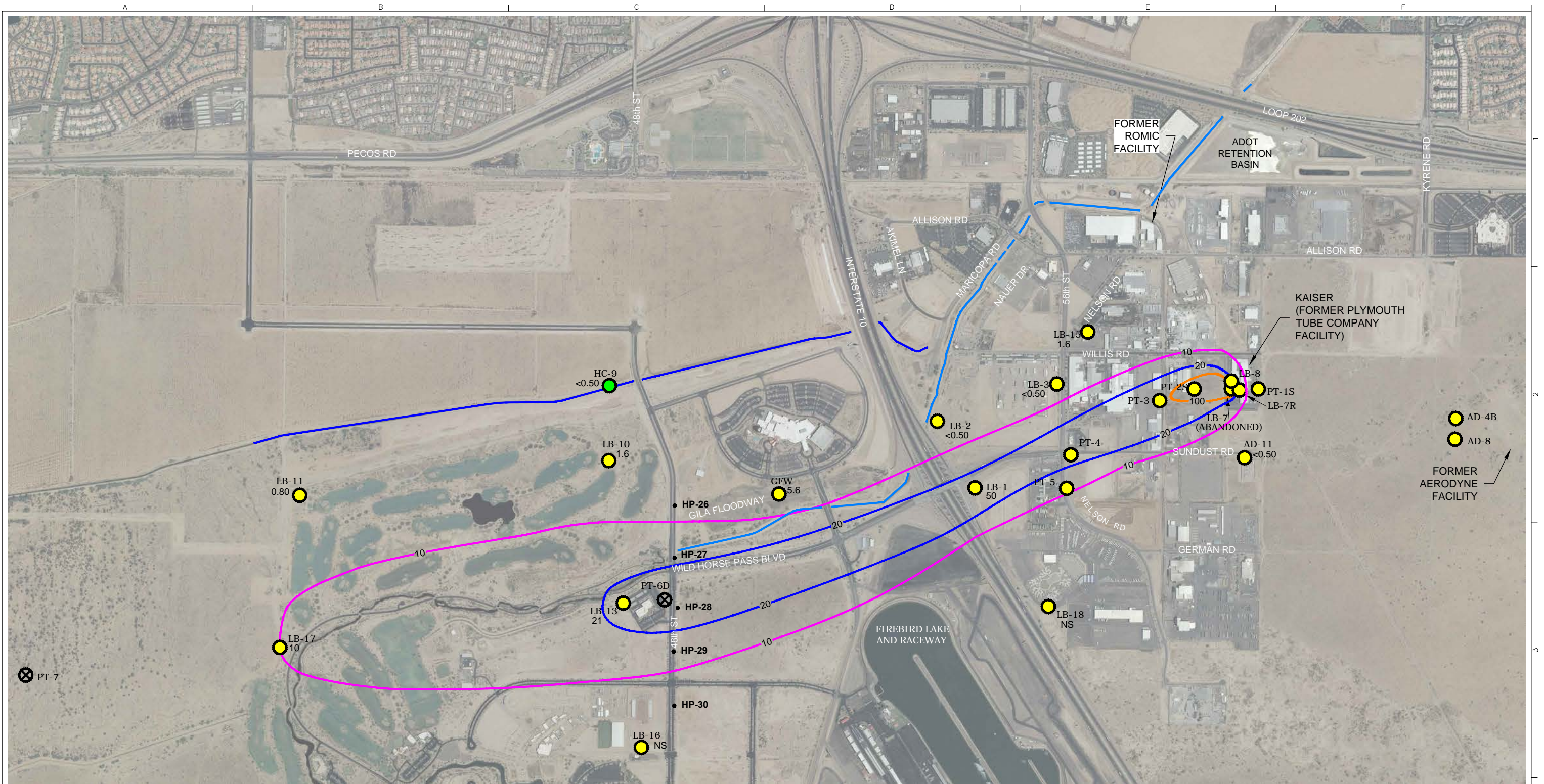
Phoenix, AZ

September 2015

Figure:

4

N:\NV5\PLYMOUTH TUBE\CSM REPORT\PLYMOUTH CSM FIG 34 PLAN 2013



2010 AERIAL IMAGE FROM USDA: GEOSPATIAL GATEWAY

TCE Concentration Contour		EXPLANATION	
100	TCE Concentration in $\mu\text{g/L}$ (8/23/12, 8/29/12, 8/30/12)	● LB-1	Monitor Well
100		● HC-9	Agricultural Well
NS	Not Sampled, Well Analytical Results have always been Non-Detect ($<0.5 \text{ g/L}$)	⊗ PT-6D	Proposed Monitor Well (D=Deep)
		● HP-□	Proposed Hydropunch Location
		—	Gila Drain
		—	Unlined Irrigation Canal

0 650 1,300
APPROXIMATE SCALE IN FEET

APPROXIMATE LATERAL DISTRIBUTION OF
DISSOLVED PHASE TCE
AUGUST 2012
Former Plymouth Tube Company
Chandler, Arizona



www.NV5.com
1 W. Deer Valley Road, Bldg. 2, Suite 305
Phoenix, AZ 85027
P:623.374.6637

Phoenix, AZ

September 2015

Figure:
6