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SulTRAC

July 25, 2019

Mr. Jeffrey Gore
Work Assignment Manager
U.S. Environmental Protection Agency (EPA)
77 W. Jackson Blvd. (SR-6J)
Chicago, IL 60604

Subject: **Final Feasibility Study Report**
For the Remedial Investigation/Feasibility Study at
West Troy Contaminated Aquifer Superfund Site
Troy, Miami County, Ohio
Remedial Action Contract (RAC) 2 No. EP-S5-06-02
Work Assignment No. 199-RICO-B5SV

Dear Mr. Gore:

SulTRAC is submitting one hard copy and one electronic copy (on CD) of the Final Feasibility Study Report for the above-referenced project.

SulTRAC is also submitting one electronic copy of the report on CD directly to the Ohio Environmental Protection Agency.

If you have any questions regarding this submittal, please call me at (312) 201-7748.

Sincerely,

R. Mastrolonardo

Ray Mastrolonardo
SulTRAC Project Manager

Enclosure

cc: Daniel Olsson, EPA Contracting Officer (letter only)
Mindy Gould, SulTRAC Program Manager (letter only)
Leslie Williams, Ohio EPA Site Coordinator (letter and one CD)
File

FINAL
FEASIBILITY STUDY REPORT
FOR
WEST TROY CONTAMINATED AQUIFER SITE
TROY, MIAMI COUNTY, OHIO

Prepared for
U.S. Environmental Protection Agency
Region 5
77 West Jackson
Chicago, Illinois 60604

Work Assignment No.	:	199-RICO-B5SV
Contract No.	:	EP-S5-06-02
Date Prepared	:	July 25, 2019
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ACRONYMS

µg/L	Microgram per liter
µg/m^3	Microgram per cubic meter
Apex	Apex Racing
ARAR	Applicable or relevant and appropriate requirement
AS/SVE	Air sparging/soil vapor extraction
ATSDR	Agency for Toxic Substances and Disease Registry
bgs	Below ground surface
Bob's Auto	Bob's Automotive Repair
Bowser-Morner	Bowser-Morner Associates, Inc.
BTEX	Benzene, toluene, ethylbenzene, and xylene
BUSTR	Bureau of Underground Storage Tank Regulations
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cis-DCE	cis-1,2-Dichloroethene
cm/sec	Centimeters per second
COC	Chemical of concern
COPC	Chemical of potential concern
COPEC	Chemical of potential ecological concern
CTE	Central tendency exposure
CWA	Clean Water Act
DERR	Ohio EPA Division of Emergency and Remedial Response
DNAPL	Dense nonaqueous-phase liquid
EA	Exposure area
EM	Electromagnetometer
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
ERD	Enhanced reductive dechlorination
ESI	Expanded site inspection
ESV	Ecological screening value
ETCA	East Troy Contaminated Aquifer
FS	Feasibility study
FSP	Field sampling plan
ft/day	Feet per day
ft^2/day	Square feet per day
ft/year	Feet per year

GAC	Granular activated carbon
GMR	Great Miami River
gpm	Gallon per minute
GPR	Ground penetrating radar
GPS	Global positioning system
GRA	General response action
HHRA	Human health risk assessment
HRS	Hazard Ranking System
HQ	Hazard quotient
HVAC	Heating, ventilation, and air conditioning
IC	Institutional control
IDW	Investigation-derived waste
ik	Distribution of relative hydraulic conductivity
ISCO	In situ chemical oxidation
ISCR	In situ chemical reduction
MCD	Miami Conservancy District
MCL	Maximum Contaminant Level
MGD	Million gallons per day
MNA	Monitored natural attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOD	Natural oxidant demand
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
O&M	Operation and maintenance
ODH	Ohio Department of Health
ODNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
OSFM	Ohio State Fire Marshall
OUPS	Ohio Utilities Protection Service
PA/SI	Preliminary assessment/site inspection
PCE	Tetrachloroethene
PHA	Public Health Assessment
PID	Photoionization detector
POE	Point of entry
POTW	Publicly owned treatment works
POU	Point of use
ppb	Part per billion
PRG	Preliminary remediation goal
PVC	Polyvinyl chloride
RAC	Remedial Action Contract
RAO	Remedial action objective
RCRA	Resource Conservation and Recovery Act
RD	Remedial design
RI	Remedial investigation

RME	Reasonable maximum exposure
ROD	Record of Decision
ROI	Radius of influence
RSL	Regional Screening Level
SAP	Sampling and analysis plan
SDWA	Safe Drinking Water Act
SESI	Supplemental expanded site inspection
SL	Screening level
SLERA	Screening level ecological risk assessment
SVE	Soil vapor extraction
TBC	To be considered
TCE	Trichloroethene
TDS	Total dissolved solids
TOT	Time of travel
TPH	Total petroleum hydrocarbon
TSCA	Toxic Substances Control Act
UST	Underground storage tank
VAP	Voluntary Action Program
VAS	Vertical aquifer sampling
VI	Vapor intrusion
VISL	Vapor intrusion screening level
VOC	Volatile organic compound
WA	Work assignment
WTCA	West Troy Contaminated Aquifer
ZVI	Zero-valent iron

1.0 INTRODUCTION

SulTRAC prepared this final feasibility study (FS) report for the U.S. Environmental Protection Agency (EPA) under EPA Remedial Action Contract No. EP-S5-06-02 (RAC), Work Assignment No. 199-RICO-B5SV. Under this work assignment, EPA tasked SulTRAC to conduct an FS to develop and screen potential remedial alternatives for the West Troy Contaminated Aquifer (WTCA) site. Specifically, SulTRAC developed a list of potential remedial alternatives to address chemicals of concern (COC) associated with groundwater and soil vapor at the WTCA site. SulTRAC prepared this FS report in accordance with the EPA Guidance for Conducting Remedial Investigations and Feasibility Studies under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (EPA 1988a).

The primary goals of the FS are to (1) establish site-specific remedial action objectives (RAO) protective of human health and the environment for the WTCA site; (2) propose general response actions (GRA) for the WTCA site by defining actions to satisfy RAOs; (3) screen remedial technologies and process options to ensure that only applicable technologies are retained; (4) develop a range of remedial alternatives in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and screen each alternative for effectiveness, implementability, and cost; (5) conduct a detailed analysis of each remedial alternative; and (6) conduct a comparative analysis of each remedial alternative. The FS also includes an estimate of the extent of contaminated media at the WTCA site as well as preliminary identification of applicable or relevant and appropriate requirements (ARAR) relative to the site.

This FS report evaluates technologies and process options for addressing groundwater, an affected private well, and soil vapor separately from each other and presents three separate sets of remedial alternatives. By choosing and combining an alternative from each of these groups that complement each other, a comprehensive site-wide remedy will be established.

This FS is organized into seven major sections. Section 1.0 provides a summary of historical activities that have occurred at the WTCA site as well as a summary of the remedial investigation (RI) and risk assessment. Section 2.0 discusses the identification of RAOs, ARARs, and areas requiring remediation. Section 3.0 provides GRAs and identifies potentially applicable remedial technologies and process options. Section 4.0 provides a screening of remedial technology types and process options. Section 5.0 describes the remedial alternatives assembled for the WTCA site. Section 6.0 presents a detailed evaluation of each remedial alternative. Section 7.0 presents a comparative analysis of each remedial alternative. References are provided in Section 8.0. Figures are located after Section 8.0. Four appendices are also included. Appendix A, presents preliminary identification of ARARs. Appendix B presents physiochemical parameter results for groundwater samples collected during the RI using the Waterloo groundwater sampling system. Appendix C presents site geologic cross sections. Appendix D presents cost estimates and assumptions for each of the remedial alternatives. Appendix E presents 3-dimensional plume images using groundwater sample results collected during the RI using the Waterloo groundwater sampling system.

1.1 WTCA SITE BACKGROUND AND HISTORY

The following sections provide a description of the WTCA site, its operational history, and a summary of previous investigations and activities conducted at the site.

1.1.1 Site Description

The site description presented in this section pertains to the WTCA site only. Groundwater contamination observed in the city’s East Municipal Drinking Water Wellfield (East Wellfield) is being addressed under a separate RI/FS (the East Troy Contaminated Aquifer [ETCA] site) and is not discussed in this report.

The WTCA site is located in both the north end of the City of Troy and an adjacent unincorporated portion of Miami County, Ohio (see Figure 1-1). The site consists of a plume of volatile organic compounds (VOC) that has impaired water quality in the local sand and gravel aquifer. The aquifer is the sole source of drinking water in the area and supplies water to the City of Troy’s West Municipal Drinking Water Wellfield (West Wellfield), which is located east of the Great Miami River (GMR) (see Figure 1-2). The suspected source areas of contamination detected in the West Wellfield are located west of the GMR, near County Road 25A (also referred to as N. Elm Street). Groundwater contamination was first detected in a City of Troy well in 1986. Tetrachloroethene (PCE) is the primary VOC detected in a city well and in the groundwater plume. In particular, PCE has been periodically detected in samples from Troy Production Well P-12W at concentrations above the EPA Maximum Contaminant Level (MCL) established under the Safe Drinking Water Act (SDWA). Lower concentrations of other VOCs – primarily trichloroethene (TCE) and cis-1,2-dichloroethene (cis-DCE) – have also been detected in this well on occasion, but at concentrations below MCLs. The compound cis-DCE has also been occasionally detected at concentrations below its MCL in well P-3W.

The City of Troy currently utilizes an air stripper to pre-treat water obtained from Production Well P-12W before it enters the city’s water treatment plant and distribution system.

Site features located within the Phase I investigation area are shown in Figure 1-3. These features include several commercial properties located between N. Elm Street and the GMR. The Apex Racing (Apex) property and the Bob's Automotive Repair (Bob's Auto) property were the primary focus of the RI. In addition to these commercial properties, a filled and capped former gravel pit known as the Hobart Lagoon is present between Bob's Auto Repair and the GMR. Several commercial properties, including Webster's Auto and the former Troy Dairy Barn, also exist on the west side of N. Elm Street. A man-made drainage feature, known as Morgan's Ditch, flows eastward through the investigation area toward the GMR, conveying drainage from areas north, west, and south of the site to the GMR. The City of Troy maintains a public park (Treasure Island Park) located south of Morgan's Ditch along the west bank of the GMR.

The site geology consists of sand and gravel glacial outwash deposits interbedded with fine-grained materials (till and lacustrine clay). Based on soil boring logs from previous investigations conducted by Ohio EPA and data collected during the RI, a clay till layer is present at a depth of about 50 feet below ground surface (bgs) in some portions of the investigation area. The unconsolidated deposits overlie bedrock, which is encountered at depths of approximately 200 feet bgs or greater. Groundwater exists in the unconsolidated deposits in what is known as the GMR buried valley aquifer system. This aquifer system is a federal-designated sole source aquifer, and the underlying bedrock is not used as a source of water in the investigation area. Groundwater has historically been encountered at a depth of about 10 to 12 feet bgs in the investigation area. Regional groundwater flow is toward the south or southeast, following the GMR valley; however, groundwater flow varies locally and is affected by pumping in the West Wellfield. Previous studies described the aquifer as a "shallow system" and "deep system" separated by an aquitard; however, a continuous aquitard may not be present throughout the entire site area. For example, pump tests conducted by Ohio EPA indicate that hydraulic communication exists between the shallow and deep groundwater west of the GMR and the West Wellfield on the east side of the GMR (Ohio EPA 2011). The suspected source areas located on the west side of the GMR are therefore within the West Wellfield capture zone.

Investigations completed before the RI have indicated that the contamination detected in the West Wellfield originated from one or more sources on the west side of the GMR. The general areas from where the plume is currently migrating have been identified; however, the original specific sources of the PCE have not been confirmed. Based on historical information from previous investigations conducted prior to the RI, the plume is believed to originate at or near the former Wampler Buick/GMC (507 N. Elm Street) and Affordable Auto (515 N. Elm Street) properties (see Figure 1-3). Throughout the RI report, the property at 507 N. Elm Street is referred to as either Wampler (the name when most of the previous investigations occurred) or Bob's Auto (the current property name). The property at 515 North Elm Street is referred to as either Affordable Auto (the name when most of the previous investigations occurred) or Apex (the current property name). Although the names for these two properties sometimes differ, they refer to the properties at 507 and 515 N. Elm Street. N. Elm Street is also sometimes referred to as County Road 25A.

These two properties are located about 1,500 feet northwest of Troy Production Well P-12W. The plume extends from these areas under the GMR and to the West Wellfield located on the east side of the GMR. Information derived from previous investigations indicated that the VOC plume extends from the former Wampler area to Production Well P-12W. In addition to VOCs detected in Production Well P-12W, low levels of cis-DCE have also been occasionally detected in Production Well P-3W.

1.1.2 Site History

The WTCA site is located in both the north end of the City of Troy and an adjacent unincorporated portion of Miami County, Ohio. The City of Troy operates two municipal drinking water wellfields (the East Wellfield and the West Wellfield) located along a 1.25-mile stretch of the GMR. Both wellfields are located on the east side of the GMR (see Figure 1-3). The East Wellfield and the West Wellfield have been contaminated by VOCs originating from separate sources located on two separate Superfund sites. This summary pertains only to the WTCA site; the ETCA site is being addressed as a separate site. VOCs have been detected in the West Wellfield and are believed to have originated from one or more sources on the west side of the GMR.

Monthly sampling results were provided by the City of Troy (City of Troy 2017). Table 1-1 summarizes more recent (January 2016 through July 2018) monthly sample results for the West Wellfield wells. Prior to March 2018, results above the laboratory reporting limit were provided. Beginning with March 2018 data, results above the laboratory method detection limit were provided; therefore, it appears as if the frequency of detection has increased in 2018 (see Table 1-1). Historical sample results through July 2018 for Troy Production Wells P-12W and P-3W indicate the following:

Production Well P-12W

- Since 1997, PCE has consistently been detected at concentrations sometimes above its MCL of 5 micrograms per liter (µg/L); however, PCE has been detected above its MCL only three since October 2014 (February and April 2016 and April 2018)

- Since 1997, TCE has occasionally been detected; however, concentrations have never been above its MCL of 5 µg/L (typically detected at less than 1 µg/L), and TCE has been detected very sporadically since September 2013
- Since 2003 when it was first detected, cis-DCE has frequently been detected; however, concentrations have never been above its MCL of 70 µg/L (typically detected at less than 2 µg/L), and cis-DCE has been detected sporadically since January 2015

Production Well P-3W

- Since 2010 when monthly sampling began, PCE and TCE have not been detected
- Since 2010, cis-DCE has occasionally been detected; however, concentrations have never been above its MCL of 70 µg/L (consistently detected at less than 1 µg/L), and cis-DCE has been detected only sporadically since September 2013

Groundwater analytical data have historically indicated the presence of VOCs, including PCE, on two properties (507 and 515 N. Elm Street) located along County Road 25A/Elm Street, between the road and the GMR. These properties are located about 1,400 to 1,600 feet northwest of Troy Production Well P-12W. Both properties are currently covered with asphalt or gravel, and structures exist that are currently in use.

The property at 507 N. Elm Street contains one large subdivided building, which is connected to the City of Troy municipal water system. The majority of the building is currently used by Bob's Auto and includes office areas and eight vehicle service bays. Smaller portions of the northern end of the building are currently used as the lodge for the local chapter of the Loyal Order of Moose (Moose Lodge) and as a realty office (Schaeffer Realty) with separate addresses of 511 and 509 N. Elm Street. The property was previously owned and operated as an auto dealership and service facility at least since the 1950s. Wampler Buick-GMC, Inc., sold and repaired automobiles from 1979 to 1991 and operated a body shop at the site from 1979 to 1986. From 1979 to 1985, waste oil and waste solvents generated during automobile repair were poured down a drain inside the building that discharged to an underground waste oil tank. The contents of the waste oil tank were hauled away by Trojan Asphalt until sometime in 1985 and then by Safety Kleen thereafter. Wampler Buick-GMC, Inc., officials have stated that spent solvents were stored separately and were no longer discharged to the waste oil tank after they contracted with Safety Kleen for liquid waste removal.

Before the Wampler Buick-GMC, Inc. operation, Val Hemm Motors (1956-1977) and Studebaker Buick, Inc. (1977-1979) occupied the property at 507 N. Elm Street. Based on the names, it is presumed that these occupants also sold automobiles. Historical aerial photography indicates that the building and service bays have been present at least since the 1960s. No other information is available regarding specific operations at these businesses.

The property immediately north of 507 N. Elm Street (515 N. Elm Street) is occupied by Apex Racing and has one building. According to the property owner, the site originally was a "Big Boy" drive-in restaurant, then a pizza restaurant, and later was used as an office for the Affordable Auto Group used-car dealership before its current use as an office for Apex Racing.

Local land use in the vicinity is mixed. The Bob's Auto Repair property is bordered on the east by the former Hobart Lagoon site. The lagoon was a man-made feature adjacent to the GMR, reportedly created by Hobart Equipment Company to test dredging equipment. The lagoon was drained, filled with debris, and capped in 2004 by Illinois Tool Works pursuant to the Ohio Voluntary Action Program (VAP). The Hobart Lagoon site contains soil contaminated with metals; however, the voluntary action showed no evidence that PCE was disposed within or released from the lagoon. The City of Troy has since taken ownership of the lagoon property, which may be used for a bike trail or other recreational uses in the future. The covenant-not-to-sue issued by Ohio EPA for the lagoon property specified that groundwater use is restricted and a 2-foot soil cap must be maintained to prevent direct contact with contaminants present in the soil under the cap.

The RI area includes areas both within, and outside of, the Troy city limits. The city limits extend just north of Morgan's Ditch and also include the former Hobart Lagoon. All areas within the Troy city limits are served by the Troy municipal water system, and Troy city ordinances limit the use of private wells within the City's service area. For these reasons, the majority of residences south of the city limits do not have private wells. Although some addresses north of the city limits (for example, the Bob's Auto, Moose Lodge, and realty office) are connected to the public water supply, many residents and businesses north of the city limits primarily use private wells that draw water from the local sand and gravel aquifer.

1.1.3 Previous Investigations

VOCs have been detected in both the Troy and East and West wellfields since the late 1980s and early 1990s. The Ohio EPA Division of Emergency and Remedial Response (DERR) began compiling information on the Troy well fields in 1991. In 1992, four underground storage tanks (USTs) were removed from the Wampler (currently Bob's Auto Repair) property and a soil investigation was conducted for an UST closure assessment report. The first Ohio EPA field investigation began in 1997. Subsequent investigations were focused separately on either the east or the west wellfields, although there was some overlap. Ohio EPA and its contractors have conducted four main investigations since 1997 (in

2001, 2004, 2005, and 2010) to identify potential sources of VOC contamination and the migration of contaminants to neighboring properties and private wells. The investigations resulted in the inclusion of the site in the EPA Superfund Program in 2012. In addition, the Agency for Toxic Substances and Disease Registry (ATSDR) conducted a public health assessment in 2013 (ATSDR 2013). The following text summarizes previous investigations conducted at the site.

1.1.3.1 Bowser-Morner UST Closure Assessment (November 1992)

In November 1992, Bowser-Morner Associates, Inc. (Bowser-Morner) conducted an UST closure assessment. During the UST closure assessment, Bowser-Morner removed four USTs from the Wampler (currently Bob's Auto Repair) property, including two 2,000-gallon gasoline USTs located on the west side of the building. In addition, one 550-gallon gasoline UST and one 550-gallon waste oil UST were located on the east side of the building. The gasoline USTs appeared to be in good condition when they were removed, but the waste oil UST showed signs of deterioration. The excavation for the waste oil UST was observed to contain petroleum product at the bottom, indicating a release. Bowser-Morner collected nine soil samples from the UST excavation cavities for analysis of benzene, toluene, ethylbezene, and xylene (BTEX), and total petroleum hydrocarbons (TPH).

Laboratory analytical results indicated no release of BTEX compounds from the gasoline USTs, as BTEX compounds were all less than 2 parts per billion (ppb) with TPH less than 30 ppb. Laboratory analytical results indicated that a release of TPH from the waste oil UST was likely, as TPH was detected at 13,000 ppb in a soil sample collected in the center of the excavation. The release was reported to the Ohio State Fire Marshal (OSFM) Bureau of Underground Storage Tank Regulations (BUSTR).

1.1.3.2 Ohio EPA Field Investigation (1997)

The first Ohio EPA field investigation began in 1997. During the 1997 investigation, Ohio EPA considered both wellfields as one site, the Troy Well Field. The 1997 investigation documented that contamination affecting the two wellfields was not coming from the same sources. Subsequent investigations were focused separately on either the east or the west wellfields, although there was some overlap.

Results from the 1997 field investigation were presented in the Troy, Ohio, Well Field Investigation Summary Report and Data Package (Earth Tech 1997). At the time, the highest concentration of PCE detected at the Bob's Auto Repair property was 18.0 µg/L in monitoring well MW-3. PCE was detected at less than 10 µg/L west of Bob's Auto Repair in Geoprobe samples on Harrison Street adjacent to the Miami County Garage. PCE was detected south and southwest of Bob's Auto Repair at 16.2 µg/L and 12.7 µg/L in Geoprobe samples along Atlantic Avenue and south of Morgan's Ditch. The 1997 report recommended that additional samples be collected on the west, south, and east sides of Bob's Auto Repair.

Groundwater samples were also collected on Staunton Street, northeast of Troy Production Well P-12W. No PCE was detected in these Geoprobe samples. TCE was detected in soil boring GB13 at 0.8 µg/L. Ohio EPA used these results to rule out a source in this direction (northeast of P-12W).

1.1.3.3 Ohio EPA Preliminary Assessment/Site Inspection and Field Investigation (2001 and 2004)

Both the combined preliminary assessment/site inspection (PA/SI) conducted in 2001 and a state-lead investigation in 2004 focused on locating a potential source of the PCE at Bob's Auto Repair. The pattern of contamination suggested to Ohio EPA investigators that PCE was released to shallow groundwater somewhere near 515 N. Elm Street and that the contamination had migrated to the southeast and vertically downward to Troy Production Well P-12W. P-12W is located east of the GMR and is screened from 66 to 86 feet bgs.

1.1.3.4 Ohio EPA Expanded Site Inspection (2005)

In May and June 2005, Ohio EPA conducted an expanded site inspection (ESI) at the site. During the ESI, 11 borings were advanced using direct-push equipment to approximately 44 feet bgs at Bob's Auto Repair. Continuous soil samples were collected from three borings, but field screening did not detect elevated VOC concentrations. Based on results for direct-push groundwater samples, five monitoring wells (OEPA-14, OEPA-15, OEPA-16, OEPA-17, and OEPA-18) were installed at 507 and 515 N. Elm Street. These wells were sampled as part of the ESI. The highest concentration of PCE was found in monitoring well OEPA-17 at 23 µg/L, slightly upgradient of the Bob's Auto Repair buildings along County Road 25A. PCE was also detected in Troy Production Well P-12W at 5.7 µg/L. The 2005 ESI confirmed that the aquifer was still contaminated with PCE but did not provide any additional evidence identifying the specific source or sources of VOCs affecting P-12W.

1.1.3.5 Ohio EPA Supplemental Expanded Site Inspection (2010)

In 2010, Ohio EPA conducted a supplemental expanded site inspection (SESI) and presented the results (along with the result of their previous investigations) in a 2011 SESI report (Ohio EPA 2011). An aquifer pumping test conducted during the SESI indicated that Troy Production Well P-12W drew groundwater even from the west side of the river, making Bob's Auto Repair and other properties located on the west side of the river potential sources of contamination in P12W. However, data from the 2005 ESI and 2010 SESI could not positively link groundwater contamination found at Wampler (currently

Bob's Auto Repair) to the contamination found in P-12W. That is, the investigations could not confirm VOCs at Bob's Auto Repair to be the source of VOCs in P-12W.

1.1.3.6 Summary of Previous Investigations

Sampling results from past investigations are summarized on Figure 1-4. Results of past investigations indicated that PCE was present in groundwater west of the GMR and that the suspected source of PCE detected in Troy Production Well P-12W was west of the river. Ohio EPA ruled out potential sources from other directions such as the north, northeast, and east for the following reasons:

- Neither PCE, TCE, nor cis-DCE have been detected in P-4W, which is located north of P-12W
- None of these VOCs were detected in Troy Monitoring Wells MW-K, MW-V, and Miami Conservancy District (MCD) Monitoring Well T-20S; (location of MW-V is not shown on Figure 1-4; however, it is northeast of the Apex property near Monitoring Well Hob 1)
- Contamination was not detected in groundwater samples collected from direct-push borings (GB-13 through GB-18) drilled along Staunton Road (Riverside Drive north of Adams Street) located east of the GMR and northeast of P-12W (see Figure 1-4), except for a trace detection of TCE in the sample closest to Adams Street (GB-13)

Therefore, Ohio EPA ruled out potential source areas north and northeast of P-12W. Additionally, VOCs were not detected in SESI samples from MCD monitoring wells T-6 and T-4S, located approximately 1,800 feet south and 900 feet southwest from P-12W. These findings, along with the absence of PCE in Troy Production Wells P-3W, P-19, and P-16, provide evidence that the groundwater contamination is not likely to be entering P-12W and P-3W from the south and southwest.

As a result of PCE detected in Production Well P-12W, Troy had reduced use of this well in past years. During that time, routine monthly sampling began detecting VOCs in Production Well P-3W, suggesting that the decrease in pumping and capture at well P-12W was allowing VOCs to migrate farther downgradient and southeast to well P-3W. This observation, along with the combined evidence from past investigations, points to an area located west of P-12W (on the west side of the GMR in the vicinity of 507 and 515 N. Elm Street) as the most likely source areas. However, the actual source or sources of VOCs affecting Troy Production Well P-12W were not positively confirmed during previous investigations.

1.1.3.7 Hazard Ranking System Documentation Record (March 2012)

In March 2012, EPA prepared a Hazard Ranking System (HRS) Documentation Record with scoring based on the (1) groundwater migration pathway and (2) surface water migration (EPA 2012a). Most of the data used in the scoring process had been obtained during the Ohio EPA 2005 ESI. The soil exposure pathway and air migration pathway were not scored because the groundwater and surface water migration pathways were sufficient for this HRS scoring to qualify the WTCA site for inclusion on the National Priorities List (NPL).

1.1.3.8 Final Listing on the NPL (September 2012)

The WTCA site was entered in the final listing of the NPL in September 2012 (EPA 2012a).

1.1.3.9 ATSDR Public Health Assessment (2013)

A public health assessment (PHA) is required at all sites proposed for or listed on the EPA's NPL. The WTCA PHA was prepared by the Health Assessment Section at the Ohio Department of Health (ODH) under a cooperative agreement with ATSDR. The PHA reviewed the available environmental sampling data collected by Ohio EPA and EPA regarding contamination of groundwater at the WTCA site and made conclusions and recommendations for actions that may be necessary to protect the public's health. The PHA evaluated the primary contaminants of concern at the site: PCE, TCE, and cis-DCE and in 2013 it concluded the following (ATSDR 2013):

- VOCs found in public well P-12W in Troy's west well field currently do not harm people's health, because the City of Troy effectively keeps VOCs below detectable limits in the finished drinking water. In the future, however, the city's public wells may continue to be impaired until the source of the groundwater contamination is remediated. The groundwater contamination may continue to affect Troy's drinking water supply wells if actions are not taken to mitigate potential exposures to chlorinated solvents.
- Area groundwater has been contaminated by the chlorinated solvent PCE. Troy's finished tap water currently does not show any detections of PCE, although detections of PCE had been sporadic in the past. Neither TCE nor cis-DCE has ever been detected in the finished water.
- Currently, exposures to plume-related VOCs in indoor air are unlikely to occur based on the lack of homes and buildings in the immediate vicinity of the plume. The area of the suspected plume does not appear to underlie individual homes that may be affected by vapor intrusion (VI). However, the source or sources of contamination and the precise extent of the groundwater plume have not been identified. If the suspected plume migrates to the west or if contamination exists farther west, it could underlie some properties on the west side of Elm Street and possibly affect these structures through VI.

1.1.3.10 Production Well Water Treatment (2014)

During discussions held in late 2014, the City of Troy indicated that Production Well P-12W is the only well currently operating in the West Wellfield; the majority of the municipal water supply is currently sourced from the East Wellfield. Water obtained from Production Well P-12W is treated by an air stripper before the water enters the water treatment plant. The air stripper became operational at the end of 2014. All production wells in the West and East Wellfields are sampled by the City of Troy on a monthly basis. Table 1-1 summarizes 2016 through 2018 sample results for the West Wellfield wells.

1.2 SUMMARY OF RI ACTIVITIES

In August 2014, EPA issued the fund-lead RI/FS work assignment (WA) to SulTRAC. This section summarizes the Phase I and II RI activities that were conducted at the WTCA site. The RI employed an iterative process consisting of two extensive phases of field sampling. At the start of the RI, SulTRAC obtained a utility map from the Miami County Engineer. Additionally, a subsurface geophysical survey was conducted prior to any intrusive investigation activities. The utility map and subsurface geophysical results were used to identify potential preferential contaminant migration pathways and this information was in turn used to select soil gas, soil, and discrete groundwater sampling locations. Sampling was then conducted during two phases of field work at the site. Activities conducted under each phase are described in detail in the RI report (SulTRAC 2017) and summarized below.

1.2.1 Summary of Phase I Activities

Phase I RI activities were conducted in accordance with the EPA-approved sampling and analysis plan (SAP) (SulTRAC 2015). All Phase I activities were closely coordinated with EPA, Ohio EPA, and City of Troy personnel. Prior to each investigation, the Ohio Utilities Protection Service (OUPS) was contacted and public utilities were cleared and marked. Phase I RI activities conducted from July 2015 to September 2015 are listed below.

- A site reconnaissance trip to identify and mark Phase I sampling locations
- A geophysical survey using ground penetrating radar (GPR) and electromagnetics (EM) on the Apex Racing and Bob's Auto properties to evaluate the potential presence of unknown contaminant sources such as buried drums or tanks and to locate private utilities that could be damaged by drilling
- An ecological habitat assessment to document the general environmental settings and determine if any potential sensitive environments exist and if further environmental surveys should be conducted during a Phase II study
- A soil gas investigation on the Apex Racing and Bob's Auto properties to better identify and delineate source areas
- Staff gauge installation within Morgan's Ditch to provide reference elevation points for surface water measurements
- A groundwater vertical profiling investigation along multiple east-west trending transects with two transects located on the Apex Racing property and two transects located on the Bob's Auto property

- Monitoring well drilling and installation at select locations chosen based on results of the geophysical, soil gas, and groundwater profiling investigations
- Monitoring well sampling of newly installed wells
- Disposal of Phase I investigation-derived waste (IDW)

When sampling was complete, monitoring well and staff gauge elevations were surveyed and all Phase I sampling locations were identified using a global positioning system (GPS). Phase I RI sampling locations are shown on Figures 1-5 through 1-10.

1.2.2 Summary of Phase II Activities

From April 2016 to January 2017, Phase II RI activities were conducted in accordance with the EPA-approved SAP and SAP addendum (SulTRAC 2015, 2016). The Phase II RI included additional sampling that was not specified in the field sampling plan (FSP) and FSP addendum; however, additional activities were generally conducted in accordance with the procedures specified in the FSP and FSP addendum. All Phase II activities were closely coordinated with EPA, Ohio EPA, and City of Troy personnel. Phase II RI activities are listed below.

- A site reconnaissance trip to identify Phase II sampling areas and logistics
- A groundwater vertical profiling investigation to supplement the Phase I profiling investigation
- A first round of sub-slab and indoor air sampling at Apex Racing and indoor air sampling at Bob’s Auto (summer event)
- Soil sampling at Apex Racing and Bob’s Auto properties
- Re-developing older (pre-RI) monitoring wells
- Assessing damaged staff gauges that were installed in Phase I, and repairing staff gauges as necessary
- Monitoring well sampling (Phase I RI wells and older existing pre-RI wells)
- Surface water and sediment sampling within Morgan’s Ditch
- A deep vertical aquifer sampling (VAS) investigation downgradient of the suspected source area (along the east and west sides of the GMR)
- Installing and sampling two Phase II monitoring wells
- Surveying well and sampling locations
- Additional soil sampling south of Hobart Lagoon
- Site restoration
- Disposal of Phase II IDW

- A second round of sub-slab and indoor air sampling at Apex Racing and indoor air sampling at Bob's Auto (winter event).

Prior to each intrusive investigation, OUPS and Miami Valley Lighting were contacted and public utilities were located and marked. All activities for work conducted at or near Treasure Island Park were closely coordinated with the City of Troy or MCD, depending on the specific locations. When sampling was complete, monitoring well and surface water reference elevations were re-surveyed and all Phase II sampling locations were identified using GPS. Phase II RI sampling locations are shown on Figures 1-10 through 1-16.

1.3 SUMMARY OF RI RESULTS

The findings of the RI and risk assessment are presented in the final RI report for the WTCA site (SulTRAC 2017). The final RI report includes a detailed discussion of RI activities and results as well as the site risk assessment. The following sections summarize key findings of the RI and risk assessment for the WTCA site.

1.3.1 Regional and Site Geology

The WTCA site lies above a deep, pre-glacial bedrock valley that trends north to south, down the approximate center of the southern half of Miami County. The GMR follows the course of this valley; the river and valley are the most significant geomorphic features in the county.

Miami County is generally covered by glacial drift left behind by retreating continental glaciers during the Pleistocene epoch. These drift deposits covered the bedrock and filled existing pre-glacial stream valleys. The drift is more than 250 feet thick in some areas of the filled valleys. Bedrock is generally exposed at the surface only in upland areas adjacent to streams, where erosion has removed the thinner drift deposits (Ohio Department of Natural Resources [ODNR 2014]).

Two dominant types of glacial drift deposits are present: (1) outwash deposits consisting of sand and gravel deposited by running melt water from the glacial ice, and (2) glacial till or "ground moraine," consisting largely of clay mixed with boulders, gravel, sand, and silt deposited directly by glacial ice. Tills (clay and silt layers mixed with varying amounts of sand and gravel) are often found interbedded within or overlying the outwash deposits, resulting in an extremely complex, heterogeneous subsurface that can be high variability in composition over very short distances.

In the upland areas outside of the pre-glacial valleys, the uppermost bedrock consists primarily of Silurian-aged carbonate bedrock of the Lockport group. In the WTCA site vicinity and other areas where the pre-glacial valleys deeply incised bedrock, erosion completely removed the later Silurian carbonate rock and the glacial drift directly overlies earlier low-permeability Ordovician era shale and limestone of the Cincinnati Series (ODNR 2014).

During the WTCA RI, site-specific geologic information was obtained from the following activities:

- Four soil borings drilled and logged for monitoring well installation in Phase I
- 30 shallow soil borings for soil sampling in Phase II
- Two soil borings drilled and logged for monitoring well installation in Phase II
- Eight soil borings drilled for additional soil sampling in Phase II
- Eight additional Phase II deep VAS soil borings

Information gathered from the activities listed above was supplemented by indirect geologic logging data acquired at 42 locations during the Waterloo groundwater vertical profiling programs. Additional information is also available from geologic logs for Ohio EPA and Wampler monitoring wells installed prior to the RI; and the logs for City of Troy production and monitoring wells in and near the West Wellfield.

Ground surface elevations in the site vicinity range from about 810 to 850 feet above mean sea level. The subsurface at the site consists of a thick sequence of sand, gravel, silt, and clay overlying Ordovician-age interbedded shale and limestone bedrock (Panterra 1994, City of Troy 2009, ODNR 2014). The RI focused on the unconsolidated materials; thus, bedrock was not encountered in any of the borings completed for the RI. The deepest borings during the RI ranged from about 65 to 85 feet bgs for deep VAS conducted downgradient of the site near the west and east banks of the GMR.

In the Troy area, the unconsolidated materials are often discussed in terms of three zones, loosely based on differentiations among (1) the zone used for the municipal water supply (“lower” aquifer), (2) the shallow sand and gravel deposits (“upper” aquifer), and (3) less permeable fine-grained materials, limited in extent, that occur at variable depths but in some areas form a localized “middle zone” encountered between the “upper” and “lower” sand and gravel deposits. However, although clays and silts of significant thickness are present in some areas, such fine-grained materials are absent in other areas, and no consistently distinct horizon fully separates the sand and gravel units into clearly defined upper and lower zones at the site (Panterra 1994, City of Troy 2009, ODNR 2014).

Generalized geologic cross sections are depicted on Figures 1-17 through 1-19B. The cross sections in Figures 1-17 and 1-18 illustrate generalized geologic conditions encountered along two north-south and two east-west transects within the main investigation area. The figures also include a north-south cross section (Figure 1-19A) along the west side of the GMR (between the main investigation area and across from Troy Production Well P-12W located on the east side of the GMR) and Figure 1-19B that extends from the northwest to the southeast (from the site to Production Well P-12W). In cross section 1-19B, all well and boring logs were generated during the RI except for the production well log which was generated by the well driller at the time of well installation.

Near-surface soils encountered have been regraded during the long history of commercial, industrial, and recreational uses in the area. As shown in the cross sections, the following unconsolidated materials were generally observed (from shallow to deep):

- Topsoil or fill
- Sandy or silty clay
- Fine to coarse sand with varying amounts of gravel
- Stiff dense clay till (not always encountered) or silty clay

When encountered, fine-grained materials (silts or clays) were most often mixed with sand and gravel (for example, silty sand and gravels or clayey gravels). However, relatively uniform stiff, silty or clayey zones, limited in horizontal extent were observed at some locations, interspaced within the coarser deposits.

In addition to the soil boring logs, data were gathered regarding the relative distribution of hydraulic conductivity (ik) during Waterloo groundwater profiling. The index of hydraulic conductivity is generated by slowly pumping water down into the geologic materials encountered as the sampler is advanced. The rate at which the water flows through the formation provides a real-time indication of relative changes in hydraulic conductivity. These data indicated that sandy or silty clay is present to a depth ranging from about 5 to 10 feet bgs across much of the site. Fine to coarse sand and gravel underlie the clay. A hard gray clay till was frequently encountered beneath the sand and gravel; however, the till was not encountered at every location. Where present, the till was generally encountered at depths of about 45 to 55 feet bgs. Probe refusal depths also provided information regarding subsurface conditions.

Refusal and low ik readings (indicative of the till) were encountered as shallow as 27 to 30 feet bgs at some locations (VAS-10, VAS-14, and VAS-15) and 19 feet bgs (VAS-20). However, it should be noted that the presence of coarse gravel and cobbles also may have resulted in refusal at some locations. Site geology in the general area extending from Morgan's Ditch to Treasure Island Park was similar to the geology encountered in the Apex and Bob's Auto area. Given the site geology observed at borings VAS-D1 through VAS-D4, it appears that a somewhat laterally extensive silty clay layer exists at about 50 feet bgs. However, this layer was not observed at Monitoring Well MW-06, Troy Monitoring Well MW-S, and Troy Production Well P-12W.

1.3.2 Regional and Site Hydrogeology

Groundwater within Miami County occurs in both glacial (unconsolidated) and bedrock (consolidated) aquifers. The thick sequences of sand and gravel in the valley of the GMR and its major tributaries comprise a highly productive aquifer system. More localized sand and gravel units within the surficial glacial drift are also used as a source of water in some parts of the county. The high-yielding permeable valley-fill sand and gravel glacial outwash deposits are the primary zone through which most groundwater moves in the site area. The fine-grained glacial deposits, such as tills and lake-deposits of clays and silts, generally yield little or no groundwater and are not typically used for water supplies, but are of significance because of their impact on groundwater flow and contaminant transport (ODNR 2014). Although Silurian-age carbonate bedrock provides a source of water in some parts of Miami County, it is not present in the site vicinity, and bedrock is not used as a source of water near the WTCA site (ODNR 2014).

The sand and gravel aquifer within the present-day GMR Valley is a federal-designated Sole Source Aquifer System, a designation to protect drinking water supplies in areas with few or no alternative sources of drinking water (Ohio EPA 2011). The sole source aquifer designation protects an area's groundwater resources by requiring EPA review of any proposed projects within the designated area that are receiving federal financial assistance. The buried valley sand and gravel aquifer is heavily used throughout much of the Miami Valley as a source of water by both municipal entities and private residences. Troy supplies the entire city water system from wells that draw water from the sand and gravel deposits that comprise the GMR Sole Source Aquifer (City of Troy 2009, Eagon & Associates 2012).

Groundwater within the sand and gravel outwash in the GMR Valley is generally encountered under unconfined conditions, but locally confining conditions are encountered in some areas, where higher permeability sands and gravels underlie dense layers of lower permeability till or lacustrine clay.

Regional groundwater flow is down the GMR Valley, generally north to south on a regional scale, but with local variations (Panterra 1994, Malcolm Pirnie, 2004 and 2010, Eagon & Associates 2012, ODNR 2014).

The following sections describe site-specific hydrogeology of the WTCA site. Hydrogeologic aspects of the WTCA site were evaluated through various data acquisition activities, including:

- Review of extensive background information in reports by Troy, Ohio EPA, and other entities
- Review of logs of local production and monitoring wells
- Advancement of 38 soil borings, eight VAS borings, and installation of six groundwater monitoring wells during the RI
- Acquisition of multiple rounds of groundwater elevation data from the newly installed RI monitoring wells and other existing monitoring wells in the area
- Acquisition of data regarding stratigraphy and relative hydraulic conductivity of the subsurface during the Waterloo VAS programs

1.3.2.1 General Site Hydrostratigraphy

As previously discussed in Section 1.3.2.1, the unconsolidated materials beneath the site are often discussed in terms of three zones, loosely based on differentiations among (1) the zone used for the municipal water supply ("lower" aquifer), (2) the shallow sand and gravel deposits ("upper" aquifer), and (3) less permeable fine-grained materials, limited in extent, that occur at various depths but in some areas form a localized zone between and separating the "upper" and "lower" sand and gravel deposits sometimes referred to as the "middle" zone. Flow across the middle zone occurs by leakage though the fine-grained deposits, as well as by flow through areas where the fine-grained deposits comprising the middle zone are absent.

Geologic and contaminant data gathered during the RI indicate that no continuous, distinct separation exists between the "upper" and "lower" sand and gravel zones. Generally, observations from borings completed during the RI indicate that, although clays of varying thickness were present in some areas such as VAS-D1 through VAS-D4, clays and fine-grained materials were absent in other areas such as MW-06. Therefore, given the variable thickness and composition of this layer as well as its absence at some locations, the silty clay layer (sometimes referred to as the “middle zone”) does not appear to be a true confining layer separating two completely distinct water-bearing zones.

Soils encountered at deeper boring locations appeared to be continuously saturated from the water table to the maximum depth of exploration (about 85 feet bgs), with the exception of some thin hard dense clay till zones encountered. Based on these observations as well as published regional geologic information, the total estimated thickness of unconsolidated saturated materials in the site vicinity likely ranges from about 100 to 175 feet, exclusive of unsaturated clay layers that may be present at some locations. Troy Production Well P-12W is screened from 66 to 86 feet bgs.

1.3.2.2 Groundwater Elevations and Flow

Depth to groundwater at the site is relatively shallow, typically ranging from approximately 5.5 to 15 feet bgs (in monitoring wells), but varies depending on location and seasonal variations. Generally, site topography is flat with a relatively consistent slope toward and in the downstream direction of the GMR, and therefore, depth to groundwater tends to gradually decrease progressing from west to east across the site. In addition, the Treasure Island Park area lies about 5 to 10 feet lower in elevation than the terrace where the Bob’s Auto and Apex properties are located, and the depth to water decreases closer to Treasure Island Park and the GMR.

Figures 1-20 through 1-22 show piezometric head elevations measured during September 2015 and October 2016. The events represent groundwater elevations primarily during late summer and early fall seasonal (low water) conditions. As shown in Figures 1-20 through 1-22, groundwater generally flows eastward across the site toward the GMR. It should be noted that monitoring wells were installed during the RI at locations and depths where contamination was detected during VAS activities. Therefore, well screen elevations are variable from one well to another, and the piezometric measurements may be slightly influenced by vertical gradients. Given this variability, there may be some uncertainty with respect to precise groundwater flow patterns. Prior investigations by Ohio EPA and the City of Troy have indicated flow in the area ranging from southeast to south. Based on RI results and past observations, the flow direction may vary temporally and is likely affected by pumping in the city’s West Wellfield. Based on previous wellfield studies by others, groundwater flow at the site on the west side of the river is influenced by pumping at the West Wellfield, and the general site area is within the modeled 1-year time of travel (TOT) of the West Wellfield production wells (Arcadis 2013). Groundwater – surface water interaction is discussed in section 1.3.2.6.

1.3.2.3 Troy Municipal Wellfield Pumping

Troy obtains its municipal water supply from production wells east of the GMR in two wellfields, and each wellfield contains five production wells (Figure 1-2). The production wells in both wellfields are screened in the “lower” aquifer, although the confining unit is absent over a significant portion of the wellfields. The East Wellfield wells (wells P-4E, P-13, P-14, P-17 and P-18) are screened from depths ranging from approximately 64 to 124 feet bgs (Malcolm Pirnie 2010). Currently, only Production Well P-12W is in use in the West Wellfield, and it is screened from a depth of 66 to 86 feet bgs (Malcolm Pirnie 2010). West Wellfield wells P-4W, P-3W, P-16, and P-19 are not currently in use as the city shut down these wells in order to prevent pulling the plume in other directions.

The East Wellfield is hydraulically downgradient of the West Wellfield and is located in the area along the GMR approximately 0.5 mile to 1 mile downstream of the West Wellfield. Wells in the East Wellfield are operated in pairs on a rotating basis. Total Troy municipal pumping rate is approximately 4.1 million gallons per day (MGD) on average. Average production from the West Wellfield (P-12W) is about 1.8 MGD or 1,250 gallons per minute (gpm) (44 percent), and the average production from the East Wellfield is about 2.3 MGD or 1,597 gpm (56 percent) (Arcadis 2013). The aquifer is highly transmissive, with reported transmissivity in the East Wellfield ranging from about 9,800 to 18,900 square feet per day (ft^2/day). The wells in the East Wellfield are reportedly capable of yielding in excess of 1,000 gpm with approximately 10 to 20 feet of drawdown (City of Troy 2009). Based on the similar geologic characteristics, the aquifer properties in the West Wellfield area are anticipated to be similar to those in the East Wellfield. Yield test data collected when P-12W was installed in 1981 indicated 1,390 gpm with 2.8 feet of drawdown over a 45-hour test; the rated capacity of the well is 1,150 gpm, although pumping rate is typically reduced, because of limitations of the capacity of the delivery piping to the water plant (Malcolm Pirnie 2010; Arcadis 2013).

Troy has developed and updated groundwater flow models for the West Wellfield to support its wellhead protection and wellfield sustainability programs. The entire WTCA RI investigation area lies well within the modeled 5-year time of travel (TOT) of the West Wellfield, with most of the site area within the 1-year TOT (Panterra 1994, Malcolm Pirnie 2004 and 2010, Eagon &Associates 2012).

1.3.2.4 Horizontal Hydraulic Gradients

As shown in Figures 1-21 and 1-22, the horizontal hydraulic gradient is generally less in the Apex Racing and Bob’s Auto Repair areas and increases from the east side of the Bob’s Auto Repair building toward the GMR. The calculated horizontal gradient, based on data acquired during the two October 2016 measurement events, was about 0.003 feet/foot.

1.3.2.5 Hydraulic Conductivity and Flow Velocity

Literature values for hydraulic conductivities differ from one source to another and vary over a large range. Ranges are typically provided to account for variations within a specific soil type. In general, the calculated hydraulic conductivity values based on pump test data reported for the local aquifer are within typical ranges for the predominant hydrostratigraphic materials present at the well screen intervals. The following summarizes various hydrogeologic parameters associated with the subsurface materials in the local aquifer system:

Parameter	Value/Range	Source
Horizontal Gradient – Range (upper and lower zones):	0.003	Measured at site monitoring wells during RI in 2016
Horizontal Hydraulic Conductivity:		
Upper Zone	100 to 150 ft/day	Panterra 1994, Malcolm Pirnie 2004, 2010
	125 to 200 ft/day	Mill Creek 2002
Middle Zone	0.0004375 to 0.22 ft/day	Panterra 1994
Lower Zone	75.7 to 140 ft/day	City of Troy 1994; Panterra 1994, Malcolm Pirnie 2004, 2010
Vertical Hydraulic Conductivity:		
Upper Zone	20 ft/day	Malcolm Pirnie 2004, 2010
Middle Zone	0.0004375 to 0.22 ft/day	Malcolm Pirnie 2004, 2010
Lower Zone	14 ft/day	Malcolm Pirnie 2004, 2010
Porosity (Reported):		
Upper Zone	0.405	Malcolm Pirnie 2004, 2010
Middle Zone	0.179 to 0.344	Malcolm Pirnie 2004, 2010
Lower Zone	0.405	Malcolm Pirnie 2004, 2010
Transmissivity		
Upper Zone	2,160 ft^2/day to 4,100 ft^2/day	Mill Creek 2002
Lower Zone	9,800 ft^2/day to 18,900 ft^2/day	Malcolm Pirnie 2004, 2010

Notes:

ft/day – Feet per day
ft^2/day – Square feet per day

A range of advective groundwater flow velocities was calculated using the highest and lowest reported hydraulic conductivity values of 75 and 200 feet per day (ft/day), a horizontal hydraulic gradient value of 0.003 feet/foot, and an effective porosity value of 0.30. Groundwater flow velocity was calculated using the following equation:

$$V = k \times i/n$$

where:

V is velocity
k is hydraulic conductivity
i is the hydraulic gradient
n is the effective porosity

According to this equation, estimates of advective groundwater velocity range from 0.75 to 2.0 ft/day or 2.7E-04 to 7.1E-04 centimeters per second (cm/sec). Assuming an average velocity of 1.38 ft/day (4.9E-04 cm/sec), the average advective groundwater flow rate is about 504 feet per year (ft/year). However, and notably, actual velocities can vary significantly depending on subsurface materials present in specific areas, which are highly variable in glacial depositional settings. Moreover, flow velocities in areas closer to the West Wellfield are expected to accelerate because of the induced gradients caused by production well pumping; this acceleration is consistent with the results of modeling completed to assess the 1- and 5-year TOT zones for the West Wellfield (Malcolm Pirnie 2004 and 2010, Arcadis 2013).

1.3.2.6 Groundwater – Surface Water Interaction

The GMR is hydraulically connected to the upper sand and gravel aquifer. However, the GMR is relatively shallow and the aquifer system extends to depths much lower than the current river channel bottom. For example, water in the river, when not affected by significant rain events, is generally about 2 to 3 feet deep near the site. Groundwater flow modeling completed for the Troy Wellfields indicates that the pumping influence from the West Wellfield extends to the contaminant plume areas on the west side of the river (Panterra 1994, Malcolm Pirnie 2004 and 2010, Eagon & Associates 2012). This observation is consistent with the results of pumping tests completed by Ohio EPA that found groundwater levels in monitoring wells on the Apex Racing and Bob's Auto properties (west of the river) responded to variations in pumping rates in West Wellfield production wells (Ohio EPA 2011). For these reasons, the river is not a physical barrier to groundwater flow and likewise would not be expected to be a physical barrier to contaminant migration through deeper portions of the aquifer below the bottom of the river channel.

Leakage studies by the City of Troy indicated that the GMR represents a shallow aquifer-discharge boundary upstream from the West Wellfield. The GMR also reportedly acts as a shallow discharge boundary downstream from the East Wellfield. However, the Troy studies indicate that the GMR recharges the aquifer and is a losing stream in the segment of the river that lies adjacent to the WTCA site (and both Troy Wellfields). The Troy studies also indicated that the locations where the GMR changes from a gaining to a losing stream in the area vary depending on flow in the river and pumping conditions in the wellfield (City of Troy 1994, Panterra 1994, Malcolm Pirnie 2004 and 2010).

1.3.3 Nature and Extent of Contamination

During the RI, various environmental media were sampled in Phase I and II. These media include (1) groundwater, (2) soil, (3) surface water and sediment, and (4) soil gas, sub-slab vapor, and indoor air. Results for each of these media are discussed in detail in the RI report (SulTRAC 2017) and summarized below.

1.3.3.1 Groundwater

This section summarizes the results for all groundwater sampling conducted during the RI. The primary site-wide groundwater characterization activity consisted of Waterloo groundwater profiling samples collected in Phases I and II. Waterloo groundwater profiling consisted of advancing a depth-discrete sampling tool using direct-push drilling to advance the tool. As a result, this activity generated a large data set by obtaining samples at numerous depths at 42 locations. The Waterloo profiling was supplemented by deep VAS samples collected downgradient of the main investigation area in Phase II. Deep VAS was conducted using sonic drilling to collect groundwater samples at depths greater than what was achieved using direct-push drilling and the Waterloo profiling system. Based on Waterloo VAS results, a total of six monitoring wells (four Phase I wells and two Phase II wells) were installed to supplement the existing wells that were installed during previous investigations. Monitoring well samples were collected in Phases I and II to obtain groundwater results from fixed locations that can be sampled again in the future to evaluate trends in contaminant concentrations. In addition to sampling monitoring wells, the private well at Apex was sampled twice during the RI and both times the PCE concentration was approximately 10 µg/L , which exceeded the MCL of 5 µg/L (SulTRAC 2017). This concentration is similar to PCE concentrations reported in available historical Ohio EPA documents

(Ohio EPA 2011). EPA discussed the MCL exceedance with Ohio EPA during the RI and notified the property owner of the sampling results.

Sample results obtained during the RI were compared with EPA screening levels (SL) to assess whether a chemical exceeds a given SL, and if so, the extent of its distribution. RI results indicate that groundwater contamination exists beneath the Apex and Bob's Auto properties. PCE is the primary VOC present above its MCL; however, benzene was also detected above its MCL in three samples in a localized area between Bob's Auto and the former Hobart Lagoon. (The MCL for PCE and benzene is 5 µg/L.) Waterloo sampling results for PCE and benzene are shown in Figures 1-23 and 1-24. Deep VAS results are shown in Figure 1-25. Monitoring well sampling results for PCE and benzene are shown in Figures 1-26 and 1-27. PCE contamination extends west of the GMR to Troy Production Well P-12W, where it is being captured by the pumping influence of the production well; however, the flow path of the PCE plume from the west side of the GMR to Troy well PW-12 was not conclusively identified, as PCE was detected only in VAS-1 at a low concentration (1.9 µg/L). Key findings of the groundwater investigation include:

- In general, the PCE plume is shallower near Apex and Bob's Auto and becomes deeper to the southeast (between former Hobart Lagoon and Morgan's Ditch) in the direction of groundwater flow.
- The maximum concentrations of PCE detected in Waterloo groundwater samples were 101 µg/L at VAS-21 (60 feet bgs) and 75 µg/L at VAS-32 (42 feet bgs) and the maximum concentration detected in monitoring well samples was 66 µg/L at MW-06, south of the former Hobart Lagoon.
- Benzene was detected above its MCL in a discrete area between Bob's Auto and the southwest portion of the former Hobart Lagoon. Benzene was detected above its MCL in Waterloo groundwater samples at 23 µg/L at VAS-34 (13.5 feet bgs), at 10.9 µg/L at VAS-20 (18 feet bgs), and 6.3 µg/L at VAS-35 (23 feet bgs). City of Troy monitoring results through July 2018 indicated that benzene has not been detected in production well P-12W.
- Of the eight deep VAS borings drilled adjacent to the west and east sides of the GMR, VOCs were detected above MCLs at only one location (VAS-D1). TCE was detected at this location on the west side of the GMR above its MCL of 5 µg/L at a concentration of 5.6 µg/L in the sample at 60 to 65 feet bgs. PCE was also detected in this sample at a concentration of 1.9 µg/L (below its MCL of 5 µg/L).
- Based on RI results, the plume appears to deepen as it moves toward P-12W as groundwater is drawn toward the production well and downward toward the well screen intake depth. In addition, the physical limitations from the "Island" at the north end of the park and the river between the site and the production well dictated the location of the deep VAS boring. Therefore, it is possible that the VAS borings may not have encountered PCE drawn deeper in the aquifer or the borings might not have been located right on the plume axis, where PCE concentrations would be the highest.
- Waterloo and monitoring well results showed that PCE was not detected above its MCL north of the Apex property or west of the Bob's Auto property (west of N. Elm Street). These results define the upgradient extent of the PCE plume.

- The plume appears to originate on the Apex and Bob's Auto properties and migrates east-southeast toward the GMR and eventually to Troy Production Well P-12W. A definitive source of the PCE in groundwater was not identified during the RI. It appears that one or more releases occurred on the Apex and Bob's Auto properties.
- Several possible explanations exist for the elevated PCE detected in Monitoring Wells MW-05 and MW-06 as well as several VAS borings south of the former Hobart Lagoon: (1) the PCE detected south of the former Hobart Lagoon originated at Apex or Bob's Auto and has migrated laterally and downward to this area, (2) a release from the Bob's Auto property was directly conveyed through sewer laterals, leach fields, or other preferential pathways resulting in elevated PCE in this area, (3) the former Hobart Lagoon area could contain another source of PCE, or (4) the higher concentrations of PCE detected south of Hobart lagoon are due to residual PCE from a previous release persisting in this area (as opposed to PCE that has migrated from the Bob's Auto or Apex properties) as a result of geochemical or hydrostratigraphic factors. What is certain is that an old UST existed on the eastern side of Bob's Auto and the UST leaked prior to being removed. Furthermore, the elevated PCE concentrations south of the former Hobart Lagoon are located in the groundwater flow path from Bob's Auto and the former UST, to Troy production well P-12W. Therefore, PCE from the leaking UST (and other potential releases on that property) could have migrated toward the production well as a result of the gradient induced by Production Well P-12W, which is drawing water from a depth of 66 to 86 feet bgs. The exact locations of PCE releases remain unknown, and therefore, desorption from soil organic carbon, matrix diffusion from fine-grained (i.e. low permeability) soils, or both are valid explanations for the cause of persistent PCE concentrations in this area.
- Trihalomethane compounds (chloroform, bromodichloromethane, and dibromochloromethane) were detected in some groundwater samples and were also detected in samples of potable water obtained for drilling and decontamination purposes. These compounds are typically associated with chlorination of public water and resulting byproducts; therefore, they are not considered to be site-related compounds.

1.3.3.2 Soil

This section presents the results for all soil sampling during the RI. The primary site-wide soil characterization activity consisted of soil sampling at the Apex and Bob's Auto properties in Phase II. Soil sampling locations were selected based on the results of the geophysical survey, Waterloo groundwater profiling investigation, and soil gas investigation and were biased toward areas showing any potential for soil contamination. Additional soil sampling was conducted in Phase II in the area south of the former Hobart Lagoon, near MW-06 and VAS-21, which exhibited the highest concentrations in groundwater observed at the site. Soil borings were advanced in this area because odors and elevated photoionization detector (PID) readings were observed during installation of well MW-06.

Soil sample results indicated that VOCs detected were at low concentrations below residential and industrial direct contact SLs. Although some VOC detections were above MCL-based protection of groundwater SLs (using a dilution attenuation factor of 1), PCE was not detected in soil at concentrations that would indicate the presence of a vadose zone source area that could act as a continuing source of contamination to groundwater. Soil sampling results at the Apex and Bob's Auto properties are presented in Figure 1-28. Soil sampling results for the area south of the former Hobart Lagoon near MW-06 and VAS-21 are presented in Figure 1-29.

1.3.3.3 Surface Water and Sediment

Collocated surface water and sediment samples were collected at five locations. Samples were collected in Morgan's Ditch and in the inlet at Treasure Island Park. Very few low-level VOCs were detected in surface water and sediment samples from Morgan's Ditch and the GMR. PCE, the main contaminant in groundwater, was not detected in any surface water or sediment samples. The types of VOCs detected and their low concentrations (orders of magnitude below site SLs) indicate that site-related surface water and sediment impacts are not occurring.

1.3.3.4 Soil Gas, Sub-Slab Vapor, and Indoor Air

This section presents the results for soil gas samples collected in Phase I as well as the two rounds of indoor air/sub-slab samples collected in Phase II. Results for soil gas sampling are presented in Figure 1-30. Results for both indoor air/sub-slab soil gas events are presented in Figure 1-31. Results of these sampling events are discussed below.

VOCs were detected in exterior soil gas, sub-slab, and indoor air samples. Results of soil and shallow groundwater samples collected near the Apex and Bob's Auto buildings were evaluated to evaluate whether the VOCs detected in indoor air are a result of VI. Of the VOCs detected in one or more indoor air samples at concentrations above residential or commercial SLs (1,2-dichloroethane, benzene, carbon tetrachloride, chloroform, ethylbenzene, and TCE), only 1,2-dichloroethane was detected in soil samples collected at four locations on the Apex and Bob's Auto properties. Results from the shallowest groundwater sampling interval at each Waterloo vertical profiling location were compared with vapor intrusion screening levels (VISL) to see if any of the VOCs detected in indoor air were present in shallow groundwater at concentrations that could result in VI. Benzene, ethylbenzene, and 1,2-dichloroethane were detected above VISLs in just one shallow groundwater sample collected about 100 feet east of the Bob's Auto building near the western edge of the former Hobart Lagoon. Chloroform was detected above its VISL in two shallow groundwater samples. Carbon tetrachloride and TCE were not detected in any shallow groundwater samples.

VOCs detected above SLs in indoor air samples cannot be conclusively attributed to site-related (soil or groundwater) contamination based on (1) the sub-slab sample results at Apex, (2) the presence of benzene and carbon tetrachloride in an ambient air sample, (3) the nature of the operations occurring at Apex and

Bob's Auto, and (4) the lack of VOCs detected in soil and shallow groundwater samples near the Apex and Bob's Auto buildings. In addition, it should be noted that the southern portion of the Bob's Auto building is an active auto repair facility in use 6 days a week and both the realty office and Moose Lodge are located within this same building. Therefore, there is no conclusive evidence that VOCs present in indoor air samples are a result of VI, rather than resulting from chemicals related to operations and cleaning in these buildings. Although multiple lines of evidence suggest that VOC detections in indoor air are likely a result of indoor air interferences, temporal variability or preferential migration pathways could also be factors relating to the presence of VOCs in indoor air. Even though RI results do not clearly show a connection between PCE in groundwater and PCE detected below SLs in indoor air, the low levels of PCE in indoor air could be a result of VI, given that PCE is the most prevalent VOC at the site. Additional information is presented in the risk assessment summary below in Section 1.3.4, Table 1-2, and Section 2.1.3.

1.3.4 Risk Assessments

The human health risk assessment (HHRA) and the screening level ecological risk assessment (SLERA), including a conceptual site model, are presented as Appendix I of the WTCA RI report (SulTRAC 2017). The risk assessments were prepared consistent with EPA and Ohio EPA guidance. Appendix I of the RI report contains details regarding methodologies, assumptions, and results of the risk assessments. Summaries and conclusions of the HHRA and SLERA are presented below.

1.3.4.1 HHRA Summary and Conclusions

The HHRA was conducted to evaluate current and potential future health risks and hazards associated with exposure to site-related chemicals of potential concern (COPC) at the WTCA site. The primary objectives of the HHRA are as follows:

- To determine if site-related constituents detected in environmental media pose unacceptable risks to current and future human receptors under baseline (unremediated) conditions;
- To provide information to support decisions regarding the need for further evaluation or action based on current and reasonably anticipated future land use.

As discussed in the HHRA (presented as Appendix I to final RI report), the WTCA site was subdivided into six general exposure areas for the HHRA, according to locations of current and historical commercial land use, as well as surface water features, and a municipal wellfield (SulTRAC 2017). Two of the exposure areas evaluated (Morgan's Ditch and Treasure Island Lagoon) were eliminated because no COPCs were identified in these areas. Therefore, the four exposure areas for which risks and hazards were quantitatively or qualitatively evaluated include Area 1 – Apex, Area 1 – Bob's Auto, Area 2, and the City of Troy West Wellfield (specifically well P-12W was evaluated). The site-specific groundwater plume was divided into two portions – Area 1 and Area 2. The risk assessment evaluated these two areas separately based on current and potential future land use. Both Apex and Bob's Auto are located above the plume within Area 1 and Area 2 is south of the former Hobart Lagoon. Human health risk exposure areas are presented in Figure 1-32. Although Areas 1 and 2 were established for risk assessment purposes, the distinction between these two areas is not relevant to the FS because groundwater is being addressed on a site-wide basis.

The HHRA includes the following components: (1) data evaluation and selection of COPCs, (2) exposure assessment, (3) toxicity assessment, and (4) risk characterization. COPCs were selected following EPA guidance based on screening of maximum detected concentrations against medium-specific screening levels.

The receptors considered quantitatively or qualitatively in the HHRA include Current and Future Commercial/Industrial Workers, Current and Future Construction and Utility Workers, and Future Residents.

HHRA results are summarized in Table 1-2. Table 1-2 is subdivided into three parts: Table 1-2A, summarizing risk and hazards for both current and future land use; Table 1-2B, summarizing risk and hazards for current land use only; and Table 1-2C, summarizing risk and hazards for future land use. The results presented in Table 1-2 indicate the following:

- No total risks for any receptors exceeded 1E-04, the upper end of EPA's target risk range.
- Total risks within EPA's target risk range of 1E-04 to 1E-06 were identified for the following receptor and exposure area combinations: current industrial/commercial workers in Area 1 (Apex and Bob's Auto), future industrial/commercial workers in Area 1 (Apex and Bob's Auto) and in Area 2, current/future utility workers in Area 1 (Bob's Auto), and future residents in Area 1 (Apex and Bob's Auto) and Area 2.
- Risks exceeding Ohio EPA's target risk of 1E-05 (as specified in Ohio EPA's Technical Decision Compendium Guidance, *Human Health Cumulative Carcinogenic Risk and Non-carcinogenic Hazard Goals for the DERR Remedial Response Program*) were identified for future industrial/commercial workers at Area 1 – Bob's Auto (2E-05) and future residents at Area 1 – Apex (5E-05) and Bob's Auto (7E-05).
- Total risks less than 1E-06, and considered insignificant were identified for the following receptor and exposure area combinations: current/future construction workers in Area 1 (Apex and Bob's Auto) and Area 2, and current/future utility workers in Area 1 (Apex) and Area 2.
- Total hazards exceeded 1 only for future residents at Area 1 (Bob's Auto) and Area 2.

- Groundwater COCs based on potential exposure to water from the site "plume" are as follows: Area 1 - 1,4-dichlorobenzene, benzene, PCE, carbon tetrachloride, ethylbenzene, 1,2-dichloroethane (Bob's Auto only), and trichloroethene; Area 2 - PCE and TCE. (Note: PCE is the only COC for potable groundwater in both Areas 1 and 2, with an exposure point concentration (EPC) of 14 µg/L in Area 1 and 66 µg/L in Area 2, these EPCs exceed the PCE MCL (5 µg/L).
- Significant VI risks (≥ 1E-06) or hazards (>1) – based on measured indoor air concentrations (Area 1 – Apex and Area 1 – Bob's Auto) and VISL modeling (Area 2) were identified for the following receptor and exposure area combination: benzene, carbon tetrachloride, and ethylbenzene (Area 1 Apex - future resident only); 1,2-dichloroethane, benzene, ethylbenzene, TCE, and carbon tetrachloride (Area 1 Bob's - future resident only); and PCE (Area 2 – future resident only).
- Significant VI risks (≥ 1E-06) or hazards (> 1) – based on modeled trench air concentrations were identified only for current/future utility workers at Area 1 – Bob's Auto (driven by potential inhalation of 1,4-dichlorobenzene and benzene).
- Potential exposure to untreated groundwater from the City of Troy West Wellfield is unlikely to result in any significant risks (≥ 1E-06) or hazards (> 1) for any potential receptors based on current plume conditions. (Note: PCE detections in Production Well P-12W have been documented since at least the late 1990s. Furthermore, PCE concentrations in groundwater west of the GMR in the apparent source area, which has been shown to lie within the West Wellfield's 1-year TOT, have remained relatively consistent over that time. For these reasons, the long-term data do not appear to suggest a strong likelihood that significantly higher concentrations of PCE will migrate to the West Wellfield in the future).
- Measured indoor air concentrations of 1,2-dichloroethane, benzene, ethylbenzene, and carbon tetrachloride are likely primarily or entirely the result of indoor releases associated with current commercial/industrial operations (and related stored materials) and are unlikely related to VI from contaminant sources outside of the Apex and Bob's Auto buildings.
- The total risks and hazards calculated under central tendency exposure (CTE) conditions are about 3 to 10 times lower than those calculated under reasonable maximum exposure (RME) conditions, depending on the receptor considered.

1.3.4.2 SLERA Summary and Conclusions

A SLERA was conducted to evaluate the likelihood that adverse ecological effects are occurring or could occur as a result of site-specific constituent concentrations in environmental media. The SLERA conservatively characterized potential ecological risks associated with the WTCA site under conditions at the time of the RI (unremediated conditions).

Land use throughout the site and surrounding areas is predominantly developed with residential, community, and light/heavy commercial and industrial sites that are adjacent to the edge of the GMR. Residential and light commercial properties are the predominant land use throughout the boundaries of the WTCA site, with the exception of an approximately 3-acre area of open grassland (the former Hobart Lagoon), which is surrounded by mature hardwood trees. Beyond the site boundary, the other major habitat is the aquatic habitat associated with the GMR and Morgan's Ditch. Therefore, this SLERA focused on the riverine habitat associated with the GMR and Morgan's Ditch.

Chemicals of potential ecological concern (COPEC) were identified to provide a conservative evaluation of the potential for adverse ecological effects related to constituent concentrations in environmental media. This step combines the ecological screening values (ESV) with exposure information to yield an estimate of potential ecological risks at the site. The SLERA focused on aquatic receptors (fish and invertebrates) for the aquatic portions of GMR.

The specific assessment endpoints evaluated in the WTCA site SLERA are:

- Ensure protection of the benthic and aquatic communities in the GMR and Morgan's Ditch from the deleterious effects of acute and chronic exposures to site-related constituents present in the river.
- Ensure protection of threatened and endangered species (including candidate species) and species of special concern and their habitats from the deleterious effects of acute and chronic exposures to site-related constituents.

Two approaches were taken to evaluate the potential impact of the contaminated groundwater discharges to the aquatic community in the GMR and Morgan's Ditch. First, analytical results from surface water and sediment samples from the GMR and Morgan's Ditch were compared with surface water and sediment ESVs. No VOCs detected in the surface water and sediment exceeded the ESVs. In the second step, results from the groundwater concentrations from monitoring or direct-push wells closest to the GMR were compared with surface water ESVs. The purpose was to identify whether any constituents were present at concentrations that could cause a potential impact to the aquatic receptors in the GMR. Three constituents were detected; only one maximum detected concentration resulted in a hazard quotient (HQ) exceeding the EPA threshold value of 1, and that was PCE at a concentration of 66 µg/L from MW-06. The surface water ESV is 53 µg/L. This well is approximately 100 feet upgradient of Morgan's Ditch and the well is screened at the depth of 55 to 65 feet bgs, while the result for MW-05 adjacent to Morgan's Ditch MW-05 was below the surface water ESV. This information indicates a limited potential for ecological effects from groundwater discharging to surface water.

- Based on the SLERA methodology, aquatic receptors exposed to GMR and Morgan's Ditch surface water are not at risk for adverse effects from groundwater discharges at the current time. The groundwater data were also evaluated for the potential additive impacts for maximum concentrations for the wells adjacent to the GMR, and no significant risk was identified.

2.0 REMEDIAL ACTION OBJECTIVES, ARARs, AND AREAS REQUIRING REMEDIATION

This section identifies RAOs, preliminary ARARs, and estimated areas of media (where applicable) that will require remediation for the WTCA site. Each of these topics is discussed below.

2.1 REMEDIAL ACTION OBJECTIVES

As specified in the NCP, RAOs should specify (1) COCs, (2) exposure routes and receptors, and (3) numeric standards (preliminary remediation goals, or PRGs). RAOs for the WTCA site were developed for three categories – groundwater, an affected private residential well at the Apex Racing property, and soil vapor intrusion. Results of the HHRA are presented in Section 1.3.4 and summarized in Table 1-2.

Potential PRGs were identified by using established cleanup criteria such as MCLs, Regional Screening Levels (RSL), and VISLs. RAOs for groundwater, addressing the affected private well, and VI (and associated proposed PRGs) are discussed below.

2.1.1 RAOs for Groundwater

As discussed in Section 1.3.3, the extent of groundwater contamination exceeding RSLs was identified in the RI. For the HHRA, sample results were grouped into two exposure areas (EAs) (Areas 1 and 2) to identify groundwater COCs in each area and evaluate risk associated with those COCs in each area. SulTRAC evaluated multiple exposure scenarios for each EA, assuming various current and future land uses. Based on this evaluation, COCs associated with potable groundwater uses under one or more scenario include PCE; TCE; benzene; and 1,4-dichlorobenzene (see Table 1-2). As seen in Table 1-2, none of the COCs is present in site groundwater at levels that pose a target cancer risk greater than 1E-04. For further context, Ohio EPA’s cancer risk goal is 1E-05 for CERCLA cleanup sites. Additionally, Table 1-2 presents the following key points with respect to groundwater:

- All current industrial/commercial worker risks are less than 1E-05 and hazards are less than 1
- All future industrial/commercial worker risks are less than 1E-05 and hazards are less than 1
- All current and future construction and utility worker risks are less that 1E-06 and hazards are less than 1 (with the exception of utility worker risks in the Bob’s Auto portion of Area 1, which are 4E-06).
- In Area 1 (both Apex and Bob’s Auto), future resident risks (potable groundwater use) are 3.5E-05 and hazards are less than 1
- In Area 2, future resident risks (potable groundwater use) are less than 1E-05 and hazards are 1.6.

The distribution of the groundwater COCs is further summarized on a site-wide basis in Figure 2-1 to focus the remedial objectives for the site. Of the four groundwater COCs, TCE and 1,4-dichlorobenzene are not wide-spread and were detected in very localized areas. For example, 1,4-diclorobenzene was not detected in any VAS samples and detected in only one monitoring well sample (W-6) at a concentration of 11 µg/L. (The MCL is 75 µg/L.) TCE was detected at low levels in some VAS and monitoring well samples. However, TCE did not exceed 1 µg/L in any of the monitoring well samples and the only locations where TCE exceeded 1 µg/L were VAS-21, VAS-35, VAS-37, MW-06, and deep VAS-D1. Of these locations where TCE exceeded 1 µg/L, it only exceeded the MCL of 5 µg/L once with a maximum concentration of 5.6 µg/L (4.9 µg/L in the duplicate sample) at VAS-D1. Benzene is present above its MCL of 5 µg/L in one particular area that is much smaller than the PCE plume with a maximum concentration of 23 µg/L detected at VAS-34. Benzene was detected in only one monitoring well (W-6) at a concentration of 4.9 µg/L (just below the MCL). PCE is the most widespread COC and the PCE plume encompasses all other areas where other COCs were detected. The maximum concentration of PCE detected was 101 µg/L at VAS-21 (the MCL is 5 µg/L) and the maximum concentration detected in monitoring wells was 66 µg/L at well MW-06. The estimated site-wide extent of PCE and benzene (exceeding their MCLs of 5 µg/L) is based on a compilation of all monitoring well and Waterloo VAS RI results and is shown in Figure 2-1.

Therefore, site-wide groundwater RAOs were developed to address actual or potential future risk to human receptors within the area shown in Figure 2-1. No unacceptable risks are posed by groundwater to ecological receptors at the WTCA site.

As such, the following RAOs have been developed to address groundwater:

- Restore groundwater to its beneficial use by reducing VOC groundwater contamination associated with the site to levels less than MCLs
- Prevent potential future residents from exposure to unacceptable potable groundwater risk related to site contaminants of concern via the groundwater pathway

The following PRGs are proposed to satisfy the groundwater RAOs. The proposed PRGs for groundwater COCs are based on the EPA SDWA MCLs as identified below.

- PCE – 5 µg/L
- TCE – 5 µg/L
- Benzene – 5 µg/L
- 1,4-dichlorobenzene – 75 µg/L

2.1.2 RAOs for Residential Well

In addition to site-wide groundwater discussed in the previous section, PCE was detected in a private well (designated as RW-5) on the Apex Racing property at a maximum concentration of 10 µg/L. The proposed remedial approach also includes addressing the private well present at the Apex Racing property. For organization purposes, the remedial objective and remedial options considered in this FS for the residential well are discussed separately from those considered for the overall site-wide groundwater plume.

The following RAO has been developed to address the private well:

- Prevent current and future occupants of the 515 N. Elm St. property from exposure to groundwater contaminated with PCE above the MCL from the existing private well

2.1.3 RAOs for Vapor Intrusion

The relationship of groundwater COCs to indoor air via the VI pathway was also evaluated with respect to VOCs detected in groundwater. It was evaluated by comparing VOC concentrations in groundwater with VISLs to determine whether groundwater concentrations potentially resulted in VI and by evaluating the results of indoor air samples that were collected during two separate rounds of sampling in the RI.

All chemical-specific cancer risks for VI are within EPA's target cancer risk of 1E-06 to 1E-04 (see Table 1-2). As shown in Table 1-2, VI risks exceed 1E-06 for future residents in Areas 1 and 2. It should be noted that current land use cancer risks are within EPA's target cancer risk range of 1E-06 to 1E-04 and are less than 1E-05 (see Table 1-2B) and only future residential land use exceeds Ohio EPA's risk goal of 1E-05 (see Table 1-2C). Therefore, Table 1-2 presents the following key points with respect to VI:

- All current and future industrial/commercial worker risks are less than 1E-05 and hazards are less than 1
- All current and future construction and utility worker risks are less that 1E-06 and hazards are less than 1 (with the exception of utility worker risks in the Bob's Auto portion of Area 1 which are 4E-06).
- In the Apex Racing portion of Area 1, future resident risks (VI) are 1.2E-05 and hazards are less than 1
- In the Bob's Auto portion of Area 1, future resident risks (VI) are 3.6E-05 and hazards are 3.6.
- In Area 2, future resident risks (VI) are less than 1E-05 and hazards are 1.1.

Therefore, for Areas 1 and 2, target cancer risks greater than 1E-05 and noncancer hazards greater than 1 are associated only with the future resident land-use scenario.

Other VOCs (benzene; ethylbenzene; carbon tetrachloride; and 1,2-dichloroethane) were detected in indoor air at the Bob's Auto, part of Area 1; however, for multiple reasons, they are not considered site-related COCs (SulTRAC 2017). These reasons include:

- The absence of these VOCs in soil samples collected adjacent to the Bob's Auto building
- The absence of these VOCs in groundwater samples from the shallowest depth interval of Waterloo profiling locations adjacent to and near the Bob's Auto building

VOCs would have to volatilize from soil or groundwater and migrate through the vapor phase into indoor air for VOCs detected in indoor air samples to be a result of VI. The absence of benzene; ethylbenzene; carbon tetrachloride; and 1,2-dichloroethane in soil and shallow groundwater samples collected adjacent the Bob's Auto building implies that the VOCs detected in indoor air samples may be related to Bob's Auto operations rather than a result of VI.

As such, the following RAO has been developed to address VI:

- Prevent potential future residents from exposure to unacceptable indoor air risk related to site contaminants of concern via the vapor intrusion pathway

The following PRGs are proposed to satisfy the VI RAO. The proposed PRGs for indoor air COCs are based on the EPA residential air RSLs (the lower of the 1E-05 cancer risk and non-cancer HQ = 1) as identified below.

- PCE – 42 micrograms per cubic meter ($\mu g/m^3$)
- TCE – 2.1 $\mu g/ m^3$

2.2 ARARs

The following sections present an overview of ARARs and identify potential ARARs and other chemical-, action-, and location-specific criteria, advisories, guidance, and proposed standards to be considered (TBC).

2.2.1 Overview of ARARs

Under Section 121(d)(2)(a) of CERCLA, on-site remedial actions must attain a level or standard of control that achieves any standard, requirement, criterion, or limitation under any federal environmental law determined to be legally applicable or relevant and appropriate, including, but not limited to, the Resource Conservation and Recovery Act (RCRA); the Toxic Substances Control Act (TSCA); the SDWA; the Clean Air Act (CAA); the Clean Water Act (CWA); the Marine Protection, Research, and Sanctuaries Act; and the Solid Waste Disposal Act.

CERCLA also requires remedial actions to achieve a level or standard of control that attains any promulgated standard, requirement, criterion, or limitation under a state environmental or facility citing law that is more stringent than any federal standard, requirement, criterion, or limitation and is legally applicable or relevant and appropriate.

Section 121(d)(4) of CERCLA provides for waivers of ARARs under six types of circumstances:

- When the remedial action is an interim measure and the final remedy will attain the ARAR when it is completed
- When compliance with an ARAR will result in a greater risk to human health and the environment than other options
- When compliance with an ARAR is technically impractical from an engineering perspective
- When an alternative remedial action will attain the equivalent standard of performance of the ARAR
- When the ARAR is a state requirement that the state has not consistently applied (or when the state has demonstrated the intent to apply consistently in similar circumstances)
- For CERCLA Section 104 Superfund-financed remedial actions, when compliance with the ARAR will not provide a balance between protecting human health and the environment and Superfund money that is available for response actions at other sites.

CERCLA Section 121(e) states that no federal, state, or local permit will be required for any portion of any remedial action conducted entirely on site. “On site” is defined as the areal extent of contamination and all suitable areas in close proximity to the contamination necessary for implementation of the response action. This exemption applies only to the administrative requirements of the permit. On-site actions must still comply with the substantive requirements that permits enforce. Substantive requirements pertain directly to actions or conditions in the environment. Health- or risk-based restrictions (such as MCLs), technology-based requirements (such as incinerator standards), and location restrictions (such as those that apply to wetlands) are examples of substantive requirements.

Administrative requirements are mechanisms that facilitate implementation of the substantive requirements of a statute or regulation. Examples of these requirements include approving and issuing permits as well as reporting and recordkeeping requirements.

The NCP identifies two categories of remedial action requirements: ARARs and requirements that are to be considered (TBCs) (EPA 1990). An ARAR can be either applicable or relevant and appropriate to a remedial action. Applicable requirements are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law. These requirements specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a site.

Relevant and appropriate requirements are cleanup standards, standards of control, or other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that are not applicable to circumstances at a site but that do address problems or situations sufficiently similar to those encountered at the site that their use is well suited to the particular site.

TBCs are other federal and state criteria, advisories, guidance, and proposed standards that are not legally binding but that may provide useful information or recommended procedures. For example, a TBC can be used to set cleanup levels when no ARAR exists for a specific situation or when an existing ARAR does not ensure protectiveness. TBCs generally fall within the following four categories:

- Health effects information
- Technical information
- Policy requirements
- Proposed rules and regulations.

Potential federal and state ARARs for the WTCA site are listed in Appendix A. The ARAR list is also expected to be further refined based on input from EPA and Ohio EPA.

The ARARs are divided into the following three categories as defined in EPA's RI/FS guidance (EPA 1988a):

- Chemical-specific requirements
- Action-specific requirements
- Location-specific requirements.

Chemical-specific ARARs are usually health- or risk-based requirements, often expressed as numerical values that, when applied to site-specific conditions, establish the acceptable amount of a chemical that can be detected in or discharged to the ambient environment. Action-specific ARARs are usually technology- or activity-based requirements triggered by the remedial activities selected to accomplish a remedy, such as capping, air stripping, or other remedies. Location-specific ARARs are requirements that place restrictions on either the concentrations of hazardous substances or on the conduct of activities solely because activities are in specific locations (such as wetlands, floodplains, historic places, and other locations).

Chemical-, action- and location-specific ARARs and TBCs are discussed individually below.

2.2.2 Chemical-Specific ARARs and TBCs

Chemical-specific ARARs include federal and state requirements that regulate contaminant levels in various types of media. TBCs include proposed regulations and policy or guidance documents. ARARs and TBCs are important in developing remedial objectives that comply with regulatory requirements or guidance (as appropriate). Summaries of potential chemical-specific ARARs for groundwater and vapor intrusion are presented in Appendix A.

2.2.3 Action-Specific ARARs

Action-specific ARARs are regulatory requirements that define acceptable treatment and disposal procedures. The potential action-specific ARARs for groundwater and VI are summarized in Appendix A.

2.2.4 Location-Specific ARARs

Location-specific ARARs are requirements for contaminant concentrations or remedial activities resulting from a site's physical location. For example, federal and state ARARs exist for sites where remedial activities would affect wetlands, flood plains, critical habitats, wilderness areas, fault zones, or areas of historic or significant artifacts. These ARARs are summarized in Appendix A.

2.3 AREAS THAT REQUIRE REMEDIATION

This section discusses the estimated areas of groundwater and VI that would be addressed through the remedial action for the site. These estimated areas are based on data collected during the RI and the results of the risk assessment, as well as factors described in Sections 2.1.1 and 2.1.3 (RAOs for groundwater and VI). A single private well at the Apex Racing property is also to be addressed by the remedial action; however, aerial extent is not relevant to the remedy for this well. Groundwater and VI areas, which would be addressed are discussed below.

2.3.1 Groundwater Areas

During the RI, groundwater samples were collected at multiple depths at each Waterloo sampling location (VAS samples) and at existing and newly installed monitoring wells. Analytical results were used in the RI and risk assessment to evaluate the vertical and lateral extent of groundwater contamination and associated site-related risks. Groundwater sampling locations exceeding PRGs are shown on Figures 1-23 through 1-27. Individual locations exceeding groundwater PRGs were then combined to show overall areas exceeding site PRGs (see Figure 2-1). As shown in Figure 2-1, the PCE plume encompasses the western and southern portions of the Apex Racing property, the northern and central portions of the Bob's Auto property, the area south of the former Hobart Lagoon and Morgan's Ditch), and extends to Production Well P-12W. In addition, there is a smaller area within the PCE plume where benzene also exceeds its PRG. The benzene area is located between Bob's Auto and the former Hobart Lagoon and extends slightly south of the former Hobart Lagoon.

Based on extensive Waterloo groundwater profiling conducted during the RI, the depth of PCE contamination in groundwater is relatively shallow near Apex and the north side of Bob's Auto and relatively deep to the east/southeast (downgradient) of Bob's Auto and toward the production well. As discussed in the final RI report, logistical issues, such as limited physical access prevented sampling near the GMR at some locations and depths (SulTRAC 2017).

As shown in Figure 2-2, the PCE plume is approximately 1,600 feet long and has a maximum width of 300 feet. This plume extends to Production Well P-12W and occupies an estimated area of 410,000 square feet or 9.4 acres. The depth to groundwater varies at the site but is typically 12 to 15 feet bgs. Within the source area, the bottom of the plume is approximately 30 feet bgs at the southern part of Apex Racing and northern part of Bob's Auto. From there, the plume increases in depth to approximately 60 feet bgs at the southern end of the former Hobart Lagoon. The PCE plume increases in depth as it approaches the screen level of P-12W (66-86 feet). Given that the GMR is shallow near the site and the top of the observed plume is deeper than the GMR, the plume does not seem to impact the GMR (see Section 1.3.2.6 for discussion of groundwater-surface water interaction). Based on this information obtained during the RI, the plume thickness on the west side of the GMR ranges from about 15 feet at the upgradient (northwest) end to about 45 feet at the downgradient (southeast) end and is about 30 feet thick, on average. PCE concentrations increase from Apex Racing southeast toward the GMR and appear to peak near the former Hobart Lagoon. (The GMR is immediately downgradient of this location. No data were collected below the GMR because of access limitations.) From there, PCE concentrations are estimated to decrease in the direction of groundwater flow. This can be seen in Appendix E, which includes a series of 3-dimensional PCE plume maps. These maps, originally presented in the RI report (SulTRAC 2017), have been included in this FS report for convenience.

2.3.2 Vapor Intrusion Areas

Potential VI was assessed during the RI by collecting soil gas, sub-slab, and indoor air samples. In addition, groundwater sample results were compared to VISLs to assess the potential for VI. Analytical results were used in the RI and risk assessment to evaluate the extent of soil vapor contamination and site-related risks.

The general area where VI could be an issue if the site is redeveloped for residential land use include (1) a portion of the Apex Racing property, (2) the majority of the Bob's Auto property, and (3) an open area south and southwest of the former Hobart Lagoon. The areal extent of property where VI may pose risks is conservatively shown on Figure 2-2 and estimated at 172,000 square feet (approximately 4 acres). As discussed in Section 1.3.4.1, results for samples collected during the RI were used in the site risk assessment and the risk assessment showed that VI risks and hazards are applicable only to a future residential land-use scenario.

3.0 GENERAL RESPONSE ACTIONS, TECHNOLOGY TYPES, AND PROCESS OPTIONS

According to EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA" (EPA 1988a), GRAs are broad categories of actions to be taken at a site, such as containment, institutional actions, collection, treatment, and discharge. One or more GRAs may be necessary to achieve RAOs discussed in Sections 2.1.1, 2.1.2, and 2.1.3. Separate GRAs for the WTCA site have been developed for groundwater, a private well, and potential VI associated with the site, and several technology types and process options are discussed under each GRA. The GRAs intended to achieve the RAOs are summarized in Figures 3-1, 3-2, and 3-3 and are discussed below.

3.1 GRAs, TECHNOLOGY TYPES, AND PROCESS OPTIONS FOR GROUNDWATER

GRAs for groundwater at the WTCA site include no action, land use controls, monitoring, containment, in situ treatment, removal, ex situ treatment, and disposal. These GRAs, along with remedial technologies and process options for groundwater, are presented in Figure 3-1 and discussed below.

3.1.1 No Action

No action means that nothing would be done to address the existing groundwater contamination. The NCP requires evaluation of a no action alternative to provide a baseline that can be used to compare other remedial alternatives. Therefore, this GRA is carried forward for analysis.

3.1.2 Land Use Controls

Land use controls include institutional controls (IC) and engineering controls (EPA 2012b). Institutional controls are primarily administrative and legal controls that minimize the potential for exposure to contamination by prohibiting (where possible) or discouraging certain actions. ICs for groundwater at the WTCA site may employ a legal or administrative action to prohibit installation of water wells at certain locations and depths to prevent exposure to contaminated groundwater. Engineering controls (such as restricting access via signs or barriers) are typically not applicable to groundwater and are therefore absent from Figure 3-1.

3.1.3 Monitoring

Monitoring is a GRA that simply provides information regarding site conditions. Almost every remedial alternative includes monitoring because every remedy must be monitored to gauge its performance and to decide when the remedy has met its goals. Monitoring typically includes monitoring well installation, measurement of water levels, measurement of field parameters (such as pH), groundwater sampling, and chemical analysis of water samples.

3.1.4 Containment

Containment is a GRA that isolates contamination to control its migration into the environment and limit exposure to receptors. Containment for groundwater might take the form of a physical barrier such as a wall or a hydraulic barrier that manipulates hydraulic gradients to control flow. For example, a slurry wall or sheet piling around a contaminant source might prevent ongoing pollution of groundwater, or strategically placed groundwater extraction wells could hydraulically contain a targeted portion of the plume.

3.1.5 In Situ Treatment

In situ treatment refers to actions that remove groundwater contaminants or transform them in place. In situ treatment may employ technologies that treat groundwater using physical, chemical, or biological processes. Technologies under this GRA include monitored natural attenuation, bioremediation (such as enhanced reductive dechlorination and aerobic bioremediation), chemical oxidation or reduction, and air sparging.

3.1.6 Removal

Removal refers to extraction of contaminated groundwater so that it can be treated aboveground. This GRA may employ pumping to extract groundwater via horizontal groundwater collection trenches or vertical wells. Removal is typically combined with ex situ treatment or disposal.

3.1.7 Ex Situ Treatment

Ex situ treatment refers to actions that remove or destroy contaminants in groundwater that has been extracted from the formation. This GRA includes technologies such as air stripping, carbon adsorption, and advanced oxidation. (The City of Troy currently utilizes an air stripper to pre-treat water obtained from Production Well P-12W.)

3.1.8 Disposal

Disposal refers to actions that manage process water. For instance, extracted groundwater, once treated, could be managed by discharging it to surface water, injecting it back into groundwater, or discharging it to a publicly owned treatment works (POTW).

3.2 GRAs, TECHNOLOGY TYPES, AND PROCESS OPTIONS FOR PRIVATE WELL

This section presents GRAs for a private well located on the Apex Racing property. Addressing this well is included as part of the overall site remedy because PCE was detected in this well at concentrations of approximately 10 µg/L (above the MCL of 5 µg/L). Although the property owner, is aware of this issue and reports that well water is not used for drinking, a long-term remedy must be evaluated. GRAs for the private well are identified in EPA's guidance for providing alternate water supplies (EPA 1988b) and include no action, monitoring, providing supplied water, installing a whole-house filter, installing an upgradient or deeper private well, and connecting to a public or private water supply. These GRAs, along with remedial technologies and process options identified for the private well, are shown in Figure 3-2 and discussed below.

3.2.1 No Action

No action means that nothing would be done to address the contaminated private well. The no action GRA will be carried forward in the screening evaluation as a baseline that represents the current private well conditions, as required by the NCP.

3.2.2 Monitoring

Private well monitoring would include periodic sampling of water from the well followed by laboratory analysis of samples. Monitoring would be conducted for two primary reasons including (1) to assess trends in VOC concentrations and (2) to evaluate the need for additional actions to mitigate risk.

3.2.3 Alternate Water Supply

Alternate water supply would involve providing an alternate source of potable water to the building currently supplied by the private well. Various alternate water supply options are described below.

Alternate water could be obtained by providing bottled water to building occupants for consumption purposes. Bottled water is typically provided as a short-term solution until a more permanent solution can be developed.

Alternate water can be supplied by installing a new private well and abandoning the existing private well. A new shallow well could be installed in the same aquifer upgradient of the groundwater contamination. Alternately, a new deeper well could be installed near the current well but screened much deeper so that it draws uncontaminated groundwater from a different deeper aquifer.

Another option for an alternate water supply would be to abandon the existing well and connect the building to a public (municipal) or private (independently operated) water distribution system. The type of water system would depend on the types of systems currently available in the area. For instance, at the WTCA site, a city water main runs below the west side of N. Elm Street near the Apex Racing building, and it would be possible to install a new lateral connecting the public water main to the building.

3.2.4 Treatment

Treatment may also be a viable GRA for the private well. A treatment system could be installed at the point of use (POU) or point of entry (POE) to remove VOCs from well-water. A POU filter would be installed at each point of use, such as a faucet or a spigot. A POE filter would treat the well-water at the source before it enters the building. Both POU and POE treatment commonly use physical or chemical process to remove contaminants from water. Physical processes using sorptive media such as activated carbon are commonly used for individual private wells to remove VOCs from well water. Additionally, particulate filtration is sometimes needed for POE systems to reduce clogging of sorptive media.

3.3 GRAs, TECHNOLOGY TYPES, AND PROCESS OPTIONS FOR VAPOR INTRUSION

This section presents VI GRAs for buildings that may be potentially affected by the WTCA site. Based on information presented in the RI report and HHRA, no risks greater than 1E-05 were found in existing buildings. However, unacceptable risks associated with the VI pathway could exist in future buildings if the area were to be developed for residential use. GRAs for VI include no action, land use controls, monitoring, containment, and treatment. Each GRA, remedial technology and process option is discussed below and presented in Figure 3-3.

3.3.1 No Action

No action means that nothing would be done to address the potential VI issues. The no action GRA will be carried forward in the screening evaluation as a baseline that represents current site conditions, as required by the NCP.

3.3.2 Land Use Controls

Land use controls would include site access restrictions and ICs such as administrative constraints or zoning requirements on land use to prevent potential long-term human exposure of future residents via inhalation of indoor contaminant vapors. ICs would be appropriate for future construction, if necessary.

3.3.3 Monitoring

VI monitoring would include periodic sampling of soil gas, sub-slab vapor, or indoor air (or a combination of one or more types of sampling). VI monitoring would be used to assess risk, evaluate trends, and determine the need for additional actions to mitigate risk.

3.3.4 Containment

Containment refers to the isolation of vapor sources from living spaces, more commonly termed VI-mitigation. VI-mitigation may be accomplished through use of one or more technologies such as vapor barriers (manufactured geomembranes or cured-in-place liners), passive venting, sub-slab depressurization, sub-slab ventilation, building pressurization, or sub-slab pressurization. VI mitigation technologies can be incorporated into new building design or installed to retrofit existing buildings. At the WTCA site, VI mitigation is not deemed necessary for existing buildings but would be considered if future residential structures were built at locations above the plume where VI could pose unacceptable risk to human health.

3.3.5 Treatment

Contaminated indoor air would be treated using technologies such as carbon adsorption and photocatalytic oxidation (ultraviolet light) to remove or destroy VOCs. Treatment systems could be installed in line with heating, ventilation, and air conditioning (HVAC) ductwork, so that indoor air is circulated through the treatment media when the HVAC blower is operating. At the WTCA site, treatment is not deemed necessary for existing buildings but would be considered if future residential structures were built at locations where VI could pose unacceptable risk to human health.

4.0 SCREENING OF REMEDIAL TECHNOLOGY TYPES AND PROCESS OPTIONS

This section identifies and evaluates remedial technology types and process options for groundwater, the private well, and VI at the WTCA site based on effectiveness, implementability, and cost. For the effectiveness evaluation, each technology or process option was evaluated against the other options within the same technology type in accordance with Title 40 Code of Federal Regulations (CFR) Part 300.430(e)(7)(i).

The effectiveness evaluation focused on the following factors:

- Potential effectiveness of a process option for in meeting the RAOs
- Potential impact on human health and the environment during implementation of a process option
- Reliability and performance of a process option over time, considering conditions at the WTCA site

The implementability evaluation considered both the technical and the institutional feasibility of implementing each remedial technology type and process option at the WTCA site. Institutional aspects were considered in the detailed evaluation, which included permit requirements, available treatment capacity at off-site facilities, available equipment, available on-site space, and skilled labor requirements. Some remedial technology types are proven and readily available, but others are in the research and development stages. Insufficiently developed remedial technology types are generally screened out in accordance with 40 CFR 300.430 (e)(7)(ii).

Each process option was evaluated to assess whether its cost was high, low, or comparable with other process options for the same remedial technology type, in accordance with 40 CFR 300.430 (e)(7)(iii). At this stage of the evaluation, cost was considered the least important criterion when compared with the technical and institutional aspects of the process options. Relative capital and operation and maintenance (O&M) costs were evaluated instead of detailed estimates.

The factors considered in the initial screening included (1) areas and volumes of contaminated groundwater; (2) the contaminants present in groundwater; (3) site geology and hydrogeology; (4) the lack of a specific source or high-concentration area within the vadose zone that could continue to leach contaminants to groundwater; (5) evaluation of a representative process options for each technology and the applicability of similar process options, if deemed necessary; (6) the fact that the water obtained from Production Well P-12W in the city's West Wellfield is currently treated by the City of Troy using an air stripper and treatment is expected to continue; and (7) potential future land uses at or near the site. For example, the Apex Racing and Bob's Auto properties are currently used for commercial operations and lie in a commercial corridor along N. Elm Street. The open area southeast of Bob's Auto is bounded by the former Hobart Lagoon to the north (where City of Troy groundwater use restrictions and prohibition of intrusive work are already in place), the GMR to the east, and Morgan's Ditch to the south. Given these factors, the types and locations of future development in these areas are expected to be limited.

The screening of process options for groundwater, the private well, and VI are discussed below, followed by a summary of process options retained for alternative development. Remedial technology types and process options that are not considered suitable for the WTCA site were eliminated from further consideration.

4.1 TECHNOLOGIES AND PROCESS OPTIONS FOR GROUNDWATER

Technologies and process options for groundwater are identified in Figure 3-1. Applicable technologies and process options under each GRA are discussed below and evaluated for effectiveness, implementability and cost. This evaluation is summarized on Figure 4-1 that also shows which process options will be retained for further consideration. For the purpose of technology evaluation, it is assumed that the City of Troy will continue utilizing an air stripper to pre-treat water obtained from Production Well P-12W until the RAOs are met. The technologies and process options for groundwater described below would be implemented in addition to the air stripper pre-treatment at Production Well P-12W.

4.1.1 No Action

As indicated previously, the no action GRA is carried forward as a baseline for comparison. There would be no activities under this GRA; even monitoring is excluded. Furthermore, there are no technologies or process options under this GRA.

Contaminated groundwater at the WTCA site poses unacceptable risk to human health. No action would be taken to mitigate this risk. Although natural processes can reduce contamination over time, no action implies that this natural attenuation would not be monitored. With no way to gauge progress, the no action GRA would not ensure the protection of human health. Therefore, no action would not be effective at the WTCA site. Nothing would be implemented under this option; therefore, no capital or O&M costs are associated with it.

The no action GRA is retained for comparison to other alternatives, as required by the NCP.

4.1.2 Land Use Controls

Land use controls would limit activities that could compromise a remedy or pose unacceptable risk to human health. ICs, which are one type of land use control, would be appropriate at this site and are discussed below. Engineering controls are not applicable to groundwater.

4.1.2.1 Institutional Controls

ICs include (1) proprietary controls, (2) governmental controls, (3) enforcement and permit tools, and (4) informational devices (EPA 2012b). Remedies can take a long time to implement, and ICs prevent potential human exposure to contaminated media and protect the site remedy until remediation goals are achieved. ICs for groundwater at the WTCA site may employ a legal or administrative action to prohibit installation of water wells at certain locations and depths to prevent exposure to contaminated groundwater. All of these types of ICs are low cost, can be layered with other ICs, and are easy to implement; therefore, they are retained for further consideration.

4.1.3 Groundwater Monitoring

Groundwater monitoring is a technology under the monitoring GRA. Groundwater monitoring would provide information on groundwater contaminant concentrations. Historical and future monitoring data may be used to gauge remedial progress, plan future actions, and assess potential threats to human health or the environment. Groundwater monitoring would consist of periodic sampling and analysis of groundwater from existing monitoring wells at the WTCA site. In addition, new monitoring wells may be installed, if necessary to supplement the existing well network.

Groundwater monitoring by itself does not speed progress toward remediation goals, but is essential to every long-term remedy to provide information regarding remedial progress. Monitoring would be readily implementable at low capital cost and low to moderate O&M costs. It is therefore retained for further consideration.

4.1.4 Containment

Containment technologies isolate contaminants from the environment. At the WTCA site, groundwater contaminants are present at low levels, with PCE generally ranging from 10 to 30 µg/L, except for two isolated areas. One area is near the northwest part of the Bob's Auto building with PCE detected in one sample at a concentration of 75 µg/L. The other area is south of the former Hobart Lagoon with PCE detected at a maximum concentration of approximately 100 µg/L. A much smaller, localized area contains benzene above the MCL of 5 µg/L (with a maximum concentration of 23 µg/L) and lies within the PCE plume. Contaminated groundwater already downgradient of the treatment area would continue to impair the city's West Wellfield (specifically Production Well P-12W) across the river to the east because contaminated groundwater is within the capture zone of the production well. Containment is an option to prevent additional migration of contaminants to Production Well P-12W and would eventually allow municipal use of groundwater from P-12W without air stripping. Therefore, containment technologies may be appropriate for this site and will be evaluated in the following sections.

4.1.4.1 Hydraulic Control via Extraction Wells

Pumping can be used to hydraulically contain contaminated groundwater in a target area. Strategically placed extraction wells would create a hydraulic capture zone, thereby trapping contaminants within the capture zone of the extraction wells. Maintaining the capture zone would require continuous pumping. Hydraulic control via pumping typically requires a network of extraction wells, a treatment system, and the means to dispose of treated water. Groundwater modeling would be needed to identify the optimal well locations and pumping rates for hydraulic containment of contaminated groundwater. Treated water may be disposed of in various ways including through re-injection, discharging to surface water, or discharging to a POTW (as described in Section 4.1.8).

The highly transmissive soils at this site are conducive to groundwater extraction. Therefore, pumping would be able to create the necessary hydraulic control, but may require very high flow rates. As groundwater is being contained, pumping would slowly deplete contaminants from the aquifer, but it is likely that pumping would be required for a long period of time. The potential for contaminant rebound and subsequent migration exists if pumping stops. For these reasons, pumping is considered only moderately effective. This technology is usually readily implementable, but could become more difficult to implement depending on the final placement of extraction wells and the configuration of the associated treatment and disposal components. The technology would have moderate capital and moderate to high O&M costs. This technology is not retained for further consideration as a hydraulic control option and discussed in Section 4.1.6.1 as a groundwater extraction option.

4.1.4.2 Low-Permeability Barrier

Sheet pile barriers and slurry walls are examples of low-permeability barriers that can be used to contain contaminated groundwater. At the WTCA site, this technology would be installed upgradient (west) of the GMR (either by construction of a wall or by fully surrounding [encapsulating] contaminated groundwater) to prevent the contamination from migrating to the Troy West Wellfield. Vertical barriers typically extend to the top of a low-permeability confining layer such as bedrock or a clay aquitard. A till layer was encountered at some locations at the site at depths of approximately 50 to 60 feet bgs. However, based on information obtained during the RI, the depth and presence of the till layer are not uniform, indicating it could be significantly weathered or laterally discontinuous. In either case, additional hydraulic controls (such as groundwater extraction) may be required to prevent groundwater from "mounding" on the upgradient side of the wall and flowing around or under the barrier wall or to reduce infiltration within the fully contained area, especially with the influence of an active municipal water supply well operating nearby in the West Wellfield.

Installing a vertical barrier to depths of 60 feet bgs or more would have a high cost and would require specialized equipment. Construction of a deep vertical barrier in an area with utilities and buildings would be difficult because of typically ubiquitous underground utilities in urban settings. Barrier walls generally have high capital costs and low O&M costs. This technology is not retained because of the construction difficulty, absence of a contiguous aquitard, high cost, and likelihood that it would need to be supplemented with hydraulic control (groundwater extraction wells) to be effective.

4.1.5 In Situ Groundwater Treatment

Groundwater would be treated in situ, using chemical, biological, or physical processes. These processes may remove contaminants, destroy them, transform them to less toxic forms, or make them less mobile. Various types of in situ treatment options are discussed below.

4.1.5.1 Monitored Natural Attenuation

Monitored natural attenuation (MNA) involves observing the state of the plume and monitoring the influence of natural processes to reduce concentrations of contaminants in groundwater. The information is used to determine whether natural attenuation is occurring and if it can be relied on to attain the remediation goals. The MNA analytical suite for the VOCs at the WTCA site would include VOCs and additional MNA parameters in accordance with EPA and Ohio EPA guidance. MNA would likely require installation of additional monitoring wells to supplement the existing well network. As specified in EPA guidance, MNA would also involve more robust data analysis and reporting (EPA 1998). A preliminary evaluation of MNA was conducted as part of the RI. Initial information indicates that geochemical conditions are not conducive to MNA. MNA would be readily implementable at low capital cost and moderate O&M costs. For the reason stated above, MNA is not retained for further evaluation. However, MNA or other natural processes could be further evaluated and considered in the future as a polishing step after a more aggressive technology is implemented.

4.1.5.2 Aerobic Bioremediation

PCE and less chlorinated ethenes, such as TCE, are amenable to cometabolic biodegradation by certain naturally occurring aerobic bacteria (such as *Pseudomonas*) that metabolize specific substrates (such as dextrose). Enzymes produced by these bacteria mineralize PCE and less chlorinated ethenes to carbon dioxide, water and chloride via intermediates dichloro- and trichloroacetic acid.

Historically, aerobic cometabolism of chlorinated ethenes has been shown using electron donors (such as toluene) that were not environmentally benign, although PCE degradation was not reported. More recently, proprietary bacterial cultures grown on dextrose have been shown to degrade PCE and less chlorinated ethenes (Brusenhan et. al. 2007). Most of the literature supporting PCE degradation are vendor-authored case studies and are not included in this FS. However, Ohio EPA confirmed that this product was used in Ohio and reduced PCE concentrations at some sites, although concentrations tended to rebound in the long term. One paper based on a third-party pilot study reported that this product was able to degrade PCE, TCE, cis-1,2-DCE and vinyl chloride at a dry-cleaner site in Portland, Oregon. The pilot work was performed in 2001 and 2002 (Stevens et. al. 2003). Another paper reported that this product was able to degrade TCE and cis-1,2-DCE (Balba et. al. 2008).

Aerobic bioremediation would involve injection of proprietary formulations of these bacteria into groundwater. Bacterial inoculation would be accompanied by introduction of an organic carbon food source such as dextrose. Aerobic bioremediation would therefore involve both bioaugmentation and biostimulation. Amendments and microbes could be injected into groundwater through boreholes or permanent wells. These microbes would survive only for a few months and would therefore require periodic reinjection until remediation goals are achieved. Aerobic conditions must be maintained for these microbes to thrive and degrade the target contaminants. Physiochemical parameters were measured during groundwater sampling in the RI which provide an indication of oxidation-reduction potential (ORP) and dissolved oxygen (DO) levels in groundwater (see Appendix B). Unfavorable conditions include negative ORPs and low DO concentrations (less than 2 milligrams per liter). Under such conditions, anaerobic microorganisms would compete for resources and typical reductive dechlorination daughter products such as DCE and vinyl chloride could accumulate. To avoid this competition, aerobic conditions could be maintained through injection of oxygen releasing chemicals or sparging of air or oxygen as necessary. If sparging is used, the remedy would include controls (such as soil vapor extraction or sub-slab depressurization) to mitigate VI into existing buildings, if necessary. Furthermore, if VI is a concern during remediation, indoor air would be monitored to ensure proper function of the VI mitigation system.

The travel time from the targeted treatment area to the nearest municipal well (P-12W) is estimated to be about 12 months (modeled to be within 1-year TOT zone). Neither the small amount of bioremediation amendments nor contaminant degradation intermediates are expected to last that long and are therefore not expected to migrate to municipal wells. The microorganisms themselves would not migrate more than tens of feet from the injection points. Pilot and bench-scale tests would be necessary prior to remedial design (RD). Multiple treatments would be required to reduce rebound of COC concentrations.

Capital costs are expected to be moderate to high, and O&M costs are anticipated to be low to moderate. Given moderately oxic groundwater (indicated by positive ORPs and DO concentrations greater than 2 mg/L) and the likelihood that the targeted treatment area is not close enough for aerobic bioremediation to adversely affect P-12W, aerobic bioremediation is retained for further consideration.

4.1.5.3 Enhanced Reductive Dechlorination

Reductive dechlorination is the process that transforms chlorinated organic molecules by removing their chlorine atoms and usually replacing them with hydrogen. This term is often used in reference to chlorinated ethenes and ethanes, which are common environmental contaminants. Complete dechlorination of these contaminants produces ethene or ethane.

Enhanced reductive dechlorination (ERD) uses an organic carbon substrate such as vegetable oil, molasses, or sodium lactate delivered into the subsurface to stimulate native microorganisms and create reducing conditions. In addition to serving as a source of food for microorganisms, substrates produce the hydrogen necessary for dechlorination reactions. Anaerobic bacteria proliferate under these conditions, and some of these bacteria degrade chlorinated ethenes and ethanes, primarily through halorespiration and cometabolism. Abiotic dechlorination may also occur. In some cases, ERD includes bioaugmentation, where laboratory-grown bacterial cultures acclimated to specific contaminants are introduced into the subsurface. These introduced cultures often speed up degradation and ensure complete dechlorination to ethene or ethane. Substrates and microorganisms are commonly injected into the subsurface using direct-push injection technology or permanent wells.

PCE is the primary COC detected in groundwater. PCE degradation products, TCE and cis-DCE, have been infrequently detected in groundwater (at very low levels), and vinyl chloride has not been detected. Groundwater samples were collected for MNA parameters during the RI, and a preliminary MNA evaluation was conducted (see RI Section 5.4 [SulTRAC 2017]). This evaluation suggests that anaerobic biodegradation at the site is not significantly occurring under the existing conditions. ERD could be stimulated and a pilot test would be needed to obtain design parameters. ERD amendments are typically applied via direct-push injection, which can be used to a maximum depth of 75 to 100 feet bgs, depending on the site soil characteristics. ERD amendments can remain active in the aquifer for up to 5 years, sometimes making re-application of ERD amendments unnecessary.

ERD would produce PCE degradation products TCE, DCE, and vinyl chloride. DCE and vinyl chloride would eventually degrade to ethene, but concentrations during remediation may temporarily increase and migrate to municipal wells. The air stripper currently used to treat municipal well water would be able to strip these contaminants. However, additional information would be necessary to confirm that the air stripper could sufficiently treat the different chemicals in the influent. ERD would require injection of a large quantity of an organic carbon food source, and the resulting dissolved organic carbon could migrate a few hundred feet from the treatment area. Although unlikely, under extreme conditions, this could elevate dissolved organic carbon concentrations at municipal wells, increasing well-downtime and maintenance to address biofouling.

Capital costs are expected to be moderate to high and O&M costs are anticipated to be low to moderate. ERD is not retained for further consideration because of potential complications related to municipal well biofouling and formation of PCE degradation products.

4.1.5.4 In Situ Chemical Oxidation

Chemical oxidation uses oxidants to transform harmful contaminants into less toxic ones. In situ chemical oxidation (ISCO) involves injection of oxidants into groundwater using direct-push technology or injection wells. Gaseous oxidants, such as ozone, would be sparged. After injection, the oxidant spreads into the surrounding soil and groundwater, where it reacts with contaminants.

Permanganate, persulfate, ozone, and hydrogen peroxide are commonly used oxidants that could treat chlorinated VOCs on site. Hydrogen peroxide is sometimes combined with a catalyst or ozone to produce the highly reactive hydroxyl free radical; technologies that employ these free radicals to degrade contaminants are better known as advanced oxidation processes.

ISCO would likely be effective at this site for treating PCE in groundwater. ISCO is typically applied via direct-push injection, which can be used to a maximum depth of 75 to 100 feet bgs, depending on the site soil characteristics. ISCO chemistry is short-lived in the aquifer and often requires follow-up treatments or continuous injection to reduce contaminant concentrations to below RAOs.

ISCO would require careful consideration in the vicinity of municipal wells because it could create an oxidant plume, increase total dissolved solids (TDS) concentration, and temporarily mobilize naturally occurring heavy metals. This would likely be the case with ISCO using permanganate or persulfate. Advanced oxidation using hydroxyl free radicals could also temporarily mobilize heavy metals, but would not increase TDS concentration or produce an oxidant plume capable of migrating to municipal wells. Therefore, advanced oxidation using hydroxyl free radicals is the presumptive process options for ISCO.

If the oxidant is sparged into the aquifer, the remedy would include controls (such as soil vapor extraction or sub-slab depressurization) to mitigate VI into existing buildings, if necessary. Furthermore, if VI is a concern during remediation, indoor air would be monitored to ensure proper function of the VI mitigation system.

ISCO has moderate to high capital costs and low to moderate O&M costs. High natural oxidant demand (NOD) can make ISCO cost-prohibitive for some applications; however, NOD does not drive oxidant demand in advanced oxidation processes because the oxidant degrades spontaneously regardless of NOD. Advanced oxidation can produce unwanted byproducts and may be limited by the presence of hydroxyl radical scavengers. ISCO is retained for further consideration.

4.1.5.5 In Situ Chemical Reduction

In situ chemical reduction (ISCR) involves placement of reducing agents in groundwater to destroy or immobilize contaminants. Zero-valent iron (ZVI) is a commonly used reducing agent used to treat chlorinated VOCs, such as those present at the WTCA site. ZVI may be used in its pure form, in combination with an organic carbon substrate, or impregnated in activated carbon. ZVI corrosion reactions result in abiotic dechlorination of chlorinated aliphatics, producing nontoxic ethene or ethane. Activated carbon-impregnated ZVI causes dechlorination through the same mechanism as pure ZVI, but may work faster because of greater surface area and possible catalysis through sorption.

ISCR products may be introduced into the subsurface through injection, soil mixing, or excavation and backfilling. ISCR products at the WTCA site would likely be injected via direct-push injection, which can be used to a maximum depth of 75 to 100 feet bgs, depending on the site soil characteristics.

ISCR products can remain active in the aquifer for up to 5 years, and sometimes do not require re-application. Commercially available ISCR products are typically blends of ZVI and organic carbon. Like ERD, ISCR would produce PCE degradation products, although at lower concentrations. ISCR would also produce a dissolved organic carbon plume that could migrate a few hundred feet from the treatment area. Neither PCE degradation products nor dissolved organic carbon are likely to migrate to municipal wells except under extreme conditions. If this technology were selected, design and operation of the air stripper currently treating water from municipal wells would need to be evaluated. If PCE degradation products migrated to municipal well P-12W, air stripper operation could require modification, as cis-DCE is more difficult to remove via air stripping. Similarly, migration of dissolved organic carbon and dissolved iron could cause biofouling (potentially with iron bacteria) and affect municipal well operation and maintenance.

ISCR would have a high capital cost and low to moderate O&M cost. ISCR is not retained for further consideration because of potential complications related to municipal well biofouling and formation of PCE degradation products.

4.1.5.6 Air Sparging

Air sparging is a physical process used to strip dissolved volatile organics from liquids. It transfers liquid-phase contaminants to the vapor phase. The vapor phase is simultaneously collected via soil vapor extraction (SVE), then discharged to the atmosphere with or without treatment. The need for treatment is based on the estimated mass of contaminants discharged and where that mass lies in relation to discharge limits established by the state.

Air sparging involves the injection of air into groundwater through multiple air sparge wells. The air is supplied by an oil-free air compressor. Dissolved contaminants partition into the injected air and are carried into the vadose zone where they are captured by an SVE system. The SVE system would consist of a network of vapor extraction wells or horizontal collection pipes connected to a blower and off-gas processing equipment. Off-gas processing equipment usually includes a moisture separator, and sometimes treatment systems that sorb or destroy contaminants.

The sandy aquifer is amenable to air sparging and PCE concentrations can be reduced via sparging. Air sparging is best suited in situations where vapors produced by sparging can be captured by SVE. The ability to capture vapors is especially relevant when VI into indoor air is a concern. Air sparging increases DO concentrations and creates oxidizing conditions in the aquifer — both of which inhibit anaerobic biodegradation of PCE. Additionally, dissolved iron and hardness can cause occlusion in the soil pore spaces, reducing the effectiveness over time. The area and depth of the groundwater contamination at the site would likely require installation of numerous air sparge wells (and SVE wells or collection trenches to capture vapors from sparging). If VI is a concern during remediation, indoor air would be monitored to ensure proper function of the VI mitigation measure.

However, unlike other treatment technologies, air sparging would not generate byproducts that could migrate to the city's wellfield.

Air sparging has moderate capital and moderate to high O&M costs and is retained for further consideration.

4.1.6 Groundwater Extraction

Groundwater would be cleaned up by extracting contaminated groundwater from the subsurface. This section focuses on extraction. Treatment of extracted groundwater is discussed separately in the following section.

4.1.6.1 Extraction Wells

Extraction wells use the same technology previously discussed under containment in Section 4.1.4.1; however, the objective in this case would be to clean up rather than contain contaminated groundwater. Extraction wells would have significant yields and could be widely spaced because of the transmissive soils at this site. Cleaning up groundwater to RAOs would take several pore volume exchanges to flush out contaminants to acceptable levels. The use of extraction wells could also generate large volumes of unimpacted and relatively "clean" water, which would have to be managed. Once pumping is discontinued, contaminant rebound is often observed, requiring further pumping. This technology is generally easy to implement and has moderate capital and moderate to high O&M costs. Extraction wells are retained for further consideration.

4.1.7 Ex Situ Treatment

This refers to ex-situ treatment of extracted groundwater also commonly referred together as "pump and treat." The VOCs at this site are conducive to treatment via air stripping, carbon adsorption, and chemical oxidation. These technologies and process options are described below.

4.1.7.1 Air Stripping

Air stripping is used to remove dissolved VOCs from pumped groundwater. There are primarily two types of air strippers: packed towers and tray strippers. Packed towers are known for their high flow rates, and tray strippers are known for being easier to maintain. Extracted groundwater is introduced at the top of the tray stripper or packed tower and flows downward through the media while large volumes of air are blown upwards through the perforated trays or tower. VOCs separate from the dissolved phase in the water to the vapor phase in the air. The VOC concentrations in site groundwater are relatively low, and it is unlikely that that air stripper off-gas would require treatment; however, the need for treatment would be evaluated during the RD.

Air stripping would be effective and easy to implement. However, dissolved iron and hardness can cause scaling of the air stripper, requiring the addition of acid or sequestering agents to reduce scaling, which could increase maintenance costs and would have to be evaluated during the RD. Air stripping is already used at the site to treat water from P-12W, and lessons learned from this implementation would be applied to any additional implementation of air stripping at the site. This technology has low to moderate capital and O&M costs. Air stripping is retained for further consideration.

4.1.7.2 Carbon Adsorption

Carbon adsorption is used to remove contaminants that have an affinity for organic carbon, such as VOCs. Contaminated water is passed through activated granular activated carbon (GAC) media, contaminants sorb to the carbon, and clean water is discharged. When the activated carbon becomes saturated, it is replaced and the spent media is sent off site for regeneration or disposal. Carbon adsorption is generally used as a polishing technology for treatment of low concentrations of contaminants. At high concentrations, the technology — although effective — can become cost-prohibitive because of the high cost of media replacement. Extracted groundwater usually needs to be pre-filtered to prevent particulate fouling of the carbon media. In some cases, anti-scaling chemicals are needed to reduce scaling of the carbon media.

Carbon adsorption would be effective and easy to implement. This technology has moderate capital costs and moderate to O&M costs. Carbon adsorption is retained for further consideration.

4.1.7.3 Advanced Oxidation

Advanced oxidation refers to chemistries that produce hydroxyl free radicals, which then oxidize and destroy organic COCs. Most advanced oxidation processes employ some type of hydrogen peroxide catalyst to generate the hydroxyl free radical. This technology is commercially available and is often able to produce effluents that require no further treatment.

Advanced oxidation would be effective and easy to implement. It has high capital and moderate O&M costs. Advanced oxidation systems are typically much more expensive and complicated to design, construct, operate, and maintain than air strippers or carbon adsorption. Additionally, in some cases, advanced oxidation can generate byproducts, such as acetone or brominated compounds. Thus, advanced oxidation is not retained for further consideration.

4.1.8 Disposal

This refers to disposal of treated water when removal and ex situ treatment GRAs are used. Treated water may either be discharged to injection wells, discharged to surface water, or discharged to a POTW. These process options are discussed below.

4.1.8.1 Discharge to Injection Wells

Treated water would be injected into groundwater using permanent wells or an injection gallery. Although a permit would not be required under CERCLA, the action would require compliance with all substantive requirements of permitting conditions. Compliance would require periodic effluent monitoring and close coordination with Ohio EPA. The injection wells or trenches would be positioned to avoid detrimental impact to operating remedies. Potentially, the injection wells could be installed on the upgradient side of the site to increase the hydraulic flux through the site aquifer, increasing pore volume exchanges and shortening the remedial timeframe.

Transfer piping would be installed from the treatment system to the injection wells. Pipeline installation could require trenching in roadways, on public property, and where underground utilities may be present. Some wells and pipelines may have to be installed on private property, requiring obtaining access agreements and easements.

Disposal through reinjecting treated groundwater would be effective. It would conserve groundwater by returning it to the formation from which it was extracted. Reinjection would require fairly extensive modeling and design work to ensure that changes in hydraulic gradients as a result of reinjection do not spread the plume. This technology would have moderate capital and O&M costs. Given the proximity of the site to Morgan's Ditch and the GMR, discharging treated groundwater to surface water would be a favorable option; therefore, discharging treated water to injection wells is not retained for further consideration.

4.1.8.2 Discharge to Surface Water

Treated water would be discharged to nearby surface water — either Morgan's Ditch or directly to the GMR. Although a permit would not be required under CERCLA, the action would require compliance with National Pollutant Discharge Elimination System (NPDES) permitting conditions and would require periodic effluent monitoring. A pipeline would be installed from the treatment system to the river. Pipeline installation could require trenching on public or private property, requiring obtaining access agreements and easements.

Disposal through discharge to surface water would be effective. This technology would be easy to implement given the proximity of the surface water body (GMR) to the site. This technology would have low capital and O&M cost. Standards for discharge to surface water are typically the most stringent of all discharge process options; which could increase treatment cost. However, considering the close proximity of the site to the GMR, this technology is retained for further consideration.

4.1.8.3 Discharge to POTW

Treated water would be discharged to the City of Troy's sanitary sewer system. This water would mingle with wastewater from the city and ultimately be discharged to a POTW. Discharge to the sewer system would require compliance with the city's pre-treatment standards. Effluent quality would need to be monitored and reported. A transfer pipeline would be installed to the nearest sanitary sewer line with sufficient capacity to channel the discharge. As a result, some work in roadways or on private property may be necessary.

Disposal through discharge to a POTW would be effective. The implementability of this process option depends on the proximity of a suitable discharge point. The city would also have to allow such a discharge. There is typically a nominal and ongoing cost associated with discharging to a POTW, which can increase the cost of disposal. However, this cost may be offset by less stringent treatment standards, requiring less expensive treatment than other discharge options. Additionally, the POTW may not accept the discharge because the discharge of treated water to the POTW would dilute and possibly upset the POTW's biological wastewater treatment process. Depending on the POTW discharge fees, O&M costs can range from moderate to high. Because of the highly transmissive aquifer at the site, groundwater extraction flow rates are likely to be very high (possibly greater than 1,000 gpm), which could significantly dilute the POTW influent and would result in high discharge fees. This process would have low capital and moderate to high O&M costs. Discharge of treated groundwater to a POTW is not retained for further consideration.

4.1.9 Summary of Retained Process Options for Groundwater

The process options retained for groundwater are listed below.

Retained Groundwater Process Options
No Action
Land Use Controls (four sub-types)
Groundwater Monitoring
Aerobic Bioremediation
In Situ Chemical Oxidation (advanced oxidation using hydroxyl free radicals)
Air Sparging
Groundwater Extraction (removal)
Air Stripping
Adsorption
Discharge to Surface Water

4.2 TECHNOLOGIES AND PROCESS OPTIONS FOR PRIVATE WELL

The GRAs, remedial technologies, and process options for the affected private well are identified in Figure 3-2. Figure 4-2 summarizes the screening of each process option for effectiveness, implementability, and cost. Process options associated with each GRA for the private well are discussed below.

4.2.1 No Action

The no action GRA will be carried forward in the screening evaluation as a baseline that represents current site conditions, as required by the NCP.

4.2.2 Monitoring

Groundwater monitoring is a technology under the monitoring GRA. In this case, groundwater monitoring would consist of periodic sampling and analysis of groundwater from the existing private well at the Apex Racing property. Periodic monitoring of the private well water would provide information on groundwater contaminant concentrations.

Monitoring by itself does not achieve the private well RAOs, but it could be a necessary component of other long-term remedies. For example, if other alternate water supply or treatment options were implemented, monitoring would provide information on the effectiveness of those remedies. Monitoring information could also be used to plan future actions, if necessary. Monitoring would be readily implementable at low capital cost and low to moderate O&M costs. It is therefore retained for further consideration.

4.2.3 Alternate Water Supply

Alternate water supply would involve providing an alternate source of potable water to the building currently supplied by the private well. Various alternate water supply options identified in Section 3.2.3 are screened below.

4.2.3.1 Bottled Water

Alternate water could be obtained by providing bottled water to building occupants for consumption. Bottled water is typically provided as a short-term solution until a more permanent solution can be developed. Providing bottled water to the property owner of the private well would be an option that would be relatively effective and easily implementable — at least to address the immediate need for clean water supply. Scheduled deliveries of bottled water and an order not to consume, cook, or bathe using the well water would be issued. Currently, there is no evidence that the building owner uses the private well for drinking water, bathing, or cooking. Additionally, the building that is supplied by the private well is a business and not a residence. The building owner has informed EPA that the building is used for commercial purposes and that no one lives in the building or uses the well water for drinking, bathing, or cooking. According to the building owner, the water is used for occasional hand washing. Supplied water does not eliminate the presence of the groundwater contamination, so the overall long-term effectiveness of this option would be low.

Capital and O&M costs are low, as no system would need to be installed nor maintained other than a vendor-supplied water cooler. However, ongoing costs would be moderate over time for the price of electricity required to run the water cooler and also for providing continuous water bottle deliveries, with the timeframe possibly lasting many years.

Because (1) this option does not provide a long-term groundwater remediation solution, and (2) the property owner has informed EPA that the private well is not used for drinking water, bathing, or cooking (the property is used for business only), this option will not be retained for further consideration.

4.2.3.2 Installing a New Private Well

Alternate water can be supplied by installing a new private well and abandoning the existing private well. The installation of another private well either (1) at a deeper depth into the aquifer (in an area not contaminated), or (2) at a shallower depth upgradient of the current private well would achieve a clean water supply. Although installing a new private well would be effective as a means of providing alternate water, locating a new well could be challenging. For example, a new shallow well installed on the Apex Racing property would have to be a significant distance from the existing well and could draw contamination to it over time. Furthermore, regional geology information discussed in Section 1.3.2 indicates that although Silurian-age carbonate bedrock provides a source of water in some parts of Miami County, it is not present in the site vicinity and bedrock is not used as a source of water near the WTCA site. In addition, the existing private well would need to be abandoned according to state and county health department regulations. If installing a new private well was feasible, capital costs would be moderate (for a shallow well) and moderate to high (for a deep well) and O&M costs would be moderate. Therefore, this option is not retained for further consideration.

4.2.3.3 Connecting to Public or Private Water Supply

Another option for an alternate water supply would be to abandon the existing well and connect the building to a public (municipal) or private (independently operated) water distribution system. For the WTCA site, a public water supply is viable because a city water main runs below the west side of N. Elm Street near the Apex Racing building. It would be possible to install a new lateral connecting the water main to the building. The connection of the building's water pipe to the public water supply is highly effective as it obtains an immediate clean water supply for the property owner. The technical implementability would be high, as it would require simply a construction crew excavating down to the water main depth and installing a connection from the main to the building water line entrance. Capital costs and O&M costs would be low. This option is retained for further consideration.

4.2.4 Treatment

Treating water obtained by the existing private well would be moderate to highly effective in removing VOCs from the groundwater entering the building. Many types of physical water treatment processes could be considered but not all are feasible for treating VOCs in water from an individual private well. For example, air stripping is effective in removing VOCs; however, the relatively high capital and O&M costs make this option cost prohibitive. Phase separation is another process commonly used; however, free-phase (non-aqueous) contamination is not an issue at the site. Therefore, these processes are not retained.

As discussed in Section 3.2.4, there are two types of potential treatment systems for consideration: a POU filter and POE filter. A POU filter would be relatively easily implemented, as it is installed at each location in the building that the private well water would be accessed, such as at any faucet, shower, or bath. This option would include a carbon filter to remove any VOCs entering the building through the water well connection. However, the property owner would be required to change out the carbon filters occasionally as the filters are expended. Some effort on the part of the property owner would be required to maintain this filter replacement schedule. This filter would have low to moderate capital and O&M costs based on the duration of treating the water in this manner over a long period of time.

Another consideration to remove VOCs from groundwater is the use of a POE filter. This process involves installing a custom-built carbon filtration system at the water well pipe connection to the building, which would treat the water before it is used inside. Implementability would be moderate, as the system is more complex that a POU filter. In addition, carbon filters would need to be changed out on a regular basis and there is the potential for biofouling and scaling issues affecting the performance of the POE system. Capital costs would be moderate and O&M costs would be moderate to high to install and maintain the system.

The POE option using carbon filtration (and potentially pre-filtering to remove suspended solids) is retained for further consideration.

4.2.5 Summary of Retained Process Options for Private Well

The process options retained for addressing the private well are listed below.

Retained Private Well Process Options
No Action
Groundwater Monitoring
Connecting to Public Water Supply
Treatment

4.3 TECHNOLOGIES AND PROCESS OPTIONS FOR VAPOR INTRUSION

The GRAs, remedial technologies, and process options for VI are identified in Figure 3-3. Figure 4-3 summarizes the screening of each process option for effectiveness, implementability, and cost. Process options associated with each GRA for VI are discussed below.

4.3.1 No Action

The no action GRA will be carried forward in the screening evaluation as a baseline that represents current site conditions, as required by the NCP.

4.3.2 Land Use Controls

Risks associated with VI may exist in a future residential scenario if a residential structure was built on or near a property overlying the groundwater contaminant plume. ICs may be put in place on an interim or permanent basis to protect human health while groundwater remedies are being implemented. The different types of ICs were discussed in Section 4.1.2. Restricting land use by prohibiting construction of residential buildings at specific locations or requiring vapor mitigation systems or building control technologies for new construction near the groundwater plumes, would prevent future potential VI issues. However, any ICs could require legal actions or local ordinance changes to limit the use of certain properties or to require installation of vapor mitigation technologies. The areas to be addressed for potential VI includes an area where commercial properties currently exist along the east side of N. Elm Street and an open area just south of an area (the former Hobart Lagoon) that previously underwent closure through Ohio EPA's VAP. Because the open area is situated south of the former Hobart Lagoon and just north of Morgan's Ditch, it is unlikely that residential structures would be constructed there in the future. General site monitoring would be conducted to evaluate the effectiveness of ICs. General site monitoring would consist of periodic site visits to assess any changes in land use as well as other institutional actions deemed necessary to ensure that the alternative remains protective. Therefore, ICs may be effective alone or in combination with other actions and they are retained for further consideration.

4.3.3 Vapor Intrusion Monitoring

VI monitoring may be conducted to evaluate vapor phase migration into nearby buildings or to evaluate the performance of technologies deployed to mitigate VI, if necessary. Air monitoring would consist of one or more of the following, depending on the location: (1) soil gas monitoring at locations adjacent to existing buildings, (2) installing and sampling permanent sub-slab probes in affected buildings, and (3) conducting indoor air monitoring and background ambient air monitoring. The VI monitoring network would be sampled on a periodic basis (such as quarterly, semi-annually, or annually, for example) to measure contaminant concentrations seasonally over time. Additional actions may be necessary if monitoring indicates that contaminant concentrations are increasing. The types and frequency of monitoring would be established as part of the RD for the site. Monitoring sub-slab vapors or indoor air would require consent by and coordination with building occupants.

VI monitoring has low capital cost, low O&M cost, and is easy to implement physically. Vapor intrusion is not a concern in the long-term because the site is not residential. Therefore, VI monitoring is not retained for further consideration.

4.3.4 Containment

Containment options for VI at the WTCA site could include installation of passive barriers, passive venting, active sub-slab depressurization systems (and similar technologies), and active pressurization systems. Containment is not applicable to existing buildings at the WTCA site and would be considered if future residential structures were built at locations where VI could pose unacceptable risk to human health. Therefore, because containment options are not applicable under current site conditions, they are not retained as options to be implemented at this time.

4.3.5 Treatment

Treatment options consist of indoor air treatment systems such as carbon sorption and photocatalytic oxidation. Indoor air treatment can remove VOC air contaminants within the building in a specific room. Treatment is not applicable to existing buildings at the WTCA site and could be considered if future residential structures were built at locations where VI could pose unacceptable risk to human health;

however, indoor air treatment is generally used only for existing buildings because other types of more cost-effective systems can typically be installed during new building construction (ITRC 2007). Therefore, because treatment options are not applicable under current site conditions, they are not retained as options to be implemented at this time.

4.3.6 Summary of Retained Process Options for Vapor Intrusion

The process options retained for VI are listed below.

Retained Vapor Intrusion Process Options
No action
Institutional Controls

5.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section describes development of remedial alternatives for the WTCA site. The alternatives include only the remedial process options that merited further evaluation after the initial screening discussed in Section 4.0. Each alternative was developed to achieve the RAOs identified in Section 2.0 and to achieve the overall objective of protecting human health and the environment.

Alternatives have been developed to address site-wide groundwater contamination, an affected private well on the Apex Racing property, and the potential for VI associated with future residential land use. Conceptual components of the overall site remedial approach are presented in Figure 5-1. These alternatives are organized by the medium to be addressed and are presented as three separate sets of alternatives. Where appropriate, Section 6.0 discusses the compatibility of alternatives that when used in combination will provide a comprehensive remedy for the site.

According to Section 4.1.2.1 of EPA's "Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA," (EPA 1988a), alternatives may be screened before the detailed analysis if the list of alternatives could be shortened. The purpose of the screening evaluation is to potentially reduce the number of alternatives that will undergo a more thorough and extensive analysis in the FS. The following three criteria will be used to screen alternatives:

- Effectiveness – the degree to which an alternative is protective of human health and the environment
- Implementability – the technical and administrative feasibility of constructing, operating, and maintaining a remedial alternative
- Cost – relative qualitative estimate of capital and O&M costs

The alternatives described below were assembled by combining process options retained in Section 4 and were developed to allow EPA a range of alternatives to choose from.

5.1 DESCRIPTION OF ALTERNATIVES FOR GROUNDWATER

Four remedial alternatives have been developed by combining the process options retained in Section 4.1.8 and shown in Figure 4-1. For additional context, the proximity of the site to the 1- and 5-year TOT boundaries for the municipal wellfields is shown on Figure 5-2. All groundwater remedial alternatives developed in this section assume that the City of Troy would continue utilizing an air stripper to pre-treat water obtained from Production Well P-12W until RAOs are attained. The groundwater alternatives described in the following sections would be implemented in addition to the air stripper pre-treatment of water from P-12W.

Groundwater remedial alternatives were developed in consideration of the following factors:

- Groundwater contamination exists as a diffuse plume with no obvious source, and its persistence at low concentrations suggests it is sustained by mass transfer from fine-grained soils.
- The municipal wellfield should be protected from undesired effects of remediation. Therefore, remedial alternatives must ensure minimal risk of migration of remediation chemicals, byproducts, and other detrimental geochemical to the municipal wellfield.

All alternatives (except the no action alternative) would require ongoing inspections and 5-year reviews. Each of these alternatives is described below and screened for their effectiveness, implementability, and cost.

5.1.1 Groundwater Alternative GW-1: No Action

The no action alternative provides a baseline for evaluating the other alternatives. Under Alternative GW-1, no action would be taken to prevent exposure to contaminated groundwater and no action would be taken to remediate groundwater at the WTCA site. Therefore, continued operation of the city's treatment system (pre-treatment of water obtained from P-12W) is assumed to continue as an "existing condition," which will be considered; however, it is not an actual component of the no action alternative.

5.1.1.1 Effectiveness

Alternative GW-1 rates low for effectiveness. It would do nothing to reduce risk or restore groundwater to beneficial uses at the WTCA site and would therefore not protect human health or the environment.

5.1.1.2 Implementability

Alternative GW-1 rates low for implementability. Although implementable in the physical sense, it would not be administratively implementable because it would not gain acceptance from EPA or the Ohio EPA. The alternative would therefore be impossible to implement.

5.1.1.3 Cost

Alternative GW-1 rates well for cost because there would be no associated capital or O&M costs.

5.1.1.4 Decision

Alternative GW-1 is retained to serve as a baseline that can be used to compare other alternatives during detailed analysis.

5.1.2 Groundwater Alternative GW-2: Institutional Controls and Monitoring

This alternative would consist of a combination of ICs and periodic groundwater monitoring. ICs would be established for the Apex Racing and Bob's Auto properties as well as the grassy area owned by the City of Troy that lies between Morgan's Ditch and the former Hobart Lagoon. One or more ICs discussed in Section 4.1.2.1 would be used to prevent current and future occupants from using contaminated groundwater for potable purposes. Periodic groundwater monitoring would be conducted to evaluate changes in groundwater contamination over time. Several monitoring wells exist at the site, and additional wells may be needed to establish a suitable long-term monitoring well network.

5.1.2.1 Effectiveness

If ICs were enforced and maintained, this alternative would help prevent risk of potential human exposure to contaminated groundwater at locations where ICs were implemented. However, this alternative may not reduce or eliminate contaminant migration toward the West Wellfield and may not restore groundwater to beneficial uses in a reasonable timeframe. Groundwater monitoring would be conducted to evaluate changes in VOC concentrations over time and to assess whether natural processes are effective in reducing VOC concentrations and restoring groundwater to remedial objective levels or whether additional actions may be warranted.

5.1.2.2 Implementability

Groundwater monitoring would be fairly easy to implement, both technically and administratively. Periodic groundwater sampling is a routine activity at many sites. ICs could be established to restrict groundwater use and prevent future residential land use in the area. Implementing ICs would require administrative coordination with the city, county, and individual property owners.

5.1.2.3 Cost

This alternative has moderate capital and low to moderate O&M costs. The majority of O&M costs would be associated with periodic groundwater sampling and sample analysis.

5.1.2.4 Decision

Because this alternative may not reduce or eliminate contaminant migration toward the west wellfield and may not restore groundwater to beneficial uses in a reasonable timeframe, it is not retained as a stand-alone alternative for further analysis. However, ICs and groundwater monitoring are retained as components of other alternatives described below.

5.1.3 Groundwater Alternative GW-3: Targeted In Situ Treatment, Institutional Controls, and Monitoring

In addition to groundwater monitoring and ICs described above for Alternative GW-2, this alternative includes in situ treatment of a portion of the contaminant plume to reduce PCE and benzene concentrations. The conceptual treatment areas roughly correspond to the areas where PCE exceeds 20 µg/L and are shown on Figure 5-1. A small benzene plume is also present within the treatment area, where benzene exceeds its MCL of 5 µg/L.

The maximum PCE concentration in groundwater at the WTCA site was 101 µg/L and the maximum benzene concentration was 23 µg/L. Sorbed contamination and low-permeability units in the area with the highest PCE concentrations may be acting as a long-term source, feeding the plume. However, dense nonaqueous-phase liquid (DNAPL) was not observed during the RI and the dissolved-phase PCE concentrations do not suggest the presence of DNAPL at the site. To further evaluate site geology in the proposed treatment areas, boring logs were compiled and generalized geologic cross sections were prepared (see Appendix C). If necessary, additional geologic characterization would be conducted during the RD in specific treatment areas.

The goal of this alternative is to deplete this source so that (1) PCE does not exceed its MCL at Production Well P-12W (allowing the City of Troy to eventually discontinue ongoing pre-treatment of PCE-contaminated water obtained from P-12W), and (2) the aquifer is restored to beneficial use. In situ treatment process options retained from Section 4.3 include air sparging, ISCO, and aerobic bioremediation. Pilot test or treatability studies would be needed for the selected option to refine design parameters and evaluate cost effectiveness. For example, pilot tests may be needed to select the actual type and dosage of injectant, evaluate injection pressures and radius of influence (ROI), and determine the final configuration of injection points (such as grid or transect arrangement). These three process options are discussed below under Alternative GW-3, as GW-3A, GW-3B, and GW-3C.

5.1.3.1 Groundwater Alternative GW-3A: Targeted In Situ Treatment Using Air Sparging and SVE, Institutional Controls, and Monitoring

Air sparging and SVE (AS/SVE) would include a series of air sparge wells and SVE trenches installed within the targeted treatment area. The sandy soils at the site are suitable for air sparging, facilitating high flow rates and ROI. The sparge wells may be constructed of 2-inch to 4-inch-diameter polyvinyl chloride (PVC) slotted screens and risers installed below the water table, at the depth of contamination in the saturated zone. However, SVE may be more challenging because the vadose zone is predominantly fine-grained. SVE ROI in this type of soil may be small, requiring many wells. Therefore, to develop this alternative it assumed that SVE would involve horizontal collection pipes installed in trenches. The SVE system would include minimum 4-inch-diameter perforated PVC pipes installed within granular bedding material in trenches terminating several feet above the water table. Air sparged into groundwater would strip dissolved VOCs, carrying them to the vadose zone for capture via SVE. The SVE trenches would convey vapors to a blower through buried piping. The SVE blower and other process equipment (such as the moisture separator) would be housed in a small building. SVE off-gas would vent to the atmosphere through an exhaust stack with or without treatment. Treatment would be required only if the total mass of VOCs discharged is higher than allowed by state or federal regulations. Because VOCs are present in groundwater at low concentrations, it is unlikely that off-gas would require treatment. However, if off-gas must be treated, vapor-phase GAC would likely be used. SVE off-gas would be sampled periodically to monitor performance as well as compliance. Groundwater monitoring would be used to monitor progress and assess whether additional treatment is required. This approach allows for additional treatment or discontinuation of treatment, as required. The ultimate objective is to attain the RAOs presented in Section 2.1.1 by reducing VOC concentrations to MCLs within a reasonable timeframe (e.g. 30 years).

Groundwater monitoring would be necessary to monitor and evaluate the effectiveness of the groundwater remedy by demonstrating that groundwater contaminant concentrations have decreased as a result of the remedy and show a continued decrease over time. ICs restricting potable groundwater use would be required until RAOs have been attained. Groundwater monitoring and ICs are described under Alternative GW-2.

5.1.3.1.1 Effectiveness

Alternative GW-3A would protect human health and the environment and rates high for effectiveness. VOC contamination within the targeted treatment area would be reduced to levels that achieve remedial goals. ICs would prevent exposure to contaminated groundwater until MCLs are attained and groundwater is restored to beneficial use. Factors that could limit effectiveness include (1) possible occlusion in the soil pore spaces reducing the effectiveness over time, (2) the limited ability to effectively strip VOCs from localized areas of fine-grained soils (such as silt and clay) in the saturated zone, and (3) limited effectiveness when extracting soil vapors from fine-grained soils in the vadose zone.

5.1.3.1.2 Implementability

Alternative GW-3A rates moderate for implementability, with the primary challenge being access to construct, operate, and maintain a system on public and private property. Sparging and vapor extraction wells, as well as associated system components and piping, would need to be installed in a manner not to interfere with commercial operations. This alternative would also include O&M associated with an operating remediation system and would require access to test, maintain, and repair system components as needed.

5.1.3.1.3 Cost

Alternative GW-3A would have moderate capital costs and O&M costs.

5.1.3.1.4 Decision

Because this alternative effectively prevents exposure to contaminated groundwater and restores the aquifer to beneficial uses, it is retained for further analysis.

5.1.3.2 Groundwater Alternative GW-3B: Targeted In Situ Treatment Using ISCO, Institutional Controls, and Monitoring

In situ treatment using ISCO would consist of delivering an oxidant to the groundwater using injection wells or direct-push injection within the treatment area. The oxidant would likely be ozone or ozone with hydrogen peroxide. Although ozone sparging is the representative process option for this FS, the decision to use ozone alone or ozone with hydrogen peroxide would be made during the RD based on pilot testing. Transfer tubing would be installed to supply oxidants from process equipment to injection wells; installation of this tubing would require trenching. Process equipment could be located in the southern portion of the treatment area between the former Hobart Lagoon and Morgan’s Ditch.

If ISCO is selected, adequate contact would be achieved by injecting the oxidant within the targeted treatment zone. Given the proximity of Production Well P-12W to the groundwater treatment area, advanced oxidation using hydroxyl free radicals would be the preferred process option for ISCO because permanganate and persulfate are more persistent and could result in migration of oxidant and TDS.

Injection wells would be designed to avoid preferential flow and facilitate vertical distribution of the oxidant throughout the targeted area. Active remediation would operate continuously or intermittently, as necessary, to optimize performance. Groundwater monitoring would be used to monitor progress and assess whether additional treatment is required. This approach allows for additional treatment or discontinuation, as required. The ultimate objective is to attain the RAOs presented in Section 2.1.1 by reducing VOC concentrations to MCLs within a reasonable timeframe (e.g. 30 years).

Groundwater monitoring would be necessary to evaluate the effectiveness of the groundwater remedy by demonstrating that contaminant concentrations in groundwater have decreased as a result of the remedy and show a continued decrease over time. ICs restricting potable groundwater use would be required until RAOs have been attained. Groundwater monitoring and ICs are described under Alternative GW-2.

5.1.3.2.1 Effectiveness

Alternative GW-3B would protect human health and the environment and rates high for effectiveness. VOC contamination within the targeted treatment area would be reduced to levels that achieve remedial goals. ICs would prevent exposure to contaminated groundwater until MCLs are attained and groundwater is restored to beneficial use. Factors that could limit the effectiveness of ISCO include (1) the ability to deliver the oxidant throughout the targeted treatment area (such as the lower-permeability silt and clay lenses), and (2) potential rebound requiring additional treatment events to achieve remedial goals.

5.1.3.2.2 Implementability

Alternative GW-3B rates moderate for implementability, with the primary challenge being access to public and private property. Injection wells, as well as associated system components and piping, would need to be installed in a manner not to interfere with commercial operations. ISCO would require temporary infrastructure and O&M associated with an operating remediation system and would require access to operate, maintain, and repair system components as needed. ISCO would involve handling and storage of dangerous chemicals, requiring health and safety considerations and notification of local authorities.

5.1.3.2.3 Cost

Alternative GW-3B would have moderate capital costs and O&M costs.

5.1.3.2.4 Decision

Because this alternative effectively prevents exposure to contaminated groundwater and restores the aquifer to beneficial uses, it is retained for further analysis.

5.1.3.3 Groundwater Alternative GW-3C: Targeted In Situ Treatment Using Aerobic Bioremediation, Institutional Controls, and Monitoring

Aerobic bioremediation could be implemented using injection wells, boreholes, or both. Injection wells would be appropriate when the targeted soils are coarse-grained, and boreholes would be appropriate when the targeted soils are fine-grained. The means and methods of delivering amendments into groundwater would be determined during the RD. However, to develop this alternative, it is assumed that amendments would be pressure-injected into multiple discrete vertical intervals within boreholes advanced using direct-push drilling techniques. Injections would include aerobic microbial culture, dextrose, and water. Aerobic microorganisms would be a proprietary formulation known to cometabolically degrade PCE and less chlorinated ethenes under aerobic conditions. Achieving RAOs may require multiple injection events repeated periodically (for example every 6 months). Injection point spacing depends on injection ROI and the distance between injection points is typically about 15 to 30 feet in sand and gravel and 10 to 20 feet in silt and clay. However, actual injection point spacing would be established during the RD after ROI has been measured via pilot tests. Pore volume displacement during injection would depend on the volume of injectant, which is typically less than 20 percent of the pore volume. Injectant volume can affect ROI and would be determined based on pilot tests. The aquifer is moderately oxic with mostly positive ORP and DO concentrations greater than 2 mg/L (see Appendix B). However, if the aquifer requires oxygenation to increase aerobic activity and inhibit anaerobes, oxygenation would be achieved either by injecting oxygen-releasing chemicals or by sparging air or oxygen into groundwater. Oxygen-releasing chemicals would be injected only through boreholes, not wells. If oxygen or air is sparged (biosparging), permanent infrastructure similar to that described for air sparging in Alternative GW-3A would be necessary. However, because biosparging would infuse oxygen into groundwater and not physically strip contaminants, flow rates would be much lower than air sparging flow rates, and SVE would not be needed.

Active remediation would operate continuously or intermittently, as necessary, to optimize performance. Groundwater monitoring would be used to monitor progress and assess whether additional treatment is required. This approach would allow for additional treatment or discontinuation, as required. The ultimate objective is to attain the RAOs presented in Section 2.1.1 by reducing VOC concentrations to MCLs within a reasonable timeframe (e.g. 30 years).

Groundwater monitoring would be necessary to evaluate the effectiveness of the groundwater remedy by demonstrating that groundwater contaminant concentrations have decreased as a result of the remedy and show a continued decrease over time. ICs restricting potable groundwater use would be required until RAOs have been attained. Groundwater monitoring and ICs are described under Alternative GW-2.

5.1.3.3.1 Effectiveness

Alternative GW-3C would protect human health and the environment by reducing contaminant mass and maintaining ICs until remediation goals are achieved. This alternative rates high for effectiveness because of its ability to target contamination trapped in fine-grained soil. Multiple treatments would deplete the contaminant source (especially in fine-grained soil) enough to allow the contaminant concentrations to attain MCLs within a reasonable duration. Factors that could limit the effectiveness of aerobic bioremediation include aquifer geochemistry, competition from other microorganisms, and the difficulty in estimating nonaqueous contaminant mass and therefore the number of treatment events needed.

5.1.3.3.2 Implementability

Alternative GW-3C rates moderate for implementability, with the primary challenge being access to public and private property. If direct-push injection is used, there would be no permanent infrastructure to maintain, operate, and eventually dismantle, which is advantageous. However, the large number of injection points would include challenges such as avoiding buried utilities and performing pressurized injections in a manner that would minimize amendment surfacing. Minor challenges would include safe handling of oxygen-releasing amendments if they are used. Multiple injection events would be needed to reduce rebound of COC concentrations.

5.1.3.3.3 Cost

Alternative GW-3C would have moderate capital costs and O&M costs.

5.1.3.3.4 Decision

Because this alternative effectively prevents exposure to contaminated groundwater and restores the aquifer to beneficial uses, it is retained for further analysis.

5.1.4 Groundwater Alternative GW-4: Extraction, Treatment, and Discharge with Institutional Controls and Monitoring

Alternative GW-4 would actively remediate the plume using a pump-and-treat system. A pump-and-treat system would involve installation of one or more groundwater extraction wells, transfer piping, a treatment system, and a treated water discharge system. To the extent possible, pipelines and wells would be located on public property. Process equipment could potentially be located in the southern portion of the treatment area south of Bob's Auto or between the former Hobart Lagoon and Morgan's Ditch. The number of extraction wells, locations, and flow rates would be determined during the RD. Assumptions made for the purpose of estimating the cost of this alternative are detailed in Appendix D. Designing the remedy would require additional groundwater sampling for water quality parameters to evaluate the potential for corrosiveness, precipitate/scale formation, and discharge options. Groundwater modeling would be required to determine the number, locations, and depths of the extraction wells, and to determine the required flow rates to achieve the desired hydraulic capture.

Air stripping would be the representative process option for treating extracted groundwater, although carbon adsorption may also be considered during the RD. Treated water would likely be discharged to Morgan's Ditch but other discharge options (such as discharge directly to the GMR) could be evaluated during the RD. Treated water would require installation of transfer piping.

Active remediation would be complete when COC concentrations are permanently reduced below MCLs in the targeted treatment area.

Groundwater monitoring would be necessary to evaluate the effectiveness of the groundwater remedy by demonstrating that groundwater contaminant concentrations have decreased as a result of the remedy and show a continued decrease over time. ICs restricting potable groundwater use would be required until RAOs have been attained. Groundwater monitoring and ICs are described under Alternative GW-2.

5.1.4.1 Effectiveness

Alternative GW-4 rates high for effectiveness. This alternative would protect human health and the environment because groundwater would be remediated, and ICs would reduce risk of human exposure until remedial objectives are reached. Groundwater contaminant concentrations are relatively low and aquifer transmissivity is high, so this alternative would require extracting and treating large volumes of water to meet remedial objectives. The use of extraction wells could also generate large volumes of unimpacted and relatively "clean" water, which would have to be managed. Pump-and-treat technology would likely show an initial reduction in dissolved-phase concentrations in the diffuse plume, followed by a slow and steady reduction over time. However, concentrations in groundwater may rebound after the pumping stops and contaminants desorb from the soil matrix. Therefore, the pump-and-treat system may need to operate for a long duration (continuously or intermittently) for it to be effective and achieve RAOs. Fate and transport modeling would be conducted, if necessary, during the RD to estimate the approximate cleanup timeframe.

5.1.4.2 Implementability

Alternative GW-4 rates moderate for implementability, with the primary challenge being access to public and private property. Permanent extraction wells, as well as associated piping and treatment system components, would need to be installed in a manner not to interfere with commercial operations. This alternative would include O&M associated with an operating remediation system and would require access to test, maintain, and repair system components as needed.

5.1.4.3 Cost

Alternative GW-4 would have moderate capital costs and moderate to high O&M costs.

5.1.4.4 Decision

Because this alternative effectively prevents exposure to contaminated groundwater and restores the aquifer to beneficial use, it is retained for further analysis.

5.2 DESCRIPTION OF ALTERNATIVES FOR PRIVATE WELL

Retained technologies presented in Section 4.2.9 and on Figure 4-2 have been developed into three remedial alternatives for addressing the affected private well at the Apex Racing property. All alternatives (except the no action alternative) would require ongoing inspections and 5-year reviews. Each alternative is described below and screened for effectiveness, implementability, and cost.

5.2.1 Private Well Alternative PR-1: No Action

Alternative PR-1 would take no action to address the affected private well on the Apex Racing property at the site.

5.2.1.1 Effectiveness

Alternative PR-1 rates low for effectiveness. It would not reduce existing risk posed from contaminated well water at the WTCA site and would therefore not protect human health or the environment.

5.2.1.2 Implementability

Alternative PR-1 rates low for implementability. Although physically easy to implement, it would not gain acceptance from EPA or Ohio EPA. The alternative would therefore not be possible to implement.

5.2.1.3 Cost

Alternative PR-1 rates high for cost because there would be no associated capital or O&M costs.

5.2.1.4 Decision

Alternative PR-1 is retained for detailed analysis and will serve as a baseline that can be used to compare other alternatives.

5.2.2 Private Well Alternative PR-2: Treatment and Monitoring

Alternative PR-2 would treat well water using a POE filter. The actual type of system to be installed would be determined during the RD. The system would likely include a sediment filter and activated carbon media to remove VOCs. POE filters require upkeep and maintenance to ensure they are working properly. In addition, the private well would be sampled periodically to determine whether filtration of well water should continue or could be terminated. Private well sampling would include both influent (pre-treated water) and effluent (treated water) samples.

5.2.2.1 Effectiveness

Alternative PR-2 rates high for effectiveness. Activated carbon would remove PCE from the water. However, the property owner would be required to change out the carbon filters occasionally as the filters are expended. Some effort on the part of the property owner would be required to maintain this filter replacement schedule; failure to do so would increase exposure to PCE and reduce the overall effectiveness of this alternative.

5.2.2.2 Implementability

Alternative PR-2 rates high for implementability. POE filters could be easily installed by vendors of home water treatment systems. Obtaining access to the building to initially install filters would be required.

5.2.2.3 Cost

POE filters have low capital and low to moderate O&M costs. O&M costs would increase depending on the duration of treatment.

5.2.2.4 Decision

This alternative is retained for further consideration.

5.2.3 Private Well Alternative PR-3: Connect to City Water and Abandon Private Well

This alternative consists of connecting the building to a public (municipal) water distribution system and abandoning the existing private well. A public water main runs below the west side of WTCA near the Apex Racing building. The infrastructure is already in place to install a new lateral connecting the water main to the building; however, the property is outside city limits. To be eligible for city water supply, the property would have to be annexed by the city.

5.2.3.1 Effectiveness

Alternative PR-3 rates high for effectiveness. The connection of the building’s water pipe to the public water supply would provide a permanent clean water supply for the property owner. Furthermore, abandonment of the existing well would eliminate the potential for exposure to contaminated water.

5.2.3.2 Implementability

Alternative PR-3 rates high for implementability, as it would basically be the same as installing a new water connection to a residential property. The work would involve horizontal drilling, trenching and plumbing, requiring easily available services. Annexation by the city would require property owner consent.

5.2.3.3 Cost

Alternative PR-3 would have a low capital cost associated with legal fees resulting from annexation and no O&M costs. The property owner would be required to pay water usage bills associated with a public utility.

5.2.3.4 Decision

This alternative is retained for further consideration.

5.3 DESCRIPTION OF ALTERNATIVES FOR VAPOR INTRUSION

Alternatives for VI are intended to address VI issues that would be associated with residential structures if constructed in the future. Therefore, active remedies to address current site conditions are not warranted. Additionally, if the groundwater remedy achieves groundwater RAOs, future residential VI may no longer be of concern. Based on these factors, the VI remedial alternatives evaluated for the WTCA site include: (1) no action and (2) ICs and monitoring. The ICs and monitoring alternative would require ongoing inspections and 5-year reviews. Each of these alternatives is described below.

5.3.1 Soil Vapor Alternative VI-1: No Action

The no action alternative provides a baseline that can be used to compare other alternatives. Under Alternative VI-1, no action would be taken to address VI at the WTCA site. Under the no action alternative, no mitigation or removal system would be installed and ICs would not be put in place as a protective measure.

5.3.1.1 Effectiveness

The no action alternative would not be protective of human health if residential structures are constructed in the future.

5.3.1.2 Implementability

Although this alternative would be easily implemented, the administrative feasibility of selecting this alternative is very low. It is unlikely that EPA or Ohio EPA would approve of this alternative because it would not provide a mechanism for ensuring adequate protection of human health.

5.3.1.3 Cost

No capital or O&M costs are associated with this alternative.

5.3.1.4 Decision

The no action alternative is retained to serve as a baseline that can be used to compare other alternatives during detailed analysis.

5.3.2 Soil Vapor Alternative VI-2: Institutional Controls and Monitoring

This alternative would prohibit residential land use and construction of commercial buildings within a specific area, unless the hypothetical future developer employs vapor mitigation and monitoring in new construction design. ICs would include approval of new construction design, pre-design monitoring, and long-term monitoring plans for residential and commercial development. VI monitoring associated with hypothetical new construction would likely be similar to the options described in Section 4.3.3 and is not specified here, except that such monitoring must verify that the VI mitigation system is effective and protective of building occupants. Monitoring associated with existing conditions would involve administrative reviews and site inspections to ensure that the site's land-use is complying with any restrictions mandated by the ICs.

ICs would likely consist of legal actions (such as restrictive covenants, prohibitions, and advisories). IC monitoring would include annual site visits and review of records to ensure that the site is being used in a manner that complies with ICs.

5.3.2.1 Effectiveness

This alternative would be effective in protecting human health because ICs, if maintained and enforced, would be effective in prohibiting construction of future residential property or requiring developers to install a vapor mitigation system as part of the building design. Monitoring would be effective in determining if the mitigation systems are performing as expected and whether site conditions have changed over time.

5.3.2.2 Implementability

This alternative would be moderately easy to implement. ICs are readily implementable and administratively feasible. Monitoring would be readily implementable and would require installation of permanent sub-slab soil gas probes and access agreements to collect sub-slab vapor and indoor air samples. Sample collection from private properties would be possible only if the property occupant grants access.

5.3.2.3 Cost

This alternative would have low capital costs and low to moderate O&M costs. The majority of the O&M costs are associated with long-term soil vapor monitoring. The number of monitoring points and the frequency of soil vapor monitoring would affect the overall O&M costs. Costs associated with ICs pertain to administrative costs only. The actual vapor mitigation technologies used for new construction would be based on the type of future construction planned. Mitigation system costs would therefore be incurred by the builder or developer, and actions and costs associated with mitigation or control systems for future construction are not included in this alternative.

5.3.2.4 Decision

This alternative is retained for further analysis.

5.4 SUMMARY OF RETAINED ALTERNATIVES

The following alternatives for groundwater, the private well at Apex, and VI are retained and will undergo detailed analysis in Section 6.0.

Alternative No.	Alternative Name
Groundwater	
GW-1	No Action
GW-3 (3A, 3B, and 3C)	Targeted In Situ Treatment, Institutional Controls, and Monitoring
GW-4	Extraction, Treatment, and Discharge with Institutional Controls and Monitoring
Private Well	
PR-1	No Action
PR-3	Well Treatment and Monitoring
PR-4	Connect to City Water and Abandon Private Well
Vapor Intrusion	
VI-1	No Action
VI-2	Institutional Controls and Monitoring

6.0 DETAILED ANALYSIS OF ALTERNATIVES

This section presents detailed analysis of the groundwater, private well, and VI remedial alternatives. The criteria that will be used to evaluate alternatives are specified in Subsection 300.430(e)(9)(iii) of the NCP and address the statutory requirements in Section 121 of CERCLA. Although separate alternatives are presented for each medium, the alternatives selected for each medium must be compatible. The interaction of alternatives across media must be considered so that the overall site remedy is sound.

The WTCA site encompasses contaminated groundwater that originates west of the GMR and extends under the river to Production Well P-12W in the city's West Wellfield. Remedial activities would be limited to areas west of the GMR, on both public and private property, and would be subject to access agreements.

The alternatives described in this section are conceptual and provide sufficient detail to estimate costs and perform evaluations. Cost estimating assumptions are presented in Appendix D and supporting figures are provided for some remedial alternatives. These figures are not intended to specify the layout of the final remedy or stipulate its limits. Specifics of the final remedy, such as the boundaries of the targeted treatment area, will be developed during the RD. A description of the evaluation criteria is presented below.

6.1 DESCRIPTION OF EVALUATION CRITERIA

The nine evaluation criteria specified in the NCP are as follows:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of the toxicity, mobility, or volume of contaminants through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

Remedial alternatives for groundwater, the private well at Apex, and VI are analyzed in Sections 6.2, 6.3, and 6.4, based on the nine criteria listed above (with the exceptions discussed below). State and community acceptance will be evaluated after the public comment period. The results of the analysis are used to provide a comparative evaluation of the alternatives in Section 7.0.

Remedial alternatives are evaluated in this FS according to the first seven of nine NCP evaluation criteria. The nine criteria can be subdivided into three categories: threshold criteria, primary balancing criteria, and modifying criteria. The threshold criteria (overall protection of human health and the environment; compliance with ARARs) relate to statutory requirements that each alternative must satisfy to be eligible for selection. The primary balancing criteria (long-term effectiveness; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost) are the technical criteria used as the basis for the detailed analysis. The modifying criteria (state and community acceptance) are assessed formally after the public comment period, although, to the extent they are known, they are factored into the identification of the preferred alternative. The nine NCP evaluation criteria are numbered and defined in the following paragraphs as they pertain to this FS (EPA 1988a, 1990).

In addition, a sustainability criterion has been added for further evaluation of alternatives in this FS report. Although sustainability is not one of the nine CERCLA-prescribed criteria, it has been included in accordance with EPA Region 5's Greener Cleanup Interim Policy (EPA 2009). Sustainability criteria may be taken into consideration, yet are not required for remedial alternative selection.

6.1.1 Overall Protection of Human Health and the Environment

Alternatives are assessed for their ability to protect human health and the environment in both the short and long term. Alternatives receive qualitative ratings for reducing unacceptable risks posed by hazardous substances, pollutants, or contaminants through elimination, reduction, or control. That is, they are rated for their ability to attain remedial objectives and goals developed in accordance with 40 CFR 300.430(e)(2)(i). The overall assessment of protection considers other criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

6.1.2 Compliance with ARARs

Each alternative is assessed for its ability to meet ARARs under federal environmental laws and state environmental or facility citing laws. If an alternative cannot meet ARARs, EPA may invoke one of the waivers under 40 CFR 300.430(f)(1)(ii)(C), and the agency would decide whether an ARAR would be waived under Section 121 of CERCLA. All chemical-specific, location-specific, and action-specific

ARARs identified would be considered in making this decision. Potential federal and state ARARs for the WTCA site are listed in Appendix A.

6.1.3 Long-Term Effectiveness and Permanence

Alternatives are assessed for the degree of long-term effectiveness and permanence they would provide. Factors considered may include: (1) the magnitude of residual risk associated with residual contamination after the conclusion of remedial activities, and (2) the adequacy and reliability of the remedy.

6.1.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Alternatives are assessed for their ability to reduce the toxicity, mobility, or volume of contamination through treatment (or recycling). Factors considered may include: (1) the type of treatment process employed; (2) the amount of contaminated material treated or recycled; (3) the estimated reduction in contaminant toxicity, mobility, or volume of contamination; and (4) permanence of the changes produced by treatment.

6.1.5 Short-Term Effectiveness

Assessment of alternatives for short-term effectiveness may include: (1) evaluation of short-term risks to the community during remedial action, (2) risks to workers involved in remedial activities and the reliability of protective measures, (3) potential environmental impacts and reliability of measures to mitigate such impact, and (4) the time required to implement the remedial alternative.

6.1.6 Implementability

Assessing the ease or difficulty of implementing an alternative may include: (1) its technical feasibility or challenges associated with its construction and operation, the ease of undertaking additional action, and the ability to monitor the remedy; (2) its administrative feasibility or non-technical challenges to implementation, such as the need for approvals or permits and the associated time and effort ; (3) the availability of technical services and materials; and (4) the availability of necessary equipment or other resources.

6.1.7 Cost

Cost estimates for the remedial alternatives are presented in Appendix D. The estimated costs include: (1) capital costs (construction and professional); (2) O&M costs; (3) contingency costs; and (4) the net present value of capital and O&M costs.

Capital costs refer to the initial expense of installing the remedy and include construction and professional costs. Construction costs include labor, equipment, materials, and waste disposal. Professional costs include engineering, legal fees, administrative fees, oversight, and management.

O&M costs refer to post-construction expenses, including the cost to operate, maintain, and monitor the remedy. These costs may include labor, equipment and material, energy, waste disposal, administration, fees, and periodic site review.

The cost estimates presented in this report were developed using unit costs from RS Means (2017 cost book), National Construction Estimator via Get-a-Quote.net (2017 cost book), RACER® software (2015 cost database), quotations from vendors, and SulTRAC's experience with similar projects. The net present value of each alternative was calculated by summing the present values of capital and O&M costs. The present value is the estimated value of a future expense in current year dollars. Present values were calculated by discounting future costs using a 7 percent discount rate prescribed by *A Guide to Developing and Documenting Costs Estimates During the Feasibility Study* (EPA 2000). Therefore, the estimated cost of every alternative is calculated in 2018 dollars and projected over the anticipated duration of each alternative.

A 30 percent contingency is factored into the estimated capital cost for each alternative to account for unforeseen expenses arising from changes to scope or pricing. The accuracy of these cost estimates is expected to range from +50 percent to -30 percent, which is consistent with EPA guidelines for feasibility studies (EPA 1988a). As described above, pre-design investigations will help refine assumptions and improve estimates.

Monitoring remedial progress and the extent of the groundwater contaminant plume would require a network of monitoring wells. Up to ten monitoring wells would be added to the existing network of wells. These wells would be located within targeted treatment zones to support pre-design investigations and to monitor the performance of the remedy. To estimate cost, it is assumed that ten additional wells would be installed (five paired shallow and deep wells).

General cost assumptions are presented in Appendix D. These assumptions are provided solely to clarify the cost estimates and are not intended to define the scope, means, or methods of the selected remedy.

6.1.8 Sustainability

As previously mentioned, a sustainability criterion has been added for further evaluation of alternatives in this FS Report. Although sustainability is not one of the nine CERCLA-prescribed criteria, it has been included in accordance with EPA Region 5's Greener Cleanup Interim Policy (EPA 2009).

Sustainability criteria may be taken into consideration, yet they are not required for remedial alternative selection. Sustainability criteria, specified in EPA Region 5's 2009 Interim Policy, are used to evaluate an alternative's ability to reduce air pollutant emissions, reduce greenhouse gas production, minimize impacts to water quality and water resources, support sustainable human and ecological use and reuse of remediated land, minimize material use and waste production, and conserve natural resources and energy.

6.2 DETAILED ANALYSIS OF GROUNDWATER ALTERNATIVES

Six remedial alternatives for groundwater were described in Section 5.2. Alternative GW-2 was not retained after initial screening; therefore, detailed analyses of the five retained groundwater alternatives are presented below. Table 6-1 provides a summary of the detailed analysis of groundwater alternatives.

6.2.1 Detailed Analysis of Groundwater Alternative GW-1: No Action

Alternative GW-1 would take no action to address contaminated groundwater at the WTCA site. That is, no action would be taken to clean up, contain, or monitor contaminated groundwater, or prevent exposure to contaminated groundwater. Contaminated private wells would continue to operate and there would be no restrictions against drilling new private wells within contaminated areas. Contaminated groundwater would continue to migrate to the city's Production Well P-12W, and the city would continue to pre-treat water obtained from P-12W via air stripping. (Pre-treatment at P-12W is considered an existing condition and, while not a component of the no action alternative, pretreatment is assumed to continue if no action is taken.) In accordance with the NCP, this alternative is evaluated only to provide a benchmark for comparison to other alternatives.

6.2.1.1 Overall Protection of Human Health and the Environment

Alternative GW-1 would not protect human health or the environment because nothing would be done to control existing risks. The public could be exposed to contaminated groundwater through use of existing and new private wells. The public might also be exposed through intrusion of vapors into future residential developments within contaminated areas. The city's Production Well P-12W would be protected because the city would continue to pre-treat water obtained from this well. Contaminants in groundwater would continue to degrade the environment as well as endanger human health through uncontrolled potential exposure pathways.

6.2.1.2 Compliance with ARARs

Alternative GW-1 would not comply with chemical-specific ARARs.

6.2.1.3 Long-Term Effectiveness and Permanence

The factors evaluated under long-term effectiveness and permanence, described in Section 6.1.3, are assessed below for Alternative GW-1.

Magnitude of Residual Risks

Natural processes would slowly reduce the extent of contamination over an extended duration. Although natural processes may eventually attain remediation goals, they would take very long because of the apparent persistence of the plume. Therefore, the extent of contamination may only slightly decrease in the foreseeable future. Residual risk would depend on exposure pathways, which may change, causing risk to decrease or increase.

Adequacy and Reliability of Controls

There would be no site controls put in place.

6.2.1.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

This alternative does not involve treatment. Therefore, it would not reduce toxicity, mobility, or volume of contaminants through treatment.

6.2.1.5 Short-Term Effectiveness

The alternative would not pose new health risks to the community, current site occupants, workers, or the environment because Alternative GW-1 involves no remedial activities or construction. This alternative would require no time to implement.

6.2.1.6 Implementability

No construction or other activities would be required to implement Alternative 1; therefore, the alternative is technically feasible. However, this alternative is not likely to receive regulatory approval because it would not protect human health or the environment. Therefore, the alternative would not be administratively feasible.

6.2.1.7 Cost

No capital or O&M costs are associated with Alternative GW-1.

6.2.1.8 Sustainability

This alternative would not consume any energy and would therefore conserve energy sources; however, it does not address degradation of a sole-source aquifer resource that provides water to over 25,000 residents in Troy and would not provide progress toward restoring this resource. Therefore, overall, this alternative would rate low for sustainability.

6.2.2 Detailed Analysis of Groundwater Alternative GW-3A: Targeted In Situ Treatment Using Air Sparging and SVE, Institutional Controls, and Monitoring

AS/SVE would consist of installing air sparge wells and vapor extraction trenches within targeted treatment areas. Air injected into sparge wells would cause dissolved-phase VOCs to partition from the aqueous to the vapor phase. These vapors would rise through the aquifer into the vadose zone where they would be captured by the SVE system and discharged to the atmosphere. Pre-design investigations and a pilot test would be performed to measure ROI, determine flow rates, and measure mass transfer parameters and geochemical parameters such as dissolved iron. This information would be used to design air sparge well layout, size AS/SVE equipment, and select monitoring well locations. A conceptual layout of this alternative is shown on Figure 6-1. Details such as the number and locations of air sparge wells are only included to support the cost estimate and are not intended to define the scope or specify the means and methods to implement this alternative.

To estimate cost, the following assumptions were made. Sparge wells would be arranged in a staggered grid pattern and SVE would utilize horizontal wells in trenches. AS/SVE equipment, such as the blower, compressor, and other process equipment would be housed inside a small building. SVE off-gas would vent to the atmosphere through an exhaust stack without treatment. Treatment is not anticipated because the site would emit less than 10 lbs of VOCs a day. SVE off-gas would be sampled to monitor performance and calculate VOC mass discharge to ensure emissions comply with regulatory standards. AS/SVE equipment would be sized to operate approximately one-fourth of the AS/SVE wells at any given time. Manifolds would direct airflow from the compressor to the desired section of the wellfield to be operated. As progress slows down, airflow would be directed to the next section. Similarly, the series of AS/SVE wells would be sparged in sequence, targeting one section at a time. Each section of AS/SVE wells may operate one or more months at a time n, and the number of times it is targeted would depend on the extent of contaminant concentration rebound after treatment. AS/SVE would end when progress becomes asymptotic or when concentrations can decline naturally without additional active treatment. To estimate cost, it is assumed that the AS/SVE system would operate for 8 years, or an average of 2 year per wellfield section. After AS/SVE, contaminant concentrations would slowly decrease to MCLs. To estimate cost, it is assumed MCLs would be attained 30 years from the start of AS/SVE. This duration is based on professional judgment given the apparent historical persistence of the plume. A more accurate estimate of remedial duration would require further characterization followed by fate and transport modeling, which is beyond the scope of this FS.

A network of existing and new groundwater monitoring wells would be used to monitor remedial progress. To estimate groundwater monitoring costs, it is assumed ten new monitoring wells would be installed. Monitoring data would be used to make decisions on the remediation schedule including sequencing and termination, so that RAOs (see Section 2.1.1) can be attained in 30 years or less.

ICs would restrict use of contaminated groundwater until RAOs have been attained. ICs would involve legal instruments such as covenants (agreements between property owners and agencies) because most of the site is outside city limits and therefore not subject to zoning restrictions or city ordinances.

6.2.2.1 Overall Protection of Human Health and the Environment

Alternative GW-3A would reduce PCE and benzene concentrations over time, restoring the aquifer to beneficial use. Until then, ICs would prevent inadvertent exposure to contaminated groundwater. Progress would partly depend on the system's ability to capture COCs stripped from groundwater by sparging. Capturing stripped vapors would be challenging because of the shallow water table and a predominantly fine-grained (silt and clay) vadose zone. COCs that are not captured by the SVE system could re-dissolve in groundwater, slowing progress. Furthermore, air sparging would not significantly strip contaminants trapped within fine-grained strata because of preferential flow through or around these strata. Groundwater treatment would pose no additional threat to City of Troy Production Well P-12W. Existing contamination of Production Well P-12W poses no threat to the public because the city pre-treats water obtained from this well. As groundwater remediation progresses and groundwater contaminant concentrations are reduced at Production Well P-12W, the city would be able to stop pre-treating water from this well. This would likely happen before attainment of remediation goals within the treatment area.

Workers and the community would be protected during remediation through safe work practices and engineering controls. Therefore, this alternative would protect human health and the environment in both the short and long term.

6.2.2.2 Compliance with ARARs

Alternative GW-3A would comply with federal and state ARARs. Specifically, PCE and benzene levels in groundwater would attain MCLs, which are chemical-specific ARARs. Vapors vented to the atmosphere during remediation would comply with state regulations.

6.2.2.3 Long-Term Effectiveness and Permanence

Factors affecting long-term effectiveness and permanence, described in Section 6.1.3, are evaluated below for Alternative GW-3A.

Magnitude of Residual Risks

After the remediation goals are attained, residual risk would be eliminated. Air sparging would remove COCs from coarse-grained soils (such as sand) but would be limited by fine-grained soils (such as silt and clay) because of preferential flow. Stripping contaminants from fine-grained soils via sparging is challenging because air sparged below the contaminated soil (which is standard practice) would preferentially flow through more permeable soil, leaving the fine-grained soil mostly untreated. SVE within a fine-grained vadose zone is similarly challenging because low permeability would limit the ability of SVE to draw in stripped vapors. Another limiting factor is possible pore-space occlusion by dissolved iron (if present at a significant concentration), which could be precipitated by sparging, slowing down remediation.

Adequacy and Reliability of Controls

SVE would reduce fugitive emission of contaminants by capturing recoverable vapors resulting from sparging. SVE off-gas would be discharged at a safe distance from buildings and above roof level to avoid degrading indoor or ambient air quality. Off-gas monitoring would provide notice of changing conditions, allowing system retrofitting for off-gas treatment, if necessary. Long-term groundwater monitoring would track remedial progress as well as provide information that could be used to optimize the remedy. ICs would prevent inadvertent exposure to contaminants by restricting use of contaminated groundwater until RAOs are attained.

6.2.2.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

The ability of Alternative GW-3A to satisfy the evaluation criterion of contaminant toxicity, mobility, or volume through treatment, described in Section 6.1.4, is discussed below.

Destruction of Toxic Hazardous Substances

Alternative GW-3A would transfer PCE from groundwater to the atmosphere, where the contaminants would be slowly degraded by natural processes (such as photooxidation). Off-gas treatment is unlikely to be needed because daily VOC emissions are expected to comply with regulatory standards without treatment. Therefore, PCE would not be destroyed via treatment. However, GW-3A would promote aerobic biodegradation of benzene, resulting in destruction of some fraction of the benzene mass.

Reduction of Total Mass of Toxic Hazardous Substances

Alternative GW-3A would reduce the mass of PCE in groundwater by transferring dissolved mass to the atmosphere, and therefore would not reduce PCE mass through treatment. However, part of the benzene mass in groundwater would be reduced by aerobic biodegradation.

Irreversible Reduction of Hazardous Substance Mobility

Alternative GW-3A would not reduce the mobility of COCs.

Reduction of Total Volume of Contaminated Media

Alternative GW-3A would reduce the extent of the plume over time, and therefore reduce the volume of contaminated groundwater, although not through treatment.

6.2.2.5 Short-Term Effectiveness

The four short-term effectiveness factors described in Section 6.1.5 are assessed below for Alternative GW-3A.

Protection of Community

Risks during construction may include contaminated waste spills (from well construction), hazardous material spills, damage to utilities, environmental releases through wind and storm water erosion, dust generation, physical hazards from heavy equipment, traffic disturbance resulting from construction traffic, and noise. The majority of materials used for remediation would be nonhazardous, and fuel for construction equipment would comprise the bulk of hazardous materials stored on site. Engineering controls and safe work practices would minimize these risks. Discharge of VOCs to the atmosphere would be well below regulatory limits and would not significantly increase risk to the community.

Protection of Workers

Physical hazards from heavy equipment would pose the majority of risk to workers. Workers may also be exposed to contaminated or hazardous materials. Construction work and drilling near utilities would add to worker risks. These risks would be minimized by following safe work practices and using PPE. Engineering controls, such as dust suppression and utility clearance, would further reduce risk to workers.

Environmental Impacts

Groundwater mounding caused by sparging within treatment areas could temporarily affect localized groundwater flow, although this may not have significant implications. Generation of greenhouse gases by construction equipment and personnel vehicles would be the only certain environmental impact during construction. Generation of greenhouse gasses and energy consumption would result in environmental impacts associated with long-term system O&M. Accidental releases of contaminated or hazardous material could also affect the environment, but could be mitigated through good housekeeping and spill prevention and countermeasures.

Time Required to Implement Remedial Action and Achieve RAOs

It is estimated that it will take 6 months to complete pre-design tests and 6 months to complete the design. Once AS/SVE begins, treatment would be performed for 8 years (considered the amount of time needed for contaminant concentrations to decrease) such that residual contamination can dissipate over time without further treatment. Groundwater monitoring would be conducted during this period to evaluate progress. After AS/SVE ends, groundwater would be monitored annually until contaminant concentrations are at or below MCLs. The duration of groundwater monitoring is assumed to be 30 years from the start of AS/SVE operation. It is also assumed that ICs would be in place for a 30-year period.

6.2.2.6 Implementability

The technical and administrative feasibility of implementing Alternative GW-3A and the availability of required resources are discussed below.

Technical Feasibility

Installation of an AS/SVE system would be straightforward. Trenching and installation, conveyance piping, manifolds, and crossing of Morgan's Ditch would be moderately difficult because of the numerous wells.

Administrative Feasibility

In general, Alternative GW-3A is anticipated to meet the requirements of all regulatory agencies. However, developing the details of implementation to the satisfaction of all parties involved (including property owners) may require significant effort. These details may include access to private property, traffic control, obtaining state approval for underground injection control (UIC), location of infrastructure, groundwater monitoring, and contingency measures.

Availability of Required Resources

All materials and services necessary to construct and implement the remedy would be readily available.

6.2.2.7 Cost

The cost estimates in this FS for Alternative GW-3A conservatively assume treatment of groundwater from 15 feet bgs to 60 feet bgs, west of the GMR. This reflects the majority of areas requiring treatment, although some areas in the vicinity of Apex and Bob's Auto buildings would require treatment to shallower depths. Furthermore, the estimated numbers and locations of injection points and remediation wells are approximate and will be refined during the RD after completing pre-design investigations and pilot tests. If found within targeted treatment zones, limited hydraulic conductivity strata would require additional considerations during the RD.

In addition, the estimated remedial timeframes for Alternative GW-3A are based on the RAO of achieving aquifer restoration (MCLs) for the entire plume. These timeframes are conservative estimates based on professional judgment given the historical persistence of the plume.

The estimated cost of Alternative GW-3A (using rounded values) is $4.67 million, including $1.45 million in capital expenses, $2.14 million (present worth) in O&M expenses, and $1.08 million in contingency expenses (30 percent of capital and O&M). The cost estimate and assumptions for Alternative GW-3A are presented in Appendix D.

6.2.2.8 Sustainability

Alternative GW-3A would reduce contaminant mass and would be a significant step toward restoring a sole-source aquifer, removing a threat to the city's water supply, and reducing VI potential. This alternative would be energy intensive and would consume significant quantities of natural resources to attain remediation goals. However, if the remedy was not implemented, future consumption of natural resources to decontaminate the city's water supply for an indefinite duration could be equally significant. With the benefit of remediation outweighing the expense, Alternative GW-3A appears sustainable.

6.2.3 Detailed Analysis of Groundwater Alternative GW-3B: Targeted In Situ Treatment Using ISCO, Institutional Controls, and Monitoring

ISCO would involve injection of oxidants into groundwater within targeted treatment areas. As discussed in Section 5.1.3.2, more than one oxidant could be used. For example, ozone may be used alone or combined with hydrogen peroxide. For developing and evaluating this alternative, ozone sparging was chosen as the representative process option and the need for hydrogen peroxide injection would be determined during the RD. Pre-design investigations and a pilot test would be performed to measure ROI, determine the preferred oxidant and dosage, and observe geochemical effects. ISCO can produce oxidation byproducts which are chemical species that may not be related to the target contaminant. A variety of byproducts can be formed depending on the concentrations of naturally occurring organic matter and various inorganic species. For example, ozonation can produce bromoform or bromates when bromide ion is present (Huang et. al. 2003). Some byproducts degrade faster than others. ISCO would not be used if there is potential for a byproduct to reach the municipal wellfield at a concentration above its tap water screening level. If oxidation byproducts are detected during the pilot test, ISCO would be abandoned and a different technology would be selected.

The ROI used to estimate the number of wells would be measured via pilot testing, as stated in Section 5.1.3. Pilot testing information would also be used to design the wellfield, size ISCO equipment, and determine monitoring well locations. The ISCO system would be designed, operated, and monitored to safeguard against vapor intrusion into structures that may put human health at risk. A conceptual layout of this alternative is shown on Figure 6-2. Details, such as the number and locations of ISCO injection wells and monitoring wells would be refined during the RD. The ISCO alternative outlined in the FS includes assumptions to support the cost estimate which are not intended to define the scope or specify the means and methods to implement this alternative.

To estimate cost, the following assumptions were made. Each ISCO well would include one injector screened at the maximum depth of contamination. The ISCO injection wells would be divided into sections to reduce the size of ISCO equipment needed to operate the wells. The ISCO equipment would be sized for approximately one-sixth of the injection wells. A pre-engineered, automated, trailer-mounted system would generate ozone. A manifold trailer would direct flow from the ISCO equipment to one of six sections of the ISCO injection wells at any given time. As progress slows down, flow would be directed to the next section. Similarly, the entire set of ISCO injection wells would be treated in sequence, targeting one section at a time. The ISCO system may operate one or more months at a time at each section, and the number of times a section is targeted would depend on the extent of contaminant concentration rebound after treatment. ISCO would end when progress becomes asymptotic or when concentrations can be allowed to decline naturally without further treatment. It is assumed that the ISCO system would operate for 6 years, or an average of 1 year per section of ISCO injection wells. After ISCO ceases, contaminant concentrations would gradually decrease to MCLs within 30 years from the start of ISCO. This duration is based on professional judgment given the apparent historical persistence of the plume.

A network of existing and new groundwater monitoring wells would be used to monitor remedial progress. To estimate cost, it is assumed ten new monitoring wells would be installed. Monitoring data would be used to make decisions on the remediation schedule, including sequencing and termination, so that RAOs (see Section 2.1.1) can be attained in 30 years or less.

ICs would restrict use of contaminated groundwater until RAOs have been attained. ICs would involve legal instruments such as covenants (agreements between property owners and agencies) because most of the site is outside city limits and therefore not subject to zoning restrictions or city ordinances.

6.2.3.1 Overall Protection of Human Health and the Environment

Alternative GW-3B would protect human health and the environment because it would clean up groundwater and prevent unintended exposure to contaminated water until remediation goals are attained. There would be minimal risk to the community from physical hazards. There would be some risk of chemical hazards, such as from ozone intrusion into buildings on site, which could be controlled. Workers would face slightly higher risks, which would be reduced by health and safety measures.

6.2.3.2 Compliance with ARARs

Alternative GW-3B would comply with ARARs. Specifically, PCE and benzene levels would be reduced to below MCLs which are chemical-specific ARARs for the site.

6.2.3.3 Long-Term Effectiveness and Permanence

The factors evaluated under long-term effectiveness and permanence, described in Section 6.1.3, are assessed below for Alternative GW-3B.

Magnitude of Residual Risks

After attainment of remediation goals, residual risk would be eliminated. However, factors that could limit effectiveness include (1) fine-grained soils (such as silt and clay) in the saturated zone which would be difficult to remediate by sparging because of preferential flow, and (2) organic matter, which could increase oxidant demand and react to form byproducts. Although challenging, fine-grained soil may be partially remediated by ozone sparging because, even if preferential flow developed, dissolved ozone could migrate outward from the flow path and destroy contaminants in place. Contaminants inaccessible to ozone would not be destroyed.

Adequacy and Reliability of Controls

ISCO may oxidize naturally occurring heavy metals, temporarily mobilizing them. The pilot test would determine whether metals may be mobilized. If metals are mobilized, they would be detected in monitoring wells during monitoring events, and steps could be taken to control migration of metals. These steps could include adjusting oxidant dose, temporarily turning off specific injection wells that may have mobilized metals, or continuing operation if metals are observed to migrate only short distances. In general, design and operational considerations can control metals migration and metals mobilized by ISCO are known to return to their natural insoluble states when oxidation stops. Another concern would be the potential for migration of ozone into nearby buildings, which could be controlled by VI mitigation systems. As an additional protective measure, continuous indoor monitors could also be used to monitor ozone and shut down the remediation system if an unsafe condition is detected. Byproduct formation would not be a significant concern because this technology would not be used if byproducts are observed during the pilot test. ICs would prevent inadvertent exposure by restricting use of contaminated groundwater. Long-term groundwater monitoring would track remedial progress as well as provide information that could be used to optimize the remedy.

6.2.3.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

The ability of Alternative GW-3B to satisfy the evaluation criterion of contaminant toxicity, mobility, or volume through treatment, described in Section 6.1.4, is discussed below.

Destruction of Toxic Hazardous Substances

Alternative GW-3B would mineralize PCE and benzene in targeted treatment areas, producing chloride, carbon dioxide, and water. COC destruction would be irreversible.

Reduction of Total Mass of Toxic Hazardous Substances

Alternative GW-3B would reduce the mass of COCs in groundwater by destroying them.

Irreversible Reduction of Hazardous Substance Mobility

Alternative GW-3B would not reduce the mobility of COCs.

Reduction of Total Volume of Contaminated Media

Alternative GW-3B would reduce the extent of the plume over time, and therefore reduce the volume of contaminated groundwater.

6.2.3.5 Short-Term Effectiveness

The four short-term effectiveness factors described in Section 6.1.5 are assessed below for Alternative GW-3B.

Protection of Community

Risks during construction could include contaminated waste spills (from well construction), hazardous material spills, damage to utilities, environmental releases through wind and storm water erosion, dust generation, physical hazards from heavy equipment, traffic disturbance resulting from construction traffic, and noise. Ozone is a hazardous material, presenting some potential risk to nearby buildings. This risk would be minimized through engineering controls.

Protection of Workers

Physical hazards from heavy equipment would pose the majority of risk to workers. Workers could also be at risk of exposure to contaminated materials and ozone. Earthmoving and drilling near utilities would add to worker risks. These risks would be minimized by following safe work practices and using PPE. Engineering controls, such as dust suppression and utility clearance, would further reduce risk to workers.

Environmental Impacts

Generation of greenhouse gases by construction equipment and personnel vehicles would be the only certain environmental impact. Accidental releases of contaminated or hazardous material could also affect the environment but could be mitigated through good housekeeping and spill prevention and countermeasures.

Time Required for Implementation of the Remedial Action and to Achieve RAOs

It is estimated that it will take 6 months to complete pre-design tests and 6 months to complete the design. Once ozone sparging begins, it is estimated that it would be performed for 6 years (that is, 1 year in each of five assumed remediation wellfield sections) such that residual contamination can dissipate over time without further treatment. Groundwater monitoring would be conducted during this period to evaluate progress. After treatment ends, groundwater would be monitored annually until contaminant concentrations are at or below MCLs. The duration of groundwater monitoring is assumed to be 30 years from the start of ISCO. It is also assumed that ICs would be in place for 30 years.

6.2.3.6 Implementability

The technical and administrative feasibility of implementing Alternative GW-3B and the availability of required resources are discussed below.

Technical Feasibility

Installation of ISCO wells would be straightforward. Trenching and installation, conveyance piping, manifolds, and crossing of Morgan's Ditch would be moderately difficult because of the numerous wells.

Administrative Feasibility

In general, Alternative GW-3B is anticipated to meet the requirements of all regulatory agencies. However, developing the details of implementation to the satisfaction of all parties involved would require significant effort. These details may include access to private property, traffic control, state approval for UIC, location of infrastructure, groundwater monitoring, and contingency measures.

Availability of Required Resources

All resources would be readily available. Longer lead times may be necessary for procurement of ISCO equipment. All materials necessary to construct and implement the remedy would also be readily available.

6.2.3.7 Cost

The cost estimates in this FS for Alternative GW-3B conservatively assume treatment of groundwater from 15 feet bgs to 60 feet bgs, west of the GMR. This reflects the majority of areas requiring treatment, although some areas in the vicinity of Apex and Bob's Auto buildings would require treatment to shallower depths. Furthermore, the estimated numbers and locations of injection points and/or remediation wells are approximate and would be refined during the RD after completing pre-design investigations and pilot tests. If found within targeted treatment zones, limited hydraulic conductivity strata would require additional considerations during the RD.

In addition, the estimated remedial timeframes for Alternative GW-3B are based on the RAO of achieving aquifer restoration (MCLs) for the entire plume. These timeframes are conservative estimates based on professional judgment given the historical persistence of the plume.

The estimated cost of Alternative GW-3B (using rounded values) is $6.06 million, including $2.61 million in capital expenses, $2.05 million (present worth) in O&M expenses, and $1.40 million in contingency expenses (30 percent of capital and O&M). The cost estimate and assumptions for Alternative GW-3B are presented in Appendix D.

6.2.3.8 Sustainability

Alternative GW-3B would reduce contaminant mass and would also be a significant step toward restoring a sole-source aquifer, removing a threat to the city's water supply, and reducing VI potential. This alternative would be energy intensive and would consume significant quantities of natural resources to attain remediation goals. However, if the remedy is not implemented, future consumption of natural resources to decontaminate the city's water supply for an indefinite duration could be equally significant. With the benefit of remediation outweighing the expense, Alternative GW-3B appears sustainable.

6.2.4 Detailed Analysis of Groundwater Alternative GW-3C: Targeted In Situ Treatment Using Aerobic Bioremediation, Institutional Controls, and Monitoring

Aerobic bioremediation would involve bioaugmentation and biostimulation. Bioaugmentation would involve injection of a proprietary formulation of *Pseudomonas* microorganisms, which are known to cometabolically degrade PCE and less chlorinated ethenes under aerobic conditions. Biostimulation would involve injection of an electron donor (dextrose) and an electron acceptor amendment (such as an oxygen-releasing chemical) to provide a food source and create aerobic conditions. Apart from stimulating aerobic degradation, aerobic conditions would also discourage anaerobic degraders that produce PCE daughter products such as vinyl chloride.

Microbial cultures and amendments could be injected into groundwater via permanent wells or through temporary boreholes. As indicated in Section 5.1.3, to develop this alternative, it is assumed that pressurized injections would be performed using temporary boreholes. The number of temporary boreholes or injection points would be verified during the RD. Also, as indicated in Section 5.1.3, pre-design investigations and a pilot test would be performed to gather site-specific information, including ROI and required amendment dosage. A conceptual layout of this alternative is shown on Figure 6-3. Details, such as the number and locations of injection points, are assumptions used to support the cost estimate and are not intended to define the scope or specify the means and methods to implement this alternative.

To estimate cost, the following assumptions were made. Three injection events would take place and each subsequent event would target a 20 percent smaller area. Direct-push drilling technology would be used to inject microbes and amendments under pressure. At each location, injection would target multiple vertical intervals below the water table. Injection would commence approximately 15 feet bgs and proceed in 2-foot vertical increments to a total depth of 60 feet bgs. (Targeted depth may vary by location and would be refined during the RD.) First, the electron acceptor amendment would be injected, then the microbes and electron donor would be injected. At locations where cobbles prevent advancement of direct push tooling, a different drilling method (such as sonic drilling) would be used. After injection is complete, the borehole would be plugged and abandoned. The injections would stimulate aerobic degradation of contaminants for 3 to 6 months. PCE would be degraded by the injected microorganisms, and benzene would be degraded by native microorganisms. PCE concentrations are expected to rebound after treatment because of matrix diffusion and desorption. Therefore, additional treatments would be necessary, although the area targeted would be smaller each time. It is assumed that there would be three annual injection events for 3 years, after which residual contaminant concentrations would decline, attaining MCLs within 30 years from the start of bioremediation. This duration is based on professional judgment given the apparent historical persistence of the plume.

A network of existing and new groundwater monitoring wells would be used to monitor remedial progress. To estimate cost, it is assumed ten new wells would be installed. Monitoring data would be used to make decisions on the remediation schedule including sequencing and termination, so that RAOs (see Section 2.1.1) can be attained in 30 years or less.

ICs would restrict use of contaminated groundwater until RAOs have been attained. ICs would involve legal instruments such as covenants (agreements between property owners and agencies) because most of the site is outside city limits and therefore not subject to zoning restrictions or city ordinances.

6.2.4.1 Overall Protection of Human Health and the Environment

Alternative GW-3C would protect human health and the environment because it would clean up groundwater and prevent unintended exposure to contaminated water, via ICs, until remediation goals are attained. There would be minimal risk to the community from physical hazards or chemical exposure during remediation. Commercial truck traffic would be minimal because of the relatively small quantity of materials to be transported to and from the site, resulting in only minor disruptions to local traffic and some potential risk to the public from spills on public roads. Workers would face a slight risk from exposure to dust from remediation chemicals, but this risk would be reduced by implementing health and safety measures.

6.2.4.2 Compliance with ARARs

Alternative GW-3C would comply with ARARs. Specifically, PCE and benzene levels would attain MCLs, which are chemical-specific ARARs for the site.

6.2.4.3 Long-Term Effectiveness and Permanence

The factors evaluated under long-term effectiveness and permanence, described in Section 6.1.3, are assessed below for Alternative GW-3C.

Magnitude of Residual Risks

Although pressurized injections in discrete vertical intervals would increase access to contaminants trapped in fine-grained soils (such as silt and clay), treatment would only partially deplete the contaminant mass leaving residual concentrations to slowly decline over time. However, after MCLs are attained in the long term, there would be no residual risk.

Adequacy and Reliability of Controls

ICs would prevent inadvertent exposure by restricting use of contaminated groundwater. Long-term groundwater monitoring would track remedial progress as well as provide information that could be used to optimize the remedy. Preliminary analysis based on quantities developed for the cost estimate indicate that it is highly unlikely that byproducts, remediation chemicals, or accompanying geochemical effects could migrate to the municipal wellfield. The small potential risk of migration would be short-lived, lasting up to one year after treatment because the remediation chemicals would have short lifespans in the subsurface. Some reduction in formation permeability could occur if solid peroxides are used as an oxygen source. Pilot testing and post-treatment groundwater monitoring would be used to refine predictions and improve performance of subsequent treatment events. The primary control against unwanted effects would be a careful design employing iterative refinements because few corrective measures could intercept unwanted effects migrating toward the municipal wellfield after the remediation chemicals have been injected into groundwater.

Amendment injections would also cause minor plume dilution. If the volume of amendments injected per event is less than 10 percent of the pore volume of the targeted treatment area, the resulting dilution of COC concentrations within this area would be less than 9 percent (because plume volume would increase by 10 percent but COC mass would not change). Plume dilution would be controlled by limiting amendment injection volume to 10 percent of the target pore volume per injection event.

6.2.4.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

The ability of Alternative GW-3C to satisfy the evaluation criterion of contaminant toxicity, mobility, or volume through treatment, described in Section 6.1.4, is discussed below.

Destruction of Toxic Hazardous Substances

Alternative GW-3C would mineralize some fraction of PCE and benzene in targeted treatment areas, producing chloride, carbon dioxide and water. Destruction of COCs would be irreversible.

Reduction of Total Mass of Toxic Hazardous Substances

Alternative GW-3C would reduce the mass of COCs in groundwater by destroying them.

Irreversible Reduction of Hazardous Substance Mobility

Alternative GW-3C would not reduce the mobility of COCs but would displace contaminated groundwater. Subsurface injection of liquid amendments would displace groundwater as the amendments are forced into saturated pore space. The volume of groundwater displaced would be equal to the volume of amendments injected. Assuming the volume of amendments injected during an event is less than 10 percent of the pore volume of the target zone, less than 10 percent of the groundwater would be displaced.

Reduction of Total Volume of Contaminated Media

Alternative GW-3C would reduce the extent of the plume over time, and therefore reduce the volume of contaminated groundwater through treatment.

6.2.4.5 Short-Term Effectiveness

The four short-term effectiveness factors described in Section 6.1.5 are assessed below for Alternative GW-3C.

Protection of Community

Risks during construction may include contaminated waste spills (from well construction), hazardous material spills (such as remediation chemicals), damage to utilities, environmental releases through wind and storm water erosion, dust generation, physical hazards from heavy equipment, traffic disturbance resulting from construction traffic, and noise. Of chemicals that could be spilled on public roads, oxygen-releasing chemicals would pose the most threat. However, this risk is considered low because oxygen-releasing chemicals would be transported in solid form and would be packaged, requiring a major collision to breach containment provided by the truck enclosure and packaging. Fuel for construction equipment would comprise the bulk of hazardous materials stored on site. Engineering controls and safe work practices would minimize these risks.

Protection of Workers

Physical hazards from heavy equipment would pose most of the risk to workers. Workers may also be exposed to contaminated or hazardous materials. Drilling near utilities would add to worker risks. These risks would be minimized by following safe work practices and using PPE. Engineering controls, such as dust suppression and utility clearance, would further reduce risk to workers.

Environmental Impacts

Generation of greenhouse gases by construction equipment and personnel vehicles would be the only certain environmental impact. Accidental releases of contaminated or hazardous material could also affect the environment.

Time Required to Implement Remedial Action and Achieve RAOs

It is estimated that it will take 6 months to complete pre-design tests and 6 months to complete the design. Once aerobic bioremediation begins, it is estimated that it would be performed for 3 years, within which time contaminant concentrations would decrease enough that residual contamination could dissipate over time without further treatment. Groundwater monitoring would be conducted during this period to evaluate progress. After treatment ends, groundwater would be monitored annually until contaminant concentrations are at or below MCLs. The duration of groundwater monitoring is assumed to be 30 years from the start of bioremediation. It is also assumed that ICs would be in place for 30 years. This duration is based on professional judgment given the apparent historical persistence of the plume.

6.2.4.6 Implementability

The technical and administrative feasibility of implementing Alternative GW-3C and the availability of required resources are discussed below.

Technical Feasibility

Injection of microorganisms and amendments would be straightforward. Minimizing surfacing (escape of amendments to the surface during injection) would be a minor challenge because of the numerous injection points. Surfacing is common and is not a hazard; however, surfacing is undesirable because materials are wasted and targeted areas do not receive the necessary dose. Surfacing can be controlled by adjusting injection volumes, reducing flow rates, or altering injection methods. Avoiding buried utilities would also be a minor challenge. Subsurface utilities within targeted treatment areas would be located prior to remedial action, and injections would be performed at a safe distance from these utilities.

Administrative Feasibility

In general, Alternative GW-3C is anticipated to meet the requirements of all regulatory agencies. However, developing the details of implementation to the satisfaction of all parties involved would require significant effort. These details may include access to private property, traffic control, state approval for UIC, groundwater monitoring, and contingency measures.

Availability of Required Resources

All materials necessary to construct and implement the remedy would also be readily available.

6.2.4.7 Cost

The cost estimates in this FS for Alternative GW-3C conservatively assume treatment of groundwater from 15 feet bgs to 60 feet bgs, west of the GMR. This reflects most areas requiring treatment, although some areas in the vicinity of Apex and Bob's Auto buildings would require treatment to shallower depths. Furthermore, the estimated numbers and locations of injection points and/or remediation wells are approximate and would be refined during the RD after completing pre-design investigations and pilot tests. Low hydraulic conductivity strata would require additional considerations during the RD.

In addition, the estimated remedial timeframe for Alternative GW-3C is based on the RAO of achieving aquifer restoration (MCLs) for the entire plume. This is a conservative estimate based on professional judgment given the historical persistence of the plume.

The estimated cost of Alternative GW-3C (using rounded values) is $5.93 million, including $1.71 million in capital expenses, $2.85 million (present worth) in O&M expenses, and $1.37 million in contingency expenses (30 percent of capital and O&M). The cost estimate and assumptions for Alternative GW-3C are presented in Appendix D. The cost of this alternative would increase if more than three treatment events are necessary.

6.2.4.8 Sustainability

Alternative GW-3C would reduce contaminant mass and would be a significant step toward restoring a sole-source aquifer, removing a threat to the city's water supply, and reducing VI potential. This alternative would be less energy intensive than Alternatives GW-3A and GW-3B. However, if the remedy is not implemented, future consumption of natural resources to decontaminate the city's water could be more significant than the demands of the remedy. With the benefit of remediation outweighing the expense, Alternative GW-3C appears sustainable.

6.2.5 Groundwater Alternative GW-4: Extraction, Treatment, and Discharge in Combination with Institutional Controls and Monitoring

Alternative GW-4 would actively remediate the plume using a pump-and-treat system. A conceptual layout of this alternative is shown on Figure 6-4. Details, such as the number and locations of wells, are assumptions used to support the cost estimate and are not intended to define the scope or specify the means and methods to implement this alternative.

This alternative would involve installation of groundwater extraction wells, transfer piping, a treatment system, and a treated water outfall. This alternative would target the plume west of the GMR, hydraulically containing and cleaning up groundwater through continuous extraction and treatment. While the remedy is operating, ICs would prevent potential human exposure to contaminated groundwater. To develop this remedy, the number of extraction wells, locations, and flow rates have been estimated (without modeling) based on RI information only. It is assumed that four extraction wells pumping at 20 gpm each (80 gpm total) would be installed. Designing the remedy would require additional aquifer testing and groundwater sampling for water quality parameters relating to corrosiveness and precipitate/scale formation. Groundwater modeling would be performed during the RD to simulate groundwater capture zones and refine the number, locations, and depths of the extraction wells, and the required flow rates.

Air stripping is the representative process option for treating extracted groundwater, although carbon adsorption may also be considered during the RD. Treated water would likely be discharged to Morgan's Ditch (which flows to the GMR).

Active remediation would be complete when PCE and benzene concentrations are permanently reduced below their target concentrations (MCLs).

A network of existing and new groundwater monitoring wells would be used to monitor remedial progress. To estimate cost, it is assumed ten new wells would be installed. Monitoring data would be used to make decisions on the remediation schedule, including sequencing and termination, so that RAOs (see Section 2.1.1) can be attained in 30 years or less.

ICs would restrict use of contaminated groundwater until RAOs have been attained. ICs would involve legal instruments such as covenants (agreements between property owners and agencies) because most of the site is outside city limits and therefore not subject to zoning restrictions or city ordinances.

6.2.5.1 Overall Protection of Human Health and the Environment

Alternative GW-4 would extract contaminated groundwater and remediate the contaminant plume via pump-and-treat technology. Once groundwater is cleaned up, there would no longer be a threat to human health and the environment.

6.2.5.2 Compliance with ARARs

Alternative GW-4 would comply with ARARs. Specifically, PCE and benzene would attain MCLs and water discharged by the treatment system would comply with applicable surface water quality standards.

6.2.5.3 Long-Term Effectiveness and Permanence

The factors evaluated under long-term effectiveness and permanence, described in Section 6.1.3, are assessed below for Alternative GW-4.

Magnitude of Residual Risks

After remediation goals are attained, residual risk would be eliminated. However, it could take an unreasonably long duration to attain remediation goals because of contaminants trapped in fine-grained soils (such as silt and clay) in the saturated zone, which would not be easily remediated by pump-and-treat technology.

Adequacy and Reliability of Controls

Groundwater extraction would protect the municipal wells through hydraulic containment of the plume on site. ICs would prevent inadvertent exposure by restricting use of contaminated groundwater. Long-term groundwater monitoring would track remedial progress as well as provide information that could be used to optimize the remedy.

6.2.5.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

The ability of Alternative GW-4 to satisfy the evaluation criterion of contaminant toxicity, mobility, or volume through treatment, described in Section 6.1.4, is discussed below.

Destruction of Toxic Hazardous Substances

Alternative GW-4 would not destroy COCs. If air stripping is used to treat extracted groundwater, this alternative would remove contaminants from groundwater and transfer them to the atmosphere, where they would eventually be destroyed by natural processes (such as photooxidation). Benzene may also naturally biodegrade in groundwater.

Reduction of Total Mass of Toxic Hazardous Substances

Alternative GW-4 would not reduce the total mass of hazardous substances through treatment because contaminants would merely be transferred from one phase to another.

Irreversible Reduction of Hazardous Substance Mobility

Alternative GW-4 would not reduce the mobility of contaminants in groundwater but would prevent migration of contaminated groundwater within the treatment zone through hydraulic capture.

Reduction of Total Volume of Contaminated Media

As remediation progresses, the volume of contaminated groundwater would decrease. However, this may not be considered a reduction in volume through treatment because contaminants are merely transferred from one phase to another.

6.2.5.5 Short-Term Effectiveness

The four short-term effectiveness factors described in Section 6.1.5 are assessed below for Alternative GW-4.

Protection of Community

Risks during construction may include contaminated waste spills (from well construction), hazardous material spills, damage to utilities, environmental releases through wind and storm water erosion, dust generation, physical hazards from heavy equipment, traffic disturbance resulting from construction traffic, and noise. Engineering controls and safe work practices would minimize these risks. During system operation, contaminant vapors would be discharged to the atmosphere if air stripping is used to treat extracted groundwater. These vapors would be monitored and discharged in accordance with federal and state requirements and would not pose a significant risk.

Protection of Workers

Physical hazards from heavy equipment would pose the majority of risk to workers. Workers may also be exposed to contaminated or hazardous materials. Earth-moving equipment and drilling activities near buried or overhead utilities may add to worker risks. These risks would be minimized by following safe work practices, conducting utility surveys prior to any intrusive work, and using PPE. Engineering controls, such as dust suppression and utility clearance, would further reduce risk to workers.

Environmental Impacts

Generation of greenhouse gases by construction equipment and personnel vehicles would be the only certain environmental impact. Accidental releases of contaminated or hazardous material could also affect the environment. Best management practices such as storm water management, constructing silt fencing, etc. would be used to minimize potential impacts to the environment during construction.

Time Required for Remedial Action

It is estimated that it will take 6 months to complete pre-design tests and 6 months to complete the design. Once groundwater extraction and treatment begin, it would be performed for 30 years. Groundwater monitoring would be conducted during this period to evaluate remedial progress. Groundwater would be monitored until contaminant concentrations are at or below MCLs, with an assumed duration of 30 years. It is also assumed that ICs would be in place for a 30-year period. Pump-and-treat remediation is generally not effective in cleaning up groundwater within fine-grained soils contaminated with organic compounds; therefore, this alternative may take longer than 30 years to attain MCLs.

6.2.5.6 Implementability

The technical and administrative feasibility of implementing Alternative GW-4 and the availability of required resources are discussed below.

Technical Feasibility

Construction of the extraction and treatment system would be straightforward. The treatment system would easily meet surface water and atmospheric discharge requirements.

Administrative Feasibility

In general, Alternative GW-4 is anticipated to meet the requirements of all regulatory agencies. However, developing the details of implementation to the satisfaction of all parties involved would require significant effort. These details may include access to private property, traffic control, location of infrastructure, groundwater monitoring requirements, and contingency measures.

Availability of Required Resources

All materials necessary to construct and implement the remedy would also be readily available.

6.2.5.7 Cost

For Alternative GW-4, the cost estimate assumes that extraction wells would be used to extract groundwater from the aquifer and extracted water would be conveyed through piping to an air stripper. This alternative also assumes that the treated water would be discharged to Morgan’s Ditch, which discharges to the GMR. The exact numbers, locations, depths, and pumping rates of extraction wells would be refined during the RD after completing pre-design investigations.

The timeframe to attain remediation goals was assumed at 30 years, although as stated in Section 6.2.5.5, it could take longer. Operation beyond 30 years would increase the O&M cost associated with this alternative.

The estimated cost of Alternative GW-4 (using rounded values) is $4.62 million, including $0.95 million in capital expenses, $2.61 million (present worth) in O&M expenses, and $1.07 million in contingency expenses (30 percent of capital and O&M). The cost estimate and assumptions for Alternative GW-4 are presented in Appendix D.

6.2.5.8 Sustainability

Alternative GW-4 would restore a natural resource (a sole-source aquifer) and remove a threat to the city's water supply. This alternative would be energy intensive (long-term continuous operation of pumps and air stripper blower) and would consume significant quantities of natural resources to attain remediation goals. However, if the remedy is not implemented, future consumption of natural resources to decontaminate the city's water could be equally significant. With the benefit of remediation outweighing the expense, Alternative GW-4 appears sustainable.

6.3 DETAILED ANALYSIS OF PRIVATE WELL ALTERNATIVES

The alternatives presented in this section apply only to the private well at the Apex Racing property because Bob's Auto (the property at 507 N. Elm Street) is already connected to the City of Troy municipal water system.

Three remedial alternatives to address the private well at the Apex Racing property are described in Section 5.2. A detailed analysis of each alternative is presented below. Evaluation sub-criteria not relevant to the private well alternatives have been omitted. Table 6-2 provides a summary of the detailed analysis of private well alternatives.

6.3.1 Private Well Alternative PR-1: No Action

Alternative PR-1 would take no action to address the affected private well on the Apex Racing property at the site.

6.3.1.1 Overall Protection of Human Health and the Environment

Alternative PR-1 would not protect human health or the environment because nothing would be done to control existing risks. Although the property owner at Apex informed EPA that the occupants do not drink the water obtained from their private well, PCE in the private well recorded at a concentration of about 10 µg/L (above its MCL of 5 µg/L) would be a potential threat to current and future occupants.

6.3.1.2 Compliance with ARARs

Alternative PR-1 would not comply with chemical-specific ARARs.

6.3.1.3 Long-Term Effectiveness and Permanence

Alternative PR-1 would not be effective in the long term because the Apex property would continue to receive contaminated water. The potential for human exposure to contaminants in well water would remain.

6.3.1.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

This alternative does not involve treatment and would not reduce toxicity, mobility, or volume of contaminants through treatment.

6.3.1.5 Short-Term Effectiveness

The alternative would not pose new health risks to the community, current site occupants, workers, or the environment because Alternative PR-1 involves no remedial activities or construction; however, existing risk would continue.

6.3.1.6 Implementability

Alternative RW-1 would not require resources or specialized labor and would therefore be easy to implement, but it would not achieve RAOs. It would not be administratively feasible because it would not receive regulatory approval.

6.3.1.7 Cost

No capital or O&M costs are associated with Alternative RW-1.

6.3.1.8 Sustainability

This alternative would not consume any energy and would conserve energy sources. On the other hand, it would not protect human health and would therefore be unsustainable.

6.3.2 Private Well Alternative PR-2: Treatment and Monitoring

Alternative PR-2 would treat well water using a POE filter. The POE filter would be a pre-engineered whole-house filter designed to remove organic contaminants. The filter would be installed inside the building at the point of entry. To develop this alternative, the POE filter is assumed to consist of an activated carbon filter and a sediment filter. To estimate cost, it is assumed that two activated carbon units would be used in series in lead/lag configuration. At any given moment, one unit would be essentially the lead unit and the other would operate as a backup. Treated water would be periodically sampled, and when PCE is detected in the discharge from the lead unit, expended media would be replaced, and the lag unit turned into the lead unit. This process of testing, media changeout and lead/lag switching would continue until PCE concentration in the private well is below its MCL. Each carbon filter would be sized to require replacement no more than once every 2 years. The sediment filter would be replaced every 6 months. Influent to the treatment system and effluent from the treatment system would be sampled annually to monitor concentrations and performance. This alternative would not be compatible with groundwater remedial alternatives that alter water quality during remediation. Therefore, Alternative PR-2 could only be used with groundwater remediation Alternatives GW-1 or GW-4. To estimate cost, it is assumed that the POE filter would operate for 10 years, within which time groundwater remediation Alternative GW-4 is assumed to clean up groundwater near the Apex private well.

Additional cost assumptions are provided in Appendix D.

6.3.2.1 Overall Protection of Human Health and the Environment

Alternative PR-2 would protect human health because it would deliver clean water to the Apex property. There would also be some environmental benefit because contaminated well water would not be discharged to the sewer system via the Apex property.

6.3.2.2 Compliance with ARARs

Alternative PR-2 would comply with chemical-specific ARARs.

6.3.2.3 Long-Term Effectiveness and Permanence

Alternative PR-2 would be effective in the long term because it would supply clean water to the property, reducing the potential for exposure to contaminated well water. This alternative is a temporary solution and its reliability depends on proper operation and maintenance of the POE filter. Annual monitoring of the POE filter would ensure that it is performing as expected.

6.3.2.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Alternative PR-2 would treat private well water by immobilizing the contaminant.

6.3.2.5 Short-Term Effectiveness

The alternative would not pose new risks to the community, property occupants, or the environment. Workers would face some risk of exposure to contaminated water during filter installation and maintenance, which could be minimized through use or PPE.

6.3.2.6 Implementability

Materials and services for POE filter installation would be readily available, and the installation would be straightforward. Alternative PR-2 is technically feasible, although it could only be implemented with groundwater remedial alternatives that do not alter geochemistry. It would also comply with ARARs and would therefore be administratively feasible.

6.3.2.7 Cost

The estimated cost of Alternative PR-2 is $55,000, including $24,000 in capital expenses, $18,000 (present worth) in O&M expenses, and $13,000 in contingency expenses (30 percent of capital and O&M). The cost estimate and assumptions for Alternative PR-2 are presented in Appendix D.

6.3.2.8 Sustainability

Alternative PR-2 would not consume energy during treatment, but would require periodic maintenance, and would general spent media waste for a long duration. Therefore, overall, this alternative would rate moderate for sustainability.

6.3.3 Private Well Alternative PR-3: Connect to City Water and Abandon Private Well

Alternative PR-3 involves connecting the building to a public (municipal) water distribution system and abandoning the existing private well. The Apex property is outside city limits and would need to be annexed by the city. It is assumed that the property owners would agree to annexation. A conceptual layout of this alternative is shown on Figure 6-5; details such as the location and point of connection are merely assumptions to support the cost estimate and are not intended to define the scope or specify the means and methods to implement this alternative.

To develop this alternative, it is assumed that a new water supply lateral would be installed from the city water main to the Apex property. The lateral would be installed via horizontal drilling below the street. Connecting the lateral to the main would involve work in a right-of-way, requiring a permit and traffic control. Soil would be excavated to access the lateral, the lateral would be connected to the main, then the excavation would be backfilled and restored to existing conditions. On the Apex property, the private well would be plugged and abandoned and the new lateral would be connected to the discharge pipe from the abandoned private well. A new meter would be installed to monitor usage.

6.3.3.1 Overall Protection of Human Health and the Environment

Alternative PR-3 would protect human health because it would deliver clean water to the Apex property. There would also be some environmental benefit because contaminated well water would not be discharged to the sewer system via the Apex property.

6.3.3.2 Compliance with ARARs

Alternative PR-3 would comply with chemical-specific ARARs.

6.3.3.3 Long-Term Effectiveness and Permanence

Alternative PR-3 would be effective in the long term because it would supply clean water to the property, reducing the potential for exposure to contaminated well water. This alternative is a permanent solution, requires no operation, maintenance, or monitoring.

6.3.3.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Alternative PR-3 would not reduce toxicity, mobility, or volume of contaminants through treatment.

6.3.3.5 Short-Term Effectiveness

The alternative would not pose risks to property occupants or the environment. Workers would face short-term risk excavation, working in a right-of-way, and drilling activities associated with private well abandonment. Worker risks could be minimized through health and safety measures.

6.3.3.6 Implementability

Installing a municipal water lateral is moderately easy and the materials, equipment and services needed to complete the work would be readily available. Therefore, the alternative is technically feasible. Local permits to complete the work would be obtainable. However, to qualify for city water service, the Apex property would need to be annexed by the City of Troy. This has legal implications and would require consent by the property owner. The administrative feasibility of this alternative would therefore depend on property owner consent.

6.3.3.7 Cost

The estimated cost of Alternative PR-3 is $47,000, including $36,000 in capital expenses, $0 (present worth) in O&M expenses, and $11,000 in contingency expenses (30 percent of capital and O&M). The cost estimate and assumptions for Alternative PR-3 are presented in Appendix D.

6.3.3.8 Sustainability

After the initial effort to install and connect the lateral, Alternative PR-3 would not require energy to operate and would conserve energy resources. Therefore, overall, this alternative would rate high for sustainability.

6.4 DETAILED ANALYSIS OF ALTERNATIVES FOR VAPOR INTRUSION

There is no current VI risk. Alternatives for VI are intended to address potential VI associated with future hypothetical residential use of the site. There are no residential buildings on site, nor are there plans for such buildings. As a result, it is not appropriate to develop alternatives involving engineering controls for VI mitigation. Therefore, the VI remedial alternatives evaluated for the WTCA site include: (1) no action and (2) ICs and monitoring (that is, monitoring compliance with ICs). A detailed analysis of these alternatives is presented below. Evaluation sub-criteria not relevant to VI alternatives have been omitted. Table 6-3 provides a summary of the detailed analysis of VI alternatives.

6.4.1 Soil Vapor Alternative VI-1: No Action

The no action alternative provides a baseline that can be used to compare other alternatives. Under Alternative VI-1, no action would be taken to address potential future VI at the WTCA site. There would be no site use restrictions or monitoring.

6.4.1.1 Overall Protection of Human Health and the Environment

Alternative VI-1 would not eliminate, reduce, or control future risks to human health or the environment posed by soil vapor. Site use could change in the future, and if residential buildings are built on contaminated areas, VI may pose unacceptable risk to the occupants. This risk would not be quantifiable because the site would not be monitored.

6.4.1.2 Compliance with ARARs

Alternative VI-1 would not comply with chemical-specific ARARs under a future residential land-use scenario.

6.4.1.3 Long-Term Effectiveness and Permanence

Alternative VI-1 would not be effective in the long term if contaminated areas are used for residential developments without restrictions. Future building occupants may not be protected if the groundwater is still contaminated and contaminant vapors migrate into future buildings. There would be no monitoring or other controls to evaluate or reduce risk.

6.4.1.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

There would be no treatment and therefore no reduction in contaminant toxicity, mobility, or volume through treatment.

6.4.1.5 Short-Term Effectiveness

The alternative would not pose new health risks to the community, current site occupants, workers, or the environment because Alternative VI-1 involves no remedial activities or construction.

6.4.1.6 Implementability

No construction or other activities would be required to implement Alternative VI-1; therefore, the alternative is technically feasible. However, it would not receive regulatory approval and would therefore not be administratively feasible.

6.4.1.7 Cost

No capital or O&M costs are associated with Alternative VI-1.

6.4.1.8 Sustainability

Implementation of this alternative does not require any construction equipment or material use. Under this alternative, there is no waste production, no use of natural resources or energy, and no air pollutant or greenhouse gas production. However, this alternative would not protect human health, reducing the overall sustainability of this alternative.

6.4.2 Soil Vapor Alternative VI-2: Institutional Controls and Monitoring

Alternative VI-2 would use ICs to require VI mitigation and VI monitoring if buildings are constructed for residential use in contaminated areas. Future developers would be responsible for VI mitigation and VI monitoring. EPA or the state would be responsible for general site monitoring (including inspections and review of reports) to evaluate compliance with ICs.

It is assumed that ICs would be restrictive covenants unless other legal instruments are available. Portions of the site are outside city limits and therefore not subject to zoning or ordnances.

General site monitoring would consist of periodic site visits to assess any changes in land use, inspect engineering controls, and review VI mitigation reports submitted by property owners.

6.4.2.1 Overall Protection of Human Health and the Environment

VI is not a threat to the environment. Alternative VI-2 would protect human health because ICs would require controls to protect future building occupants at risk, and ICs would allow EPA or the state to ensure that these controls are being implemented properly.

6.4.2.2 Compliance with ARARs

Alternative VI-2 would comply with chemical-specific ARARs by placing restrictions on future residential land use at the site.

6.4.2.3 Long-Term Effectiveness and Permanence

Alternative VI-2 would be effective in the long term because ICs would require VI mitigation controls to be maintained indefinitely as long as there is risk to future building occupants. ICs would also require monitoring of these controls to ensure that they remain effective. The effectiveness of controls would depend on proper operation and maintenance.

6.4.2.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

ICs could indirectly reduce contaminant toxicity, mobility, and volume depending on the technology used to comply with the IC. However, such reduction is unlikely if current VI mitigation technologies are used.

6.4.2.5 Short-Term Effectiveness

Alternative VI-2 would not pose new health risks to the community, current site occupants, workers, or the environment because placement of legal restrictions does not involve remedial activities or construction.

6.4.2.6 Implementability

No construction or other activities would be required to implement this alternative; therefore, the alternative is technically feasible. The administrative feasibility may depend on the willingness of property owners to enter into restrictive covenants.

6.4.2.7 Cost

The estimated cost of Alternative VI-2 is $105,000, including $44,000 in capital expenses, $37,000 (present worth) in O&M expenses, and $24,000 in contingency expenses (30 percent of capital and O&M). The cost estimate for Alternative VI-2 is presented in Appendix D.

6.4.2.8 Sustainability

Applying legal restrictions does not require any construction equipment or material use. Under this alternative, there is no waste production, use of natural resources and energy, air pollutants and greenhouse gas production. However, if ICs necessitate future construction, operation and maintenance, these activities would consume energy and natural resources. In general, this alternative rates high for sustainability because the likelihood of future energy-intensive actions is low.

7.0 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

The final element of this FS presents a comparative analysis of alternatives conducted in accordance with CERCLA guidance (EPA 1988a). As previously noted, two CERCLA threshold criteria and five primary balancing criteria were considered in the comparative analysis. The two CERCLA modifying criteria of state acceptance and community acceptance are reserved for consideration after the public comment period. An eighth criterion for sustainability of the alternatives was also considered. The evaluation criteria are described in Section 6.1 but are listed below for reference.

Threshold criteria (CERCLA criteria):

- Overall protectiveness of human health and the environment
- Compliance with ARARs

Primary balancing criteria (CERCLA criteria):

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost

Modifying criteria (CERCLA criteria – reserved for use after the public comment period):

- State acceptance
- Community acceptance

Additional criterion:

- Sustainability

Threshold and primary balancing criteria are evaluated in this section. The two modifying criteria (state acceptance and community acceptance) will be evaluated after comments are received on this FS report and the proposed plan, and the criteria will be addressed in the Record of Decision (ROD). A comparative analysis of modifying criteria is therefore not presented in this FS report.

The sustainability criterion is also compared in this section. While sustainability is an important consideration in selecting the correct alternative, the sustainability comparison is not part of the

CERCLA-mandated evaluation process. Instead, the intent is to simply consider the sustainability of an alternative when assessing equally feasible alternatives.

7.1 COMPARATIVE ANALYSIS OF GROUNDWATER ALTERNATIVES

The following five remedial alternatives for the groundwater are compared below under seven CERCLA evaluation criteria.

GW-1	No Action
GW-3A	Targeted In Situ Treatment Using Air Sparging and SVE, ICs, and Monitoring
GW-3B	Targeted In Situ Treatment Using ISCO, ICs, and Monitoring
GW-3C	Targeted In Situ Treatment Using Aerobic Bioremediation, ICs, and Monitoring
GW-4	Extraction, Treatment, and Discharge in Combination with ICs and Monitoring

Although alternatives are evaluated individually here, combinations of Alternatives GW-3A, GW-3B, and GW-3C could be considered during the RD if combining technologies would improve performance or reduce cost. A comparative analysis of the groundwater alternatives is presented below.

7.1.1 Overall Protection of Human Health and the Environment

The persistence of the low-concentration contaminant plume is attributed to mass transfer from low-permeability soils. Therefore, treating these low-permeability soils is essential to achieving cleanup. While all alternatives would perform equally well in permeable soils, injection via direct-push techniques offers better access to contamination in low-permeability soils. Therefore, Alternative GW-3C is expected to deplete more contaminant mass from low-permeability soils than other alternatives, increasing the likelihood of cleaning up groundwater within a reasonable timeframe with controllable risk to the public and workers during implementation.

Alternative GW-3B would also destroy contaminants in place but would likely deplete less contaminant mass in low-permeability soils than Alternative GW-3C. This is because Alternative GW-3B, using sparging, would not distribute ozone in groundwater as effectively as Alternative GW-3C Alternative GW-3C uses direct-push pressurized injections into discrete vertical intervals to distribute bioremediation amendments. In relation to Alternative GW-3C, Alternative GW-3B entails comparable risk to the public and workers during implementation, although controls to mitigate risk from the use of ozone would be slightly more specialized for Alternative GW-3B.

Alternatives GW-3A and GW-4 would pose minimal risk to the public or the environment during treatment but may not treat low-permeability zones where the contaminant mass sustaining the plume is presumed to reside. Therefore, these alternatives are not as likely to clean up groundwater in a reasonable duration. Both Alternatives GW-3A (which involves air sparging) and GW-4 (which involves groundwater extraction) would preferentially remediate high-permeability soils.

Alternatives GW-3A, GW-3B, GW-3C, and GW-4 would all have a similar level of protectiveness afforded by ICs and monitoring.

Alternative GW-1 would be the least protective because it does not take any actions to reduce risk and does not monitor site conditions.

7.1.2 Compliance with ARARs

All alternatives except GW-1 would comply with ARARs. Alternative GW-1 would not comply with ARARs because it would take no action.

7.1.3 Long-Term Effectiveness and Permanence

Alternatives GW-3B and GW-3C are most likely to significantly reduce contaminant mass in low-permeability soils. Although these alternatives would be accompanied by geochemical effects (such as changes to pH and ORP or formation of byproducts and intermediates), these effects are expected to be localized and temporary and would not negatively affect the municipal wellfield.

Amendment injections in Alternative GW-3C would also cause minor plume dilution. If the volume of amendments injected per event is less than 10 percent of the pore volume of the targeted treatment area, the resulting dilution of COC concentrations within this area would be less than 9 percent (because plume volume would increase by 10 percent but COC mass would not change). Plume dilution would be controlled by limiting amendment injection volume to 10 percent of the target pore volume per injection event.

Alternative GW-3A, which employs air sparging, would produce minimal geochemical changes (such as increasing DO concentration) that would have the lowest potential to negatively affect the municipal wells. However, this alternative would be less effective in remediating low-permeability soil than GW-3B and GW-3C. For air sparging to remediate groundwater, it must strip and recover dissolved contaminants, and air must be sparged below the contaminated zone. Even if the sparged air did migrate through low-permeability soils, it would follow preferential pathways, leaving substantial portions of the aquifer untreated. Furthermore, the low-permeability vadose zone would make it difficult to recover stripped contaminants. Therefore, some fraction of stripped contamination would not be recovered and would return to the dissolved phase.

Alternative GW-3B, which sparges ozone, has similar challenges except that the sparged gas need not be recovered. Even if sparging produces preferential pathways in low-permeability soil, dissolved ozone could migrate outward from these pathways into contaminated soil, destroying contaminants in place. In that respect, ozone sparging would be more effective than air sparging, although not as effective as pressurized injection of liquid amendments via direct-push technology, because the latter method utilized in Alternative GW-3C would be performed on a denser three-dimensional injection grid allowing better access to contamination.

Alternative GW-4 would preferentially draw groundwater from more permeable soil with minimal effect on low-permeability soil where much of the contaminant mass is likely to reside. Therefore, contaminants trapped in low-permeability soils would diffuse into previously remediated areas increasing contaminant concentrations and making it less likely that groundwater could be cleaned up in a reasonable timeframe.

Alternative GW-1 would be the least effective because there would be no action taken to reduce risk.

7.1.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

This criterion is meant to evaluate alternatives against the statutory preference for treatment. Alternatives GW-3B and GW-3C would destroy contaminants in place, reducing toxicity and volume through treatment. Alternatives GW-3A and GW-4 would likely not destroy contaminants because low mass transfer rates from liquid to gas would allow contaminants to be discharged to the atmosphere without treatment. Therefore, Alternatives GW-3A and GW-4 would not reduce toxicity or volume through treatment. Although Alternative GW-4 would reduce the mobility of contaminants through hydraulic containment, it would not reduce mobility through treatment. None of the alternatives would decrease contaminant mobility through treatment.

Although Alternative GW-3C would not increase contaminant mobility, it would displace contaminated groundwater. Subsurface injection of liquid amendments would displace groundwater as the amendments are forced into saturated pore space. The volume of groundwater displaced would be equal to the volume of amendments injected. Assuming the volume of amendments injected during an event is less than 10 percent of the pore volume of the target zone, less than 10 percent of the groundwater would be displaced. Alternatives GW-3A and GW-3B would also displace groundwater as air or ozone is sparged, but this typically manifests as groundwater mounding. That is, sparging would mostly displace groundwater vertically with only minor displacement horizontally. Alternatives GW-3A and GW-4 would increase contaminant mobility by transferring it to the gaseous phase and discharging it without treatment, but this would pose no significant risk. Alternative GW-3B would not increase contaminant mobility.

Alternative GW-1 would do nothing to alter the toxicity, mobility or volume of contaminants.

7.1.5 Short-Term Effectiveness

Alternative GW-1 would pose the least short-term risk to workers, the community, and the environment because contaminated groundwater poses no immediate risk and this alternative would not add any new risks. Alternatives GW-3A and GW-3B involve comparable physical hazards to workers from drilling, earthwork, mechanical, and electrical work during construction. Alternative GW-4 would involve fewer physical hazards because it includes less infrastructure, and Alternative GW-3C would involve fewer physical hazards because it does not include permanent infrastructure. Alternatives GW-3A and GW-4 would involve no risk of worker exposure to hazardous remediation chemicals during construction, while Alternatives GW-3B and GW-3C would involve some risk of worker exposure to hazardous remediation chemicals during construction. Alternatives GW-3A, GW-3B, and GW-4 would not pose any chemical hazards to the public during construction. Alternative GW-3C would pose some chemical hazards to the public during construction if hazardous oxygen-releasing chemicals, such as calcium peroxide, are accidentally spilled during transport to the site. Alternatives GW-3A (operating for 8 years) and GW-4 (operating for 30 years) would release untreated VOCs to the atmosphere which would not pose significant risk to the community during operation. Alternative GW-3B (operating for 6 years) would pose controllable ozone intrusion risk to occupants of buildings on site during operation. Alternative GW-3C would pose no equivalent air pollution or intrusion risk during its 3-year remedial timeframe.

7.1.6 Implementability

Alternative GW-4 would be easy to construct and would involve installation of a few groundwater extraction wells, associated piping and a treatment system. However, Alternative GW-4 would require operation and maintenance for 30 years or more, along with groundwater monitoring. Alternative GW-3C, which includes no permanent infrastructure, would require drilling a large number of boreholes, injecting bioremediation amendments into those boreholes, then plugging the boreholes. The primary challenges with Alternative GW-3C would be avoiding underground utilities and minimizing surfacing during injections. These injection activities would be repeated two more times over a period of 3 years. Alternative GW-3C would not involve long-term field activities other than groundwater monitoring for 30 years. Although GW-3C may be implemented using permanent remediation wells, permanent wells are not the representative process option for this FS and would be evaluated during the RD if necessary. Alternatives GW-3A and GW-3B are more complex to construct because they require a significant amount of permanent infrastructure including several remediation wells, associated piping, and process equipment. Constructing these alternatives would involve more earthwork (because of large quantities of buried piping) and more maintenance (because of the many electrical and mechanical components including motors, blowers, valves and controls) than any other alternative. Both alternatives would require operation and maintenance for 5 to 8 years along with groundwater monitoring for 30 years. Alternative GW-1 although physically easy to implement is not administratively feasible (would not receive approval) because it does not reduce risk.

Cost

The present worth costs for the three groundwater alternatives, from highest to lowest, are as follows: (1) Alternative GW-3B is $6.06 million; (2) Alternative GW-3C is $5.93 million; (3) Alternative GW-3A is $4.67 million; (4) Alternative GW-4 is $4.62 million; and (5) Alternative GW-1 is $0.

7.1.7 Sustainability

Alternative GW-3C would be the most sustainable because it has no infrastructure or operation and maintenance related to infrastructure. Alternatives GW-3A and GW-3B would be next because they have a significant amount of infrastructure that would consume energy for 4 to 8 years. Alternative GW-4 follows because it would require operation of a pump-and- treat system for 30 years. Alternative GW-1 would be the least sustainable, although it would consume no energy because it would not restore a contaminated natural resource.

7.2 COMPARATIVE ANALYSIS OF PRIVATE WELL ALTERNATIVES

The following three remedial alternatives for the private well on the Apex property are compared below under seven CERCLA evaluation criteria.

PR-1 No Action
PR-2 Treatment and Monitoring
PR-3 Connect to City Water and Abandon Private Well

7.2.1 Overall Protection of Human Health and the Environment

Alternative PR-1 would not be protective because it would take no action.

Alternatives PR-2 and PR-3 would be protective because they would both reduce the potential for occupants to ingest contaminated well water. Alternative PR-3 would be more protective because it provides a permanent solution whereas Alternative PR-2 would require ongoing maintenance and monitoring to ensure its protectiveness.

7.2.2 Compliance with ARARs

Alternative PR-1 would not comply with ARARs because it would take no action. Alternatives PR-2 and PR-3 would comply with ARARs.

7.2.3 Long-Term Effectiveness and Permanence

Alternative PR-1 would be the least effective because it would take no action.

Alternative PR-3 would provide a permanent solution whereas Alternative PR-2 would require ongoing long-term maintenance and monitoring. Therefore, Alternative PR-3 would be more effective over the long term than Alternative PR-2.

7.2.4 Reduction of Contaminant Toxicity, Mobility, or Volume through Treatment

Alternatives PR-1 and PR-3 would rate the lowest because they do not reduce toxicity, mobility, or volume through treatment. Alternative PR-2 would reduce contaminant mobility through sorption to filtration media.

7.2.5 Short-Term Effectiveness

Alternative PR-1 would not be effective in the short term because it would not address potential risk posed by contaminated private well water. Alternative PR-2 would be more effective than Alternative PR-3 over the short-term because it is less complex to construct and would results in a lower risk of injury to workers during the implementation process.

7.2.6 Implementability

Alternative PR-1 would be easy to physically implement because it would require no action. However, PR-1 is not likely to receive agency approval because it would not protect human health or the environment.

Alternative PR-2 would be easier to implement than Alternative PR-3 because PR-3 would have significantly more administrative obstacles. For example, the Apex Racing property is outside the Troy city limits and would have to be annexed by the city to be eligible for municipal water service.

7.2.7 Cost

The present worth costs for the three private well alternatives, from highest to lowest, are as follows: (1) Alternative PR-2 is $55,000, (3) Alternative PR-3 is $47,000, and (3) Alternative PR-1 is $0.

7.2.8 Sustainability

Alternative PR-3 would be most sustainable because it would require no effort to operate or maintain, followed by Alternative PR-2 which would require some effort to operate and maintain. Alternative PR-1 would take no effort but would be the least sustainable because it does not protect human health.

7.3 COMPARATIVE ANALYSIS OF SOIL VAPOR ALTERNATIVES

The following two soil vapor alternatives were retained for evaluation.

VI-1 No Action
VI-2 ICs and Monitoring

Only one actionable alternative exists (Alternative VI-2) because the other alternative is the “No Action” alternative. As such, a comparative analysis of soil vapor alternatives is not necessary and was not performed.

7.4 ALTERNATIVE SUMMARY

The table below summarizes the cost and remedial duration of each remedial alternative for groundwater, the private well and vapor intrusion. Active remedial duration refers to that period of remedial action when mechanical systems are operating, or injections are being performed. Total remedial duration includes active remediation, and is the duration to install, operate, maintain and monitor the remedy. Total remedial duration includes long-term groundwater monitoring until attainment of remediation goals.

Alternative	Cost				Remedial Duration	
	Capital	O&M	Contingency	Total	Active	Total
Groundwater						
GW-3A	$1.45 M	$2.14 M	$1.08 M	$4.67 M	8 years	30 years
GW-3B	$2.61 M	$2.05 M	$1.40 M	$6.06 M	6 years	30 years
GW-3C	$1.71 M	$2.85 M	$1.37 M	$5.93 M	3 years	30 years
GW-4	$0.95 M	$2.61 M	$1.07 M	$4.62 M	30 years	30 years
Private Well						
PR-2	$24 K	$18 K	$13 K	$55 K	10 years	10 years
PR-3	$36 K	$0 K	$11 K	$47 K	NA	NA
Vapor Intrusion						
VI-2	$44 K	$37 K	$24 K	$105 K	NA	30 years

Notes:

K Thousand
M Million
NA Not applicable
O&M Operation and Maintenance

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APPENDIX A

PRELIMINARY IDENTIFICATION OF APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

TABLE A-1
SUMMARY OF POTENTIAL FEDERAL ARARs FOR WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

Requirement	Prerequisite	Citation	Comment
CHEMICAL-SPECIFIC			
Effluent limitations on point source pollutant discharges to waters of U.S.	Groundwater Discharge to Surface Water	CWA of 1977 33 U.S.C. Subsection 1251, et seq.	Not applicable or relevant and appropriate. RI results show groundwater does not discharge to surface water.
Establishes MCLs, which are health risk-based standards for public water systems.	Groundwater is current or potential source of drinking water	SDWA of 1974 40 C.F.R. 141 and 142	Applicable. All City of Troy residents supplied by municipal system; Troy prohibits private wells for potable uses, allows wells for agricultural irrigation. However, site groundwater contamination also exists north of city limits in unincorporated Miami County where there is no provision precluding use of groundwater beyond city limits.
Establishes welfare-based secondary standards for public water systems.	Groundwater is current or potential source of drinking water	SDWA of 1974 40 C.F.R. 143	Applicable. All City of Troy residents supplied by municipal system; Troy prohibits private wells for potable uses, allows wells for agricultural irrigation. However, site groundwater contamination also exists north of city limits in unincorporated Miami County where there is no provision precluding use of groundwater beyond city limits.
LOCATION-SPECIFIC			
No adverse impact to a wetland	Remedial action within an on-site wetland or disturbance to off-site wetland	CWA of 1977 40 C.F.R. 6.302(a) Appendix A	Not applicable or relevant and appropriate. No wetlands are on-site or within the footprint of the plume (reference: National Wetlands Inventory, 2014).
Facility must be designed, constructed, operated, and maintained to avoid washout.	RCRA hazardous waste; treatment, storage, or disposal of hazardous waste within a 100-year floodplain	40 C.F.R. 264.18(b)	Applicable. A portion of the West Troy Contaminated Aquifer (WTCA) site is located within the 100-year flood plain.
Preservation of historic or prehistoric resources (including structures) in National Historic Register sites.	Site (or structures) listed in National Register of Historic Places	NHPA of 1966 16 U.S.C. Subsection 470 et seq.	Not applicable or relevant and appropriate. Site (or on-site structures) not listed in Register.

TABLE A-1
SUMMARY OF POTENTIAL FEDERAL ARARs FOR
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

Requirement	Prerequisite	Citation	Comment
No adverse impacts to threatened or endangered species	This act requires federal agencies to ensure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any threatened or endangered species or adversely modify critical habitat.	16 U.S.C. § 1531 50 C.F.R. 200	Not applicable or relevant and appropriate. No endangered species that would be affected by remedial actions are known to be present at the site.
Requirements to minimize adverse effects in floodplain	This order requires federal agencies to evaluate potential adverse effects associated with direct and indirect development of a floodplain.	40 C.F.R. Part 6, Appendix A	This order is applicable to any construction activities in the Great Miami River floodplain.

TABLE A-1 (Continued)
SUMMARY OF POTENTIAL FEDERAL ARARs FOR
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

Requirement	Prerequisite	Citation	Comment
ACTION-SPECIFIC			
Effluent limitations on point source pollutant discharges to waters of U.S.	Treated Groundwater Discharge to Surface Water	NPDES, 33 USC, §§ 1251-1387, Clean Water Act NPDES Permit Program (40 CFR 122)	Potentially applicable depending on the remedial action chosen; program requirements apply to extracted groundwater discharged to surface waters.
Establishes permit requirements to regulate discharge.	This requirement establishes a permit program to regulate discharge into waters of the United States, including wetlands.	Federal Water Pollution Control Act, Section 401: Water Quality Certification	Potentially applicable depending on the remedial action chosen.
Underground injection control	These regulations protect groundwater sources of drinking water by imposing restrictions on underground injections.	40 C.F.R. 114-147	Potentially applicable depending on the remedial action chosen. Some alternatives include injecting reagents to treat groundwater; however, injection and recirculation of contaminated groundwater is not considered at this time.
Minimum design and operation criteria for land disposal of solid wastes	Regulated solid waste disposal unit	40 C.F.R. Part 257 Subpart A	Not applicable. No regulated units currently on site; substantive requirements may be relevant and appropriate for certain alternatives.
Site closure, operation and maintenance, monitoring and record-keeping at regulated waste units	RCRA Regulated Hazardous Waste Unit	40 C.F.R. Subpart G, § 264.110	Not applicable or relevant and appropriate. The WTCA site is not a RCRA hazardous waste regulated unit; no hazardous waste has been identified on site.
Requirements for Corrective Action Management Unit at RCRA-permitted transportation, storage, and disposal facilities undergoing corrective action.	Creation of a Corrective Action Management Unit	40 C.F.R. Part 264.552	Not applicable or relevant and appropriate. No hazardous waste has been identified on site.

TABLE A-1 (Continued)
SUMMARY OF POTENTIAL FEDERAL ARARs FOR
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

Requirement	Prerequisite	Citation	Comment
Land disposal restrictions prohibit disposal of hazardous waste unless treatment standards are met.	Disposal of hazardous waste on site	40 C.F.R. 268	May be relevant and appropriate if RCRA - characteristic waste is generated as part of alternative.

TABLE A-1 (Continued)
SUMMARY OF POTENTIAL FEDERAL ARARs FOR
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

Notes:

ARAR	=	Applicable or relevant and appropriate requirement
C.F.R.	=	Code of Federal Regulations
CWA	=	Clean Water Act
MCL	=	Maximum Contaminant Level
NHPA	=	National Historic Preservation Act
NPDES	=	National Pollutant Discharge Elimination System
RCRA	=	Resource Conservation and Recovery Act
SDWA	=	Safe Drinking Water Act
U.S.C.	=	United States Code
WTCA	=	West Troy Contaminated Aquifer Site

TABLE A-2
SUMMARY OF POTENTIAL STATE (OHIO) ARARs FOR THE
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

CATEGORY	ORC	OAC	PARAGRAPH	CAPTION	TYPE (Location/ Chemical/ Action-Specific)	TEXT	POTENTIAL APPLICATION
ODNR	1517.16			Channel modifications must be approved	LOCATION	No governmental body may modify the channel of any watercourse within a wild, scenic or recreational river area outside the limits of a municipal corporation without approval from the director of ODNR	Consider for any action that includes dredging or altering of riverbanks.
ODNR	1518.02			Endangered plant species	LOCATION	Prohibits removal or destruction of endangered plant species (some private property exceptions).	Applies to remediation sites where chemicals may harm endangered species. Clearly establishes that receptor plant species must be considered in risk assessments. This act may require consideration of endangered species in remediations that involve movement or displacement of large volumes of surface soil.
ODNR	1521.06			Construction permits for dams, dikes and levees	LOCATION	No dam may be constructed for the purpose of storing, conserving or retarding water, or for any other purpose, nor shall any dike or levee be constructed for the purpose diverting or retaining flood water without a permit.	The substantive requirements of this section pertain to remedies that will create or alter a dam, dike or levee. Consider for sites with on-site surface water and for sites within a floodplain.
ODNR	1521.062		A-G	Monitoring, maintenance & operation (dams, dikes, levees)	LOCATION	Dams, dikes and levees (and all appurtenances) shall monitored, maintained and operated safely in accordance with state rules, terms and conditions of the permit and other requirements issued pursuant to this section or section 1521.06 of the ORC.	The substantive requirements of this section pertain to remedies that will create or alter a dam, dike or levee. Consider for sites with on-site surface water and for sites within a floodplain.
ODNR	1531.25			Endangered animal species	LOCATION	Prohibits removal or destruction of endangered animal species	Applies to remediation sites where chemicals may harm endangered species. Clearly establishes that receptor animal species must be considered in risk assessments. This act may require consideration of endangered species in remediations that involve movement or displacement of large volumes of surface soil.
APC	3704.05		A-I	Prohibits violation of air pollution control rules	ACTION	Prohibits emission of an air contaminant in violation sec. 3704 or any rules, permit, order or variance issued pursuant to that section of the ORC.	May pertain to any site where emissions of an air contaminant occurs either as a pre-existing condition of the site or as a result of remedial activities. Should be considered for virtually all sites that require the management of solid/hazardous wastes.
HW	3734.02		(H)	"digging" where hazardous or solid waste facility was located	LOCATION	Filling, grading, excavating, building, drilling or mining on land where hazardous waste or solid waste facility was operated is prohibited without prior authorization from the director of the Ohio EPA.	Pertains to any site at which hazardous or solid waste has come to be located. Certain alternatives include excavation activities which may uncover solid and/or hazardous waste. Should those activities require the management of solid/hazardous wastes on-site, an exemption to permitting and other requirements may be warranted.
HW APC	3734.02		(I)	Air emissions from hazardous waste facilities	ACTION	No hazardous waste facility shall emit any particulate matter, dust, fumes, gas, mist, smoke, vapor or odorous substance that interferes with the comfortable enjoyment of life or property or is injurious to public health.	Pertains to any site at which hazardous waste will be managed such that air emissions may occur. Consider for sites that will undergo movement of earth or incineration.
DSIWM	3734.03			Prohibits open dumping or burning	ACTION	Prohibits open burning or open dumping of solid waste or treated or untreated infectious waste.	Pertains to any site at which solid waste has come to be located or will be generated during a remedial action.
APC DSW	3767.13			Prohibition of nuisances	ACTION	Prohibits noxious exhalations or smells and the obstruction of waterways.	Pertains to any site that may have noxious smells or may obstruct waterways.
DSW	3767.14			Prohibition of nuisances	ACTION	Prohibition against throwing refuse, oil, or filth into lakes, streams, or drains.	Pertains to all sites located adjacent to lakes, streams, or drains.
DERR	5301.00		.80 TO .92	Uniform environmental covenants act	LOCATION	Standards for environmental covenants	Consider for sites with institutional controls or use restrictions
DSW	6101.19			Conservancy districts	LOCATION	Board of directors of a conservancy district may make and enforce rules and regulations pertaining to channels, ditches, pipes, sewers, etc.	This statute pertains to any site that may affect a construction within a conservancy district.
DSW	6111.04			Acts of pollution prohibited	ACTION	Pollution of waters of the state is prohibited.	Pertains to any site which has contaminated on-site ground or surface water or will have a discharge to on-site surface or ground water.
DSW	6111.07		A,C	Water pollution control requirements - duty to comply	ACTION	Prohibits failure to comply with requirements of sections 6111.01 to 6111.08 or any rules, permit or order issued under those sections.	Pertains to any site which has contaminated ground water or surface water or will have a discharge to on-site surface or ground water.

TABLE A-2 (Continued)
SUMMARY OF POTENTIAL STATE (OHIO) ARARs FOR THE
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

CATEGORY	ORC	OAC	PARAGRAPH	CAPTION	TYPE (Location/ Chemical/ Action-Specific)	TEXT	POTENTIAL APPLICATION
DSW	6111.04.2			Rules requiring compliance with national effluent standards	ACTION	Establishes regulations requiring compliance with national effluent standards.	Pertains to any site which will have a point source discharge.
ODNR		1501:21-11	03-05	Predesign investigations (dams, dikes, levees)	LOCATION	Presents predesign requirements for dams, dikes and levees. Includes on-site construction material data, surveys and hydrologic and hydraulic investigations.	Pertains to remedies that create or alter a dam, dike or levee. Consider for sites with on-site surface water and for sites within a floodplain.
ODNR		1501:21-13	10-14	Additional design requirements for dikes and levees	LOCATION	Presents design requirements specific to dikes and levees. Includes criteria such as design storm and flood and freeboard requirements.	Pertains to remedies that create or alter a dike or levee. Consider for sites within a floodplain.
ODNR		1501:21-15	06	Operation, maintenance and inspections	LOCATION	Presents the minimum information required in a plan addressing the operation, maintenance and inspection of dams, dikes and levees.	Pertains to remedies that create or alter a dam, dike or levee. Consider for sites with on-site surface water and for sites within a floodplain.
ODNR		1501:21-21	03-04	Deficiency and O & M of dams, dikes and levees	LOCATION	Dams, dikes and levees must be operated safely. Repairs or other remedial measures shall be performed on dams, dikes and levees as necessary to safeguard life, health or property.	Pertains to remedies that create or alter a dam, dike or levee. Consider for sites with on-site surface water and for sites within a floodplain.
ODNR		1501:21-5	02-06	Design requirements for dams, dikes and levees	LOCATION	Specifies minimum information required during design for Ohio DNR to determine adequacy of proposed dam, dike or levee. Includes design reports, plans and specifications.	Pertains to remedies that create or alter a dam, dike or levee. Consider for sites with on-site surface water and for sites within a floodplain.
ODNR		1501:31-23	01, A-B	List of endangered animal species	LOCATION	List of Ohio animal species considered endangered.	May apply to remediation sites where listed species are threatened by chemical releases. May also apply at sites where remedial activities could disturb existing habitats.
ODNR		1501-18-1	03, A	List of endangered plant species	LOCATION	Plant species considered endangered in Ohio	May apply at remediation sites where chemical release threatens listed species. Should also be considered where remedial activities may disrupt habitats.
DSW		3745-1-03		Analytical and collection procedures	ACTION	Specifies analytical methods and collection procedures for surface water discharges.	Pertains to both discharges to surface waters as a result of remediation and any on-site surface waters affected by site conditions.
DSW		3745-1-04	A,B,C,D,E	The "five freedoms" for surface water	ACTION	All surface waters of the state shall be free from: a) objectionable suspended solids. B) floating debris, oil and scum. C) materials that create a nuisance. D) toxic, harmful or lethal substances. E) nutrients that create nuisance growth	Pertains to both discharges to surface waters as a result of remediation and any on-site surface waters affected by site conditions.
DSW		3745-1-05	A-C	Antidegradation policy for surface water	ACTION	Prevents degradation of surface water quality below designated use or existing water quality. Existing in stream uses shall be maintained and protected. The most stringent controls for treatment shall be required by the director to be employed for all new and existing point source discharges. Prevents any degradation of state resource waters	Requires that best available technology (bat) be used to treat surface water discharges. DWQPA uses this rule to set standards when existing water quality is better than the designated use.
DSW		3745-1-06	A,B	Mixing zones for surface water	ACTION	(a) presents the criteria for establishing non-thermal mixing zones for point source discharges (b) presents the criteria for establishing thermal mixing zones for point source discharges	Applied as a term of discharge permit to install (pti). Would pertain to an alternative which resulted in a point source discharge.
DSW		3745-1-21		Water use DES for Great Miami River	LOCATION	Establishes water use designations for stream segments within the Great Miami River basin	Pertinent if stream or stream segment is on-site and is either affected by site conditions of if remedy includes direct discharge. Used by DSW to establish waste load allocations
DSW		3745-1-34		Water quality criteria for Ohio river drainage basin	LOCATION	Establishes criteria for surface water in Ohio river drainage basin.	Pertinent if stream or stream segment is on-site and is either affected by site conditions of if remedy includes direct discharge. Used by DSW to establish waste load allocations
APC		3745-15-05	A-D	De minimis air contaminant source exemption	ACTION	Establishes limits below which air discharge permits are not needed	Pertains to any site which utilizes or will utilize air pollution control equipment on-site.
APC		3745-15-06	A1,A2	Malfunction & maintenance of air poll control equipment	ACTION	Establishes scheduled maintenance and specifies when pollution source must be shut down during maintenance	Pertains to any site which utilizes or will utilize air pollution control equipment on-site.

TABLE A-2 (Continued)
SUMMARY OF POTENTIAL STATE (OHIO) ARARs FOR THE
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

CATEGORY	ORC	OAC	PARAGRAPH	CAPTION	TYPE (Location/ Chemical/ Action-Specific)	TEXT	POTENTIAL APPLICATION
APC		3745-15-07	A	Air pollution nuisances prohibited	ACTION	Defines air pollution nuisance as the emission or escape into the air from any sources(s)) of smoke, ashes, dust, dirt, grime, acids, fumes, gases, vapors, odors and combinations of the above that endanger health, safety or welfare of the public or cause personal injury or property damage. Such nuisances are prohibited.	Pertains to any site which causes, or may reasonably cause, air pollution nuisances. Consider for sites that will undergo excavation, demolition, cap installation, methane production, clearing and grubbing, water treatment, incineration and waste fuel recovery.
APC		3745-17-08	A1,A2,B,D	Emission restrictions for fugitive dust	ACTION	All emissions of fugitive dust shall be controlled.	Pertains to sites which may have fugitive emissions (non-stack) of dust. Consider for sites that will undergo grading, loading operations, demolition, clearing and grubbing and construction utilize incineration or fuel recovery (waste fuel recovery)
APC		3745-21-09		VOC emissions control: stationary sources	ACTION	Establishes limitations for emissions of volatile organic compounds from stationary sources.	Pertains to any site with treatment systems that emit volatile organic compounds, including those with thermal desorption and air stripping.
HW		3745-270-03	A-D	Dilution prohibited as a substitute for treatment.	ACTION	Forbids dilution as a means of achieving land disposal restriction levels	Consider for remedial options including land disposal or leaving wastes in-place
HW		3745-270-07	A-E	Testing, tracking, and recordkeeping requirements	ACTION	Testing, tracking, and recordkeeping requirements for generators, treaters, and disposal facilities.	Consider for sites at which wastes are generated, stored, disposed, or treated
HW		3745-270-09	A-D	Special rules regarding characteristic wastes	ACTION	Rules applicable to land disposal of characteristic wastes	Consider for sties that generate characteristic wastes
HW		3745-270-40	A-J	Applicability of treatment standards	CHEMICAL	Detailed listing of chemical specific land treatment standards or required treatment technologies.	Consider for sites that generate wastes or with wastes disposed on-site
HW		3745-270-42	A-D	Treatment standards expressed as specified technologies	CHEMICAL	Lists specific treatment technologies required for specific wastes	Consider at all sites generating wastes or with on-site disposal
HW		3745-270-45	A-D	Treatment standards for hazardous debris	CHEMICAL	Specifies treatment technologies and performance standards for various debris.	Consider for sites with contamination by debris.
HW		3745-270-48	A	Universal treatment standards	CHEMICAL	Gives contaminant chemical specific standards for land disposal	Consider for sites with waste generation or on-site disposal
HW		3745-270-49	A-E	Land disposal restriction for contaminated soils	CHEMICAL	Specifies standards for soil treatment	Consider at sites where contaminated soils are generated
HW		3745-270-50	A-G	Prohibition on Storage of Restricted Wastes	CHEMICAL	Prohibits on site storage of restricted wastes	Consider at sites where wastes are generated by remedial activities
DSW		3745-3-04	A-D	Prohibited discharges	ACTION	Places restrictions on discharges to POTW's that may harm treatment functions or pass through to receiving stream.	Consider for sites with discharges to POTW
APC		3745-31-02	A,C,D	Permit to install, general requirements	ACTION	General requirements for permit to install air pollution sources	Consider for sites with potential for air emissions, including sites with soil vapor extraction, thermal desorption, incineration or other treatment technologies with air emissions
APC		3745-15-08	A	Circumvention	ACTION	Forbids dilution or other means to conceal emissions without actual reductions.	Consider for sites with emissions to air, air stripping, incineration, or soil vapor extractions.
UIC		3745-34-06		Prohibition of unauthorized injection	ACTION	Underground injection is prohibited without authorization from the director.	Pertains to sites at which materials are to be injected underground. Consider for technologies such as bioremediation and soil flushing.
UIC		3745-34-07		No movement of fluid into underground drinking water	ACTION	The underground injection of fluid containing any contaminant into an underground source of drinking water is prohibited if the presence of that contaminant may cause a violation of the primary drinking water standards or otherwise adversely affect the health of persons.	Pertains to sites at which materials are to be injected underground. Consider for technologies such as bioremediation and soil flushing.
UIC		3745-34-09		Requirements for wells injecting hazardous waste	ACTION	Specifies requirements for the injection of hazardous wastes underground. See 3745-34-08 for limitations.6 of the ORC.	Pertains to sites at which materials are to be injected underground. Consider for technologies such as bioremediation and soil flushing.
UIC		3745-34-26		Conditions applicable to all permits	ACTION	Specifies minimum conditions to be applied to all underground injections.	Pertains to sites at which materials are to be injected underground. Consider for technologies such as bioremediation and soil flushing.
UIC		3745-34-34		Mechanical integrity	ACTION	Specifies requirements to be met to ensure mechanical integrity of wells.	Pertains to sites at which materials are to be injected underground. Consider for technologies such as bioremediation and soil flushing.

TABLE A-2 (Continued)
SUMMARY OF POTENTIAL STATE (OHIO) ARARs FOR THE
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

CATEGORY	ORC	OAC	PARAGRAPH	CAPTION	TYPE (Location/ Chemical/ Action-Specific)	TEXT	POTENTIAL APPLICATION
HW		3745-50-44	A	Permit info required for all hazardous waste facilities	ACTION	Establishes the substantive hazardous waste permit requirements necessary for Ohio EPA to determine facility compliance. Includes information such as facility description, waste characteristics, equipment descriptions, contingency plan, facility location, topographic map, etc.	Pertains to any site which will have treatment, storage or disposal of hazardous waste occurring on-site or has existing areas of hazardous waste contamination on-site that will be capped in-place. This, along with other paragraphs of this rule, establishes the minimum information required during the remedial design stage. Corrective action for waste management units
HW		3745-50-44		Permit info required for all hazardous waste land disposal facilities	ACTION	Establishes the substantive hazardous waste land disposal permit requirements necessary for Ohio EPA to determine adequate protection of the ground water. Includes information such as ground water monitoring data, information on interconnected aquifers, plume(s) of contamination, plans and reports on ground water monitoring program, etc. Management of solid/hazardous was	Pertains to any facility/site which will have hazardous waste disposed of on-site or has existing areas of hazardous waste contamination on-site that will be capped in-place. This, along with other paragraphs of this rule, establishes the minimum information required during the remedial design stage.
HW		3745-50-58	E,I,J	Conditions applicable to all permits	ACTION	Establishes general permit conditions applied to all hazardous waste facilities in Ohio. Includes conditions such as operation and maintenance, site access, monitoring, etc.	Pertains to all alternatives that will incorporate treatment, storage or disposal of hazardous waste.
HW		3745-52-11	A-D	Evaluation of wastes	ACTION	Any person generating a waste must determine if that waste is a hazardous waste (either through listing or by characteristic).	Pertains to sites at which wastes of any type (both solid and hazardous) are located.
HW		3745-52-12	A-C	Generator identification number	ACTION	A generator must not store, treat dispose or transport hazardous wastes without a generator number	Pertains to sites where hazardous waste will be transported off-site for treatment, storage or disposal
HW		3745-52-20		Hazardous waste manifest - general requirements	ACTION	Requires a generator who transports or offers for transportation hazardous waste for off-site treatment, storage or disposal to prepare a uniform hazardous waste manifest	Pertains to sites where hazardous waste will be transported off-site for treatment, storage or disposal
HW		3745-52-22		Hazardous waste manifest - number of copies	ACTION	Specifies the number of manifest copies to be prepared	Pertains to sites where hazardous waste will be transported off-site for treatment, storage or disposal
HW		3745-52-23		Hazardous waste manifest - use	ACTION	Specifies procedures for the use of hazardous waste manifests including a requirement that they be hand signed by the generator	Pertains to sites where hazardous waste will be transported off-site for treatment, storage or disposal
HW		3745-52-30		Hazardous waste packaging	ACTION	Requires a generator to package hazardous waste in accordance with U.S. DOT regulations for transportation off-site.	Pertains to any site where hazardous waste will be generated by on-site activities and shipped off-site for treatment and/or disposal.
HW		3745-52-31		Hazardous waste labeling	ACTION	Requires packages of hazardous waste to be labeled in accordance with u.s.dot regulations for off-site transportation.	Pertains to any site where hazardous waste will be generated by on-site activities and shipped off-site for treatment and/or disposal.
HW		3745-52-32		Hazardous waste marking	ACTION	Specifies language for marking packages of hazardous waste prior to off-site transportation	Pertains to any site where hazardous waste will be generated by on-site activities and shipped off-site for treatment and/or disposal.
HW		3745-52-33		Hazardous waste placarding	ACTION	Generator shall placard hazardous waste prior to off-site transportation.	Pertains to any site where hazardous waste will be generated by on-site activities and shipped off-site for treatment and/or disposal.
HW		3745-52-34		Accumulation time of hazardous waste	ACTION	Identifies maximum time periods that a generator may accumulate a hazardous waste without being considered an operator of a storage facility. Also establishes standards for management of hazardous wastes by generators.	Pertains to a site where hazardous waste will be generated as a result of the remedial activities.
HW		3745-52-40	A-D	Recordkeeping requirements, three-year retention	ACTION	Specifies records that shall be kept for three years	Consider for sites at which hazardous wastes are generated
HW		3745-52-41	A,B	Annual report	ACTION	Requires generators to prepare annual report to Ohio EPA	Applicable at sites generating wastes for offsite shipment
HW		3745-54-13	A	General analysis of hazardous waste	ACTION	Prior to any treatment, storage or disposal of hazardous wastes, a representative sample of the waste must be chemically and physically analyzed.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-14	A,B,C	Security for hazardous waste facilities	ACTION	Hazardous waste facilities must be secured so that unauthorized and unknowing entry are minimized or prohibited.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-15	A,C	Inspection requirements for hazardous waste facilities	ACTION	Hazardous waste facilities must be inspected regularly to detect malfunctions, deteriorations, operational errors and discharges. Any malfunctions or deteriorations detected shall be remedied expeditiously.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-16		Personnel training	ACTION	Establishes requirements for training of personnel at hazardous waste facilities	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).

TABLE A-2 (Continued)
SUMMARY OF POTENTIAL STATE (OHIO) ARARs FOR THE
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

CATEGORY	ORC	OAC	PARAGRAPH	CAPTION	TYPE (Location/ Chemical/ Action-Specific)	TEXT	POTENTIAL APPLICATION
HW		3745-54-18	A,B,C	Location standards for hazardous waste t/s/d facilities	LOCATION	Restricts the siting of hazardous waste facilities in areas of seismic activity or floodplains.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-31		Design & operation of hazardous waste facilities	ACTION	Hazardous waste facilities must be designed, constructed, maintained and operated to minimize the possibility of fire, explosion or unplanned release of hazardous waste or hazardous constituents to the air, soil or surface water which could threaten human health or the environment.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-32	A,B,C,D	Required equipment for hazardous waste facilities	ACTION	All hazardous waste facilities must be equipped with emergency equipment, such as an alarm system, fire control equipment and a telephone or radio.	Pertains to any site at which hazardous is to be treated, stored or disposed of (or has been disposed of). Specifications
HW		3745-54-33		Testing & maintenance of equipment; hazardous waste facilities	ACTION	All hazardous waste facilities must test and maintain emergency equipment to assure proper operation.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-34		Access to communications or alarm system; hazardous waste facilities	ACTION	Whenever hazardous waste is being handled, all personnel involved shall have immediate access to an internal alarm or emergency communication device.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-37	A,B	Arrangements/ agreements with local authorities	ACTION	Arrangements or agreements with local authorities, such as police, fire department and emergency response teams must be made. If local authorities will not cooperate, documentation of that non-cooperation should be provided.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-52	A-F	Content of contingency plan; hazardous waste facilities	ACTION	Hazardous waste facilities must have a contingency plan that addresses any unplanned release of hazardous wastes or hazardous constituents into the air, soil or surface water. This rule establishes the minimum required information of such a plan.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-53	A,B	Copies of contingency plan; hazardous waste facilities	ACTION	Copies of the contingency plan required by 3745-54-50 must be maintained at the facility and submitted to all local police departments, fire departments, hospitals local emergency response teams and the Ohio EPA.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-54	A	Amendment of contingency plan; hazardous waste facilities	ACTION	The contingency plan must be amended if it fails in an emergency, the facility changes (in its design, construction, maintenance or operation), the list of emergency coordinators change or the list of emergency equipment.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-55		Emergency coordinator; hazardous waste facilities	ACTION	At all times there should be at least one employee either on the premises or on call to coordinate all emergency response measures.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-56	A-I	Emergency procedures; hazardous waste facilities	ACTION	Specifies the procedures to be followed in the event of an emergency.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been disposed of).
HW		3745-54-73	A,B	Operating record	ACTION	Specifies records to be kept at TSD facilities	Consider for sites with on-site treatment, storage or disposal
HW		3745-54-77	A	Additional reports	ACTION	Requires facilities to report fires, explosions or other mishaps	Consider at sites with treatment, storage or disposal on-site
HW		3745-55-11	A,B,C	General closure performance standard; hazardous waste facility	ACTION	Requires that all hazardous waste facilities be closed in a manner that minimizes the need for further maintenance, controls, minimizes, eliminates or prevents post-closure escape of hazardous waste, hazardous constituents, leachate, contaminated run-off or hazardous waste decomposition products to the ground or surface water or the atmosphere.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been treated, stored or disposed of).
HW		3745-55-12	B	Content of closure plan; hazardous waste facilities	ACTION	Specifies the minimum information required in a closure plan for Ohio EPA to determine the adequacy of the plan.	Substantive requirements pertain to any site at which hazardous waste is to be treated, stored or disposed of (or has been treated, stored or disposed of).
HW		3745-55-14		Disposal/ decon of equipment, structures & soils	ACTION	Requires that all contaminated equipment, structures and soils be properly disposed of or decontaminated. Removal of hazardous wastes or constituents from a unit may constitute generation of hazardous wastes.	Pertains to any site at which hazardous waste is to be treated, stored or disposed of (or has been treated, stored or disposed of).

TABLE A-2 (Continued)
SUMMARY OF POTENTIAL STATE (OHIO) ARARs FOR THE
WEST TROY CONTAMINATED AQUIFER (WTCA) SITE

CATEGORY	ORC	OAC	PARAGRAPH	CAPTION	TYPE (Location/ Chemical/ Action-Specific)	TEXT	POTENTIAL APPLICATION
HW		3745-55-17	B	Post-closure care and use of property	ACTION	Specifies the post-closure care requirements, including maintenance, monitoring and post-closure use of property.	Pertains to all sites with land-based hazardous waste units (landfills and surface impoundments, waste piles, land treatment units and tanks that meet requirements of landfills after closure). This includes existing land-based areas of contamination.
HW		3745-55-18	B	Post-closure plan	ACTION	Presents the information necessary for Ohio EPA to determine the adequacy of a post-closure plan.	Pertains to all sites with land-based hazardous waste units (landfills and surface impoundments, waste piles, land treatment units and tanks that meet requirements of landfills after closure). This includes existing land-based areas of contamination.
HW		3745-55-19	B	Notice to local land authority	ACTION	Requires that a record of the type, location and quantity of hazardous wastes disposed of in each unit be submitted to the local land authority and the director of the Ohio EPA. Also requires that a notation to the deed to the facility property be made indicating that the land was used to manage hazardous wastes and that certain use restrictions may apply to the property.	Pertains to all sites with land-based hazardous waste units (landfills and surface impoundments, waste piles, land treatment units and tanks that meet requirements of landfills after closure). This includes existing land-based areas of contamination.
HW		3745-57-03	A-I	Landfill design and operating requirements	ACTION	Presents design and operating requirements for landfills. Includes liner, leachate collection and removal, run-on/run-off control, etc.	Pertains to all sites at which a hazardous waste landfill will either be located or an existing landfill will be expanded. This rule also pertains to existing land-based areas of contamination.
HW		3745-57-05	A,B	Monitoring and inspections of landfills	ACTION	Requires inspection of landfills during construction or installation and operation.	Pertains to all sites at which a hazardous waste landfill will either be located or an existing landfill will be expanded. This rule pertains to existing land-based areas of contamination.
HW		3745-57-09		Surveying and record keeping	ACTION	Establishes requirements for surveying and recording locations and contents of cells	Pertains to all sites at which a hazardous waste landfill will either be located or an existing landfill will be expanded. This rule also pertains to existing land-based areas of contamination.
HW		3745-57-10	A,B	Landfill closure and post-closure care	ACTION	Specifies closure and post-closure requirements for hazardous waste landfills. Includes final cover and maintenance.	Pertains to all sites at which a hazardous waste landfill will either be located or an existing landfill will be expanded. This rule pertains to existing land-based areas of contamination.
HW		3745-57-74	A-K	Staging piles	ACTION	Design requirements for temporary waste staging piles	Pertains to remedial site where waste will be temporarily stored in piles
HW		3745-66-11	A,B,C	Closure performance standard	ACTION	Owner shall close facility in manner that minimizes need for further maintenance and reduces or eliminates pollution of ground water, surface water or atmosphere.	Consider for remedial plans that may require extended operation and maintenance of equipment. Consider alternatives with less long-term O&M. Applicable for RCRA facilities, appropriate and relevant for other sites.
DW		3745-81-11	A,B,C	Maximum contaminant levels for inorganic chemicals	CHEMICAL	Presents maximum contaminant levels for inorganics.	Pertains to any site which has contaminated ground or surface water that is either being used, or has the potential for use, as a drinking water source.
DW		3745-81-12	A,B,C	Maximum contaminant levels for organic chemicals	CHEMICAL	Presents MCLs for organics.	Pertains to any site which has contaminated ground or surface water that is either being used, or has the potential for use, as a drinking water source.
GW		3745-9-03	A-C	Monitoring well	ACTION	Standards for design and closure of wells, compliance with DDAGW guidance	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975. Would pertain during the FS if new wells are constructed for treatability studies.
GW		3745-9-05	A1,B-H	Well construction	ACTION	Specifies minimum construction requirements for new ground water wells in regards to casing material, casing depth, potable water, annular spaces, use of drive shoe, openings to allow water entry, contaminant entry.	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975. Would pertain during the FS if new wells are constructed for treatability studies.
GW		3745-9-07	A-C	Well grouting for construction of closure	ACTION	Establishes specific grouting procedures	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975. Would pertain during the fs if new wells are constructed for treatability studies.
GW		3745-9-10	A,B,C	Abandoned well sealing	ACTION	Procedures for closing and sealing wells.	Pertains to all ground water wells on the site that either will be installed or have been installed since Feb. 15, 1975.

Notes:

APC	Air Pollution Control
ARAR	Applicable or Relevant and Appropriate Requirements
CFR	Code of Federal Regulations
CWA	Clean Water Act
DERR	Division of Environmental Response and Revitalization
DSW	Division of Surface Water
DW	Drinking Water
EPA	Environmental Protection Agency
ESA	Endangered Species Act
Fac	Facility
GW	Groundwater
HAZ	Hazardous
HW	Hazardous Waste
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
O&M	Operation and Maintenance
ORC	Ohio Revised Code
POTW	Publicly-Owned Treatment Works
RCRA	Resource Conservation and Recovery Act
TSD	Treatment, Storage or Disposal
UIC	Underground Injection Control
U.S.C.	United States Code
U.S. DOT	United States Department of Transportation
VOC	Volatile Organic Compound

APPENDIX B

GROUNDWATER PHYSIOCHEMICAL PARAMETERS

Appendix B-1

Dissolved Oxygen Measurement Summary

Appendix B-1
Dissolved Oxygen Measurement Summary

VAS-01		VAS-02		VAS-03		VAS-04		VAS-05		VAS-06	
Depth (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)
-15.20	4.48	-12.80	4.72	-13.20	2.62	-13.20	4.92	-15.40	5.94	-15.10	5.28
-25.30	4.88	-23.00	4.04	-23.00	4.91	-18.00	8.61	-25.30	5.10	-25.00	4.95
-35.20	1.74	-33.30	4.17	-32.90	5.17	-28.00	5.16	-35.00	1.72	-35.10	4.63
-45.20	1.47	-43.00	1.65	-43.00	2.83	-38.00	5.10	-45.00	1.18	-45.15	2.19
-55.10	1.12	-50.50	NC	-49.70	3.49	-48.50	4.73	-55.00	1.43	-55.00	1.69
								-59.50	1.03		

VAS-07		VAS-08		VAS-09		VAS-10		VAS-11		VAS-12	
Depth (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)
-15.00	4.15	-13.35	4.51	-13.20	3.38	-15.20	5.56	-15.20	5.30	-15.00	5.29
-25.00	1.86	-23.25	3.32	-18.50	3.89	-25.20	3.67	-25.00	5.68	-25.10	NC
-35.00	3.73	-33.00	3.95	-27.40	1.77			-35.00	4.89	-35.00	4.15
-43.50	1.57	-43.00	3.90	-35.30	3.73			-45.00	2.18	-45.10	1.73
		-49.50	2.70	-45.20	3.84			-54.60	1.78	-54.80	5.38
				-50.40	1.82			-60.40	1.43		

VAS-13		VAS-14		VAS-15		VAS-16		VAS-17		VAS-18	
Depth (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)
-15.30	8.84	-17.80	5.13	-18.00	2.33	-15.00	2.91	-15.00	1.74	-13.53	1.63
-19.50	5.93	-25.65	2.73	-25.20	1.90	-25.00	3.00	-25.00	NA	-23.50	NA
-30.00	6.34					-34.10	1.75	-35.00	NA	-20.00	1.71
-40.00	4.97					-44.90	1.43	-45.10	NA	-30.00	2.09
-50.00	7.28					-55.00	1.56	-55.10	NA	-39.90	3.98
								-46.80	1.69	-48.50	1.45
								-55.20	1.89	-58.80	1.27
										-63.70	1.92

VAS-19		VAS-20		VAS-21		VAS-22		VAS-23		VAS-24	
Depth (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)
-12.50	1.24	-13.00	1.23	-13.15	8.12	-15.00	0.65	-17.80	3.11	-15.30	8.19
-22.50	2.78	-18.20	0.00	-23.20	1.58	-24.90	0.66	-28.40	4.64	-25.30	4.64
-32.50	2.60			-33.00	1.45	-35.30	1.22	-35.00	4.57	-35.20	4.59
-42.60	3.16			-41.50	2.09	-45.00	1.28	-44.90	3.50	-45.10	2.96
-48.50	1.36			-51.50	3.17	-46.70	0.82	-51.50	1.33	-51.20	6.21
				-60.20	3.19						
				-66.50	1.59						

Appendix B-1
Dissolved Oxygen Measurement Summary

VAS-25		VAS-26		VAS-27		VAS-28		VAS-29		VAS-30	
Depth (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)
-14.90	4.69	-15.20	5.76	-15.10	5.25	-15.10	4.15	-15.40	3.86	-17.10	4.64
-24.80	1.99	-25.20	5.37	-25.10	2.93	-24.90	3.85	-25.40	3.57	-24.30	2.53
-34.90	4.18	-35.40	3.83	-34.90	4.65	-35.00	3.25	-35.40	4.32	-35.00	3.57
-44.90	1.04	-45.30	2.28	-45.00	4.13	-45.00	1.13	-45.30	1.31	-45.10	4.27
-47.70	1.65	-49.50	2.00	-49.17	3.23	-47.60	1.17	-47.30	1.05	-51.60	2.90

VAS-31		VAS-32		VAS-33		VAS-34		VAS-35		VAS-36	
Depth (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)
-9.90	0.89	-15.10	4.31	-17.10	1.01	-13.50	NC	-13.00	1.12	-15.20	3.59
-19.90	1.22	-25.00	4.05	-27.10	1.33	-22.90	1.04	-23.00	0.96	-25.20	4.13
-30.10	2.43	-35.00	3.67	-37.00	2.84	-33.40	2.65	-32.90	1.02	-35.30	3.73
-40.00	4.92	-41.80	1.35	-49.30	1.41	-43.10	2.77	-43.10	1.42	-44.10	4.38
-45.50	4.50	-45.30	1.05			-49.80	1.50	-50.60	2.13		

VAS-37		VAS-38		VAS-39		VAS-40		VAS-41		VAS-42	
Depth (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)	**Depth** (ft)	**DO** (PPM)
-14.90	1.29	-12.00	7.32	-9.90	0.72	-10.10	3.09	-8.10	4.07	-8.15	0.88
-24.80	1.10	-21.30	8.46	-24.60	0.93	-20.40	3.45	-18.10	3.81	-18.18	0.68
-34.30	2.87	-31.30	4.39	-34.00	0.98	-30.10	5.35	-28.10	3.92	-23.70	2.05
-44.40	7.57	-33.40	6.70			-40.00	3.15	-38.00	3.28	-32.75	0.93
-46.50	7.41	-43.00	6.18			-44.10	3.53	-40.50	3.70		
		-51.60	5.67								

Notes:

DO Dissolved oxygen

ft Feet (negative value indicates depth below ground surface)

PPM Part per million

DO measurements greater than 2 ppm are highlighted.

Appendix B-2

Oxidation-Reduction Potential Measurement Summary

Appendix B-2
Oxidation-Reduction Potential Measurement Summary

VAS-01		VAS-02		VAS-03		VAS-04		VAS-05		VAS-06	
Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)
-15.20	197	-12.80	224	-13.20	93	-13.20	224	-15.40	28	-15.10	98
-25.30	194	-23.00	196	-23.00	94	-18.00	205	-25.30	38	-25.00	104
-35.20	155	-33.30	205	-32.90	96	-28.00	210	-35.00	40	-35.10	116
-45.20	130	-43.00	135	-43.00	98	-38.00	213	-45.00	-80	-45.15	121
-55.10	47	-50.50	NC	-49.70	97	-48.50	213	-55.00	-63	-55.00	-19
								-59.50	-63		

VAS-07		VAS-08		VAS-09		VAS-10		VAS-11		VAS-12	
Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)
-15.00	60	-13.35	197	-13.20	98	-15.20	180	-15.20	153	-15.00	86
-25.00	60	-23.25	196	-18.50	88	-25.20	175	-25.00	171	-25.10	1
-35.00	51	-33.00	182	-27.40	75			-35.00	171	-35.00	46
-43.50	87	-43.00	187	-35.30	76			-45.00	44	-45.10	58
		-49.50	182	-45.20	110			-54.60	-33	-54.80	25
				-50.40	76			-60.40	-77		

VAS-13		VAS-14		VAS-15		VAS-16		VAS-17		VAS-18	
Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)
-15.30	203	-17.80	199	-18.00	97	-15.00	31	-15.00	86	-13.53	138
-19.50	208	-25.65	190	-25.20	85	-25.00	27	-25.00	-352	-23.50	-97
-30.00	212					-34.10	-8	-35.00	-592	-20.00	-24
-40.00	212					-44.90	-47	-45.10	-556	-30.00	-1
-50.00	142					-55.00	-80	-55.10	-559	-39.90	40
								-46.80	-56	-48.50	37
								-55.20	-30	-58.80	5
										-63.70	-44

VAS-19		VAS-20		VAS-21		VAS-22		VAS-23		VAS-24	
Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)	Depth (ft)	ORP (mV)
-12.50	11	-13.00	-40	-13.15	127	-15.00	-119	-17.80	113	-15.30	241
-22.50	62	-18.20	-272	-23.20	80	-24.90	-97	-28.40	102	-25.30	241
-32.50	70			-33.00	48	-35.30	-67	-35.00	109	-35.20	232
-42.60	25			-41.50	48	-45.00	-1	-44.90	108	-45.10	226
-48.50	-164			-51.50	107	-46.70	-65	-51.50	75	-51.20	192
				-60.20	139						
				-66.50	126						

Appendix B-2

Oxidation-Reduction Potential Measurement Summary

VAS-25		VAS-26		VAS-27		VAS-28		VAS-29		VAS-30	
Depth (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)
-14.90	199	-15.20	247	-15.10	216	-15.10	151	-15.40	228	-17.10	165
-24.80	120	-25.20	243	-25.10	114	-24.90	156	-25.40	244	-24.30	152
-34.90	127	-35.40	22	-34.90	155	-35.00	160	-35.40	238	-35.00	142
-44.90	87	-45.30	94	-45.00	161	-45.00	112	-45.30	227	-45.10	237
-47.70	-97	-49.50	136	-49.17	74	-47.60	-74	-47.30	187	-51.60	227

VAS-31		VAS-32		VAS-33		VAS-34		VAS-35		VAS-36	
Depth (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)
-9.90	-55	-15.10	227	-17.10	174	-13.50	-89	-13.00	-90	-15.20	227
-19.90	-97	-25.00	221	-27.10	25	-22.90	-22	-23.00	-140	-25.20	218
-30.10	-30	-35.00	219	-37.00	49	-33.40	-52	-32.90	-110	-35.30	223
-40.00	84	-41.80	107	-49.30	-40	-43.10	16	-43.10	-106	-44.10	152
-45.50	101	-45.30	-103			-49.80	-113	-50.60	-67		

VAS-37		VAS-38		VAS-39		VAS-40		VAS-41		VAS-42	
Depth (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)	**Depth** (ft)	**ORP** (mV)
-14.90	234	-12.00	234	-9.90	194	-10.10	236	-8.10	155	-8.15	176
-24.80	161	-21.30	222	-24.60	-19	-20.40	203	-18.10	162	-18.18	-69
-34.30	126	-31.30	208	-34.00	21	-30.10	157	-28.10	132	-23.70	-79
-44.40	156	-33.40	190			-40.00	151	-38.00	122	-32.75	-94
-46.50	93	-43.00	197			-44.10	92	-40.50	59		
		-51.60	141								

Notes:

ft Feet (negative value indicates depth below ground surface)

mV Millivolt

ORP Oxidation-reduction potential

ORP measurements greater than 0 mV are highlighted.

Appendix B-3

Groundwater Profiling
Physiochemical Parameter Logs

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-01

	Started	Completed
Dates:	8/29/2015	8/29/2015

Location: Troy OH

SEI #: 15-173

Sampler(s): CJM

KPRO Box Serial # / Acquisition Laptop: 801/Probook 1

Troll Serial #: 45358

Drilling Contractor: Platform

Average Depth to Water: -13.14

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 34.02

KPRO N_2 Pressure (set via P transducer): 72.27

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.20	8/29/15 13:14	600	-13.21	990	4.48	7.22	197	
-25.30	8/29/15 13:42	700	-13.32	1023	4.88	7.23	194	
-35.20	8/29/15 14:15	800	NC	994	1.74	7.11	155	
-45.20	8/29/15 14:53	800	-12.97	966	1.47	7.10	130	
-55.10	8/29/15 15:38	1000	-13.04	862	1.12	7.15	47	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-02

Dates (Started / Completed):	8/31/2015 / 8/31/2015	KPRO Box Serial # / Acquisition Laptop:	801/Probook 1
Gas Drive or Peri Pump:	Peri Pump	Location:	Troy, OH
Troll Serial #:	45358	Atmospheric Pressure:	34.04
SEI #:	15-173	Drilling Contractor:	Platform
KPRO N_2 Pressure (set via P transducer):	67.45	Sampler(s):	CJM
Average Depth to Water:	-12.02	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-12.80	8/31/15 13:17	600	-12.01	1046	4.72	7.04	224	
-23.00	8/31/15 13:57	600	-12.04	1156	4.04	7.45	196	
-33.30	8/31/15 14:32	600	-12.05	1063	4.17	7.16	205	
-43.00	8/31/15 15:20	900	-11.98	1007	1.65	7.18	135	
-50.50	NA	100	NC	NC	NC	NC	NC	Grab Sample collected, flow stopped.

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-03

Dates: Started 8/31/2015 Completed 8/31/2015

KPRO Box Serial # / Acquisition Laptop: 809/Probook3

Gas Drive or Peri Pump: Peri Pump

Location: Troy, OH

Troll Serial #: 62572

Atmospheric Pressure: 32.90

SEI #: 15-173

Drilling Contractor: Platform

KPRO N_2 Pressure (set via P transducer): 70.55

Sampler(s): JLV

Average Depth to Water: -10.91

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-13.20	8/31/15 10:10	600	-11.11	1286	2.62	7.16	93	
-23.00	8/31/15 10:39	600	-11.02	1066	4.91	7.23	94	
-32.90	8/31/15 11:28	550	-10.95	1076	5.17	7.15	96	
-43.00	8/31/15 12:22	600	-10.65	985	2.83	7.06	98	
-49.70	8/31/15 13:00	600	-10.80	1007	3.49	6.99	97	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-04

Dates:	Started 8/31/2015, Completed 8/31/2015	KPRO Box Serial # / Acquisition Laptop:	801/Probook 1	Gas Drive or Peri Pump:	Peri Pump
Location:	Troy, OH	Troll Serial #:	45358	Atmospheric Pressure:	34.09
SEI #:	15-173	Drilling Contractor:	Platform	KPRO N_2 Pressure (set via P transducer):	71.75
Sampler(s):	CJM	Average Depth to Water:	-11.01	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-13.20	8/31/15 8:09	600	-10.85	923	4.92	6.93	224	
-18.00	8/31/15 9:16	600	NC	1021	8.61	7.77	205	
-28.00	8/31/15 9:46	600	-10.97	1128	5.16	7.21	210	
-38.00	8/31/15 10:45	600	-11.12	1050	5.10	7.18	213	
-48.50	8/31/15 11:19	600	-11.09	1050	4.73	7.16	213	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-05

Dates:	Started 8/29/2015 Completed 8/29/2015	KPRO Box Serial # / Acquisition Laptop:	809/Probook3	Gas Drive or Peri Pump:	Peri Pump
Location:	Troy, OH	Troll Serial #:	62572	Atmospheric Pressure:	32.93
SEI #:	15-173	Drilling Contractor:	Platform	KPRO N_2 Pressure (set via P transducer):	71.00
Sampler(s):	JLV	Average Depth to Water:	-12.66	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.40	8/29/15 10:52	600	-12.75	928	5.94	7.27	28	
-25.30	8/29/15 11:31	650	-12.85	992	5.10	7.58	38	
-35.00	8/29/15 12:18	650	-13.00	972	1.72	7.57	40	
-45.00	8/29/15 13:08	800	-11.60	1005	1.18	7.48	-80	
-55.00	8/29/15 14:07	700	-12.95	919	1.43	7.62	-63	
-59.50	8/29/15 15:15	700	-12.80	943	1.03	7.61	-63	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-06

Dates:	Started 8/27/2015 Completed 8/27/2015	KPRO Box Serial # / Acquisition Laptop:	801/Probook 1
Location:	Troy, OH	Troll Serial #:	45358
SEI #:	15-173	Drilling Contractor:	Platform
Sampler(s):	CJM	Average Depth to Water:	-12.65

Gas Drive or Peri Pump:	Peri Pump
Atmospheric Pressure:	34.16
KPRO N_2 Pressure (set via P transducer):	69.25
Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.10	8/27/15 12:27	700	-12.69	857	5.28	7.11	98	
-25.00	8/27/15 12:52	600	-12.65	930	4.95	7.18	104	
-35.10	8/27/15 13:31	700	-12.68	823	4.63	7.16	116	
-45.15	8/27/15 14:10	800	-12.65	864	2.19	7.08	121	
-55.00	8/27/15 15:07	900	-12.57	791	1.69	7.17	-19	ORP continuously falling, pulled sample early.

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-07

Dates: Started 8/27/2015, Completed 8/28/2015

Location: Troy OH

SEI #: 15-173

Sampler(s): JLV

KPRO Box Serial # / Acquisition Laptop: 809/Probook3

Troll Serial #: 62572

Drilling Contractor: Platform

Average Depth to Water: -12.12

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 32.95

KPRO N_2 Pressure (set via P transducer): 69.65

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.00	8/27/15 14:26	700	-12.00	924	4.15	7.07	60	
-25.00	8/27/15 16:16	700	-12.10	946	1.86	7.59	60	
-35.00	8/27/15 16:54	550	-12.02	807	3.73	6.96	51	
-43.50	8/28/15 8:05	750	-12.36	831	1.57	7.22	87	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-08

Dates (Started / Completed):	8/30/2015 / 8/30/2015	KPRO Box Serial # / Acquisition Laptop:	801/Probook 1
Location:	Troy, OH	Troll Serial #:	45358
SEI #:	15-173	Drilling Contractor:	Platform
Sampler(s):	CJM	Average Depth to Water:	-11.79
Gas Drive or Peri Pump:	Peri Pump	Atmospheric Pressure:	34.03
KPRO N_2 Pressure (set via P transducer):	67.74	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-13.35	8/30/15 12:07	600	-11.60	1127	4.51	7.02	197	
-23.25	8/30/15 12:40	800	-11.85	1185	3.32	7.00	196	
-33.00	8/30/15 13:14	600	-11.97	1136	3.95	7.36	182	
-43.00	8/30/15 13:46	600	-11.89	941	3.90	7.15	187	
-49.50	8/30/15 14:30	700	-11.62	887	2.70	7.15	182	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-09

Dates:	Started 8/30/2015 Completed 8/31/2015	KPRO Box Serial # / Acquisition Laptop:	809/Probook3	Gas Drive or Peri Pump:	Peri Pump
Location:	Troy, OH	Troll Serial #:	62572	Atmospheric Pressure:	32.91
SEI #:	15-173	Drilling Contractor:	Platform	KPRO N_2 Pressure (set via P transducer):	70.48
Sampler(s):	JLV	Average Depth to Water:	-11.29	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-13.20	8/30/15 12:29	550	-11.15	1158	3.38	6.86	98	
-18.50	8/30/15 13:07	550	-11.22	1199	3.89	7.27	88	
-27.40	8/30/15 15:03	600	-11.50	1148	1.77	7.19	75	
-35.30	8/30/15 15:42	600	-11.54	1181	3.73	7.30	76	
-45.20	8/31/15 7:51	600	-11.41	978	3.84	7.41	110	
-50.40	8/31/15 8:34	600	-10.90	960	1.82	7.43	76	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-10

Dates: Started 8/29/2015 Completed 8/29/2015

Location: Troy, OH

SEI #: 15-173

Sampler(s): CJM

KPRO Box Serial # / Acquisition Laptop: 801/Probook 1

Troll Serial #: 45358

Drilling Contractor: Platform

Average Depth to Water: -13.95

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 34.00

KPRO N_2 Pressure (set via P transducer): 68.40

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.20	8/29/15 10:04	600	-13.94	877	5.56	7.23	180	
-25.20	8/29/15 10:39	700	-13.95	1113	3.67	7.30	175	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-11

Dates: (Started / Completed)	8/26/2015 / 8/27/2015	KPRO Box Serial # / Acquisition Laptop:	801/Probook 1
Location:	Troy, OH	Troll Serial #:	45358
SEI #:	15-173	Drilling Contractor:	Platform
Sampler(s):	CJM	Average Depth to Water:	-13.48

Gas Drive or Peri Pump:	Peri Pump
Atmospheric Pressure:	34.04
KPRO N_2 Pressure (set via P transducer):	72.71
Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.20	8/26/15 16:45	600	-13.38	806	5.30	7.10	153	
-25.00	8/27/15 7:40	700	-13.63	813	5.68	7.18	171	
-35.00	8/27/15 8:16	700	-13.71	817	4.89	7.12	171	
-45.00	8/27/15 8:58	800	-13.46	924	2.18	7.27	44	
-54.60	8/27/15 9:55	900	-13.08	822	1.78	7.11	-33	
-60.40	8/27/15 10:52	900	-13.60	736	1.43	7.34	-77	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-12

Dates: Started 8/27/2015 Completed 8/27/2015	KPRO Box Serial # / Acquisition Laptop: 809/Probook3	Gas Drive or Peri Pump: Peri Pump
Location: Troy, OH	Troll Serial #: 62752	Atmospheric Pressure: 32.96
SEI #: 15-173	Drilling Contractor: Platform	KPRO N_2 Pressure (set via P transducer): 70.43
Sampler(s): JLV	Average Depth to Water: -13.26	Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.00	8/27/15 7:22	550	-12.99	765	5.29	7.47	86	
-25.10	8/27/15 9:05	650	-14.35	556	NC	8.10	1	D.O. not accurate due to turbidity
-35.00	8/27/15 11:25	600	-13.00	879	4.15	7.93	46	
-45.10	8/27/15 12:06	700	-13.20	870	1.73	7.34	58	
-54.80	8/27/15 12:47	600	-12.74	767	5.38	7.59	25	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-13

Dates (Started / Completed):	8/28/2015 / 8/28/2015	KPRO Box Serial # / Acquisition Laptop:	801/ Probook 1	Gas Drive or Peri Pump:	Peri Pump
Location:	Troy, OH	Troll Serial #:	45358	Atmospheric Pressure:	34.15
SEI #:	15-173	Drilling Contractor:	Platform	KPRO N_2 Pressure (set via P transducer):	71.09
Sampler(s):	CJM	Average Depth to Water:	-12.26	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.30	8/28/15 8:27	600	-11.87	961	8.84	6.90	203	
-19.50	8/28/15 8:55	600	-12.49	1081	5.93	6.92	208	
-30.00	8/28/15 9:30	600	-12.35	1111	6.34	6.99	212	
-40.00	8/28/15 10:01	600	-12.33	950	4.97	7.07	212	
-50.00	8/28/15 11:13	700	NC	954	7.28	7.37	142	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-14

Dates:	Started 8/30/2015 Completed 8/30/2015	KPRO Box Serial # / Acquisition Laptop:	801/Probook 1	Gas Drive or Peri Pump:	Peri Pump
Location:	Troy, OH	Troll Serial #:	45358	Atmospheric Pressure:	34.03
SEI #:	15-173	Drilling Contractor:	Platform	KPRO N_2 Pressure (set via P transducer):	69.66
Sampler(s):	CJM	Average Depth to Water:	-13.83	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-17.80	8/30/15 8:57	600	-13.87	893	5.13	7.32	199	
-25.65	8/30/15 9:52	800	-13.78	1009	2.73	7.11	190	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-15

Dates (Started / Completed):	8/30/2015 8/30/2015	KPRO Box Serial # / Acquisition Laptop:	809/Probook3	Gas Drive or Peri Pump:	Peri Pump
Location:	Troy, OH	Troll Serial #:	62572	Atmospheric Pressure:	32.93
SEI #:	15-173	Drilling Contractor:	Platform	KPRO N_2 Pressure (set via P transducer):	69.59
Sampler(s):	JLV	Average Depth to Water:	-14.77	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-18.00	8/30/15 8:21	700	-14.80	916	2.33	7.37	97	
-25.20	8/30/15 9:28	700	-14.74	1039	1.90	7.46	85	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-16

Dates:	Started: 8/26/2015 Completed: 8/26/2015	KPRO Box Serial # / Acquisition Laptop:	809/Probook3
Location:	Troy, OH	Troll Serial #:	62752
SEI #:	15-173	Drilling Contractor:	Platform
Sampler(s):	JLV	Average Depth to Water:	-12.15
Gas Drive or Peri Pump:	Peri Pump	Atmospheric Pressure:	33.00
KPRO N_2 Pressure (set via P transducer):	69.41	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.00	8/26/15 10:57	650	-12.09	818	2.91	7.58	31	
-25.00	1/1/04 11:32	600	-12.15	896	3.00	7.66	27	
-34.10	8/26/15 13:37	750	-12.25	783	1.75	7.94	-8	
-44.90	8/26/15 14:22	700	-12.06	918	1.43	7.56	-47	
-55.00	8/26/15 15:09	700	-12.22	862	1.56	7.39	-80	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-17

Dates:	Started 8/25/2015 Completed 8/26/2015	KPRO Box Serial # / Acquisition Laptop:	801/Probook 1	Gas Drive or Peri Pump:	Peri Pump
Location:	Troy, OH	Troll Serial #:	45358	Atmospheric Pressure:	34.02
SEI #:	15-173	Drilling Contractor:	Platform	KPRO N_2 Pressure (set via P transducer):	69.12
Sampler(s):	CJM	Average Depth to Water:	-13.98	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.00	8/25/15 15:54	1000	-13.37	755	1.74	7.16	86	
-25.00	8/25/15 17:13	1100	-14.13	767	NA	7.64	-352	DO probe too silty for readings.
-35.00	8/26/15 8:30	500	-14.88	423	NA	8.13	-592	DO probe too silty for readings
-45.10	8/26/15 10:00	300	-13.57	427	NA	7.97	-556	Pulled early for time constraint, DO probe too silty for readings.
-55.10	8/26/15 11:24	350	-13.96	395	NA	7.95	-559	Pulled early for time constraint. DO probe too silty for readings.

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-17A

Dates: Started 8/26/2015 Completed 8/26/2015

Location: Troy, OH

SEI #: 15-173

Sampler(s): CJM

KPRO Box Serial # / Acquisition Laptop: 801/Probook 1

Troll Serial #: 45358

Drilling Contractor: Platform

Average Depth to Water: -13.40

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 34.07

KPRO N_2 Pressure (set via P transducer): 67.82

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-46.80	8/26/15 13:28	800	-13.40	932	1.69	7.24	-56	
-55.20	8/26/15 14:44	700	NC	865	1.89	7.24	-30	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-18

Dates:	8/25/2015 (Started) 8/26/2015 (Completed)	KPRO Box Serial # / Acquisition Laptop:	809/Probook3	Gas Drive or Peri Pump:	Peri Pump
Location:	Troy, OH	Troll Serial #:	62752	Atmospheric Pressure:	32.84
SEI #:	15-173	Drilling Contractor:	Platform	KPRO N_2 Pressure (set via P transducer):	70.61
Sampler(s):	JLV	Average Depth to Water:	-12.24	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-13.53	8/25/15 10:24	750	-12.64	834	1.63	7.46	138	
-23.50	8/25/15 11:27	850	-11.92	709	NA	8.07	-97	TIP Broken
-20.00	8/25/15 14:21	650	-12.70	962	1.71	7.72	-24	
-30.00	8/25/15 15:03	650	-11.27	930	2.09	7.89	-1	
-39.90	8/25/15 16:22	600	-12.64	955	3.98	7.35	40	
-48.50	8/25/15 17:13	850	-12.66	870	1.45	7.63	37	
-58.80	8/26/15 7:59	850	-12.58	444	1.27	7.90	5	
-63.70	8/26/15 9:00	600	-11.50	833	1.92	7.60	-44	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-19

Dates (Started / Completed):	8/25/2015 / 8/25/2015	KPRO Box Serial # / Acquisition Laptop:	801/Probook 1
Location:	Troy, OH	Troll Serial #:	45358
SEI #:	15-173	Drilling Contractor:	Platform
Sampler(s):	CJM	Average Depth to Water:	-11.64

Gas Drive or Peri Pump: Peri Pump
Atmospheric Pressure: 34.04
KPRO N_2 Pressure (set via P transducer): 72.74
Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-12.50	8/25/15 10:11	1000	-11.58	1075	1.24	6.44	11	
-22.50	8/25/15 10:43	800	-11.72	892	2.78	7.05	62	
-32.50	8/25/15 11:26	900	-11.69	906	2.60	7.23	70	
-42.60	8/25/15 12:21	800	-11.74	937	3.16	7.48	25	
-48.50	8/25/15 13:26	1000	-11.48	999	1.36	7.36	-164	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-20

Dates: Started 8/28/2015 Completed 8/28/2015

Location: Troy OH

SEI #: 15-173

Sampler(s): JLV

KPRO Box Serial # / Acquisition Laptop: 809/Probook3

Troll Serial #: 62572

Drilling Contractor: Platform

Average Depth to Water: -9.70

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 32.98

KPRO N_2 Pressure (set via P transducer): 71.00

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-13.00	8/28/15 7:43	650	-9.30	1593	1.23	6.90	-40	
-18.20	8/29/15 8:53	650	-10.10	2792	0.00	9.55	-272	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-21

Dates:	Started 8/28/2015, Completed 8/29/2015	KPRO Box Serial # / Acquisition Laptop:	801/Probook 1
Location:	Troy, OH	Troll Serial #:	45358
SEI #:	15-173	Drilling Contractor:	Platform
Sampler(s):	CJM	Average Depth to Water:	-9.76

Gas Drive or Peri Pump:	Peri Pump
Atmospheric Pressure:	34.15
KPRO N_2 Pressure (set via P transducer):	71.36
Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-13.15	8/28/15 13:30	500	NC	238	8.12	8.29	127	Pulled sample before parameters stabilize. Flow slows significatly after pruging 400 mLs.
-23.20	8/28/15 14:27	700	-9.74	1139	1.58	8.14	80	
-33.00	8/28/15 15:00	700	-9.80	1581	1.45	8.02	48	
-41.50	8/28/15 15:38	800	-9.77	1341	2.09	7.44	48	
-51.50	8/28/15 17:01	520	-9.73	1435	3.17	7.48	107	
-60.20	8/29/15 7:29	800	NC	1486	3.19	7.17	139	
-66.50	8/29/15 8:30	1000	NC	1196	1.59	7.39	126	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-22

Dates:	Started 8/28/2015 Completed 8/28/2015	KPRO Box Serial # / Acquisition Laptop:	809/Probook3	Gas Drive or Peri Pump:	Peri Pump
Location:	Troy, OH	Troll Serial #:	62572	Atmospheric Pressure:	32.95
SEI #:	15-173	Drilling Contractor:	Platform	KPRO N_2 Pressure (set via P transducer):	69.39
Sampler(s):	JLV	Average Depth to Water:	-5.08	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.00	8/28/15 11:09	650	NC	819	0.65	7.24	-119	
-24.90	8/28/15 11:50	1000	-5.20	1493	0.66	7.34	-97	
-35.30	8/28/15 14:05	750	-3.70	1387	1.22	7.28	-67	
-45.00	8/28/15 14:46	900	-5.70	1195	1.28	7.26	-1	
-46.70	8/28/15 15:46	850	-5.70	1118	0.82	7.62	-65	

GROUNDWATER PROFILE LOG

Client: Tetra Tech

STONE ENVIRONMENTAL INC

Profile Location: VAS-23

Dates:	Started: 9/1/2015 Completed: 9/1/2015	KPRO Box Serial # / Acquisition Laptop:	809/Probbok3
Gas Drive or Peri Pump:	Peri Pump		
Location:	Troy, OH	Troll Serial #:	62572
Atmospheric Pressure:	33.30		
SEI #:	15-173	Drilling Contractor:	Platform
KPRO N_2 Pressure (set via P transducer):	70.50		
Sampler(s):	JLV	Average Depth to Water:	-12.40
Gas Drive Pump N_2 Pressure:	NA		

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-17.80	8/31/15 8:33	550	-12.50	910	3.11	7.21	113	
-28.40	9/1/15 10:33	600	-12.11	1037	4.64	7.62	102	
-35.00	9/1/15 11:02	600	-12.55	1082	4.57	7.39	109	
-44.90	9/1/15 11:49	600	-12.52	875	3.50	7.59	108	
-51.50	9/1/15 12:45	850	-12.30	900	1.33	7.51	75	

GROUNDWATER PROFILE LOG

STONE ENVIRONMENTAL INC

Client: Tetra Tech

Profile Location: VAS-24

Dates: Started 9/1/2015, Completed 9/1/2015

Location: Troy, OH

SEI #: 15-173

Sampler(s): CJM

KPRO Box Serial # / Acquisition Laptop: 801/Probook

Troll Serial #: 45358

Drilling Contractor: Platform

Average Depth to Water: -13.07

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 34.03

KPRO N_2 Pressure (set via P transducer): 71.43

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.30	9/1/15 8:30	800	-13.05	1211	8.19	7.09	241	
-25.30	9/1/15 9:10	600	-13.01	1043	4.64	7.09	241	
-35.20	9/1/15 9:56	600	-13.12	962	4.59	7.22	232	
-45.10	9/1/15 10:56	900	-13.10	910	2.96	7.13	226	
-51.20	9/1/15 12:48	600	NC	929	6.21	7.55	192	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: Tetra Tech

Profile Location: VAS-25

	Started	Completed
Dates:	5/20/2016	5/21/2016

Location: West Troy, OH
SEI #: 205162076
Sampler(s): EEG

KPRO Box Serial # / Acquisition Laptop: 804 / Rasc9
Sonde Serial #: 45385
Drilling Contractor: Cascade
Average Depth to Water: -10.96

Gas Drive or Peri Pump: Peri Pump
Atmospheric Pressure: 35.65
KPRO N_2 Pressure (set via P transducer): 68.08
Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-14.90	5/20/16 15:49	800	-11.75	1612	4.69	6.89	199	
-24.80	5/20/16 16:30	1000	-9.49	1716	1.99	7.01	120	
-34.90	5/20/16 17:05	700	-11.68	1611	4.18	7.07	127	
-44.90	5/21/16 8:41	1400	-10.45	1407	1.04	6.93	87	
-47.70	5/21/16 9:25	700	-11.43	1347	1.65	7.00	-97	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: **Tetra Tech**

Profile Location: VAS-26

	Started	Completed
Dates:	5/20/2016	5/20/2016

Location: West Troy, OH

SEI #: 205162076

Sampler(s): NFL

KPRO Box Serial # / Acquisition Laptop: 803/Probook 2

Sonde Serial #: 62751

Drilling Contractor: Cascade

Average Depth to Water: -10.98

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 33.98

KPRO N_2 Pressure (set via P transducer): 69.24

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.20	5/20/16 11:33	600	-11.00	1027	5.76	6.12	247	
-25.20	5/20/16 12:01	500	-11.20	1103	5.37	6.06	243	
-35.40	5/20/16 14:12	1000	-10.40	1106	3.83	6.16	22	
-45.30	5/20/16 14:55	700	-11.30	996	2.28	6.06	94	
-49.50	5/20/16 15:44	800	-11.00	953	2.00	6.06	136	

GROUNDWATER PROFILE LOG

Client: **Tetra Tech**

CASCADE DRILLING | TECHNICAL SERVICES

Profile Location: VAS-27

	Started	Completed
Dates:	5/20/2016	5/20/2016

Location: West Troy, OH
SEI #: 205162076
Sampler(s): EEG

KPRO Box Serial # / Acquisition Laptop: 8804 / Rasc9
Sonde Serial #: 45385
Drilling Contractor: Cascade
Average Depth to Water: -11.36

Gas Drive or Peri Pump: Peri Pump
Atmospheric Pressure: 35.94
KPRO N_2 Pressure (set via P transducer): 68.92
Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.10	5/20/16 10:40	800	-11.33	1691	5.25	6.90	216	
-25.10	5/20/16 11:45	800	-11.10	1781	2.93	7.04	114	
-34.90	5/20/16 12:20	700	-11.51	1683	4.65	6.96	155	
-45.00	5/20/16 12:59	700	-11.63	1621	4.13	6.95	161	
-49.17	5/20/16 13:46	900	-11.23	1595	3.23	7.00	74	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: **Tetra Tech**

Profile Location: VAS-28

	Started	Completed
Dates:	5/21/2016	5/21/2016

Location: West Troy, OH

SEI #: 205162076

Sampler(s): EEG

KPRO Box Serial # / Acquisition Laptop: 804

Sonde Serial #: 45385

Drilling Contractor: Cascade

Average Depth to Water: -12.64

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 35.64

KPRO N_2 Pressure (set via P transducer): 68.76

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.10	5/21/16 11:27	700	-12.97	1528	4.15	6.95	151	
-24.90	5/21/16 12:10	700	-12.69	1609	3.85	6.92	156	
-35.00	5/21/16 13:17	800	-13.41	1511	3.25	7.02	160	
-45.00	5/21/16 14:34	1200	-11.02	1415	1.13	6.94	112	
-47.60	5/21/16 15:47	1100	-13.11	1475	1.17	7.04	-74	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: **Tetra Tech**

Profile Location: VAS-29

	Started	Completed
Dates:	5/20/2016	5/21/2016

Location: West Troy, OH

SEI #: 205162076

Sampler(s): NFL

KPRO Box Serial # / Acquisition Laptop: 803/Probook 2

Sonde Serial #: 62751

Drilling Contractor: Cascade

Average Depth to Water: -11.46

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 33.83

KPRO N_2 Pressure (set via P transducer): 68.88

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.40	5/20/16 17:15	600	-11.10	1085	3.86	5.95	228	
-25.40	5/21/16 8:07	600	-11.80	1080	3.57	6.15	244	
-35.40	5/21/16 8:38	500	-11.80	1046	4.32	6.03	238	
-45.30	5/21/16 9:22	800	-11.30	938	1.31	5.99	227	
-47.30	5/21/16 10:05	900	-11.30	951	1.05	6.08	187	

GROUNDWATER PROFILE LOG

Client: **Tetra Tech**

CASCADE DRILLING | TECHNICAL SERVICES

Profile Location: VAS-30

	Started	Completed
Dates:	5/19/2016	5/20/2016

Location: West Troy, OH
SEI #: 205162076
Sampler(s): NFL

KPRO Box Serial # / Acquisition Laptop: 803/Probook 2
Sonde Serial #: 62751
Drilling Contractor: Cascade
Average Depth to Water: -10.00

Gas Drive or Peri Pump: Peri Pump
Atmospheric Pressure: 33.84
KPRO N_2 Pressure (set via P transducer): 64.99
Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-17.10	5/19/16 15:58	700	-8.30	1077	4.64	6.22	165	
-24.30	5/19/16 16:34	600	-9.10	1153	2.53	6.20	152	
-35.00	5/19/16 17:31	700	-11.00	1134	3.57	6.15	142	
-45.10	5/20/16 8:30	600	-10.80	1051	4.27	6.01	237	
-51.60	5/20/16 9:15	700	-10.80	1009	2.90	5.95	227	

GROUNDWATER PROFILE LOG

Client: **Tetra Tech**

CASCADE DRILLING | TECHNICAL SERVICES

Profile Location: VAS-31

	Started	Completed
Dates:	5/18/2016	5/19/2016

Location: West Troy, OH

SEI #: 205162076

Sampler(s): EEG

KPRO Box Serial # / Acquisition Laptop: 804 Rasc9

Sonde Serial #: 45385

Drilling Contractor: Cascade

Average Depth to Water: -6.67

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 35.77

KPRO N_2 Pressure (set via P transducer): 67.72

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-9.90	5/18/16 17:19	1000	-6.50	1799	0.89	6.51	-55	
-19.90	5/19/16 8:26	900	-6.72	1488	1.22	6.86	-97	
-30.10	5/19/16 9:10	1000	-6.56	1640	2.43	6.93	-30	
-40.00	5/19/16 10:31	800	-6.58	1585	4.92	6.93	84	
-45.50	5/19/16 11:25	700	-7.01	1559	4.50	7.03	101	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: **Tetra Tech**

Profile Location: VAS-32

	Started	Completed
Dates:	5/21/2016	5/21/2016

Location: West Troy, OH

SEI #: 205162076

Sampler(s): NFL

KPRO Box Serial # / Acquisition Laptop: 803/Probook 2

Sonde Serial #: 62751

Drilling Contractor: Cascade

Average Depth to Water: -12.30

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 33.72

KPRO N_2 Pressure (set via P transducer): 70.56

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.10	5/21/16 13:22	700	-11.90	872	4.31	6.22	227	
-25.00	5/21/16 13:48	500	-12.30	993	4.05	6.24	221	
-35.00	5/21/16 14:24	600	-12.60	1010	3.67	6.14	219	
-41.80	5/21/16 15:13	800	-12.50	1000	1.35	6.22	107	
-45.30	5/21/16 16:15	950	-12.20	976	1.05	6.28	-103	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: **Tetra Tech**

Profile Location: VAS-33

	Started	Completed
Dates:	5/19/2016	5/19/2016

Location: West Troy, OH
SEI #: 205162076
Sampler(s): EEG

KPRO Box Serial # / Acquisition Laptop: 804 / Rasc9
Sonde Serial #: 45385
Drilling Contractor: Cascade
Average Depth to Water: -11.56

Gas Drive or Peri Pump: Peri Pump
Atmospheric Pressure: 35.89
KPRO N_2 Pressure (set via P transducer): 69.00
Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	**Date / Time**	**Volume Purged** (mL)	**Head** (ft)	**SC** (uS/cm)	**DO** (PPM)	**pH**	**ORP** (mV)	**COMMENTS**
-17.10	1/3/04 14:31	1300	-12.06	1661	1.01	6.59	174	
-27.10	5/19/16 15:23	1300	-11.16	1700	1.33	6.78	25	
-37.00	5/9/16 16:05	800	-11.51	1680	2.84	6.97	49	
-49.30	5/19/16 17:29	1000	-11.50	1478	1.41	7.08	-40	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: **Tetra Tech**

Profile Location: VAS-34

	Started	Completed
Dates:	5/18/2016	5/19/2016

Location: West Troy, OH

SEI #: 205162076

Sampler(s): NFL

KPRO Box Serial # / Acquisition Laptop: 803/Probook 2

Sonde Serial #: 62751

Drilling Contractor: Cascade

Average Depth to Water: -8.38

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 33.92

KPRO N_2 Pressure (set via P transducer): 69.08

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-13.50	5/19/16 8:42	1150	-8.20	2239	NC	NC	-89	pH and DO values inaccurate, re-calibrated sonde after sample was collected.
-22.90	5/19/16 9:25	850	-8.50	1054	1.04	6.55	-22	
-33.40	5/19/16 10:32	900	-8.40	1078	2.65	6.25	-52	
-43.10	5/19/16 11:23	800	-8.40	1092	2.77	6.10	16	
-49.80	5/19/16 13:03	600	-8.40	989	1.50	6.30	-113	

GROUNDWATER PROFILE LOG

Client: **Tetra Tech**

CASCADE DRILLING | TECHNICAL SERVICES

Profile Location: VAS-35

	Started	Completed
Dates:	5/18/2016	5/18/2016

Location: West Troy, OH

SEI #: 205162077

Sampler(s): EEG

KPRO Box Serial # / Acquisition Laptop: 804 / rasc9

Sonde Serial #: 45385

Drilling Contractor: Cascade

Average Depth to Water: -7.67

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 35.96

KPRO N_2 Pressure (set via P transducer): 69.16

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-13.00	5/18/16 10:57	1000	-6.65	2404	1.12	6.64	-90	
-23.00	5/18/16 11:51	800	-9.50	1780	0.96	7.98	-140	
-32.90	5/18/16 12:43	1300	-6.90	1715	1.02	7.32	-110	
-43.10	5/18/16 13:51	1000	-7.62	1597	1.42	7.44	-106	

GROUNDWATER PROFILE LOG

Client: **Tetra Tech**

CASCADE DRILLING | TECHNICAL SERVICES

Profile Location: VAS-35A

Dates:	Started 5/21/2016 / Completed 5/21/2016	KPRO Box Serial # / Acquisition Laptop:	804 / Rasc9
Location:	West Troy, OH	Sonde Serial #:	45358
SEI #:	205162076	Drilling Contractor:	Cascade
Sampler(s):	EEG	Average Depth to Water:	-10.95

Gas Drive or Peri Pump: Peri Pump
Atmospheric Pressure: 35.49
KPRO N_2 Pressure (set via P transducer): 67.88
Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-50.60	5/21/16 18:17	1000	-10.95	1332	2.13	7.26	-67	

GROUNDWATER PROFILE LOG

Client: Tetra Tech

CASCADE DRILLING | TECHNICAL SERVICES

Profile Location: VAS-36

Dates: Started 5/18/2016 Completed 5/18/2016	KPRO Box Serial # / Acquisition Laptop: 803/Probook 2	Gas Drive or Peri Pump: Peri Pump
Location: West Troy, OH	Sonde Serial #: 62751	Atmospheric Pressure: 33.94
SEI #: 205162076	Drilling Contractor: Cascade	KPRO N_2 Pressure (set via P transducer): 69.50
Sampler(s): NFL	Average Depth to Water: -10.25	Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-15.20	5/18/16 11:34	500	-10.30	1144	3.59	8.02	227	
-25.20	5/18/16 12:07	500	-10.00	821	4.13	7.71	218	
-35.30	5/18/16 13:05	700	-10.80	946	3.73	8.60	223	
-44.10	5/18/16 14:16	600	-9.90	1251	4.38	8.35	152	

GROUNDWATER PROFILE LOG

Client: **Tetra Tech**

Profile Location: VAS-36A

	Started	Completed
Dates:	5/21/2016	5/21/2016

Location: West Troy, OH

SEI #: 205162076

Sampler(s): NFL

KPRO Box Serial # / Acquisition Laptop: 803/Probook 2

Sonde Serial #: 62751

Drilling Contractor: Cascade

Average Depth to Water: NC

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 33.72

KPRO N_2 Pressure (set via P transducer): 69.20

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	**Date / Time**	**Volume Purged** (mL)	**Head** (ft)	**SC** (uS/cm)	**DO** (PPM)	**pH**	**ORP** (mV)	**COMMENTS**
No Samples Collected								

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: Tetra Tech

Profile Location: VAS-37

	Started	Completed
Dates:	5/16/2016	5/16/2016

Location: West Troy, OH

SEI #: 205162076

Sampler(s): EEG

KPRO Box Serial # / Acquisition Laptop: 804/Rasc9

Sonde Serial #: 45358

Drilling Contractor: Cascade

Average Depth to Water: -6.75

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 36.03

KPRO N_2 Pressure (set via P transducer): 71.05

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-14.90	5/16/16 14:03	1400	-7.42	1417	1.29	7.22	234	
-24.80	5/16/16 14:53	1300	-7.60	1489	1.10	7.20	161	
-34.30	5/16/16 15:36	800	-6.22	1601	2.87	7.28	126	
-44.40	5/16/16 16:53	700	-6.20	1404	7.57	7.52	156	
-46.50	5/16/16 17:41	900	-6.32	1474	7.41	7.54	93	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: Tetra Tech

Profile Location: VAS-38

	Started	Completed
Dates:	5/16/2016	5/16/2016

Location: West Troy, OH
SEI #: 205162076
Sampler(s): NFL

KPRO Box Serial # / Acquisition Laptop: 803/Probook 2
Sonde Serial #: 62751
Drilling Contractor: Cascade
Average Depth to Water: -5.03

Gas Drive or Peri Pump: Peri Pump
Atmospheric Pressure: 33.98
KPRO N_2 Pressure (set via P transducer): 67.07
Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-12.00	5/16/16 12:49	700	-5.40	949	7.32	7.85	234	
-21.30	5/16/16 14:08	700	-5.40	1020	8.46	8.23	222	
-31.30	5/16/16 14:52	700	-5.00	968	4.39	8.17	208	
-33.40	5/16/16 15:40	600	-4.80	978	6.70	8.21	190	
-43.00	5/16/16 16:20	650	-5.00	859	6.18	8.20	197	
-51.60	5/16/16 17:03	600	-4.60	1018	5.67	8.31	141	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: Tetra Tech

Profile Location: VAS-39

	Started	Completed
Dates:	5/17/2016	5/17/2016

Location: West Troy OH

SEI #: 20516

Sampler(s): EEG

KPRO Box Serial # / Acquisition Laptop: 804/rasc9

Sonde Serial #: 45385

Drilling Contractor: Cascade

Average Depth to Water: -3.52

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 36.07

KPRO N_2 Pressure (set via P transducer): 68.99

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-9.90	5/17/16 9:15	1700	-3.25	1417	0.72	7.34	194	
-24.60	5/17/16 11:37	1750	-3.85	1456	0.93	7.27	-19	
-34.00	5/17/16 12:25	1300	-3.45	1598	0.98	7.09	21	

GROUNDWATER PROFILE LOG

CASCADE DRILLING | TECHNICAL SERVICES

Client: Tetra Tech

Profile Location: VAS-40

Dates (Started / Completed):	5/17/2016 / 5/17/2016	KPRO Box Serial # / Acquisition Laptop:	803/Probook 2
Location:	West Troy, Ohio	Sonde Serial #:	62751
SEI #:	205162076	Drilling Contractor:	Cascade
Sampler(s):	NFL	Average Depth to Water:	-4.26
Gas Drive or Peri Pump:	Peri Pump	Atmospheric Pressure:	34.05
KPRO N_2 Pressure (set via P transducer):	67.48	Gas Drive Pump N_2 Pressure:	NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-10.10	5/17/16 8:39	800	-4.30	1159	3.09	7.26	236	
-20.40	5/17/16 9:11	600	-4.30	862	3.45	8.01	203	
-30.10	5/17/16 10:18	500	-4.30	1187	5.35	7.79	157	
-40.00	5/17/16 10:56	800	-4.20	1127	3.15	7.92	151	
-44.10	5/17/16 11:40	800	-4.20	1066	3.53	7.89	92	

GROUNDWATER PROFILE LOG

Client: Tetra Tech

CASCADE DRILLING | TECHNICAL SERVICES

Profile Location: VAS-41

	Started	Completed
Dates:	5/17/2016	5/17/2016

Location: West Troy, Ohio

SEI #: 205162076

Sampler(s): NFL

KPRO Box Serial # / Acquisition Laptop: 803/Probook 2

Sonde Serial #: 62751

Drilling Contractor: Cascade

Average Depth to Water: -5.46

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 34.02

KPRO N_2 Pressure (set via P transducer): 68.42

Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-8.10	5/17/16 13:55	600	-5.50	839	4.07	8.27	155	
-18.10	5/17/16 14:35	700	-5.40	766	3.81	8.26	162	
-28.10	5/17/16 15:22	600	-5.40	747	3.92	8.46	132	
-38.00	5/17/16 16:02	800	-5.30	925	3.28	7.96	122	
-40.50	5/17/16 16:39	700	-5.70	1003	3.70	8.31	59	

A

Client: Tetra Tech

CASCADE DRILLING | TECHNICAL SERVICES

Profile Location: VAS-42

	Started	Completed
Dates:	5/17/2016	5/18/2016

Location: West Toy, Ohio

SEI #: 205162077

Sampler(s): EEG

KPRO Box Serial # / Acquisition Laptop: 804 / Rasc9

Sonde Serial #: 43585

Drilling Contractor: Cascade

Average Depth to Water: -5.33

Gas Drive or Peri Pump: Peri Pump

Atmospheric Pressure: 35.80

KPRO N_2 Pressure (set via P transducer): 69.12

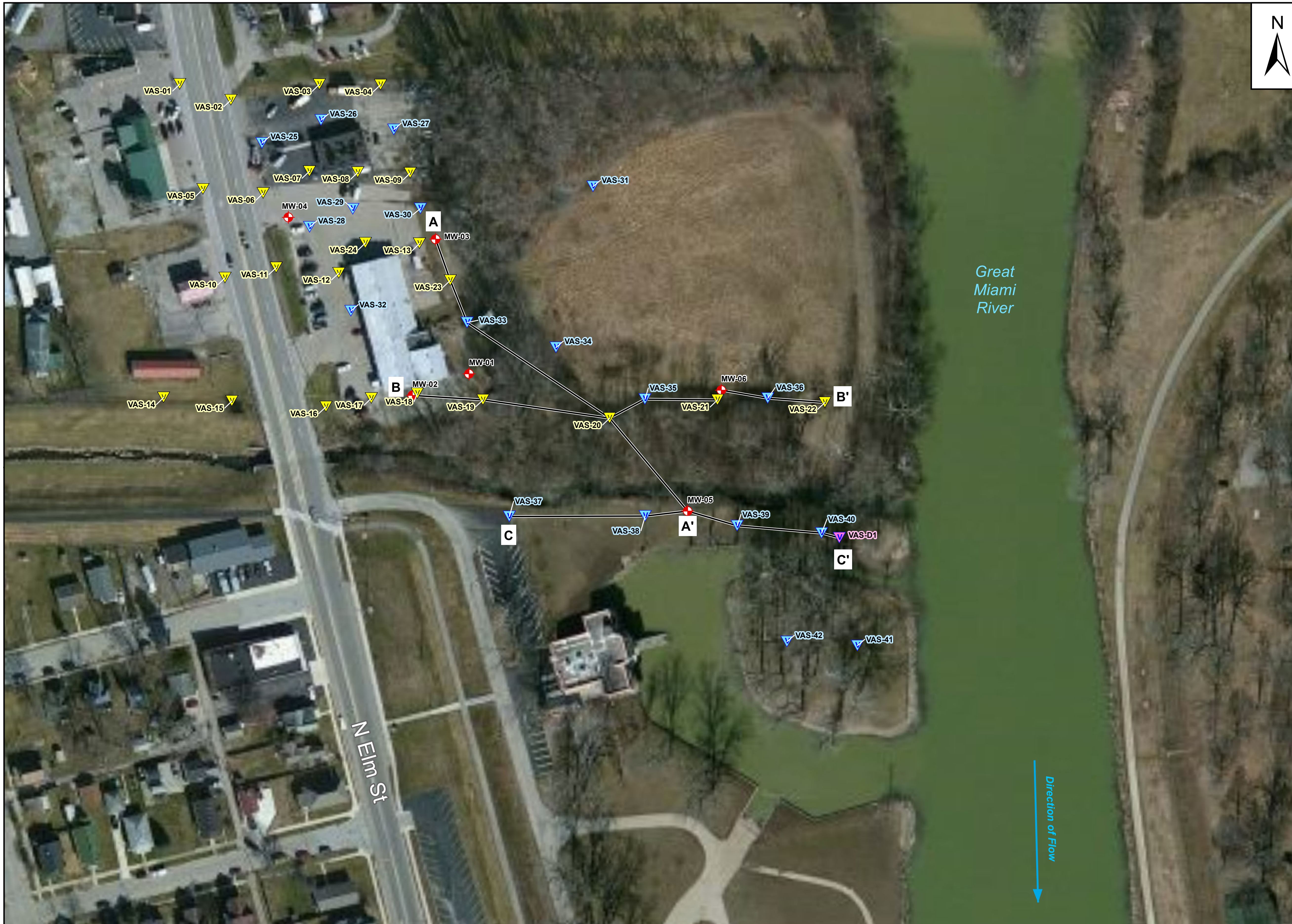
Gas Drive Pump N_2 Pressure: NA

PHYSICOCHEMICAL PARAMETERS

Depth (ft)	Date / Time	Volume Purged (mL)	Head (ft)	SC (uS/cm)	DO (PPM)	pH	ORP (mV)	COMMENTS
-8.15	5/18/16 14:28	1300	-5.68	1993	0.88	6.66	176	
-18.18	5/17/16 15:27	1300	-5.02	1410	0.68	7.02	-69	
-23.70	5/17/16 16:42	800	-5.65	1157	2.05	7.10	-79	
-32.75	5/18/16 17:33	1200	-4.97	1444	0.93	7.13	-94	

APPENDIX C

GENERALIZED GEOLOGIC CROSS SECTIONS



Legend

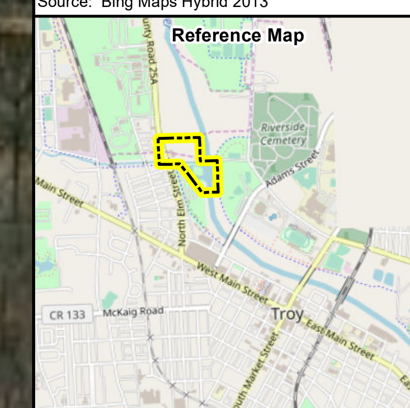
- Monitoring Well Location
- Deep VAS Sample Location
- Phase I VAS Location
- Phase II VAS Location
- Cross Section Line

VAS = Vertical Aquifer Sampling

0 100 200

Feet

Source: Bing Maps Hybrid 2013

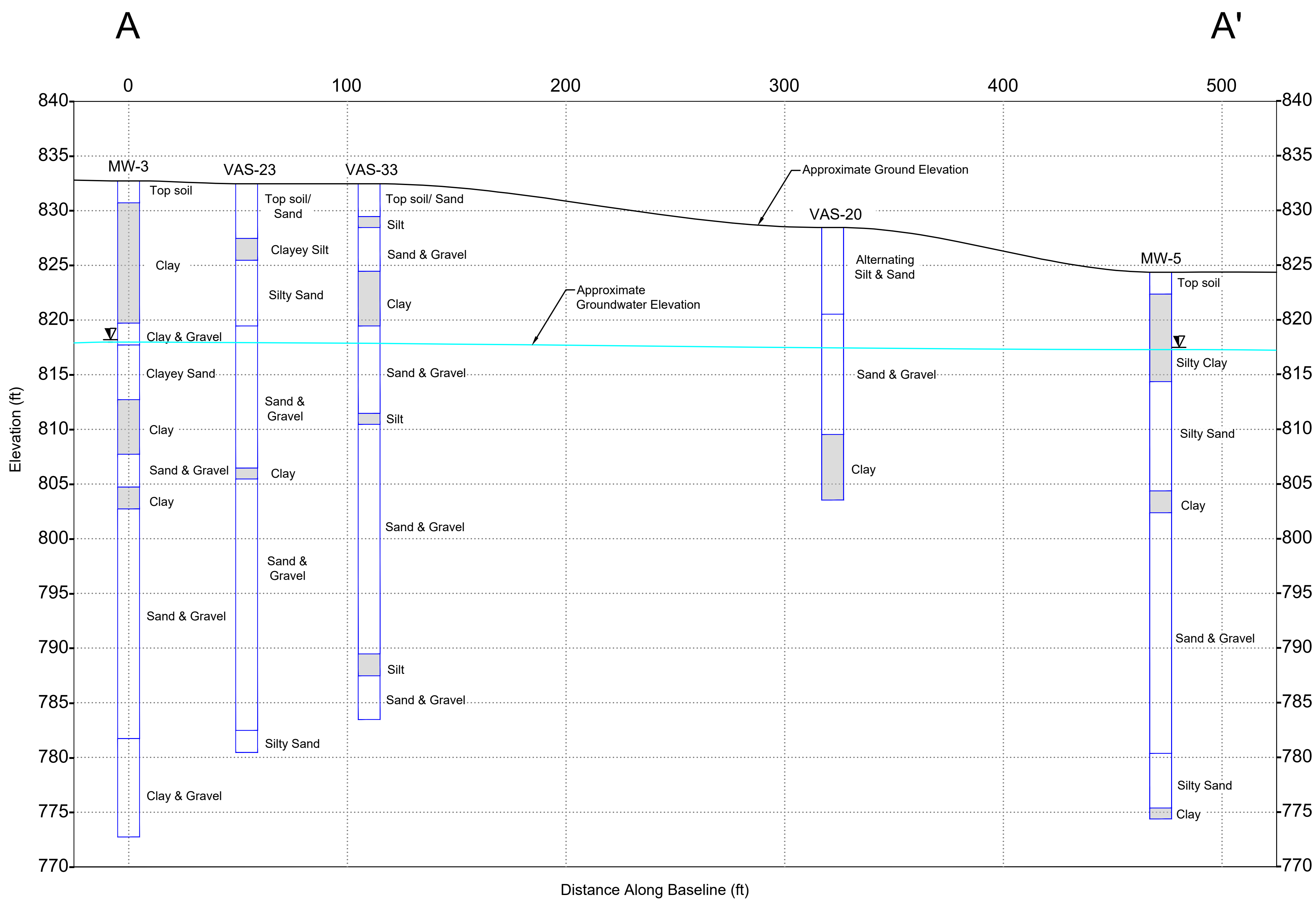


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE C-1
GEOLOGICAL CROSS SECTIONS
PLAN VIEW

ST SulTRAC

Date Saved: 8/28/2018 10:17:44 AM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2018-07\Fig-C1-GeologicalCrossSections-PlanView.mxd

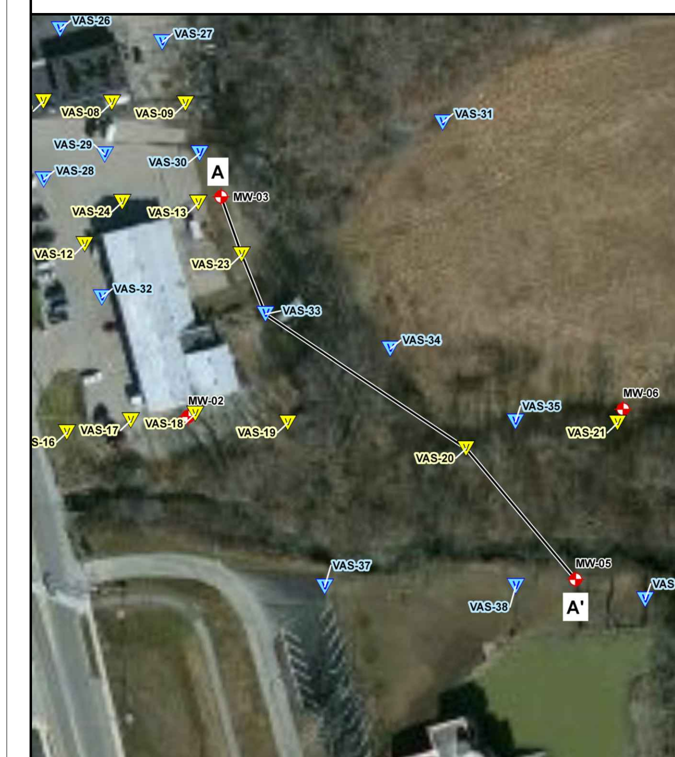


LEGEND

GROUNDWATER ELEVATION MEASURED ON 10/19/2016

LOWER PERMEABLE ZONES (PREDOMINANTLY SILT OR CLAY)

NOTE:
GEOLOGY SHOWN AT VERTICAL AQUIFER SAMPLING (VAS) LOCATION IS INTERPRETED FROM INDEX OF RELATIVE HYDRAULIC CONDUCTIVITY (IK) LOGS GENERATED BY WATERLOO ADVANCED PROFILING SYSTEM.



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE C-2
GENERALIZED GEOLOGICAL CROSS SECTION A - A'

ST SulTRAC

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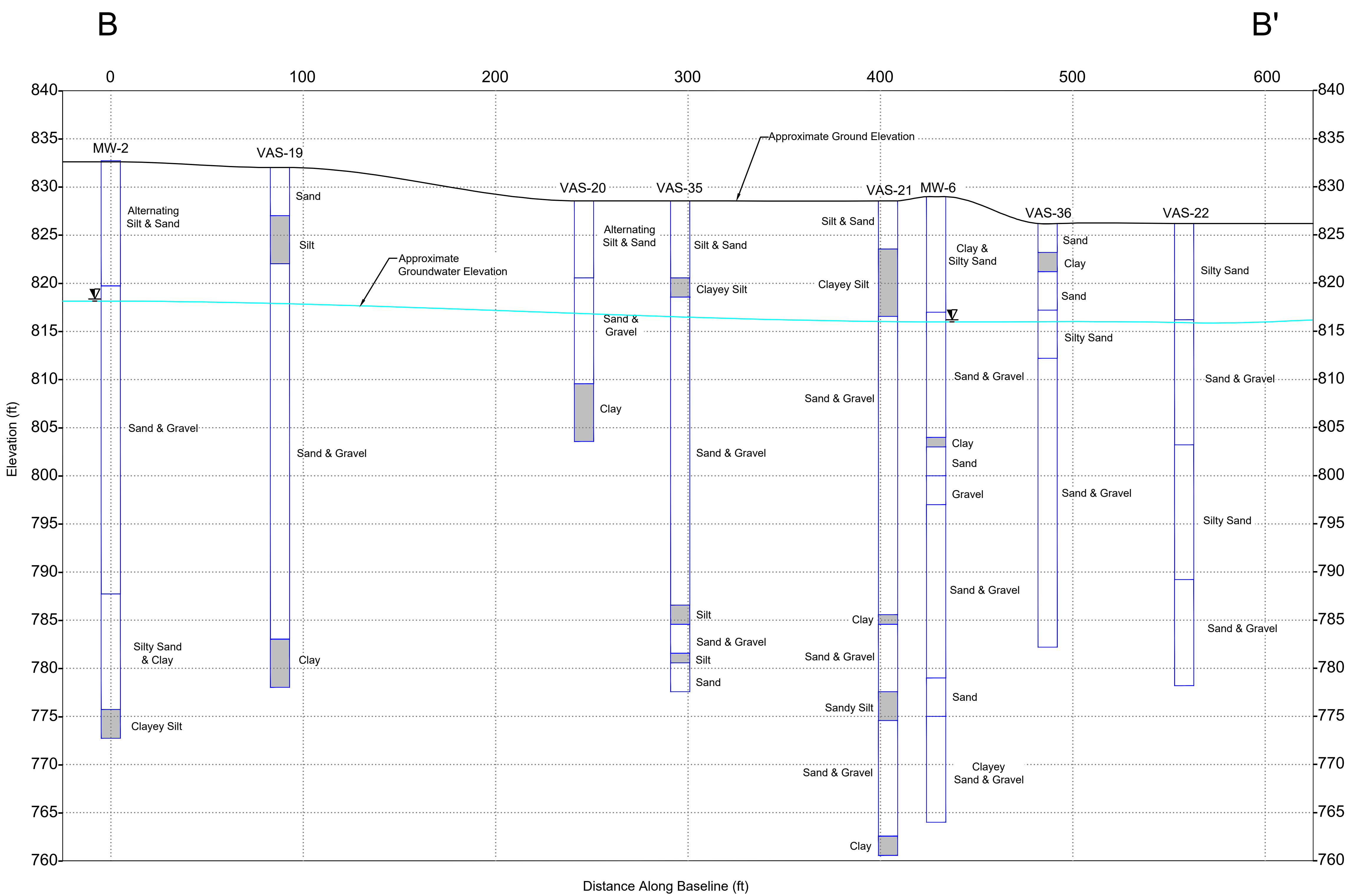
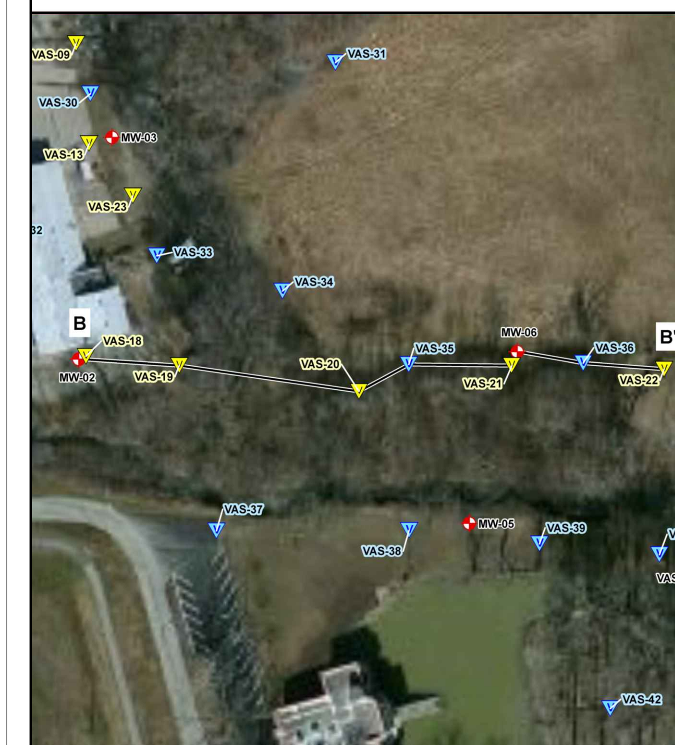


LEGEND

GROUNDWATER ELEVATION MEASURED ON 10/19/2016

LOWER PERMEABLE ZONES (PREDOMINANTLY SILT OR CLAY)

NOTE:
GEOLOGY SHOWN AT VERTICAL AQUIFER SAMPLING (VAS) LOCATION IS INTERPRETED FROM INDEX OF RELATIVE HYDRAULIC CONDUCTIVITY (IK) LOGS GENERATED BY WATERLOO ADVANCED PROFILING SYSTEM.



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE C-3
GENERALIZED GEOLOGICAL CROSS SECTION B - B'

ST SulTRAC

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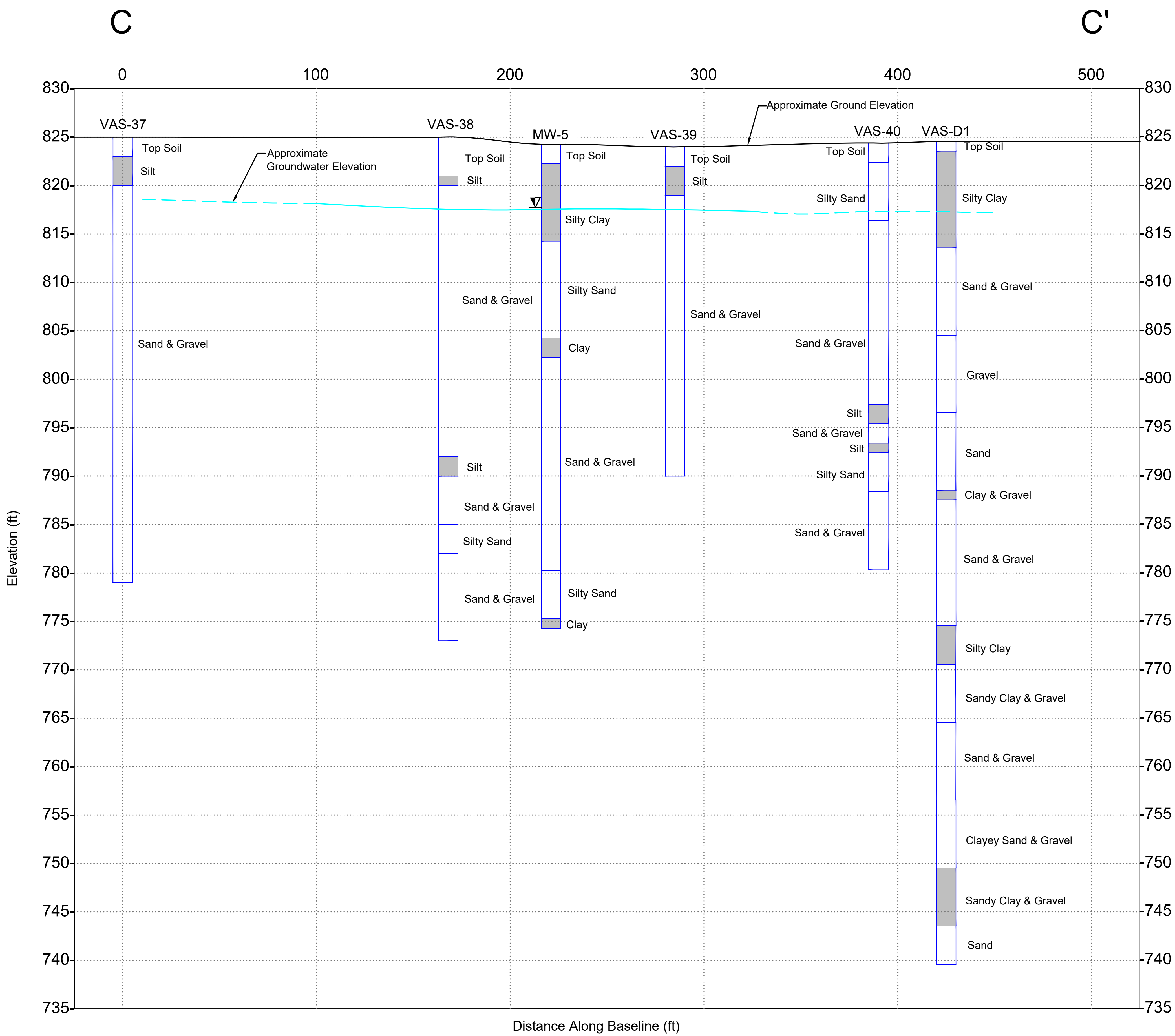
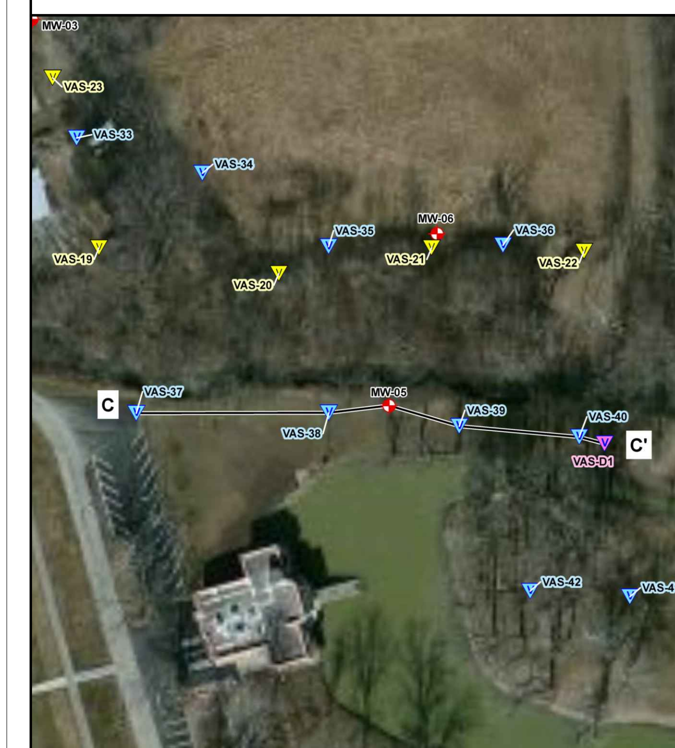


LEGEND

GROUNDWATER ELEVATION MEASURED ON 10/19/2016

LOWER PERMEABLE ZONES (PREDOMINANTLY SILT OR CLAY)

NOTE:
GEOLOGY SHOWN AT VERTICAL AQUIFER SAMPLING (VAS) LOCATION IS INTERPRETED FROM INDEX OF RELATIVE HYDRAULIC CONDUCTIVITY (IK) LOGS GENERATED BY WATERLOO ADVANCED PROFILING SYSTEM.



WEST TROY CONTAMINATED
AQUIFER SITE
TROY, OHIO

FIGURE C-4
GENERALIZED GEOLOGICAL CROSS SECTION C - C'

ST SulTRAC

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APPENDIX D

REMEDIAL ALTERNATIVE COST ESTIMATES

APPENDIX D

COST ESTIMATING ASSUMPTIONS

The cost estimates were developed using unit costs from RS Means (2017 cost book), National Construction Estimator via Get-a-Quote.net (2017 cost book), RACER® software (2015 cost database), quotations from vendors, and SulTRAC's experience with similar projects. RACER is a cost estimating software.

The net present value of each alternative was calculated by summing the present values of capital and O&M costs. The present value is the estimated value of a future expense in current year dollars. Present values were calculated by discounting future costs using a 7 percent discount rate, which is the recommended rate for non-federal facilities according to *A Guide to Developing and Documenting Costs Estimates During the Feasibility Study* (EPA 540-R-00-002). Therefore, the estimated cost of every alternative is calculated in 2019 dollars and projected over the anticipated duration of each alternative.

A 30 percent contingency is factored into the estimated cost for each alternative to account for unforeseen expenses arising from changes to scope or pricing. The accuracy of these cost estimates is expected to range from +50 percent to -30 percent, which is consistent with EPA guidelines for feasibility studies (EPA/540/G-89/004).

General assumptions for all groundwater remediation alternatives are as follows:

- All design elements described herein are assumptions based on available information and are considered conceptual at the feasibility study (FS) stage; actual design and operating parameters such as numbers; locations; and depths of injection, extraction or monitoring wells will be determined as part of the remedial design (RD).
- All work would be performed in Level D personal protective equipment.
- The objective of all alternatives is to achieve contaminant mass reduction in treatment zones such that residual contamination will dissipate within 30 years.
- The approximate extent of area requiring treatment is 90,000 square feet.
- The approximate depth of treatment is from 15 feet below ground surface (bgs) to 60 feet bgs.
- The assumed aquifer total porosity is 0.4 and the effective porosity is 0.3.
- A discount rate of 7% was used in net present value (NPV) estimates based on U.S. Environmental Protection Agency (EPA) guidance document (EPA 540-R-00-002) recommendation for non-federal facilities.

Assumptions pertaining to each of the individual remediation alternatives are presented below.

Groundwater Alternative GW-1: No Action

There are no costs associated with the No Action alternative.

Groundwater Alternative GW-2: Institutional Controls and Monitoring

There are no costs associated with this alternative as it was screened out in Section 5.0.

Groundwater Alternative GW-3A: Targeted In Situ Treatment Using Air Sparging/Soil Vapor Extraction, Institutional Controls, and Groundwater Monitoring

The estimated cost of Alternative GW-3A is based on the following assumptions:

- A pilot test would be performed during the RD to ascertain design parameters such as radius of influence (ROI), required flow rates, contaminant concentrations in off gas, and soil vapor extraction (SVE) ROI and SVE flow rate.
- Pre-design investigations would include water quality testing to measure dissolved iron and soil testing to estimate sorbed contaminant mass. This would include collection of collocated soil and groundwater samples.
- Five new shallow monitoring wells (45 feet deep) and five new deep monitoring wells (60 feet deep) would be installed.
- The ROI of a sparge well would be 20 feet with up to 5 standard cubic feet per minute (SCFM) flow to each well. This assumption is based on professional judgment.
- The sparge wellfield would consist of a total of approximately 105 wells and the wellfield would be divided into four sections, with only one section operating at any given time.
- Air sparging equipment would be sized to operate 30 sparge wells simultaneously.
- A manifold would be used to divert airflow to a given section of the sparge wellfield, and local manifolds would control flow to individual sparge wells in each section of the wellfield. Manifolds would be manually operated.
- SVE piping would be 4-inch diameter perforated polyvinyl chloride (PVC), with pipes buried in 4-foot deep trench.
- The SVE system would be divided into four sections, with only one section operating at any given time.
- Flow from any section of the extraction piping would be manually controlled via a local manifold.
- SVE equipment would be sized for 1.5 times the sparge airflow rate.
- PVC pipe would connect air sparge and SVE wells to remediation equipment with pipe diameters varying from 1 to 4 inches in diameter.
- All pipe would be buried in 4-feet deep trenches. Trench width would vary from 1 to 4 feet depending on the number of pipes in a trench section. An average trench width of 2 feet is assumed.
- Manifolds would be housed within insulated enclosures.
- Pipes carrying pressurized air above-ground would be constructed of carbon steel.

- Off gas from the SVE system would be discharged directly to the atmosphere without treatment.
- Air sparge and SVE wellfield sections would be operated in sequence, with any given section operating for one or more months while all other sections are turned off.
- Air sparging/SVE would be performed for 8 years within which time contaminant concentrations would decrease such that residual contamination can dissipate over time without further treatment.
- Groundwater would be monitored quarterly during SVE operation.
- After air sparging/SVE stops, groundwater would be monitored semi-annually for 1 year, then annually until contaminant concentrations are at or below maximum contaminant levels (MCL). The duration to attain MCLs is assumed to be 30 years from the start of air sparging/SVE operation.
- After remediation is complete, the remediation system would be decommissioned. This would include removal of all above-ground equipment and grouting of subsurface piping.
- Institutional controls (IC) would include covenants with property owners prohibiting the use of groundwater and development of the property for residential use.

Groundwater Alternative GW-3B: Targeted In Situ Treatment Using ISCO, Institutional Controls, and Groundwater Monitoring

The estimated cost of Alternative GW-3B is based on the following assumptions:

- In situ chemical oxidation (ISCO) would involve ozone sparging.
- An ozone sparging pilot test would be performed during the RD to ascertain design parameters such as ROI, required flow rates and oxidant dose. Pilot testing would also be used to select an oxidant, measure performance, and screen for oxidation byproducts. There would be no pilot test for SVE because contaminant capture is not required.
- Pre-design investigations would include water quality testing to measure dissolved iron and soil testing to estimate contaminant sorbed mass. This would include collection of collocated soil and groundwater samples.
- Five new shallow monitoring wells (45 feet deep) and five new deep monitoring wells (60 feet deep) would be installed.
- Proprietary pre-engineered ozone sparging mobile units allowing automated operation and remote monitoring of remediation wells.
- ISCO injection well ROI would be 15 feet with up to 5 SCFM flow to any well. This assumption is based on professional judgment.
- The wellfield would consist of a total of approximately 170 wells divided into six sections, with only one section operating at any given time.
- Each well would include one stainless steel ozone injector screened at the maximum depth of observed contamination.
- Ozone sparging equipment would be sized to operate 30 sparge wells simultaneously and supply up to 40 pounds per day of ozone.

- The ozone sparge equipment trailer would have 30 gas lines connecting to a manifold trailer. The manifold trailer would distribute flow to the wellfield such that only one section of the wellfield is operating at any given instant. Flow could be controlled from the ozone sparge equipment trailer and the manifold trailer.
- Gas (ozone) lines would be constructed of Teflon tubing because they are more resistant to degradation via ozone. Tubing diameters would vary from ½ inch to 1 inch. Each tube would be encased in a 1.5-inch PVC conduit.
- PVC conduit would be buried in 4-feet deep trenches. Trench width would vary from 1 to 4 feet depending on the number of conduits in a trench section. An average trench width of 2 feet is assumed.
- Wellfield sections would be operated in sequence, with any given section operating for one or more months while all other sections are turned off.
- ISCO would be performed for 6 years (that is 1 year per section) within which time contaminant concentrations would decrease such that residual contamination can dissipate over time without further treatment.
- Groundwater would be monitored quarterly during ozone system operation, then semi-annually for 1 year, then annually until contaminant concentrations are at or below MCLs. The duration to attain MCLs is assumed to be 30 years from the start of ozone system operation.
- The Apex building and Bob's Auto would be fitted with a vapor mitigation systems (sub-slab depressurization) that would operate until ozone sparging near those buildings is completed. The operating duration is assumed to be 2 years.
- Vapor mitigation system for each building would consist of a buried 4-inch diameter perforated PVC pipe connected to a high-flow low-vacuum blower mounted to the side of the building, with the exhaust gas venting above roof level.
- After remediation is complete, the remediation system would be decommissioned. This would include removal of all above-ground equipment and grouting of subsurface piping.
- ICs would include covenants with property owners prohibiting the use of groundwater and development of the property for residential use.

Groundwater Alternative GW-3C: Targeted In Situ Treatment Using Aerobic Bioremediation, Institutional Controls, and Groundwater Monitoring

The estimated cost of Alternative GW-3C is based on the following assumptions:

- Aerobic bioremediation would involve biostimulation and bioaugmentation. Biostimulation would involve injection of electron donor and oxygen, and bioaugmentation would involve injection of Pseudomonas organisms.
- Approximately 7,000 pounds of dextrose (electron donor) and 35,000 pounds of calcium peroxide (oxygen releasing chemical used to maintain aerobic conditions) would be injected per event.
- A pilot test would be performed during the RD to ascertain design parameters such as ROI, production rates, dose, and downgradient effects.
- Pre-design investigations would include water quality testing for anions, cations and contaminant sorbed mass. This would include collection of collocated soil and groundwater samples.

- Five new shallow monitoring wells (45 feet deep) and five new deep monitoring wells (60 feet deep) would be installed.
- There would be approximately 370 injection points based on an ROI of 10 feet. This assumption is based on professional judgment.
- Injections would be performed through uncased boreholes using direct-push technology proceeding from the top to the bottom of the targeted interval in 2-foot vertical increments. The borehole would be plugged and abandoned after injection is complete.
- Injections would be performed simultaneously in two boreholes at a time at a progress rate of approximately 8 boreholes per day.
- Cobbles have been encountered at this site and direct push drilling may encounter refusal at some locations. It is assumed this would happen at 10 percent of the injection points which would then have to be pre-drilled via sonic technology so that injections can be completed via direct-push technology.
- There would be three injection events over a period of three years, and the area targeted by the injection would decrease by 20 percent each time.
- Groundwater would be monitored quarterly during the first 2 years, then semi-annually for 2 years, then annually until contaminant concentrations are at or below MCLs. The duration to attain MCLs is assumed to be 30 years from the start of bioremediation.
- ICs would include covenants with property owners prohibiting the use of groundwater and development of the property for residential use.

Groundwater Alternative GW-4: Groundwater Extraction, Treatment & Discharge, Institutional Controls, and Groundwater Monitoring

The estimated cost of Alternative GW-4 is based on the following assumptions:

- Pre-design investigations would include groundwater and soil testing to estimate contaminant sorbed mass as well as aquifer testing to determine hydraulic parameters. This would include collection of collocated soil and groundwater samples, and pumping tests.
- Groundwater would be extracted from four wells screened from 15 to 60 feet bgs. The wells would be completed flush with the ground surface, and conveyance piping would be buried in 4-foot deep trenches.
- The total groundwater extraction rate would be 80 gpm based on 20 gpm per well from four wells.
- Extracted groundwater would be passed through bag filters, treated via air stripping, then discharged to Morgan's Ditch. Exhaust from the air stripper would be discharged to the atmosphere without treatment.
- Pump and treat system operation would be automated, and operating data would be logged.
- The total operating duration of the pump and treat system is assumed to be 30 years.
- Groundwater would be monitored quarterly during the first year, semi-annually for 2 years, then annually until contaminant concentrations are at or below MCLs. The duration to attain MCLs is assumed to be 30 years from the start of groundwater pumping.

- After remediation is complete, above-ground equipment would be removed, remediation and monitoring wells would be plugged and abandoned, and all buried pipes would be grouted.
- ICs would include covenants with property owners prohibiting the use of groundwater and development of the property for residential use.

Private Well Alternative PR-1: No Action

There are no costs associated with the No Action alternative.

Private Well Alternative PR-2: Treatment and Monitoring

The estimated cost of Alternative PR-2 is based on the following assumptions:

- The effect of in-situ treatment of groundwater on water quality in the Apex private well was not considered. Point of entry treatment systems may be incompatible with some types of groundwater treatment.
- The point of entry treatment system would include a sediment filter and two carbon filters in series (lead/lag) so that the system can operate on the lag carbon filter while media in the lead carbon filter are being replaced.
- A column test would be performed on site water prior to treatment system selection.
- Pre-selection investigations would include water quality testing to measure volatile organic compound (VOC) and total organic carbon concentrations.
- Groundwater from the Apex private well would contain tetrachloroethene (PCE) at 15 micrograms per liter, (approximately 1.5 times the observed maximum) and a nominal amount of naturally occurring dissolved organic carbon.
- Groundwater usage rate would be 500 gallons per day with a maximum instantaneous flow rate of 10 gallons per minute.
- The carbon filtration media typically require replacement every 4 to 8 years at sites where groundwater is not known to be contaminated. At this site, it is assumed that carbon filtration media would be replaced every 2 years, and that the sediment filter would be replaced every 6 months. The actual replacement durations would be estimated after performing a column test using site water.
- A water sample downstream of the lead carbon filter would be tested annually for VOCs.
- The system is assumed to operate for 10 years by which time in-situ treatment is assumed to clean up groundwater near the Apex property.

Private Well Alternative PR-3: Connect to City Water and Abandon Private Well

The estimated cost of Alternative PR-3 is based on the following assumptions:

- The Apex property is outside Troy city limits. To provide city water service, the city would have to annex the Apex property. It is assumed that the property owner would agree to annexation.
- A 1-inch copper service line would be installed from the city water main across the street to the location of the existing private well on the Apex property. This would require a live tap into the water main, and horizontal drilling beneath N. Elm Street.
- The service line would be approximately 150 feet long and would connect to the existing pipe currently carrying water from the private well. A new water meter would be installed.
- The private well would be plugged and abandoned.
- Tapping into the water main on the west side of N. Elm Street would include excavation in a right-of-way and traffic control. The excavation would be restored to existing conditions after the work is complete.
- All necessary local permits would be procured.

Vapor Intrusion Alternative VI-1: No Action

There are no costs associated with the No Action alternative.

Vapor Intrusion Alternative VI-2: Institutional Controls and Monitoring

The estimated cost of Alternative VI-2 is based on the following assumptions:

- ICs would prohibit construction of residential or commercial buildings on properties unless the buildings are fitted with vapor mitigation systems and monitored for the duration of occupancy.
- Some properties requiring ICs are outside city limits and would not be subject to zoning or ordinances restricting site use, therefore covenants would be required to restrict site use.
- ICs would be implemented by identifying affected properties and developing covenants for each affected property restricting site use.
- All covenanted properties would be visually inspected annually to ensure that they are complying with the ICs.

Cost Estimate Notes and Abbreviations

The notes and abbreviations presented below apply to the cost assumptions listed above as well as the cost estimate tables.

AS	Air sparging
bgs	Below ground surface
cfm	Cubic feet per minute
cy	Cubic yard
ea	Each
ECHOS	Environmental Cost-Handling Options and Solutions
EPA	U.S. Environmental Protection Agency
FID	Flame ionization detector
FS	Feasibility study
ft	Foot
GAC	Granular activated carbon
gal	Gallon
gpm	Gallons per minute
HDPE	High-density polyethylene
hr	Hour
IC	Institutional control
ISCO	In situ chemical oxidation
KWH	Kilowatt hour
lb	Pound
lf	Linear foot
ls	Lump sum
LTM	Long-term monitoring
MCL	Maximum contaminant level
mo	Month
NA	Not applicable
NPV	Net present value
O&P	Overhead and profit
PCE	Tetrachloroethene
PID	Photoionization detector
PLC	Programmable logic controller
POE	Point of entry
PVC	Polyvinyl chloride
QC	Quality control
RACER	Remedial Action Cost Engineering and Requirements System
RD	Remedial design
ROI	Radius of influence
SCADA	Supervisory control and data acquisition
SCFM	Standard cubic feet per minute
sf	Square foot
SVE	Soil vapor extraction
sy	Square yard
TD	Total depth
TO	Toxic organic
TOC	Total organic carbon
V	Volt
VOC	Volatile organic compound
wk	Week

TABLE D-1 COST SUMMARY					
Alternative	**Description**	**Capital Cost (Rounded)**	**Operation & Maintenance (Rounded)**	**Contingency (Rounded)**	**Total (Rounded)**
	GROUNDWATER				
GW-3A	Air Sparging/Soil Vapor Extraction	$ 1,451,000	$ 2,140,000	$ 1,077,000	$ 4,668,000
GW-3B	In Situ Chemical Oxidation (Ozone Sparging)	$ 2,608,000	$ 2,054,000	$ 1,398,000	$ 6,060,000
GW-3C	In Situ Aerobic Bioremediation	$ 1,707,000	$ 2,853,000	$ 1,368,000	$ 5,928,000
GW-4	Extraction, Treatment, and Discharge in Combination with Institutional Controls and Monitoring	$ 948,000	$ 2,606,000	$ 1,066,000	$ 4,620,000
	PRIVATE WELL				
PR-2	Well Treatment and Monitoring	$ 24,000	$ 18,000	$ 13,000	$ 55,000
PR-3	Connect to City Water and Abandon Private Well	$ 36,000	$ -	$ 11,000	$ 47,000
	VAPOR INTRUSION				
VI-2	Institutional Controls and Monitoring	$ 44,000	$ 37,000	$ 24,000	$ 105,000

ALTERNATIVE GW-3A
Air Sparging/Soil Vapor Extraction

Table D-2				
ALTERNATIVE GW-3A - AIR SPARGING/SOIL VAPOR EXTRACTION				
Source	**Description**	**Subtotal**	**Contingency**	**Total**
Table D-3	Design and Construction	$ 1,451,020	$ 435,306	$ 1,886,326
Table D-22	Operation and Maintenance	$ 2,139,746	$ 641,924	$ 2,781,670

Contingency	30%	$ 1,077,230	
Total			**$ 4,667,996**

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Capital Cost

Location factor (for zip code 453xx)

ECHOS	1	
Get-a-Quote	1.01	

Note: Location factor applies only to national average unit costs; it does not apply to local unit costs such as from vendors or Means.

Overhead and Profit (O&P)

General	25%	Typical general contractor overhead and profit
Means	-	
RACER	35%	Default
Contractor quote	5%	Prime contractor markup
Professional judgment	-	Not marked-up

Inflation	1.89%	Average annual inflation from 2010 to 2019

Table D-3
ALTERNATIVE GW-3A - AIR SPARGING/SOIL VAPOR EXTRACTION

Item	Description	Quantity	Unit	Unit Price (Incl. O&P)	Total Cost
	Construction Subtotal				**$ 962,410**
	Site Preparation				**$ 10,499**
1	Clear and grub	2.0	acre	$ 1,946.55	$ 3,893
2	Silt Fence	1,260.0	sy	$ 5.24	$ 6,606
	Temporary Facilities				**$ 241,542**
3	4" thick reinforced concrete equipment pad	900.0	sf	$ 6.92	$ 6,228
4	Install 480V 3 Phase connection and meter	1.0	ls	$ 1,764.87	$ 1,765
5	New pole (25') and transformer (50 KVA)	1.0	ea	$ 15,000.00	$ 15,000
6	Install Breaker Box	1.0	ea	$ 534.92	$ 535
7	Pre-engineered AS/SVE trailer (AS 150 cfm; SVE 225 cfm)	1.0	ls	$ 218,013.53	$ 218,014

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Table D-3					
ALTERNATIVE GW-3A - AIR SPARGING/SOIL VAPOR EXTRACTION					
Item	**Description**	**Quantity**	**Unit**	**Unit Price (Incl. O&P)**	**Total Cost**
	Air Sparging				**$ 617,390**
8	Chain link fence (12' high)	200	lf	$ 30.43	$ 6,087
9	Sparge Well Installation 2" SCH 40 PVC (62 feet bgs)	105	well	$ 3,683.15	$ 386,731
10	1" PVC piping from each sparge well to local manifold	14,841.0	lf	$ 2.61	$ 38,709
11	4" PVC piping from local manifold to main manifold	1,850.0	lf	$ 10.22	$ 18,913
12	Manifolds for AS (carbon steel) and SVE (PVC)	8.0	ea	$ 13,328.05	$ 106,624
13	Manifold insulated shed	4.0	ea	$ 4,106.84	$ 16,427
14	Pipe bridge (from manifold south of Morgan's Creek)	1.0	ea	$ 3,125.00	$ 3,125
15	Trench Excavation (4 feet bgs; SVE trench and sparge pipe trench)	5,802.0	lf	$ 3.96	$ 22,966
16	Backfill - Gravel	430.0	cy	$ 28.55	$ 12,276
17	Backfill - Onsite Spoils (Excludes Material Cost)	1,719.0	cy	$ 3.22	$ 5,532
	Soil Vapor Extraction				**$ 41,507**
18	SVE Well Installation (4" PVC wells, 5' screen, 8' TD)	0.0	well	$ 1,000.00	$ -
19	Horizontal SVE piping and headers (4" PVC, perforated and solid)	4,060.0	lf	$ 10.22	$ 41,507
	Monitoring Well Installation				**$ 36,058**
20	Shallow wells	5.0	ea	$ 3,194.12	$ 15,971
21	Deep wells	5.0	ea	$ 4,017.41	$ 20,087
	Measurement				**$ 15,414**
22	Existing condition and record surveys (pre- and post-remediation)	7.0	days	$ 2,201.94	$ 15,414

Construction subtotal		$ 962,410
Construction Contractor Mob./Demob., Site Prep and Submittals	10%	$ 96,241
Pre-design investigation	lump sum	$ 100,000
Pilot test	lump sum	$ 75,000
Engineering design	lump sum	$ 150,000
Project management and construction oversight	7%	$ 67,369
Capital Cost Subtotal		**$ 1,451,020**

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Operation and Maintenance

Table D-4									
Operation and Maintenance									
Item	**Description**				**Quantity**	**Unit**	**Unit Price (Incl. O&P)**		**Total Cost**
	Operation and Maintenance, 30-Year Present Value								**$ 2,139,746**
	AS/SVE System Operation and Maintenance, Annual								**$ 79,400**
23	Maintenance				12	month	$	1,000.00	$ 12,000
24	Utilities				12	month	$	1,500.00	$ 18,000
25	Field labor	10 hrs/wk	on proj for	52 weeks	520	hr	$	70.00	$ 36,400
26	Engineering	2 hrs/wk	on proj for	52 weeks	104.0	hr	$	125.00	$ 13,000
	ICs Monitoring, Annual								**$ 5,000**
26	Annual site inspection and reporting				1	ls	$	5,000.00	$ 5,000
	Performance Monitoring, Per Event								**$ 49,560**
27	Groundwater sample collection (incl. labor, equip, matl, travel)				30	ea	$	829.60	$ 24,888
28	Sample analysis (w/ QC; VOCs, field parameters, anions, dissolved iron)				40	ea	$	390.49	$ 15,620
29	Vapor monitoring (SVE wells and off gas with PID/FID)				0	days	$	1,000.00	$ -
30	Vapor sampling and analysis (influent/effluent, TO-15 analysis, incl. QC)				3	ea	$	267.46	$ 802
31	Monitoring report				1	ea	$	5,000.00	$ 5,000
32	Project management	2 hrs/wk	on proj for	13 weeks	26	hr	$	125.00	$ 3,250
	Long-Term Monitoring, Groundwater, Per Event								**$ 48,758**
33	Groundwater sample collection (incl. labor, equip, matl, travel)				30	ea	$	829.60	$ 24,888
34	Sample analysis (w/ QC; VOCs, field parameters, anions, dissolved iron)				40.0	ea	$	390.49	$ 15,620
35	Monitoring report				1	ea	$	5,000.00	$ 5,000
36	Proj. Mgmt.	2 hrs/wk	on proj for	13 weeks	26.0	hr	$	125.00	$ 3,250
	Five-Year Review								**$ 30,000**
37	Site visit and report				1	ls	$	30,000.00	$ 30,000
	Decomissioning								**$ 69,146**
38	Well Abandonment				121.0	ea	$	350.00	$ 42,350
39	Grout Conduits				20,751.0	ft	$	0.11	$ 2,296
40	Above-ground infrastructure removal				7.0	day	$	3,500.00	$ 24,500

Notes:

AS	Air sparging	PID	Photoionization detector
bgs	Below ground surface	PVC	Polyvinyl chloride
cfm	Cubic feet per minute	QC	Quality control
cy	Cubic yard	RACER	Remedial Action Cost Engineering and Requirements System
ea	Each	sf	Square foot
ECHOS	Environmental Cost-Handling Options and Solutions	SVE	Soil vapor extraction
FID	Flame ionization detector	sy	Square yard
ft	Foot	TD	Total depth
hr	Hour	TO	Toxic organic
IC	Institutional control	V	Volt
lf	Linear foot	VOC	Volatile organic compound
ls	Lump sum	wk	Week
O&P	Overhead and profit		

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

ALTERNATIVE GW-3B
In Situ Chemical Oxidation (Ozone Sparging)

Table D-5					
Alternative GW-3B - In Situ Chemical Oxidation					
Source	**Description**	**Subtotal**	**Contingency**		**Total**
Table D-6	Design and Construction	$ 2,607,901	$ 782,370		$ 3,390,271
Table D-23	Operation and Maintenance	$ 2,053,528	$ 616,058		$ 2,669,586

Contingency	30%	$ 1,398,428	
Total			**$ 6,059,857**

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Capital Cost

Location factor (for zip code 453xx)

ECHOS	1	
Get-a-Quote	1.01	

Note: Location factor applies only to national average unit costs; it does not apply to local unit costs such as from vendors or Means.

Overhead and Profit (O&P)

General	25%	Typical general contractor overhead and profit
Means	-	
RACER	35%	Default
Contractor quote	5%	Prime contractor markup
Professional judgment	-	Not marked-up

Inflation	1.89%	Average annual inflation from 2010 to 2019

Table D-6
Alternative GW-3B - In Situ Chemical Oxidation

Item	Description	Quantity	Unit	Unit Price (Incl. O&P)	Total Cost
	Construction Subtotal				**$ 1,822,992**
	Site Preparation				**$ 10,499**
1	Clear and grub	2	acre	$ 1,946.55	$ 3,893
2	Silt Fence	1,260	sy	$ 5.24	$ 6,606
	Temporary Facilities				**$ 24,152**
3	4" thick reinforced concrete equipment pad	1,000	sf	$ 6.85	$ 6,852
4	New pole (25') and transformer (50 KVA)	1.0	ea	$ 15,000.00	$ 15,000
5	Install 480V 3 Phase connection and meter	1	ls	$ 1,764.87	$ 1,765
6	Install Breaker Box	1	ea	$ 534.92	$ 535

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Table D-6					
Alternative GW-3B - In Situ Chemical Oxidation					
Item	**Description**	**Quantity**	**Unit**	**Unit Price (Incl. O&P)**	**Total Cost**
	Ozone Injection				**$ 1,692,798**
7	System start-up	1	ls	$ 11,165.70	$ 11,166
8	Ozone sparge trailer with blowers and controls (MOSU10-760)	1	ls	$ 299,250.00	$ 299,250
9	Install peroxide storage tank (500 gallon insulated HDPE)	0	ea	$ 2,500.00	$ -
10	Service and maintenance kits (includes 6 month and 12 month kits)	1	ls	$ 11,270.27	$ 11,270
11	Manifold trailer (6 banks, 30 valves/bank)	1	ls	$ 115,500.00	$ 115,500
12	Ozone rated flow meter and pressure gage	170	ea	$ 437.50	$ 74,375
13	Injection well installation, 60' deep, concrete pad, 18" manhole	170	ea	$ 3,209.54	$ 545,622
14	Ozone injectors	170	ea	$ 398.80	$ 67,796
15	Riser pipe (60' per well)	1,020	10-ft piece	$ 44.69	$ 45,581
16	Well head connections	170	ea	$ 151.04	$ 25,677
17	Ozone delivery tubing (1/2" Teflon)	57,800	lf	$ 4.55	$ 262,788
18	Peroxide delivery tubing (1/2" HDPE)	0	lf	$ 1.25	$ -
19	1" PVC conduits for tubing	57,800	lf	$ 2.61	$ 150,757
20	Tubing installation (3-person crew; 5,000 ft/day)	12	days	$ 3,040.77	$ 35,151
21	Trench excavation (3 feet bgs)	5,214	lf	$ 3.96	$ 20,638
22	Backfill - gravel	386	cy	$ 28.55	$ 11,026
23	Backfill - onsite borrow	1,545	cy	$ 3.22	$ 4,972
24	Pipe bridge (50 1" lines from wells south of Morgan's Creek)	1.0	ea	$ 5,000.00	$ 5,000
24	Chain link fence (12' high)	200	lf	$ 31.14	$ 6,229
	Vapor Mitigation System				**$ 14,896**
25	Blowers and accessories (for Apex and Bob's Auto; outdoor; high flow; installed)	2	ea	$ 5,500.00	$ 11,000
26	Gas extraction piping (4" Sch 40 PVC; perforated; installed)	104	lf	$ 10.22	$ 1,068
27	Gas extraction risers (4" Sch 40 PVC; installed)	30	lf	$ 8.52	$ 256
28	Pipe trench excavation (4 feet bgs)	139	cy	$ 6.23	$ 867
29	Backfill trench (imported sand)	35	cy	$ 39.32	$ 1,369
30	Backfill trench (spoils)	104	cy	$ 3.22	$ 336
	Monitoring Well Installation				**$ 36,058**
31	Shallow wells (2" PVC, 10' screen, 40' deep)	5	ea	$ 3,194.12	$ 15,971
32	Deep wells (2" PVC, 10' screen, 60' deep)	5	ea	$ 4,017.41	$ 20,087
	Measurement				**$ 44,589**
33	Existing condition and record surveys (pre- and post-remediation)	21	days	$ 2,123.30	$ 44,589

Construction subtotal		$ 1,822,992
Construction Contractor Mob./Demob., Site Prep and Submittals	10%	$ 182,299
Pre-design investigation	lump sum	$ 100,000
Pilot test	lump sum	$ 175,000
Engineering design	lump sum	$ 200,000
Project management and construction oversight	7%	$ 127,609
Capital Cost Subtotal		**$ 2,607,901**

Operation and Maintenance

Table D-7					
Operation and Maintenance					
Item	**Description**	**Quantity**	**Unit**	**Unit Price (Incl. O&P)**	**Total Cost**
	Operation and Maintenance, 30 Years				**$ 2,053,528**
	Treatment System Operation and Maintenance , Annual				**$ 113,519**
34	Hydrogen peroxide solution (35%, delivered, 200 gallons per month)	0	gal	$ 13.20	$ -
35	Maintenance	12	month	$ 1,500.00	$ 18,000
36	Internet service and telemetry data account	12	month	$ 100.00	$ 1,200
37	Utilities	12	month	$ 2,250.00	$ 27,000
38	Field labor 10 hrs/wk on proj for 52 weeks	520.0	hr	$ 54.46	$ 28,319
39	Engineering 6 hrs/wk on proj for 52 weeks	312.0	hr	$ 125.00	$ 39,000
	ICs Monitoring, Annual				**$ 5,000**
40	Annual site inspection and reporting	1	ls	$ 5,000.00	$ 5,000
	Performance Monitoring, Per Event				**$ 51,258**
41	Groundwater sample collection (incl. labor, equip, matl, travel)	30	ea	$ 829.60	$ 24,888
42	Sample analysis (w/ QC; VOCs, field parameters, anions, dissolved iron)	40	ea	$ 390.49	$ 15,620
43	Monitoring report	1	ea	$ 7,500.00	$ 7,500
44	Project management 2 hrs/wk on proj for 13 weeks	26	hr	$ 125.00	$ 3,250
	Long-Term Monitoring, Groundwater, Per Event				**$ 51,258**
45	Groundwater sample collection (incl. labor, equip, matl, travel)	30	ea	$ 829.60	$ 24,888
46	Sample analysis (w/ QC; VOCs, field parameters, anions, dissolved iron)	40.0	ea	$ 390.49	$ 15,620
47	Monitoring report	1	ea	$ 7,500.00	$ 7,500
48	Proj. Mgmt. 2 hrs/wk on proj for 13 weeks	26.0	hr	$ 125.00	$ 3,250
	Five-Year Review				**$ 30,000**
49	Site visit and report	1	ls	$ 30,000.00	$ 30,000
	Decomissioning				**$ 126,535**
50	Well Abandonment	200.0	ea	$ 350.00	$ 70,000
51	Grout Conduits	68,104.4	ft	$ 0.11	$ 7,535
52	Above-ground infrastructure removal	14.0	day	$ 3,500.00	$ 49,000

Notes:

bgs	Below ground surface	QC	Quality control
cy	Cubic yard	RACER	Remedial Action Cost Engineering and Requirements System
ea	Each	sf	Square foot
ECHOS	Environmental Cost-Handling Options and Solutions	sy	Square yard
ft	Foot	V	Volt
gal	Gallon	VOC	Volatile organic compound
HDPE	High-density polyethylene	wk	Week
hr	Hour		
IC	Institutional control		
lf	Linear foot		
ls	Lump sum		
O&P	Overhead and profit		
PVC	Polyvinyl chloride		

ALTERNATIVE GW-3C
In Situ Aerobic Bioremediation

Table D-8					
Alternative GW-3C - In Situ Aerobic Bioremediation					
Source	**Description**	**Subtotal**	**Contingency**	**Total**	
Table D-9	Design and Construction	$ 1,707,471	$ 512,241	$ 2,219,712	
Table D-24	Operation and Maintenance	$ 2,853,283	$ 855,985	$ 3,709,268	

Contingency	30%	$ 1,368,226	
Total			**$ 5,928,981**

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Capital Cost

Location factor (for zip code 453xx)

ECHOS	1	
Get-a-Quote	1.01	

Note: Location factor applies only to national average unit costs; it does not apply to local unit costs such as from vendors or Means.

Overhead and Profit (O&P)

General	25%	Typical general contractor overhead and profit
Means	-	
RACER	35%	Default
Contractor quote	5%	Prime contractor markup
Professional judgment	-	Not marked-up

Inflation	1.89%	Average annual inflation from 2010 to 2019

Table D-9
Alternative GW-3C - In Situ Aerobic Bioremediation

Item	Description	Quantity	Unit	Unit Price (Incl. O&P)	Total Cost
	Construction Subtotal				**$ 1,181,599**
	Site Preparation				**$ 10,499**
1	Clear and grub	2.0	acre	$ 1,946.55	$ 3,893
2	Silt Fence	1,260.0	sy	$ 5.24	$ 6,606

Table D-9					
Alternative GW-3C - In Situ Aerobic Bioremediation					
Item	**Description**	**Quantity**	**Unit**	**Unit Price (Incl. O&P)**	**Total Cost**
	First Injection Event				**$ 1,105,316**
3	Direct push and injection (2 rigs)	47.0	days	$ 6,881.25	$ 323,419
4	Sonic pre-clear (10 percent of injection points)	1.0	ls	$ 29,527.76	$ 29,528
5	Microorganism culture with dextrose (50 lbs dextrose per unit)	200.0	units	$ 2,075.50	$ 415,100
6	Oxygen releasing chemical (75% calcium peroxide)	48,500.0	lbs	$ 6.95	$ 337,269
	Monitoring Well Installation				**$ 36,058**
7	Shallow wells (2" PVC, 10' screen, 40' deep)	5.0	ea	$ 3,194.12	$ 15,971
8	Deep wells (2" PVC, 10' screen, 60' deep)	5.0	ea	$ 4,017.41	$ 20,087
	Measurement				**$ 29,726**
9	Existing condition and record surveys (pre- and post-remediation)	14.0	days	$ 2,123.30	$ 29,726

Construction subtotal		$ 1,181,599
Construction Contractor Mob./Demob., Site Prep and Submittals	10%	$ 118,160
Pre-design investigation	lump sum	$ 100,000
Pilot test	lump sum	$ 125,000
Engineering design	lump sum	$ 100,000
Project management and construction oversight	7%	$ 82,712
Capital Cost Subtotal		**$ 1,707,471**

Operation and Maintenance

Table D-10									
Operation and Maintenance									
Item	**Description**					**Quantity**	**Unit**	**Unit Price (Incl. O&P)**	**Total Cost**
	Operation and Maintenance, 30 Years								**$ 2,853,283**
	Second Injection Event								**$ 1,118,580**
1	Biostimulation and bioaugmentation (fraction of original footprint)					0.8	ea	$ 1,105,316.00	$ 884,253
2	Construction contractor mobe/demobe., site prep and submittals					10%	NA	$ 884,253.00	$ 88,425
3	Engineering design, project management and oversight					15%	NA	$ 972,678.00	$ 145,902
	Third Injection Event								**$ 838,935**
4	Biostimulation and bioaugmentation (fraction of original footprint)					0.6	ea	$ 1,105,316.00	$ 663,190
5	Construction contractor mobe/demobe., site prep and submittals					10%	NA	$ 663,190.00	$ 66,319
6	Engineering design, project management and oversight					15%	NA	$ 729,509.00	$ 109,426
	ICs Monitoring, Annual								**$ 5,000**
7	Annual site inspection and reporting					1	ls	$ 5,000.00	$ 5,000
	Performance Monitoring, Per Event								**$ 48,758**
8	Groundwater sample collection (incl. labor, equip, matl, travel)					30	ea	$ 829.60	$ 24,888
9	Sample analysis (w/ QC; VOCs, field parameters, anions, dissolved iron)					40	ea	$ 390.49	$ 15,620
10	Monitoring report					1	ea	$ 5,000.00	$ 5,000
11	Project management	2 hrs/wk	on proj for	13	weeks	26	hr	$ 125.00	$ 3,250
	Long-Term Monitoring, Groundwater, Per Event								**$ 48,758**
12	Groundwater sample collection (incl. labor, equip, matl, travel)					30	ea	$ 829.60	$ 24,888
13	Sample analysis (w/ QC; VOCs, field parameters, anions, dissolved iron)					40.0	ea	$ 390.49	$ 15,620
14	Monitoring report					1	ea	$ 5,000.00	$ 5,000
15	Proj. Mgmt.	2 hrs/wk	on proj for	13	weeks	26.0	hr	$ 125.00	$ 3,250
	Five-Year Review								**$ 30,000**
16	Site visit and report					1	ls	$ 30,000.00	$ 30,000
	Decomissioning								**$ 14,000**
17	Well Abandonment					40.0	ea	$ 350.00	$ 14,000

Notes:

ea	Each
ECHOS	Environmental Cost-Handling Options and Solutions
hr	Hour
IC	Institutional control
lb	Pound
ls	Lump sum
NA	Not applicable
O&P	Overhead and profit
PVC	Polyvinyl chloride
QC	Quality control
RACER	Remedial Action Cost Engineering and Requirements System
sy	Square yard
VOC	Volatile organic compound
wk	Week

ALTERNATIVE GW 4
Extraction, Treatment, and Discharge in Combination with Institutional Controls and Monitoring

Table D-11				
Alternative GW 4 - Extraction, Treatment, and Discharge				
Source	**Description**	**Subtotal**	**Contingency**	**Total**
Table D-12	Design and Construction	$ 947,605	$ 284,281	$ 1,231,886
Table D-25	Operation and Maintenance	$ 2,606,010	$ 781,803	$ 3,387,813

Contingency	30%	$ 1,066,085	
Total			**$ 4,619,700**

Capital Cost

Location factor (for zip code 453xx)		
ECHOS	1	
Get-a-Quote	1.01	

Note: Location factor applies only to national average unit costs; it does not apply to local unit costs such as from vendors or Means.

Overhead and Profit (O&P)		
General	25%	Typical general contractor overhead and profit
Means	-	
RACER	35%	Default
Contractor quote	5%	Prime contractor markup
Professional judgment	-	Not marked-up
Inflation	1.89%	Average annual inflation from 2010 to 2019

Table D-12
Alternative GW 4 - Extraction, Treatment, and Discharge

Item	Description	Quantity	Unit	Unit Price (Incl. O&P)	Total Cost
	Construction Subtotal				**$ 617,611**
	Site Preparation				**$ 10,499**
1	Clear and grub	2.0	acre	$ 1,946.55	$ 3,893
2	Silt Fence	1,260.0	sy	$ 5.24	$ 6,606
	Temporary facilities				**$ 29,757**
3	Chain link fence (12' high)	200	lf	$ 31.14	$ 6,229
4	4" thick reinforced concrete equipment pad	900.0	sf	$ 6.92	$ 6,228
5	New pole (25') and transformer (50 KVA)	1.0	ea	$ 15,000.00	$ 15,000
6	Install 480V 3 Phase connection and meter	1.0	ls	$ 1,764.87	$ 1,765
7	Install Breaker Box	1.0	ea	$ 534.92	$ 535

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Remedial Alternatives Cost Estimates
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Table D-12					
Alternative GW 4 - Extraction, Treatment, and Discharge					
Item	**Description**	**Quantity**	**Unit**	**Unit Price (Incl. O&P)**	**Total Cost**
	Treatment System				**$ 310,248**
8	Bag filters (150 gpm)	2.0	ea	$ 9,053.04	$ 18,106
9	Air stripper (100 gpm, stacked tray)	1.0	ls	$ 118,111.03	$ 118,111
10	Treatment building (climate controlled container)	1.0	ls	$ 34,030.74	$ 34,031
11	Installation	14.0	days	$ 10,000.00	$ 140,000
	Wells				**$ 45,372**
11	Extraction well (6" PVC casing; installed)	4.0	ea	$ 7,267.31	$ 29,069
12	Submersible pump (20 gpm; installed)	4.0	ea	$ 1,655.71	$ 6,623
13	Well Vault (steel, 2ft x 3ft, installed)	4.0	ea	$ 1,273.63	$ 5,095
14	Pressure Transducer	4.0	ea	$ 1,146.26	$ 4,585
	Piping				**$ 12,581**
15	Trunk line and laterals (2" PVC)	460.0	lf	$ 4.22	$ 1,941
16	Trunk line (4" PVC)	380.0	lf	$ 10.22	$ 3,885
7	Discharge pipe (6" PVC)	50.0	lf	$ 11.51	$ 576
8	Trench Excavation	880.0	lf	$ 3.96	$ 3,483
9	Backfill - Gravel	65.0	cy	$ 28.55	$ 1,856
10	Backfill - Spoils	261.0	cy	$ 3.22	$ 840
	Electrical				**$ 158,233**
11	Ground wire	840.0	lf	$ 1.88	$ 1,583
12	Power cables	840.0	lf	$ 0.50	$ 419
13	Control wires (2-wire)	840.0	lf	$ 0.50	$ 419
14	Electrical conduit (2" PVC)	1,680.0	lf	$ 6.44	$ 10,812
15	Motor control center	1.0	ea	$ 25,000.00	$ 25,000
16	PLC/SCADA installation and programming	1.0	ea	$ 120,000.00	$ 120,000
	Monitoring Well Installation				**$ 36,058**
17	Shallow wells	5	ea	$ 3,194.12	$ 15,971
18	Deep wells	5	ea	$ 4,017.41	$ 20,087
	Measurement				**$ 14,863**
19	Existing condition and record surveys (pre- and post-remediation)	7.0	days	$ 2,123.30	$ 14,863

Construction subtotal		$ 617,611
Construction Contractor Mob./Demob., Site Prep and Submittals	10%	$ 61,761
Pre-design investigation	lump sum	$ 100,000
Engineering design	lump sum	$ 125,000
Project management and construction oversight	7%	$ 43,233
Capital Cost Subtotal		**$ 947,605**

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Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Operation and Maintenance

Table D-13					
Operation and Maintenance					
Item	**Description**	**Quantity**	**Unit**	**Unit Price (Incl. O&P)**	**Total Cost**
	Operation and Maintenance, 30 Years				**$ 2,606,010**
	Treatment System Operation and Maintenance , Annual				**$ 77,643**
19	System operation and maintenance	12.0	mo	$ 5,000.00	$ 60,000
20	Electrical charges	14,600.0	KWH	$ 0.10	$ 1,460
21	Influent/effluent sampling (with VOC analysis; monthly)	12.0	mo	$ 765.76	$ 9,189
22	Air stripper exhaust monitoring (with PID)	12.0	mo	$ 493.63	$ 5,924
23	Air stripper exhaust sampling (One sample analyzed for TO-15)	4.0	ea	$ 267.46	$ 1,070
	ICs Monitoring, Annual				**$ 5,000**
24	Annual site inspection and reporting	1	ls	$ 5,000.00	$ 5,000
	Performance Monitoring, Per Event				**$ 89,388**
25	Groundwater sample collection (incl. labor, equip, matl, travel)	34	ea	$ 829.60	$ 28,206
26	Sample analysis (w/ QC; VOCs, field parameters, anions, dissolved iron)	44	ea	$ 390.49	$ 17,182
27	Monitoring report	1	ea	$ 5,000.00	$ 5,000
28	Proj. Mgmt. 6 hrs/wk on proj for 52 weeks	312.0	hr	$ 125.00	$ 39,000
	Five-Year Review				**$ 30,000**
29	Site visit and report	1	ls	$ 30,000.00	$ 30,000
	Decommissioning				**$ 37,097**
30	Remove pumps	4.0	ea	$ 150.00	$ 600
31	Well Abandoment	34.0	ea	$ 350.00	$ 11,900
32	Above-ground infrastructure removal	7.0	day	$ 3,500.00	$ 24,500
33	Grout underground piping	880.0	lf	$ 0.11	$ 97

Notes:

cy	Cubic yard	PLC	Programmable logic controller
ea	Each	PVC	Polyvinyl chloride
ECHOS	Environmental Cost-Handling Options and Solutions	QC	Quality control
ft	Foot	RACER	Remedial Action Cost Engineering and Requirements System
gpm	Gallons per minute	SCADA	Supervisory control and data acquisition
hr	Hour	sf	Square foot
IC	Institutional control	sy	Square yard
KWH	Kilowatt hour	TO	Toxic organic
lf	Linear foot	V	Volt
ls	Lump sum	VOC	Volatile organic compound
mo	Month	wk	Week
O&P	Overhead and profit		
PID	Photoionization detector		

ALTERNATIVE PR-2
Well Treatment and Monitoring

Table D-14				
Alternative PR-2 - Treatment and Monitoring				
Source	**Description**	**Subtotal**	**Contingency**	**Total**
Table D-15	Design and Construction	$ 23,895	$ 7,168	$ 31,063
Table D-26	Operation and Maintenance	$ 18,230	$ 5,469	$ 23,699

Contingency	30%		$ 12,637	
Total				**$ 54,762**

Capital Cost

Location factor (for zip code 453xx)		
ECHOS	1	
Get-a-Quote	1.01	

Note: Location factor applies only to national average unit costs; it does not apply to local unit costs such as from vendors or Means.

Overhead and Profit (O&P)		
General	25%	Typical general contractor overhead and profit
Means	-	
RACER	35%	Default
Contractor quote	5%	Prime contractor markup
Professional judgment	-	Not marked-up
Inflation	1.89%	Average annual inflation from 2010 to 2019

Table D-15
Alternative PR-2 - Treatment and Monitoring

Item	Description	Quantity	Unit	Unit Price (Incl. O&P)	Total Cost
	Construction Subtotal				**$ 16,268**
	Water Treatment System				**$ 16,268**
1	POE unit (GAC with sediment filter, 10 gpm)	2	ea	$ 1,655.71	$ 3,311
2	Installation kit	1	ea	$ 509.45	$ 509
3	Plumber	8	hr	$ 125.00	$ 1,000
4	Wastewater characterization	1	ea	$ 500.00	$ 500
5	Wastewater disposal, non-hazardous (55-gallon drum)	1	ea	$ 239.81	$ 240
6	Influent/effluent sampling at startup (VOCs and TOC)	2	ea	$ 354.20	$ 708
7	Laboratory column test (design, sampling, testing, reporting)	1	ea	$ 10,000.00	$ 10,000

Construction subtotal		$ 16,268
Construction Contractor Mob./Demob., Site Prep and Submittals	10%	$ 1,627
Pre-design investigation	lump sum	$ -
Bid package	lump sum	$ 5,000
Project management and construction oversight	lump sum	$ 1,000
Capital Cost Subtotal		**$ 23,895**

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Remedial Alternatives Cost Estimates
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Operation and Maintenance

Table D-16					
Operation and Maintenance					
Item	**Description**	**Quantity**	**Unit**	**Unit Price (Incl. O&P)**	**Total Cost**
	Operation and Maintenance, 10 Years				**$ 18,230**
	Operation and Maintenance, Semi-Annual (per event)				**$ 314**
8	Sediment pre-filter replacement	1	ea	$ 63.68	$ 64
9	Plumber	2	hr	$ 125.00	$ 250
	Operation and Maintenance, Biennial (per event)				**$ 1,862**
8	Carbon replacement	1	ls	$ 382.09	$ 382
9	Plumber	4	hr	$ 125.00	$ 500
10	Wastewater characterization	1	ea	$ 500.00	$ 500
11	Wastewater disposal, non-hazardous (55-gallon drum)	2	ea	$ 239.81	$ 480
	Performance Monitoring (per event)				**$ 1,068**
12	Influent/effluent sampling (with VOC analysis)	2	ea	$ 284.20	$ 568
13	Monitoring report	1	ea	$ 500.00	$ 500

Notes:

ea	Each
ECHOS	Environmental Cost-Handling Options and Solutions
GAC	Granular activated carbon
gpm	Gallons per minute
hr	Hour
ls	Lump sum
O&P	Overhead and profit
POE	Point of entry
RACER	Remedial Action Cost Engineering and Requirements System
TOC	Total organic carbon
VOC	Volatile organic compound

ALTERNATIVE PR-3
Connect to City Water and Abandon Private Well

Table D-17				
Alternative PR-3 - Connect to City Water and Abandon Private Well				
Source	**Description**	**Subtotal**	**Contingency**	**Total**
Table D-18	Design and Construction	$ 36,123	$ 10,837	$ 46,959

Contingency	30%		$ 10,837

Total	**$ 46,959**

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Remedial Alternatives Cost Estimates
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Capital Cost

Location factor (for zip code 453xx)		
ECHOS	1	
Get-a-Quote	1.01	

Note: Location factor applies only to national average unit costs; it does not apply to local unit costs such as from vendors or Means.

Overhead and Profit (O&P)		
General	25%	Typical general contractor overhead and profit
Means	-	
RACER	35%	Default
Contractor quote	5%	Prime contractor markup
Professional judgment	-	Not marked-up
Inflation	1.89%	Average annual inflation from 2010 to 2019

Table D-18
Alternative PR-3 - Connect to City Water and Abandon Private Well

Item	Description	Quantity	Unit	Unit Price (Incl. O&P)	Total Cost
	Construction Subtotal				**$ 22,327**
	Connect to City Water and Abandon Well				**$ 22,327**
1	Connection to City water and abandonment of existing private well (includes installation of 1" type K copper water service line, boring under street and parking lot, site restoration, traffic control, and required permits and inspections)	1	ls	$ 18,187.39	$ 18,187
2	Connection fee	1	ls	$ 2,139.69	$ 2,140
3	Annexation administrative expenses	1	ls	$ 2,000.00	$ 2,000

Construction subtotal		$ 22,327
Construction Contractor Mob./Demob., Site Prep and Submittals	10%	$ 2,233
Pre-design investigation	lump sum	$ -
Bid package	lump sum	$ 10,000
Project management and construction oversight	7%	$ 1,563
Capital Cost Subtotal		**$ 36,123**

Notes:

ECHOS	Environmental Cost-Handling Options and Solutions
ls	Lump sum
O&P	Overhead and profit
RACER	Remedial Action Cost Engineering and Requirements System

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Remedial Alternatives Cost Estimates
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ALTERNATIVE VI2
Institutional Controls and Monitoring

Table D-19				
Alternative VI2 - Institutional Controls and Monitoring				
Source	**Description**	**Subtotal**	**Contingency**	**Total**
Table D-20	Design and Construction	$ 44,000	$ 13,200	$ 57,200
Table D-27	Operation and Maintenance	$ 37,227	$ 11,168	$ 48,395

Contingency	30%	$ 24,368	
Total			**$ 105,595**

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Remedial Alternatives Cost Estimates
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Capital Cost

Location factor (for zip code 453xx)		
ECHOS	1	
Get-a-Quote	1.01	

Note: Location factor applies only to national average unit costs; it does not apply to local unit costs such as from vendors or Means.

Overhead and Profit (O&P)		
General	25%	Typical general contractor overhead and profit
Means	-	
RACER	35%	Default
Contractor quote	5%	Prime contractor markup
Professional judgment	-	Not marked-up
Inflation	1.89%	Average annual inflation from 2010 to 2019

Table D-20
Alternative VI2 - Institutional Controls and Monitoring

Item	Description	Quantity	Unit	Unit Price (Incl. O&P)	Total Cost
	Construction Subtotal				**$ 44,000**
	Institutional Controls				**$ 44,000**
1	Planning	200	hr	$ 150.00	$ 30,000
2	Meetings	40	hr	$ 150.00	$ 6,000
3	Legal	32	hr	$ 250.00	$ 8,000

Construction subtotal		$ 44,000
Construction Contractor Mob./Demob., Site Prep and Submittals	0%	$ -
Pre-design investigation	0%	$ -
Engineering design	lump sum	$ -
Project management and construction oversight	0%	$ -
Capital Cost Subtotal		**$ 44,000**

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Remedial Alternatives Cost Estimates
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Operation and Maintenance

Table D-21					
Operation and Maintenance					
Item	**Description**	**Quantity**	**Unit**	**Unit Price (Incl. O&P)**	**Total Cost**
	Operation and Maintenance, 30 Years				**$ 37,227**
	Institutional Controls Monitoring (per event)				**$ 3,000**
1	Annual site inspection and reporting	1	ls	$ 3,000.00	$ 3,000

Notes:

ECHOS	Environmental Cost-Handling Options and Solutions
hr	Hour
ls	Lump sum
O&P	Overhead and profit
RACER	Remedial Action Cost Engineering and Requirements System

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
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Annual Discount Rate:

30-Yr 7.00%

Table D-22						
Present Value Analysis						
	Annual Discount Factor [1, 2]	**Alternative GW 3A - AS/SVE**				
		Operation and Maintenance Costs				
Year	**30-Yr**	**Description**	**Future Cost [3]**	**Description**	**Future Cost [3]**	**Present Value (2019)**
0	1.000					$0
1	0.935	AS/SVE O&M	$79,400	ICs + Quarterly Performance Monitoring	$203,240	$264,150
2	0.873	AS/SVE O&M	$79,400	ICs + Quarterly Performance Monitoring	$203,240	$246,869
3	0.816	AS/SVE O&M	$79,400	ICs + Quarterly Performance Monitoring	$203,240	$230,718
4	0.763	AS/SVE O&M	$79,400	ICs + Quarterly Performance Monitoring	$203,240	$215,625
5	0.713	AS/SVE O&M	$79,400	ICs + Quarterly Performance Monitoring + Five-Year Review	$233,240	$222,908
6	0.666	AS/SVE O&M	$79,400	ICs + Quarterly Performance Monitoring	$203,240	$188,335
7	0.623	AS/SVE O&M	$79,400	ICs + Quarterly Performance Monitoring	$203,240	$176,014
8	0.582	AS/SVE O&M	$79,400	ICs + Quarterly Performance Monitoring	$203,240	$164,499
9	0.544			ICs + Semi-Annual Performance Monitoring	$104,120	$56,634
10	0.508			ICs + Annual LTM + Five-Year Review	$84,560	$42,986
11	0.475			ICs + Annual LTM	$54,560	$25,921
12	0.444			ICs + Annual LTM	$54,560	$24,225
13	0.415			ICs + Annual LTM	$54,560	$22,640
14	0.388			ICs + Annual LTM	$54,560	$21,159
15	0.362			ICs + Annual LTM + Five-Year Review	$84,560	$30,648
16	0.339			ICs + Annual LTM	$54,560	$18,481
17	0.317			ICs + Annual LTM	$54,560	$17,272
18	0.296			ICs + Annual LTM	$54,560	$16,142
19	0.277			ICs + Annual LTM	$54,560	$15,086
20	0.258			ICs + Annual LTM + Five-Year Review	$84,560	$21,852
21	0.242			ICs + Annual LTM	$54,560	$13,177
22	0.226			ICs + Annual LTM	$54,560	$12,315
23	0.211			ICs + Annual LTM	$54,560	$11,509
24	0.197			ICs + Annual LTM	$54,560	$10,756
25	0.184			ICs + Annual LTM + Five-Year Review	$84,560	$15,580
26	0.172			ICs + Annual LTM	$54,560	$9,395
27	0.161			ICs + Annual LTM	$54,560	$8,780
28	0.150			ICs + Annual LTM	$54,560	$8,206
29	0.141			ICs + Annual LTM	$54,560	$7,669
30	0.131	Decommissioning	$69,146	ICs + Annual LTM + Five-Year Review	$84,560	$20,192
Total Present Value of Periodic Cost						**$2,139,746**

Notes:

1	Based on discount rate of 7 percent
2	Annual discount factor = $1/(1+i)^t$, where i = discount rate (includes inflation and interest) and t = year
3	Current dollar cost of future event
AS	Air sparging
IC	Institutional control
LTM	Long-term monitoring
O&M	Operation and maintenance
SVE	Soil vapor extraction

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Remedial Alternatives Cost Estimates
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Annual Discount Rate:

30-Yr 7.00%

Table D-23						
Present Value Analysis						
	Annual Discount Factor [1, 2]	**Alternative GW 3B - ISCO (Ozone Sparging)**				
		Operation and Maintenance Costs				
Year	**30-Yr**	**Description**	**Future Cost [3]**	**Description**	**Future Cost [3]**	**Present Value (2019)**
0	1.000					$0
1	0.935	ISCO O&M	$113,519	ICs + Quarterly Performance Monitoring	$210,032	$302,384
2	0.873	ISCO O&M	$113,519	ICs + Quarterly Performance Monitoring	$210,032	$282,602
3	0.816	ISCO O&M	$113,519	ICs + Quarterly Performance Monitoring	$210,032	$264,114
4	0.763	ISCO O&M	$113,519	ICs + Quarterly Performance Monitoring	$210,032	$246,836
5	0.713	ISCO O&M	$113,519	ICs + Quarterly Performance Monitoring + Five-Year Review	$240,032	$252,077
6	0.666	ISCO O&M	$113,519	ICs + Quarterly Performance Monitoring	$210,032	$215,596
7	0.623			ICs + Annual LTM	$56,258	$35,035
8	0.582			ICs + Annual LTM	$56,258	$32,743
9	0.544			ICs + Annual LTM	$56,258	$30,601
10	0.508			ICs + Annual LTM + Five-Year Review	$86,258	$43,849
11	0.475			ICs + Annual LTM	$56,258	$26,728
12	0.444			ICs + Annual LTM	$56,258	$24,979
13	0.415			ICs + Annual LTM	$56,258	$23,345
14	0.388			ICs + Annual LTM	$56,258	$21,818
15	0.362			ICs + Annual LTM + Five-Year Review	$86,258	$31,264
16	0.339			ICs + Annual LTM	$56,258	$19,057
17	0.317			ICs + Annual LTM	$56,258	$17,810
18	0.296			ICs + Annual LTM	$56,258	$16,645
19	0.277			ICs + Annual LTM	$56,258	$15,556
20	0.258			ICs + Annual LTM + Five-Year Review	$86,258	$22,291
21	0.242			ICs + Annual LTM	$56,258	$13,587
22	0.226			ICs + Annual LTM	$56,258	$12,698
23	0.211			ICs + Annual LTM	$56,258	$11,867
24	0.197			ICs + Annual LTM	$56,258	$11,091
25	0.184			ICs + Annual LTM + Five-Year Review	$86,258	$15,893
26	0.172			ICs + Annual LTM	$56,258	$9,687
27	0.161			ICs + Annual LTM	$56,258	$9,054
28	0.150			ICs + Annual LTM	$56,258	$8,461
29	0.141			ICs + Annual LTM	$56,258	$7,908
30	0.131	Decommissioning	$126,535	ICs + Annual LTM + Five-Year Review	$86,258	$27,954
Total Present Value of Periodic Cost						**$2,053,528**

Notes:

1 Based on discount rate of 7 percent
2 Annual discount factor = $1/(1+i)^t$, where i = discount rate (includes inflation and interest) and t = year
3 Current dollar cost of future event
IC Institutional control
ISCO In situ chemical oxidation
LTM Long-term monitoring
O&M Operation and maintenance

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Remedial Alternatives Cost Estimates
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Annual Discount Rate:

30-Yr 7.00%

Table D-24						
Present Value Analysis						
	Annual Discount Factor [1, 2]	**Alternative GW 3C - Aerobic Bioremediation**				
		Operation and Maintenance Costs				
Year	**30-Yr**	**Description**	**Future Cost [3]**	**Description**	**Future Cost [3]**	**Present Value (2019)**
0	1.000					$0
1	0.935	Second injection	$1,118,580	ICs + Quarterly Performance Monitoring	$200,032	$1,232,348
2	0.873	Third injection	$838,935	ICs + Quarterly Performance Monitoring	$200,032	$907,474
3	0.816			ICs + Semi-Annual Performance Monitoring	$102,516	$83,684
4	0.763			ICs + Semi-Annual Performance Monitoring	$102,516	$78,209
5	0.713			ICs + Annual LTM + Five-Year Review	$83,758	$59,718
6	0.666			ICs + Annual LTM	$53,758	$35,821
7	0.623			ICs + Annual LTM	$53,758	$33,478
8	0.582			ICs + Annual LTM	$53,758	$31,288
9	0.544			ICs + Annual LTM	$53,758	$29,241
10	0.508			ICs + Annual LTM + Five-Year Review	$83,758	$42,578
11	0.475			ICs + Annual LTM	$53,758	$25,540
12	0.444			ICs + Annual LTM	$53,758	$23,869
13	0.415			ICs + Annual LTM	$53,758	$22,308
14	0.388			ICs + Annual LTM	$53,758	$20,848
15	0.362			ICs + Annual LTM + Five-Year Review	$83,758	$30,358
16	0.339			ICs + Annual LTM	$53,758	$18,210
17	0.317			ICs + Annual LTM	$53,758	$17,018
18	0.296			ICs + Annual LTM	$53,758	$15,905
19	0.277			ICs + Annual LTM	$53,758	$14,865
20	0.258			ICs + Annual LTM + Five-Year Review	$83,758	$21,645
21	0.242			ICs + Annual LTM	$53,758	$12,983
22	0.226			ICs + Annual LTM	$53,758	$12,134
23	0.211			ICs + Annual LTM	$53,758	$11,340
24	0.197			ICs + Annual LTM	$53,758	$10,598
25	0.184			ICs + Annual LTM + Five-Year Review	$83,758	$15,432
26	0.172			ICs + Annual LTM	$53,758	$9,257
27	0.161			ICs + Annual LTM	$53,758	$8,651
28	0.150			ICs + Annual LTM	$53,758	$8,085
29	0.141			ICs + Annual LTM	$53,758	$7,556
30	0.131	Decommissioning	$14,000	ICs + Annual LTM + Five-Year Review	$83,758	$12,842
Total Present Value of Periodic Cost						**$2,853,283**

Notes:

1 Based on discount rate of 7 percent

2 Annual discount factor = $1/(1+i)^t$, where i = discount rate (includes inflation and interest) and t = year

3 Current dollar cost of future event

IC Institutional control

LTM Long-term monitoring

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Annual Discount Rate:

30-Yr 7.00%

Table D-25						
Present Value Analysis						
	Annual Discount Factor [1, 2]	**Alternative GW 4 - Extraction, Treatment, and Discharge**				
		Operation and Maintenance Costs				
Year	**30-Yr**	**Description**	**Future Cost [3]**	**Description**	**Future Cost [3]**	**Present Value (2019)**
0	1.000					$0
1	0.935	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Quarterly Performance Monitoring	$362,552	$411,397
2	0.873	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Semi-Annual Performance Monitoring	$183,776	$228,333
3	0.816	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Semi-Annual Performance Monitoring	$183,776	$213,396
4	0.763	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$131,242
5	0.713	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM + Five-Year Review	$124,388	$144,045
6	0.666	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$114,632
7	0.623	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$107,132
8	0.582	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$100,124
9	0.544	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$93,573
10	0.508	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM + Five-Year Review	$124,388	$102,702
11	0.475	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$81,731
12	0.444	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$76,384
13	0.415	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$71,387
14	0.388	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$66,717
15	0.362	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM + Five-Year Review	$124,388	$73,225
16	0.339	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$58,273
17	0.317	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$54,461
18	0.296	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$50,898
19	0.277	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$47,568
20	0.258	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM + Five-Year Review	$124,388	$52,209
21	0.242	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$41,548
22	0.226	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$38,830
23	0.211	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$36,289
24	0.197	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$33,915
25	0.184	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM + Five-Year Review	$124,388	$37,224
26	0.172	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$29,623
27	0.161	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$27,685
28	0.150	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$25,874
29	0.141	Extraction, Treatment, and Discharge O&M	$77,643	ICs + Annual LTM	$94,388	$24,181
30	0.131	Extraction, Treatment, and Discharge O&M + Decommissioning	$114,740	ICs + Annual LTM + Five-Year Review	$124,388	$31,414
Total Present Value of Periodic Cost						**$2,606,010**

Notes:

1 Based on discount rate of 7 percent

2 Annual discount factor = $1/(1+i)^t$, where i = discount rate (includes inflation and interest) and t = year

3 Current dollar cost of future event

IC Institutional control

LTM Long-term monitoring

O&M Operation and maintenance

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Annual Discount Rate:

30-Yr 7.00%

Table D-26						
Present Value Analysis						
	Annual Discount Factor [1, 2]	Alternative PR-2 - Treatment and Monitoring				
		Operation and Maintenance Costs				
Year	30-Yr	Description	Future Cost [3]	Description	Future Cost [3]	Present Value (2019)
0	1.000					$0
1	0.935	O&M (filter changeout)	$628	Performance monitoring	$1,068	$1,585
2	0.873	O&M (filter + carbon changeout)	$2,490	Performance monitoring	$1,068	$3,108
3	0.816	O&M (filter changeout)	$628	Performance monitoring	$1,068	$1,384
4	0.763	O&M (filter + carbon changeout)	$2,490	Performance monitoring	$1,068	$2,714
5	0.713	O&M (filter changeout)	$628	Performance monitoring	$1,068	$1,209
6	0.666	O&M (filter + carbon changeout)	$2,490	Performance monitoring	$1,068	$2,371
7	0.623	O&M (filter changeout)	$628	Performance monitoring	$1,068	$1,056
8	0.582	O&M (filter + carbon changeout)	$2,490	Performance monitoring	$1,068	$2,071
9	0.544	O&M (filter changeout)	$628	Performance monitoring	$1,068	$923
10	0.508	O&M (filter + carbon changeout)	$2,490	Performance monitoring	$1,068	$1,809
11	0.475					$0
12	0.444					$0
13	0.415					$0
14	0.388					$0
15	0.362					$0
16	0.339					$0
17	0.317					$0
18	0.296					$0
19	0.277					$0
20	0.258					$0
21	0.242					$0
22	0.226					$0
23	0.211					$0
24	0.197					$0
25	0.184					$0
26	0.172					$0
27	0.161					$0
28	0.150					$0
29	0.141					$0
30	0.131					$0
Total Present Value of Periodic Cost						**$18,230**

Notes:

1 Based on discount rate of 7 percent

2 Annual discount factor = $1/(1+i)^t$, where i = discount rate (includes inflation and interest) and t = year

3 Current dollar cost of future event

O&M Operation and maintenance

Appendix D
Remedial Alternatives Cost Estimates
West Troy Contaminated Aquifer Site
Troy, Ohio

Annual Discount Rate:

30-Yr 7.00%

Table D-27						
Present Value Analysis						
	Annual Discount Factor [1, 2]	**Alternative VI 2 Institutional Controls and Monitoring**				
		Operation and Maintenance Costs				
Year	**30-Yr**	**Description**	**Future Cost** [3]	**Description**	**Future Cost** [3]	**Present Value (2019)**
0	1.000					$0
1	0.935	Institutional Controls Monitoring	$3,000			$2,804
2	0.873	Institutional Controls Monitoring	$3,000			$2,620
3	0.816	Institutional Controls Monitoring	$3,000			$2,449
4	0.763	Institutional Controls Monitoring	$3,000			$2,289
5	0.713	Institutional Controls Monitoring	$3,000			$2,139
6	0.666	Institutional Controls Monitoring	$3,000			$1,999
7	0.623	Institutional Controls Monitoring	$3,000			$1,868
8	0.582	Institutional Controls Monitoring	$3,000			$1,746
9	0.544	Institutional Controls Monitoring	$3,000			$1,632
10	0.508	Institutional Controls Monitoring	$3,000			$1,525
11	0.475	Institutional Controls Monitoring	$3,000			$1,425
12	0.444	Institutional Controls Monitoring	$3,000			$1,332
13	0.415	Institutional Controls Monitoring	$3,000			$1,245
14	0.388	Institutional Controls Monitoring	$3,000			$1,163
15	0.362	Institutional Controls Monitoring	$3,000			$1,087
16	0.339	Institutional Controls Monitoring	$3,000			$1,016
17	0.317	Institutional Controls Monitoring	$3,000			$950
18	0.296	Institutional Controls Monitoring	$3,000			$888
19	0.277	Institutional Controls Monitoring	$3,000			$830
20	0.258	Institutional Controls Monitoring	$3,000			$775
21	0.242	Institutional Controls Monitoring	$3,000			$725
22	0.226	Institutional Controls Monitoring	$3,000			$677
23	0.211	Institutional Controls Monitoring	$3,000			$633
24	0.197	Institutional Controls Monitoring	$3,000			$591
25	0.184	Institutional Controls Monitoring	$3,000			$553
26	0.172	Institutional Controls Monitoring	$3,000			$517
27	0.161	Institutional Controls Monitoring	$3,000			$483
28	0.150	Institutional Controls Monitoring	$3,000			$451
29	0.141	Institutional Controls Monitoring	$3,000			$422
30	0.131	Institutional Controls Monitoring	$3,000			$394
Total Present Value of Periodic Cost						**$37,227**

Notes:

1 Based on discount rate of 7 percent

2 Annual discount factor = $1/(1+i)^t$, where i = discount rate (includes inflation and interest) and t = year

3 Current dollar cost of future event

APPENDIX E

THREE-DIMENSIONAL PLUME IMAGES FOR TETRACHLOROETHENE

N

Legend

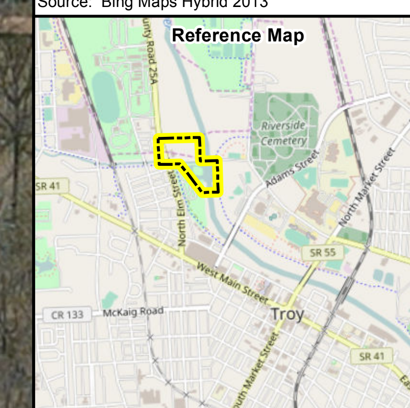
Phase I VAS Location

Phase II VAS Location

0 100 200

Feet

Source: Bing Maps Hybrid 2013



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE E-1
PHASE I AND II WATERLOO VERTICAL AQUIFER SAMPLING (VAS) LOCATIONS

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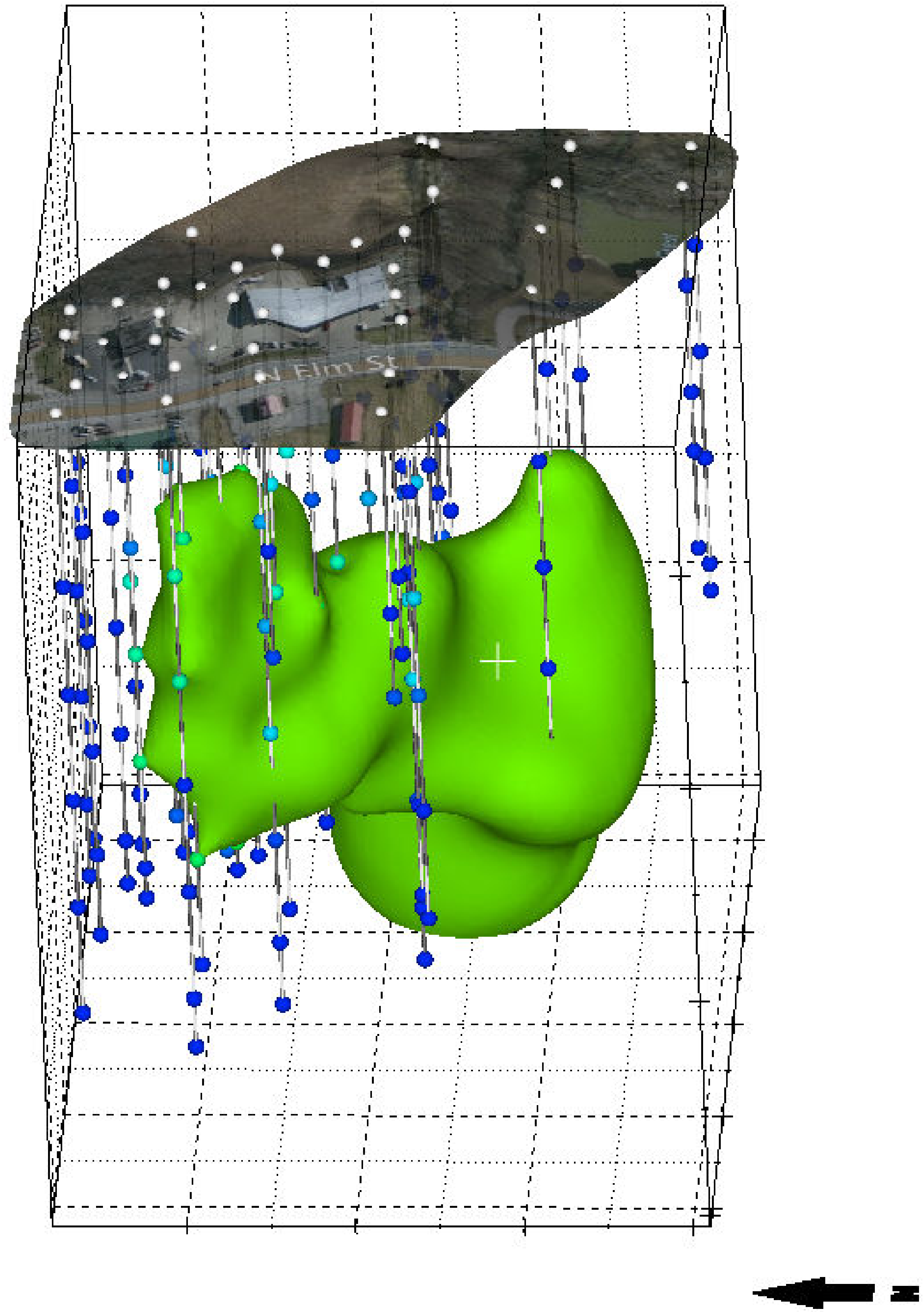


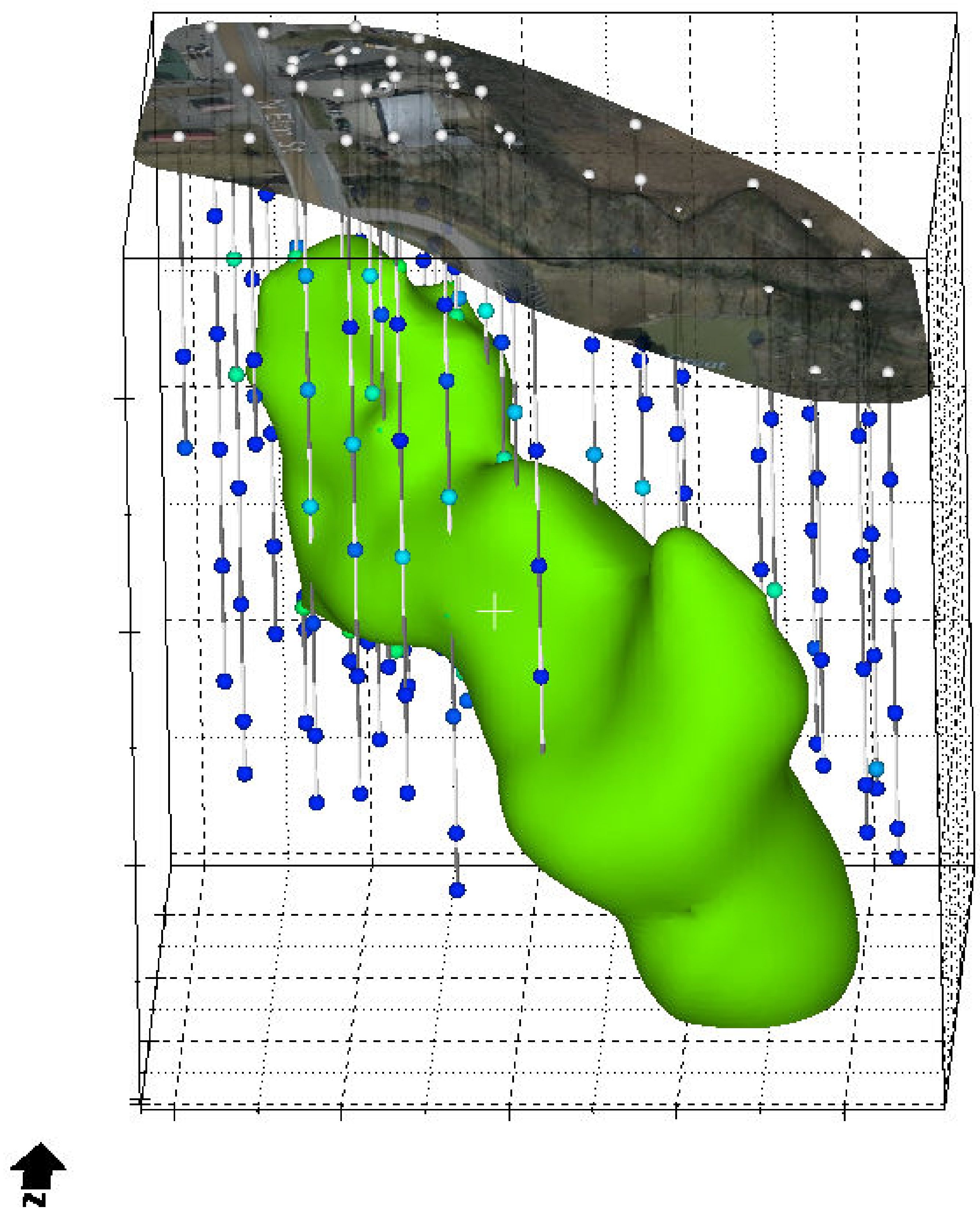
Legend

100 µg/L
30 µg/L
10 µg/L
3 µg/L
1 µg/L

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE E-2A
EXTENT OF PCE CONTAMINATION IN GROUNDWATER GREATER 5 µg/L
VIEW FACING EAST

ST SulTRAC



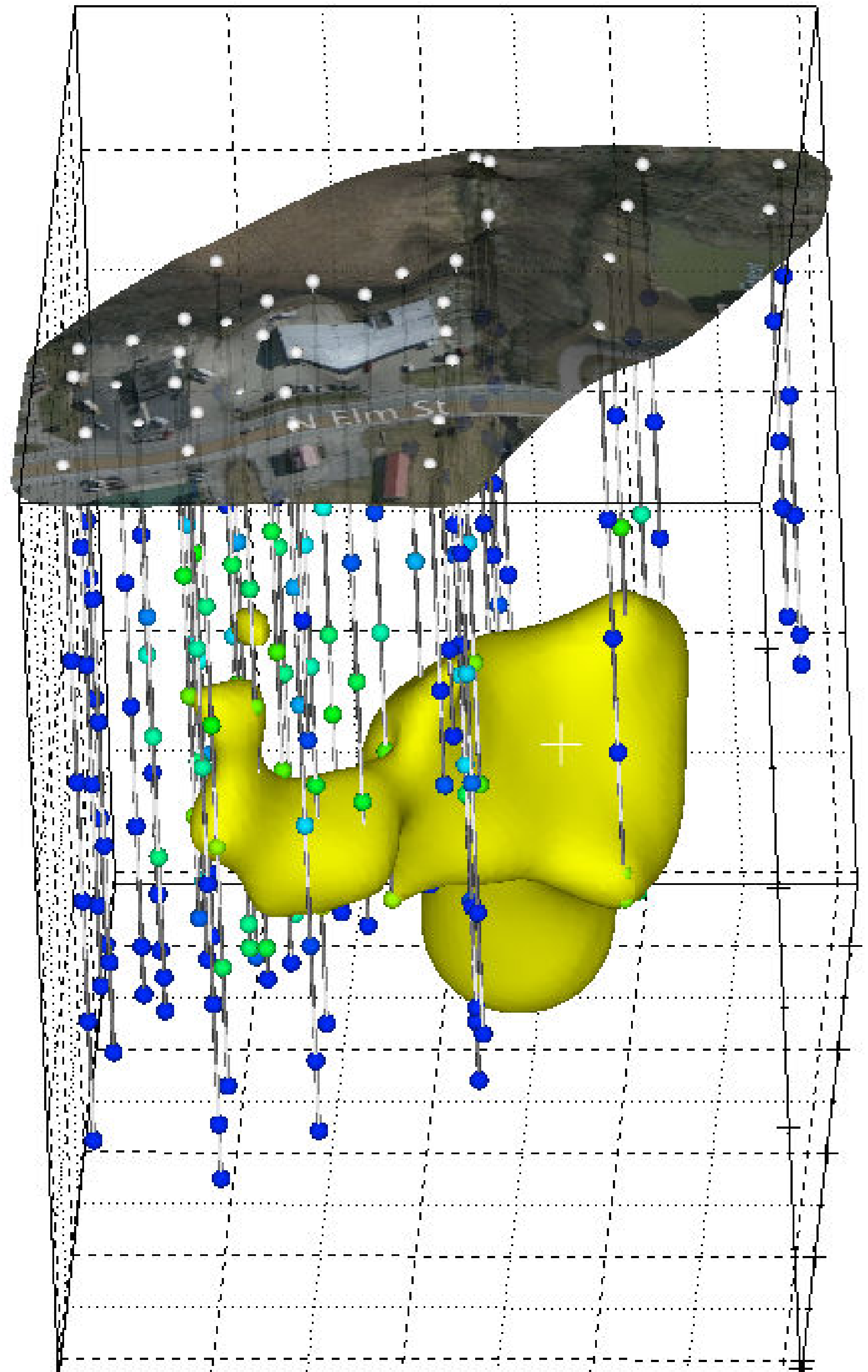
Legend

100 µg/L
30 µg/L
10 µg/L
3 µg/L
1 µg/L

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE E-2B
EXTENT OF PCE CONTAMINATION IN GROUNDWATER GREATER 5 µg/L
VIEW FACING NORTH

ST SulTRAC



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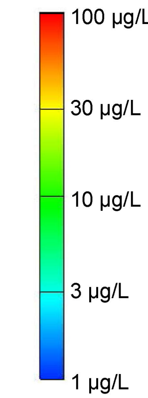
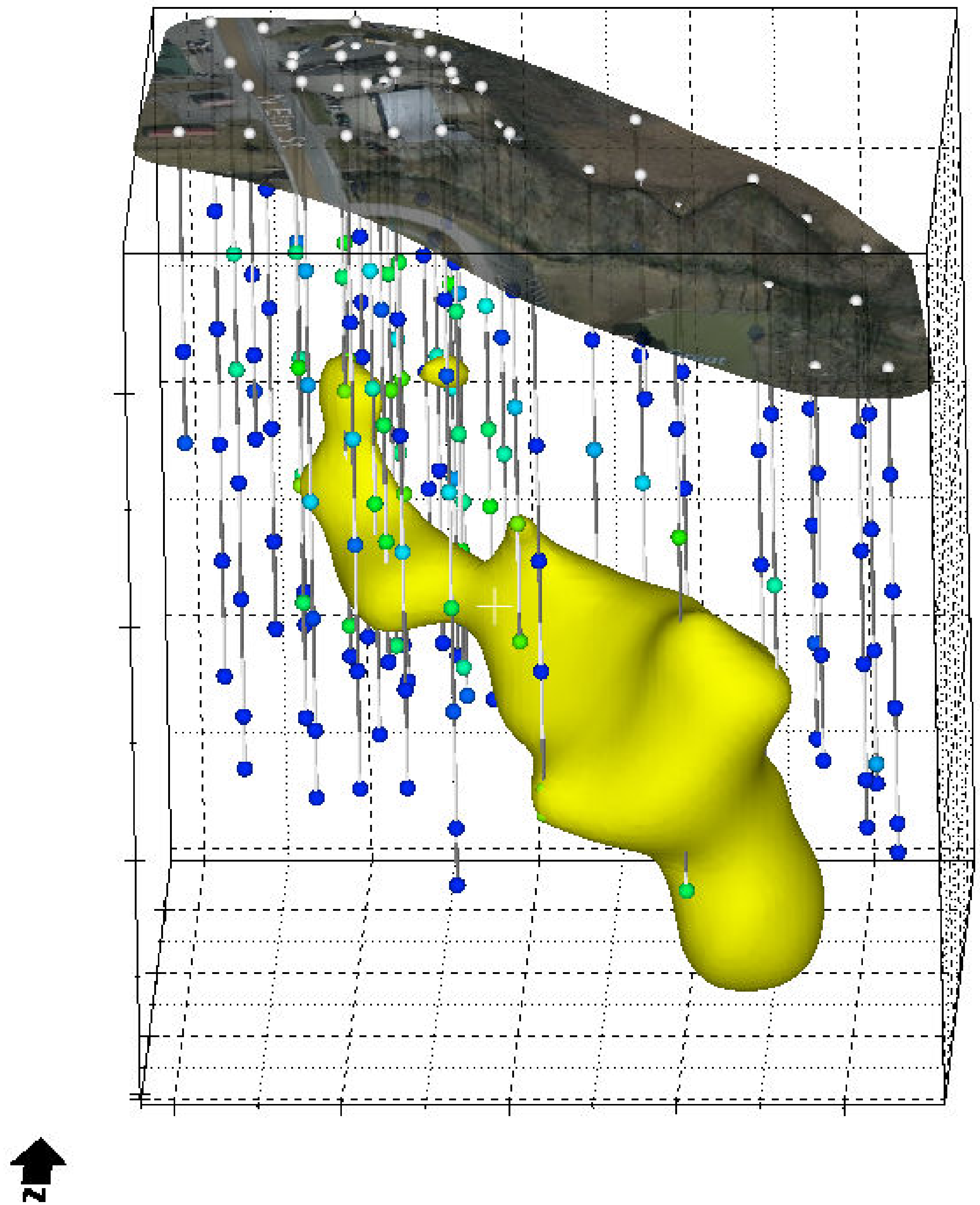


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE E-3A
EXTENT OF PCE CONTAMINATION
IN GROUNDWATER GREATER 15 µg/L
VIEW FACING EAST

ST SulTRAC



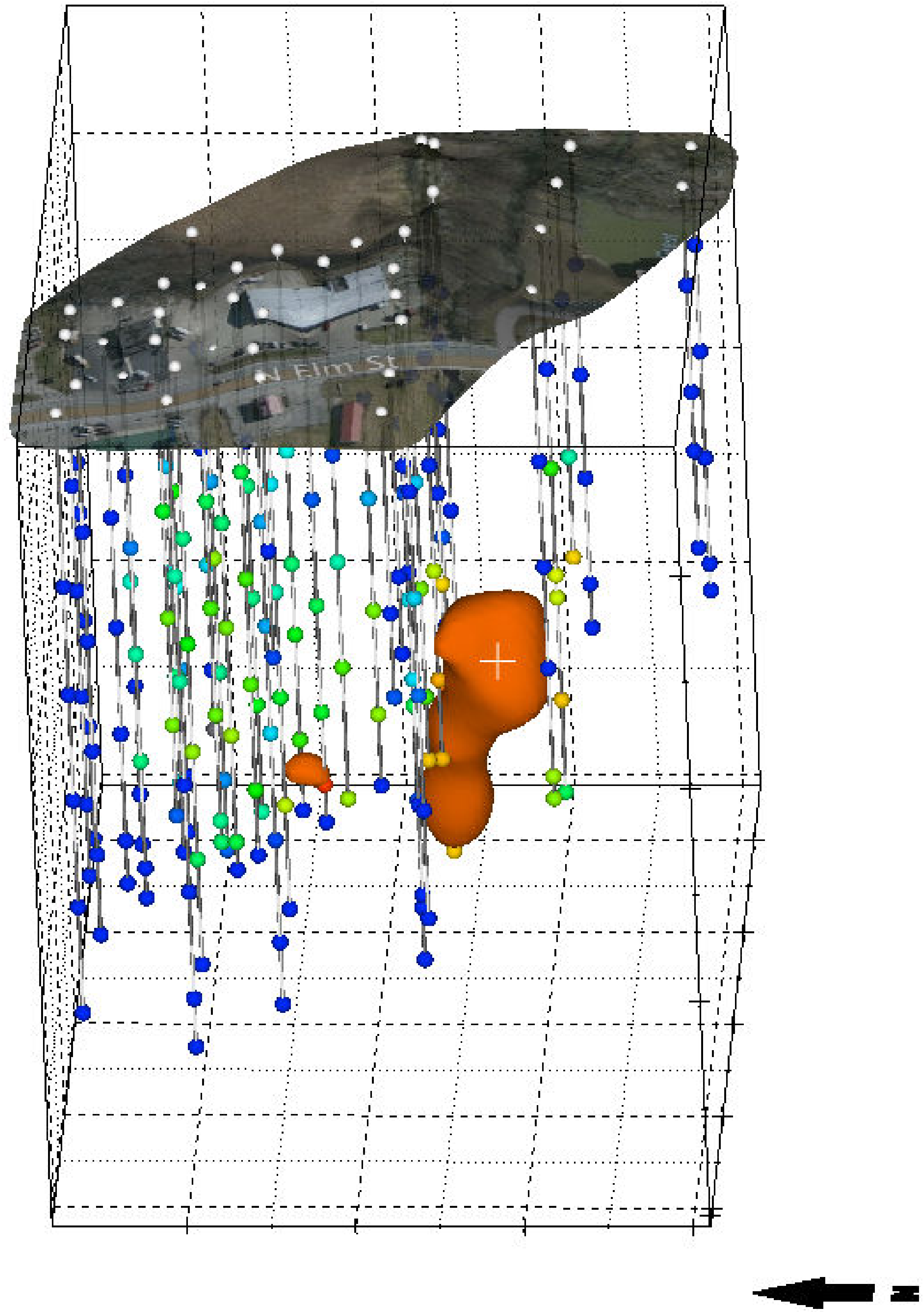
Legend

100 µg/L
30 µg/L
10 µg/L
3 µg/L
1 µg/L

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE E-3B
EXTENT OF PCE CONTAMINATION IN GROUNDWATER GREATER 15 µg/L
VIEW FACING NORTH

ST SulTRAC



Legend

100 µg/L
30 µg/L
10 µg/L
3 µg/L
1 µg/L

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE E-4A
EXTENT OF PCE CONTAMINATION IN GROUNDWATER GREATER 50 µg/L
VIEW FACING EAST

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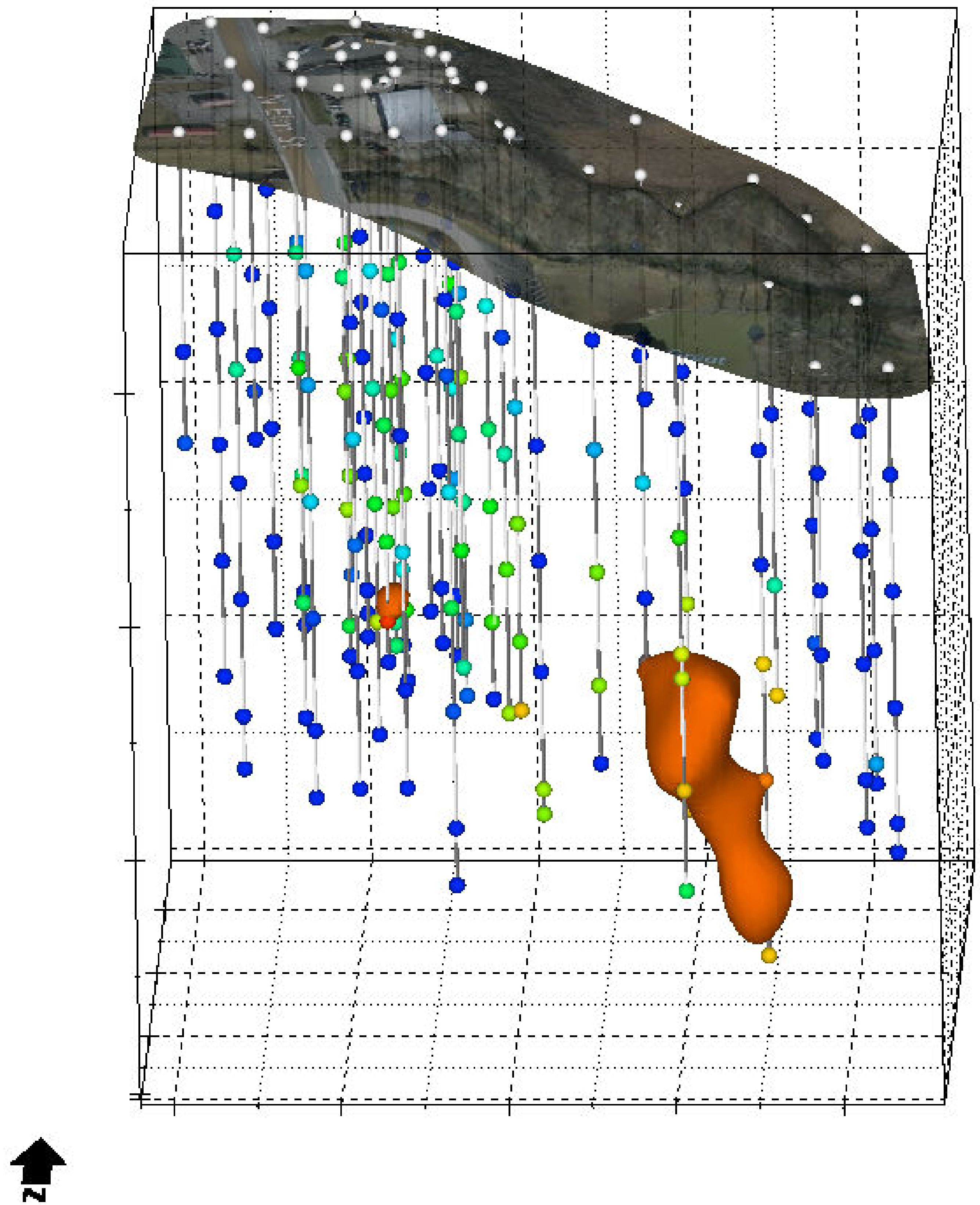

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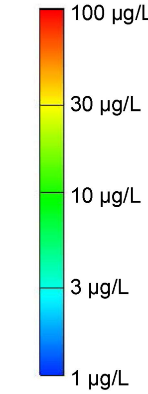
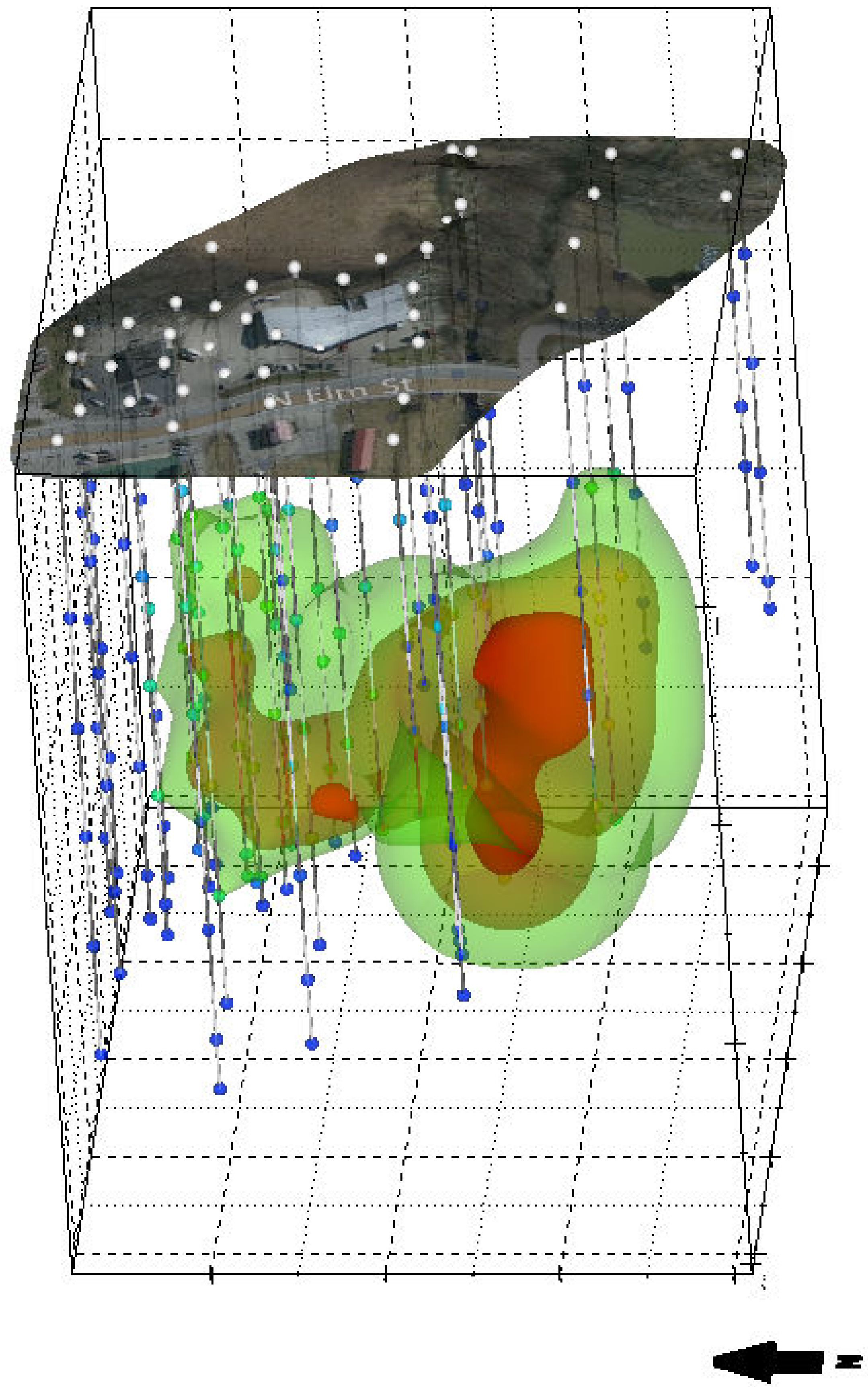


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE E-4B
EXTENT OF PCE CONTAMINATION
IN GROUNDWATER GREATER 50 µg/L
VIEW FACING NORTH

ST SulTRAC



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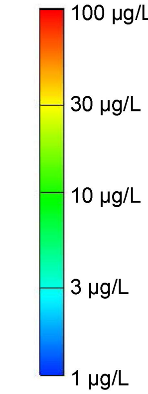

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE E-5A
EXTENT OF PCE CONTAMINATION
IN GROUNDWATER
VIEW FACING EAST

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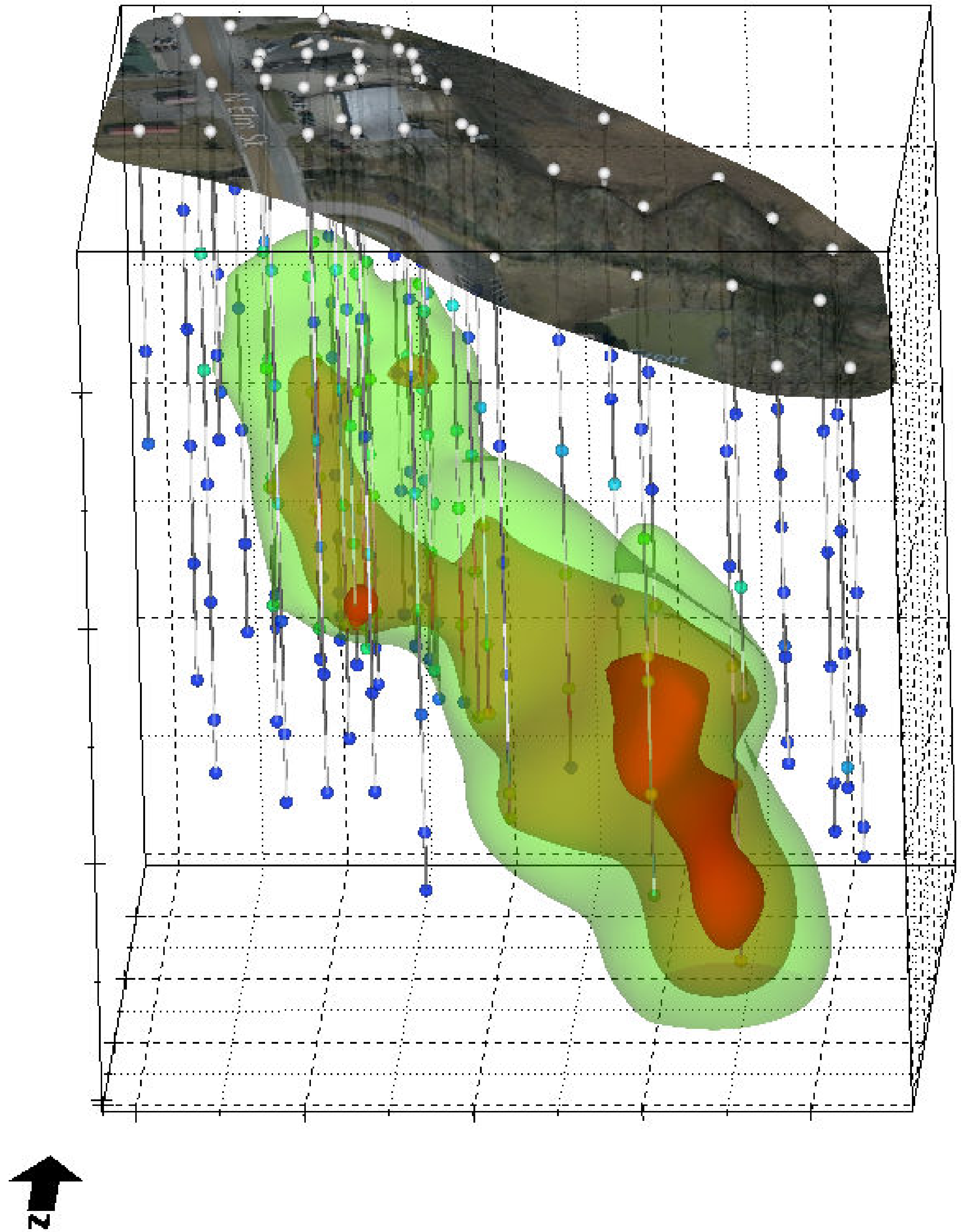

Legend

100 µg/L
30 µg/L
10 µg/L
3 µg/L
1 µg/L

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE E-5B
EXTENT OF PCE CONTAMINATION IN GROUNDWATER
VIEW FACING NORTH

SulTRAC

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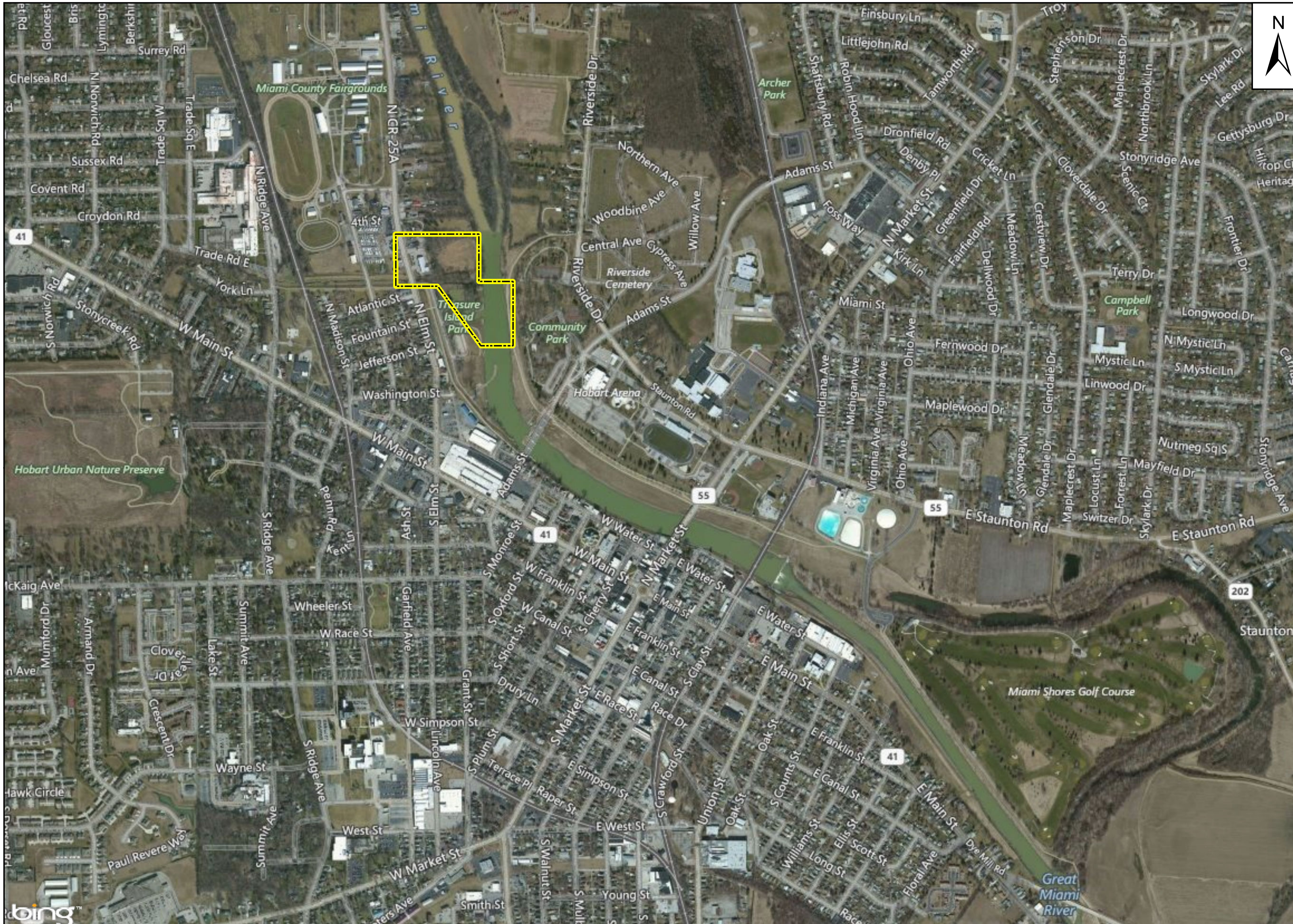
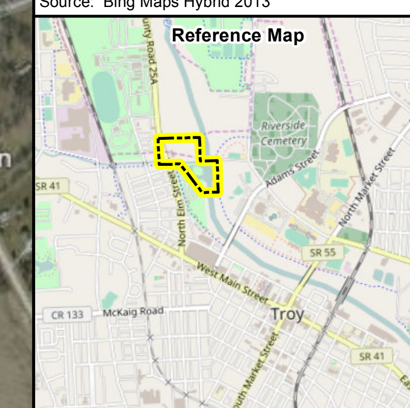




N

Legend

Approximate Remedial Investigation Area

0 1,000 2,000
Feet

Source: Bing Maps Hybrid 2013

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-1
SITE LOCATION MAP

ST SulTRAC

2/17/2017 G:\G\1852\199 West Troy\mxd\2017-02\Fig1-1-SiteLocation.mxd

N

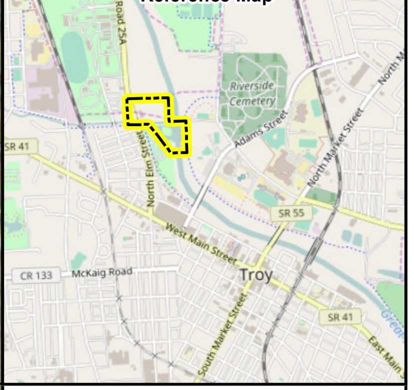
Legend

- Troy Production Well
- Approximate Remedial Investigation Area
- Troy Water Treatment Plant

0 500 1,000
Feet

Source: Bing Maps Hybrid 2013

Reference Map

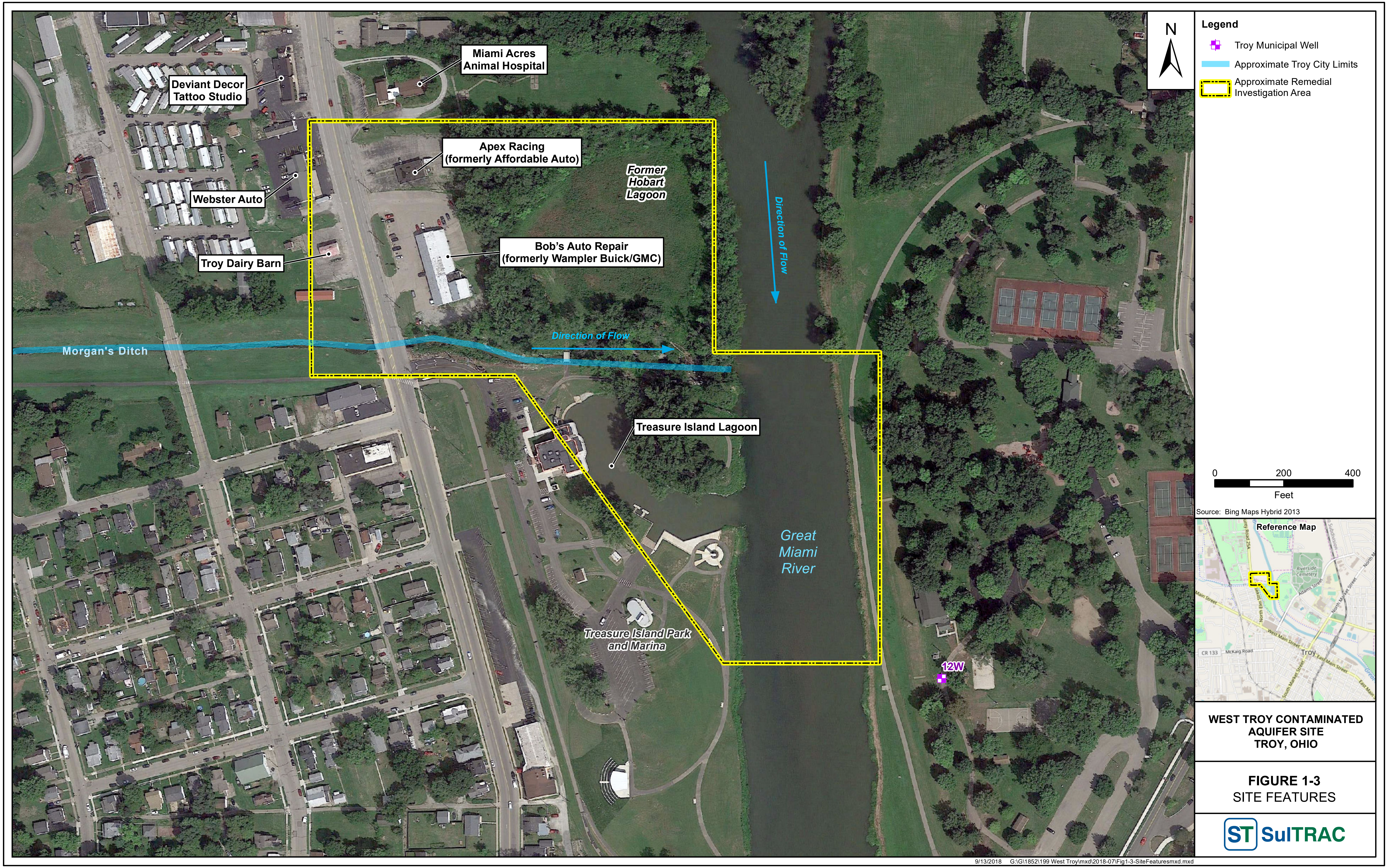


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-2
CITY OF TROY
EAST AND WEST WELLFIELD
LOCATION MAP

ST SulTRAC

2/17/2017 G:\G\1852\199 West Troy\mxd\2017-02\Fig1-2-WellfieldLocation.mxd


Miami Acres
Animal Hospital
Deviant Decor
Tattoo Studio
Apex Racing
(formerly Affordable Auto)
Former
Hobart
Lagoon
Webster Auto
Bob's Auto Repair
(formerly Wampler Buick/GMC)
Troy Dairy Barn
Direction of Flow
Direction of Flow
Morgan's Ditch
Treasure Island Lagoon
Great
Miami
River
Treasure Island Park
and Marina
12W
N
Legend
Troy Municipal Well
Approximate Troy City Limits
Approximate Remedial
Investigation Area
0
200
400
Feet
Source: Bing Maps Hybrid 2013
Reference Map
Troy
WEST TROY CONTAMINATED
AQUIFER SITE
TROY, OHIO
FIGURE 1-3
SITE FEATURES
ST SulTRAC
9/13/2018 G:\G\1852\199 West Troy\mxd\2018-07\Fig1-3-SiteFeaturesmxd.mxd

Legend

- Troy Production Well
- 1997 OEPA Geoprobe
- 2001 Hobart Lagoon Monitoring Wells
- 2001 Earhart Petroleum Monitoring Wells and Geoprobe
- 2004 and 2005 Wampler Buick Geoprobe
- 2010 SESI Wampler Buick Monitoring Wells
- 2010 SESI OEPA Monitoring Wells
- 2010 SESI Private Well
- 2010 SESI Troy Monitoring Wells
- 2010 SESI Miami Conservancy District Monitoring Wells

Source: Modified from Arcadis 2013

Results are micrograms per liter

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-4
HISTORICAL CHLORINATED VOLATILE ORGANIC COMPOUND CONCENTRATIONS

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WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-5
GEOPHYSICAL SURVEY AREA

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10/18/2017 G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-5-GeophysicalSurvey.mxd

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-6
HABITAT ASSESSMENT AREA

ST SulTRAC

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Soil Gas Sample Location

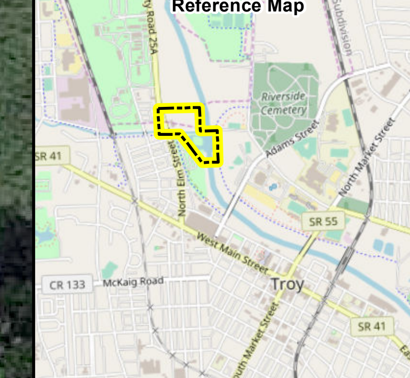
Geophysical Survey Area

0 50 100

Feet

Source: Bing Maps Hybrid 2013

Reference Map



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-7
PHASE I SOIL GAS SAMPLING LOCATIONS

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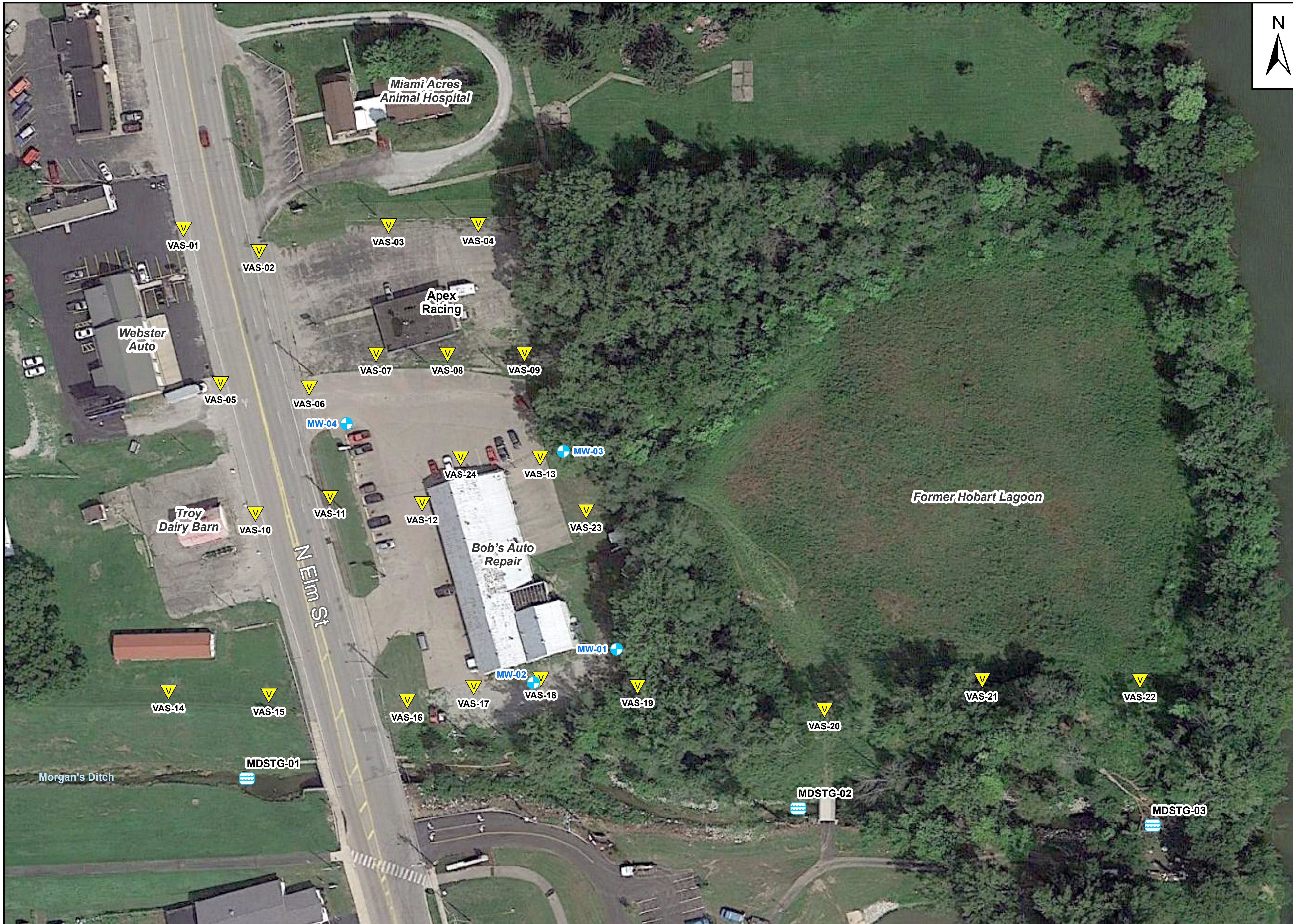
10/18/2017 G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-7-Phase1SoilGasSamples.mxd



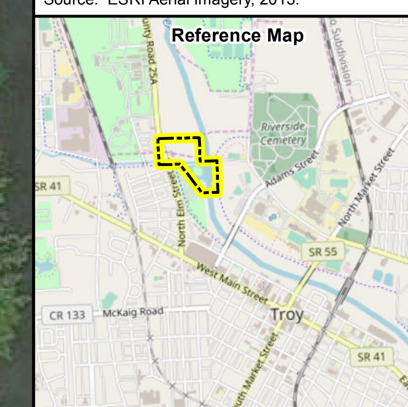
N

Legend

- Phase I VAS Location
- Phase I Monitoring Well
- Staff Gauge Location

0 50 100
Feet

Source: ESRI Aerial Imagery, 2013.



WEST TROY CONTAMINATED AQUIFER SITE TROY, OHIO

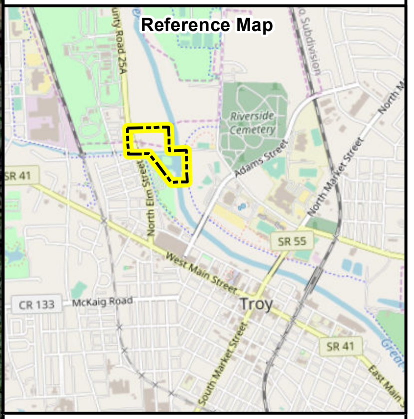
FIGURE 1-8
STAFF GAUGE, VERTICAL AQUIFER SAMPLING (VAS), AND PHASE I MONITORING WELL LOCATIONS

ST SulTRAC

10/18/2017 G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-8-StaffGaugeVASMWlocs.mxd

10/18/2017 G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-9-Phase1-MWLocations.mxd

Source: Bing Maps Hybrid 2013



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-10
PHASE I AND II WATERLOO VERTICAL AQUIFER SAMPLING (VAS) LOCATIONS

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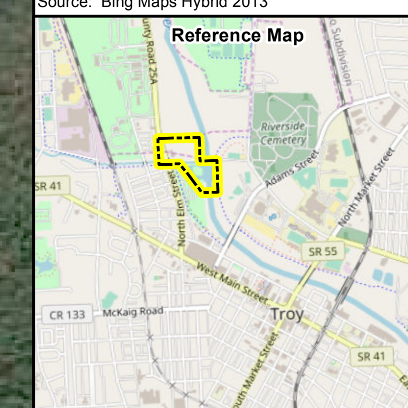
Legend

- Ambient Air Sampling Location
- Indoor Air Sampling Location
- Sub-slab and Indoor Air Sampling Location

0 50 100
Feet

Source: Bing Maps Hybrid 2013



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-11
PHASE II SUB-SLAB, AMBIENT AIR, AND INDOOR AIR SAMPLING LOCATIONS - ROUNDS 1 AND 2

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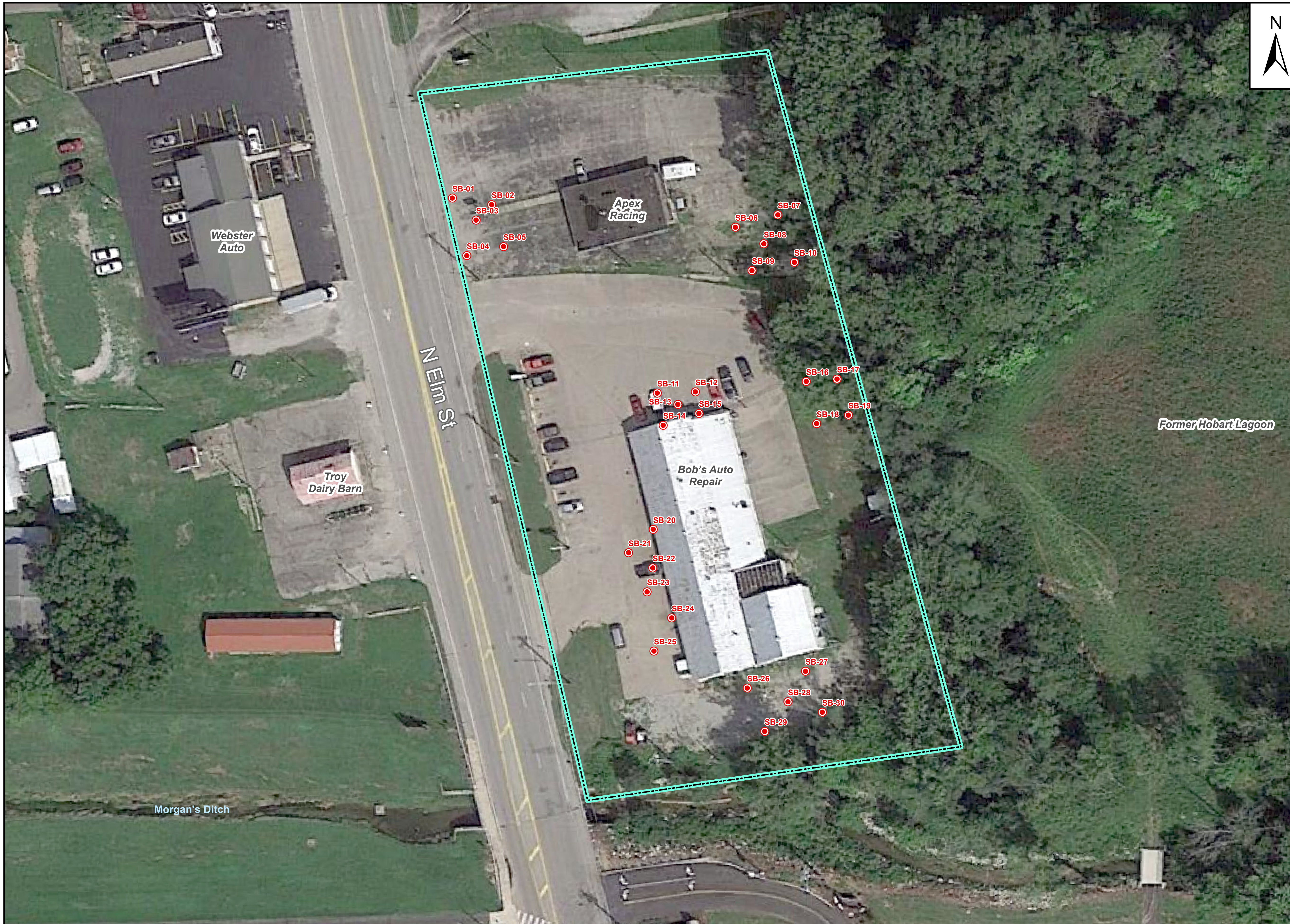
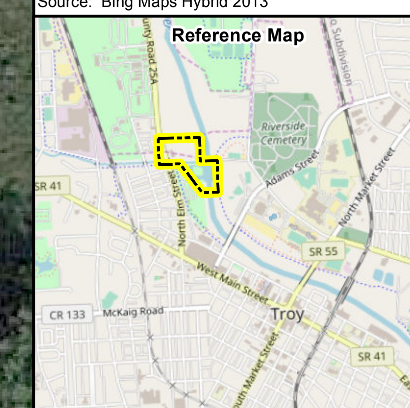


Source: Bing Maps Hybrid 2013



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-12
PHASE II SOIL SAMPLING LOCATIONS

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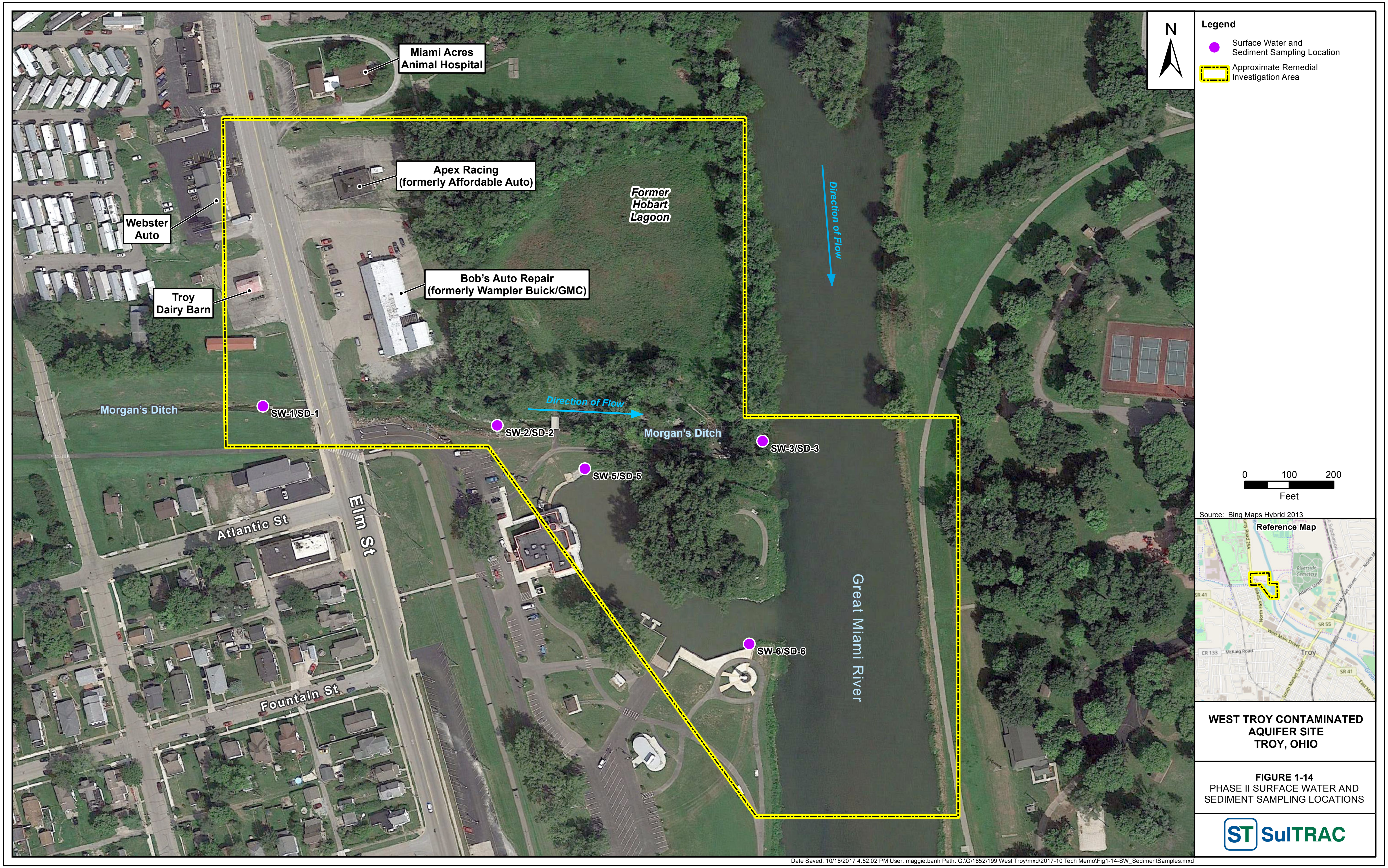
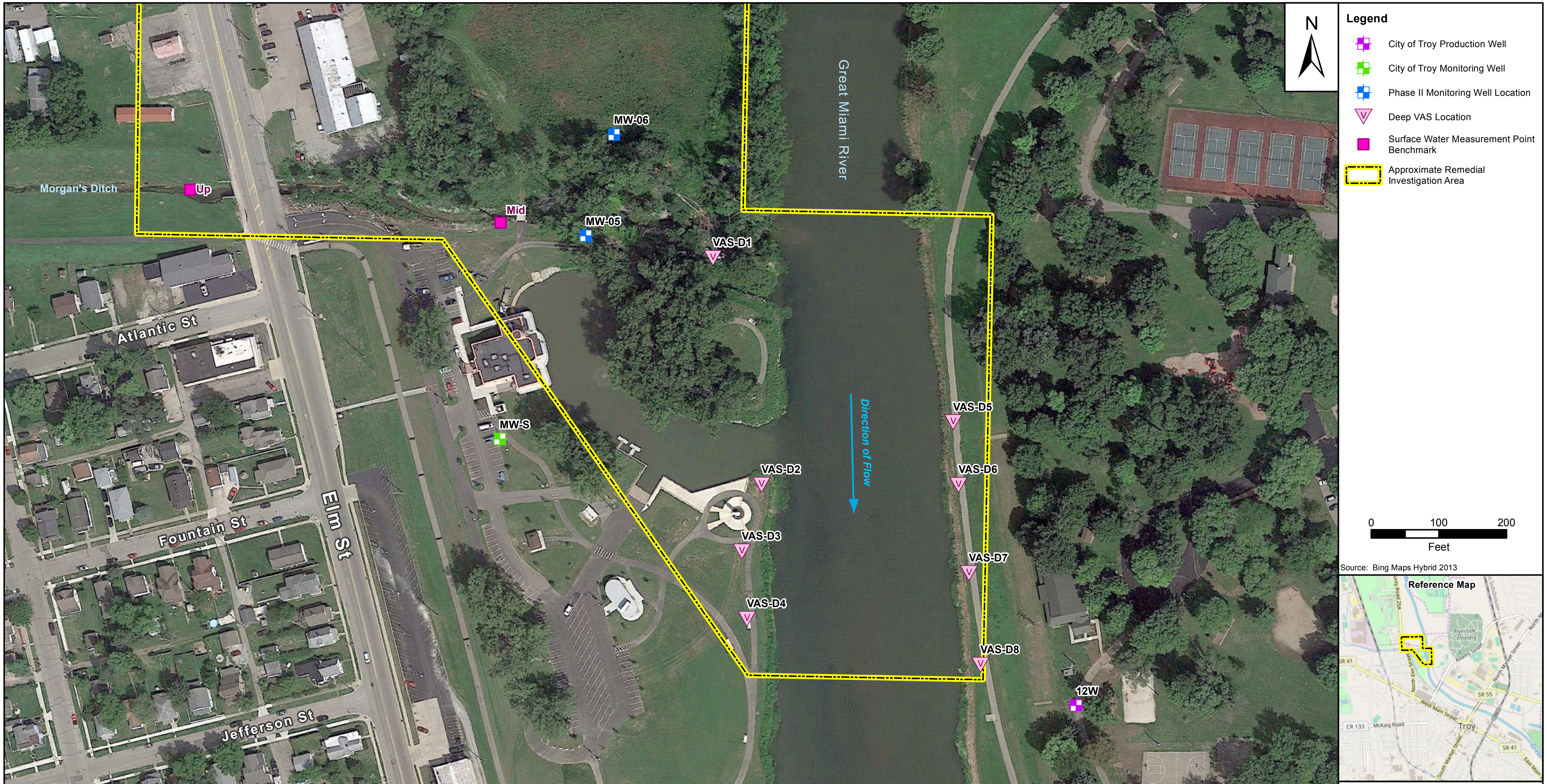
Date Saved: 10/18/2017 4:48:49 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-12-Phase2-PropSoilLoc.mxd

N
Legend
Phase I Monitoring Well
Private Well
Ohio EPA Well
Wampler Buick Monitoring Well
Miami Acres Animal Hospital
N Elm St
OEPA-15
OEPA-16
OEPA-17
OEPA-18
RW-5
Apex Racing (formerly Affordable Auto)
Webster Auto
MW-04
W-8
MW-03
W-3
W-9
Troy Dairy Barn
Bob's Auto Repair (formerly Wampler Buick/GMC)
MW-01
W-11
MW-02
Former Hobart Lagoon
Morgan's Ditch
0 50 100
Feet
OEPA - Ohio Environmental Protection Agency
Source: Bing Maps Hybrid 2013
Reference Map
Troy
WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO
FIGURE 1-13
PHASE II MONITORING WELL SAMPLING LOCATIONS
ST SulTRAC
Date Saved: 10/18/2017 4:49:53 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-13-Phase2-MWLocations.mxd



WEST TROY CONTAMINATED
AQUIFER SITE
TROY, OHIO

FIGURE 1-14
PHASE II SURFACE WATER AND
SEDIMENT SAMPLING LOCATIONS



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-15
PHASE II DEEP VAS AND MONITORING WELL LOCATIONS

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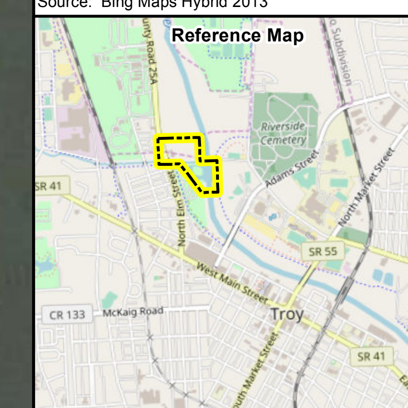
Date Saved: 10/18/2017 4:54:18 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-15-OffSiteVAS_MW_Loc.mxd

Legend

● Additional Soil Sample Location

0 50 100
Feet

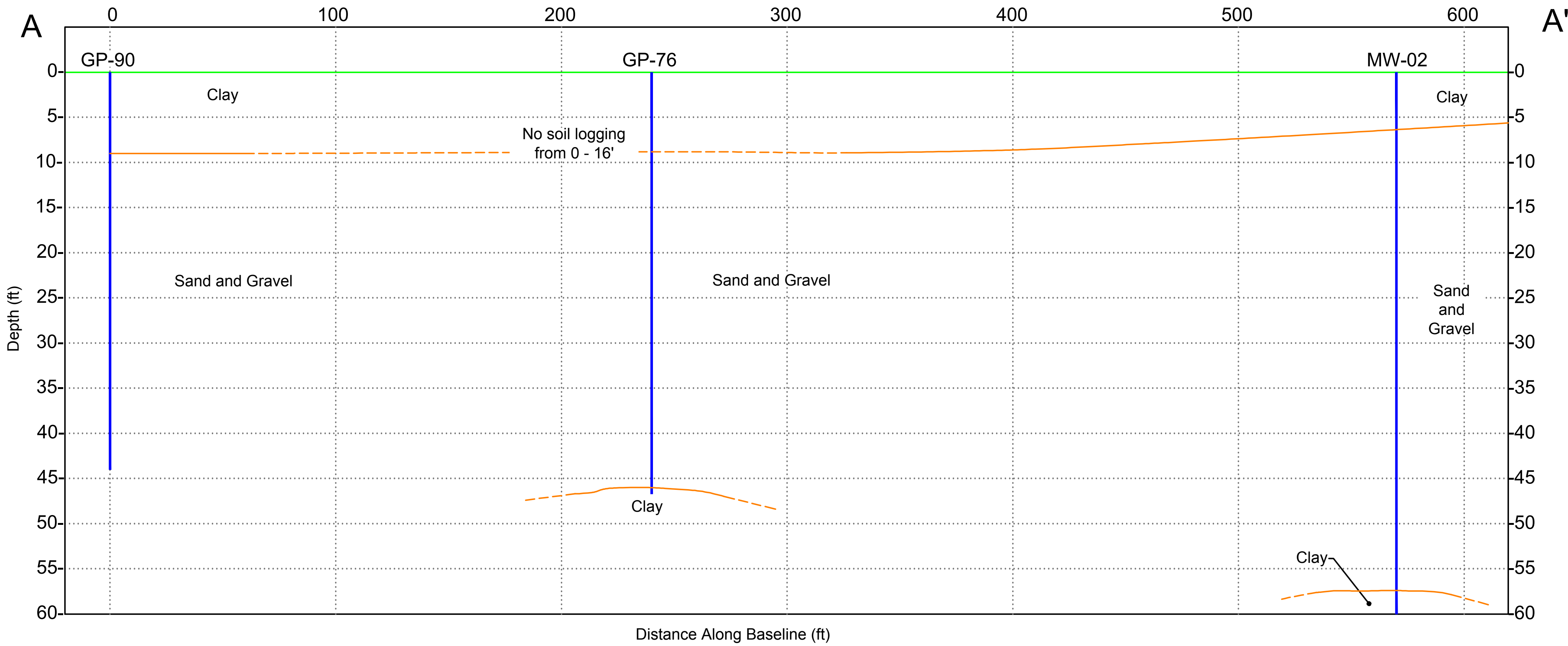
Source: Bing Maps Hybrid 2013

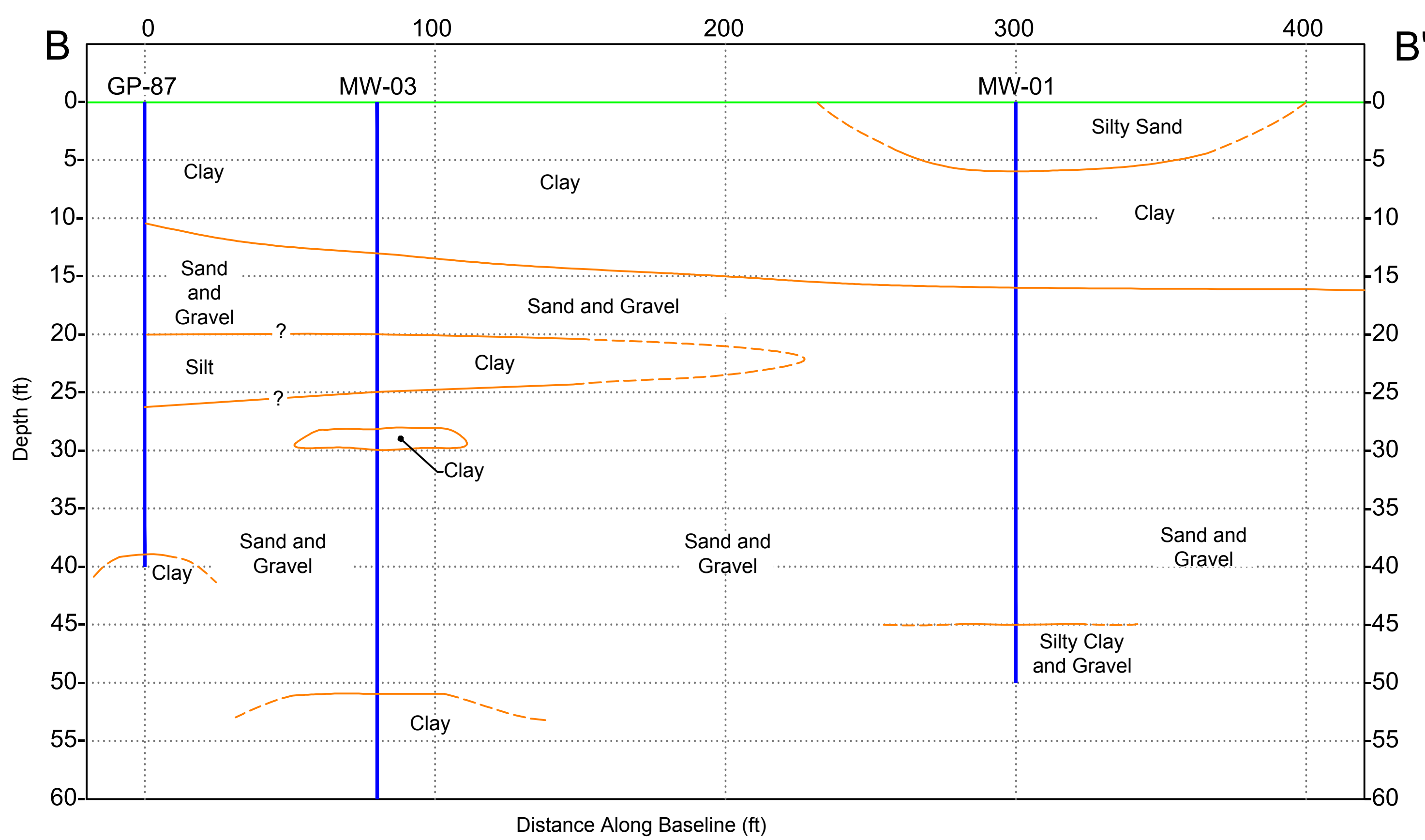


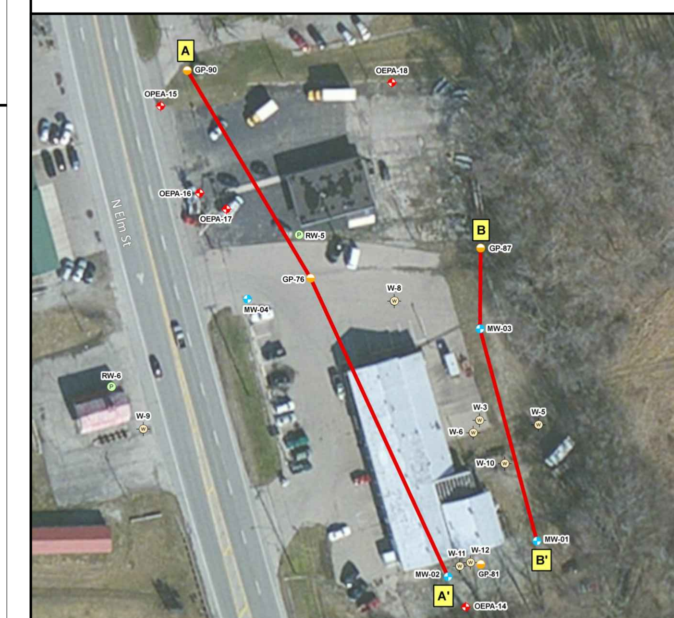
WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-16
PHASE II ADDITIONAL SOIL SAMPLING LOCATIONS

ST SulTRAC





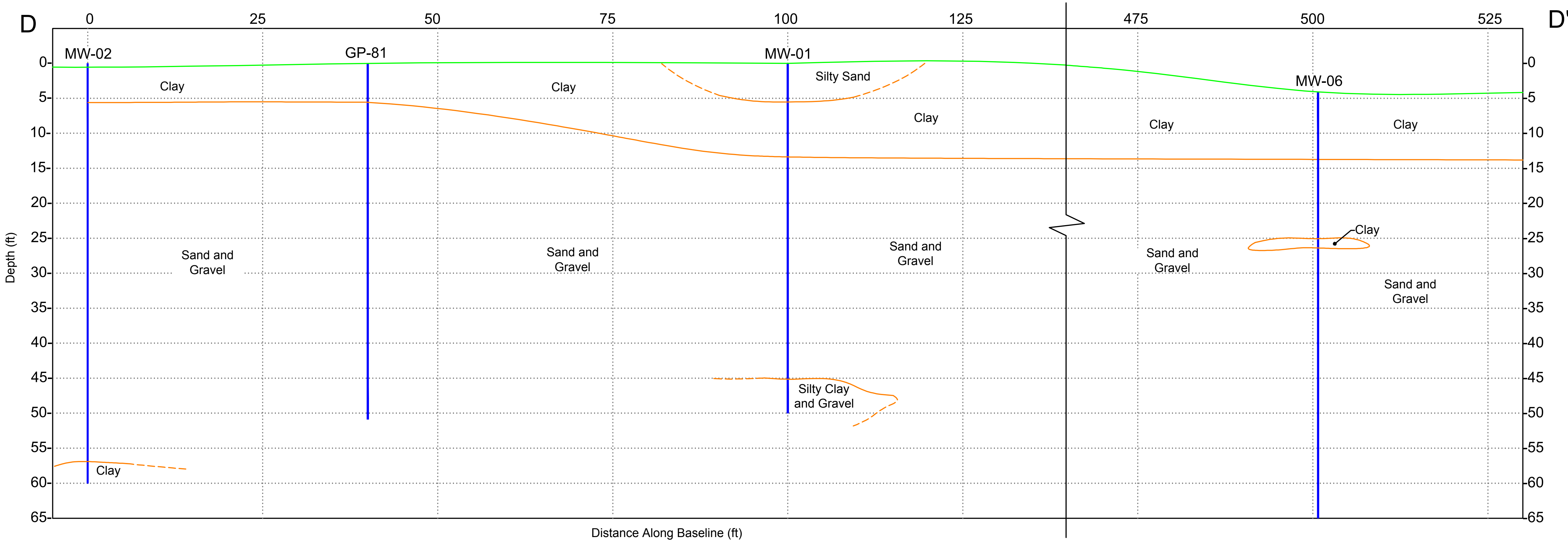


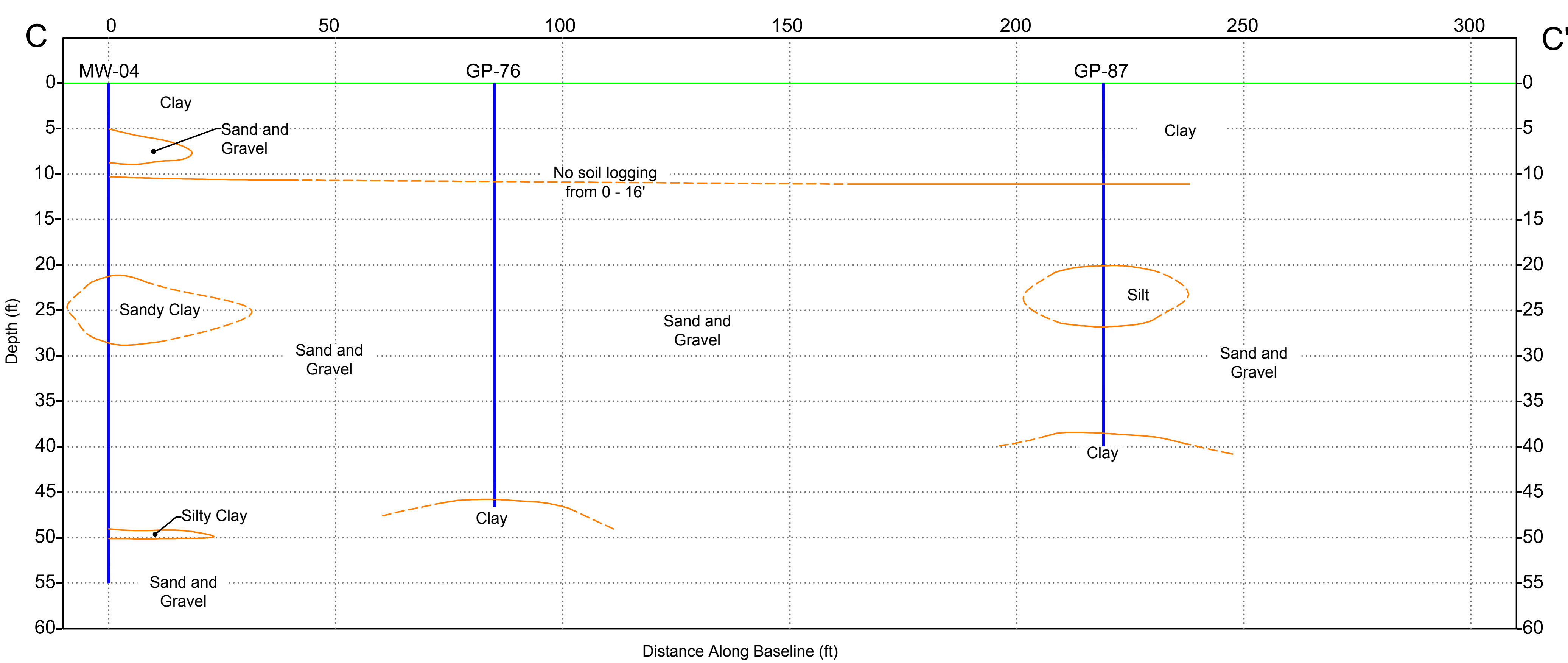
WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-17
GENERALIZED GEOLOGICAL CROSS SECTIONS
A - A' & B - B'

ST SulTRAC

G:\G\1852\199 West Troy\dwg\2017-02 RI\Cross Sections.dwg 2/22/2017





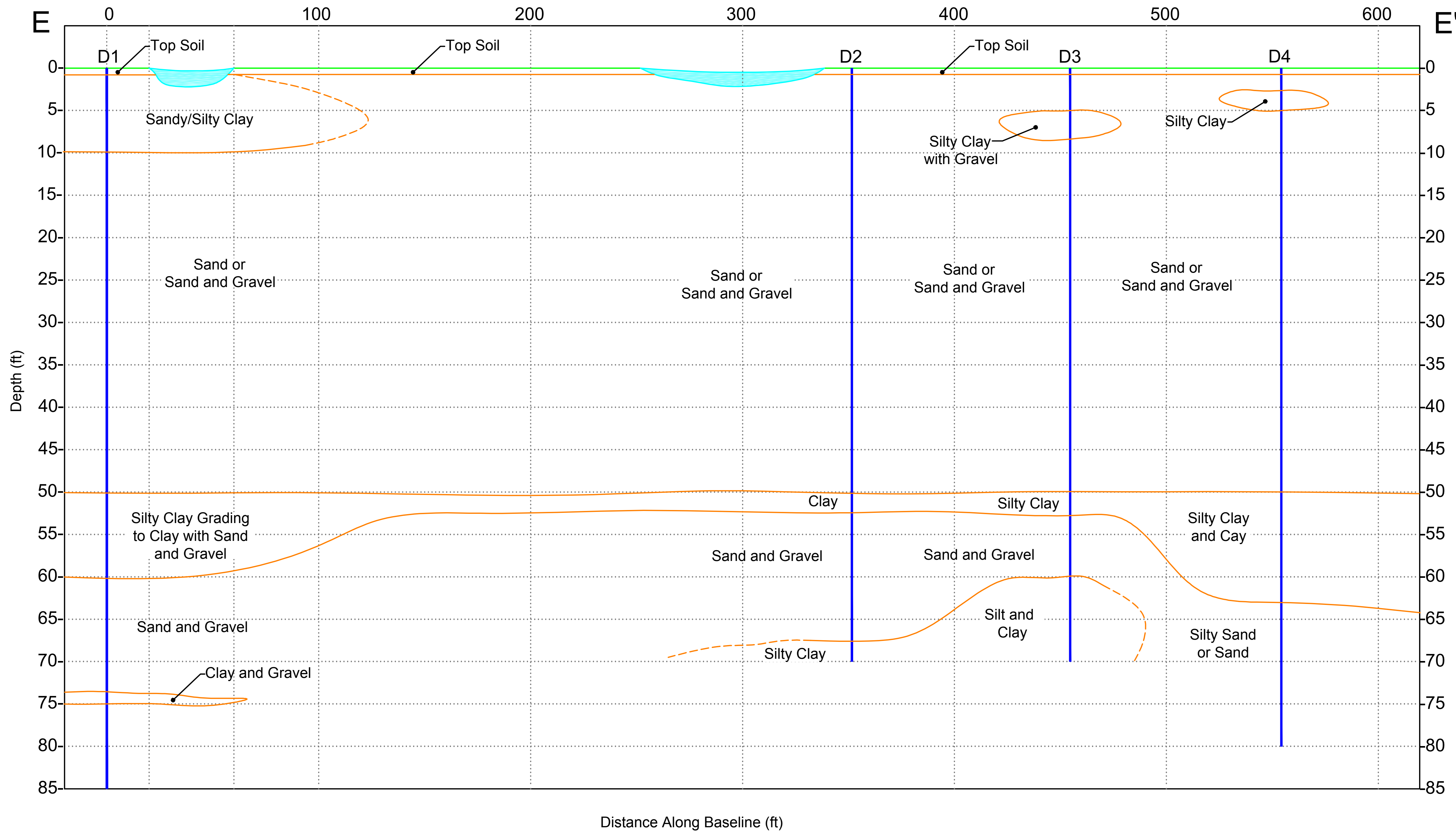
WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

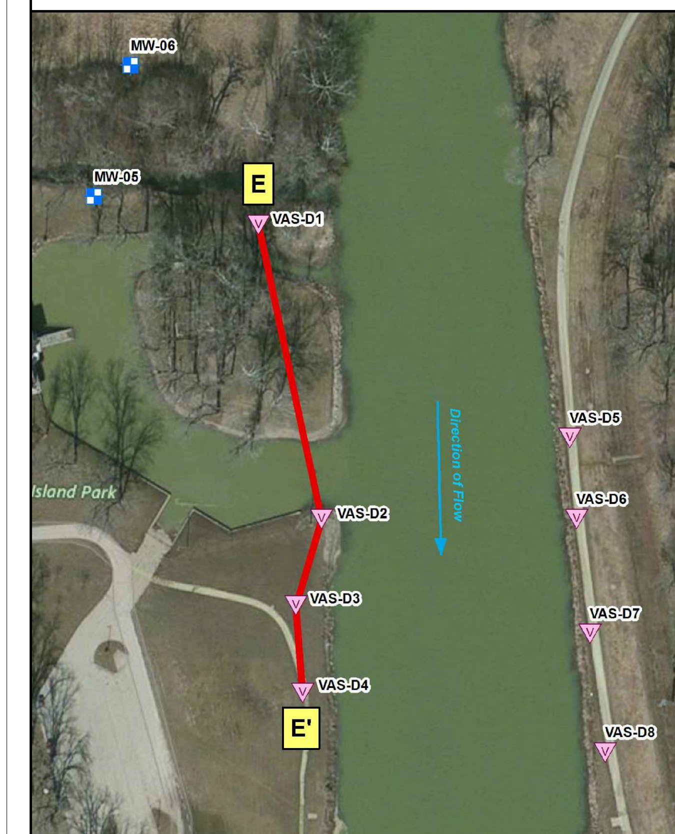
FIGURE 1-18
GENERALIZED GEOLOGICAL CROSS SECTIONS
C- C' & D - D'

SulTRAC

12/10/2015

G:\G1852\199 West Troy\dwg\2017-02 RI\Cross Sections.dwg



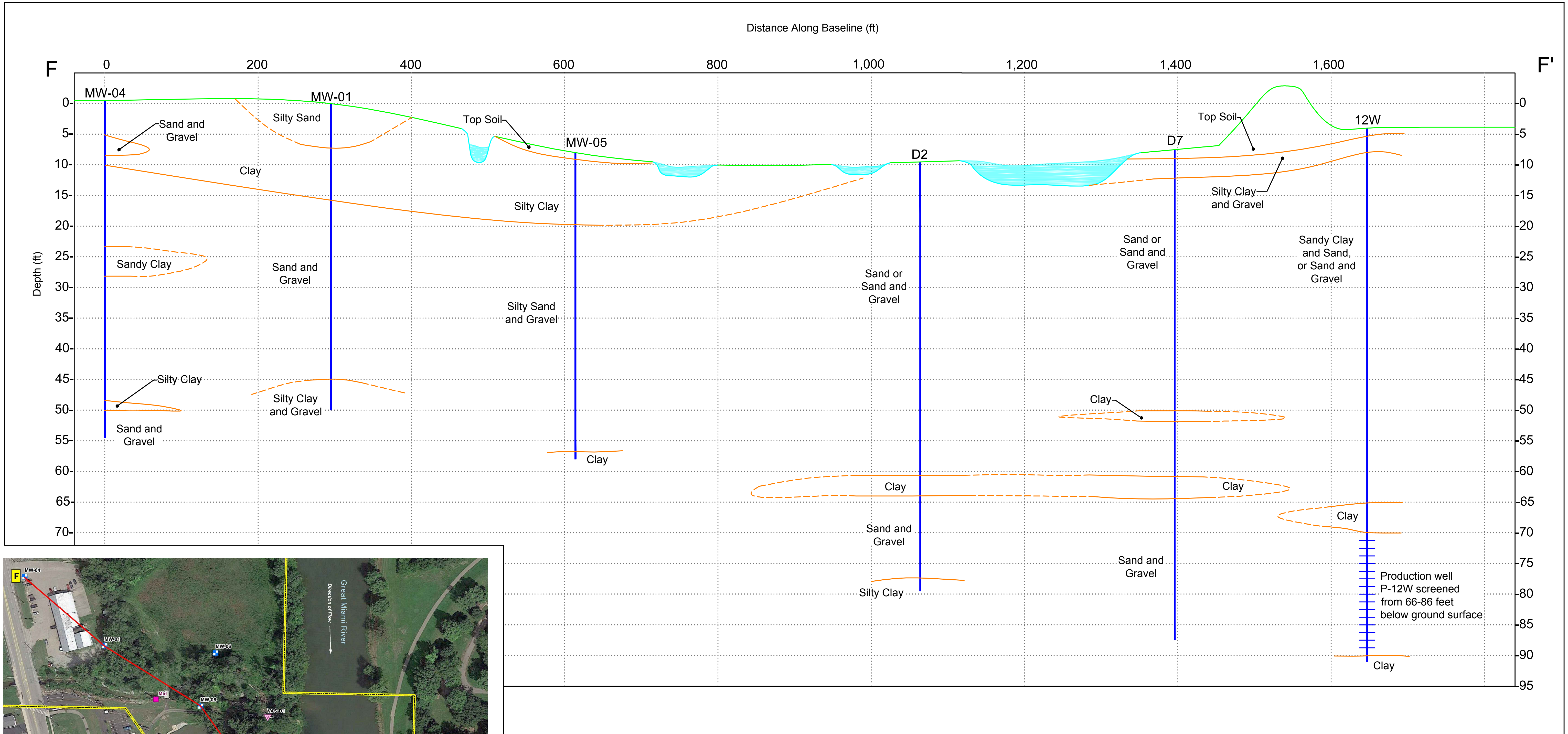


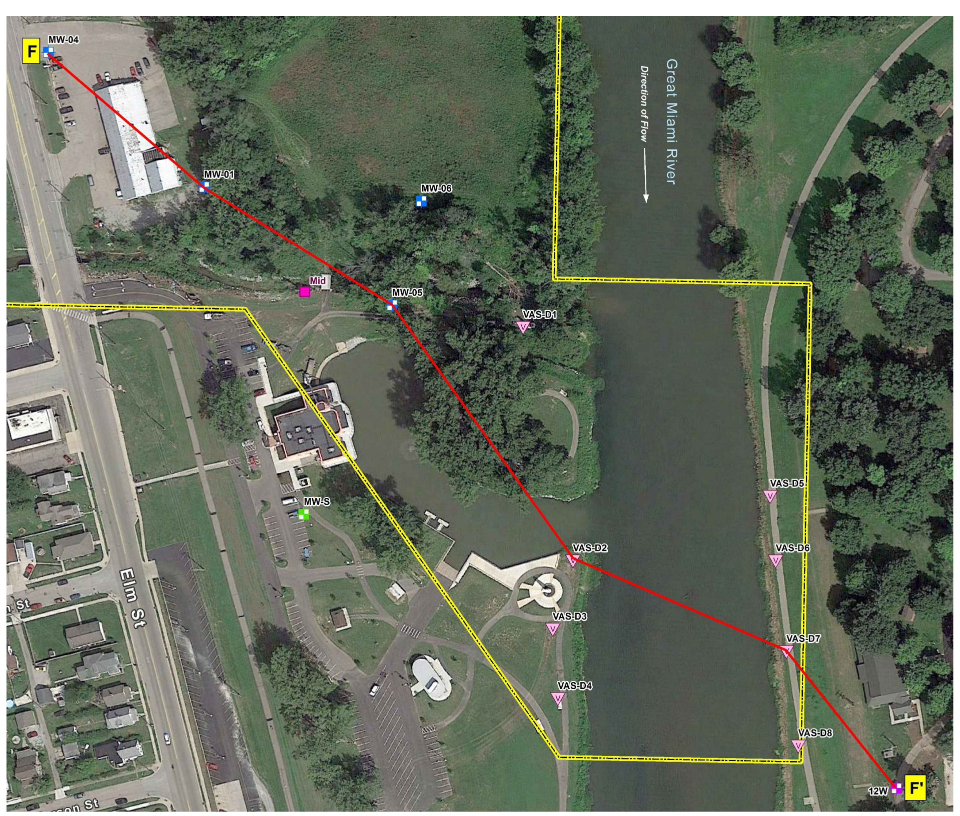
WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-19A
GENERALIZED GEOLOGICAL CROSS SECTION E - E'

SulTRAC

G:\G1852\199 West Troy\dwg\2017-02 RI\Cross Sections.dwg
2/22/2017





WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-19B
GENERALIZED GEOLOGICAL CROSS SECTION F - F'

ST SulTRAC

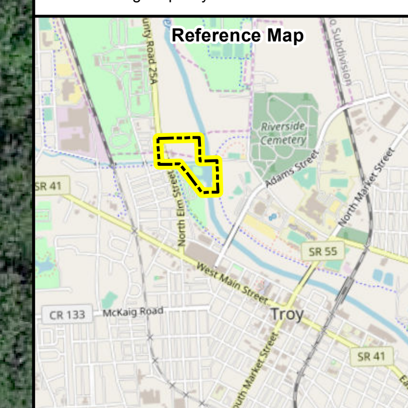
G:\G18521\99 West Troy\dwg\2018-01\Cross Sections.dwg
1/16/2018

Legend

- Phase I Monitoring Well
- Private Well
- Ohio EPA Well
- Wampler Buick Monitoring Well
- 2004 and 2005 Wampler Buick Geoprobe
- Staff Gauge Location
- Groundwater Contour Line
- Inferred Groundwater Contour Line
- **819.03** Groundwater Elevation at Well

0 50 100
Feet

OEPA - Ohio Environmental Protection Agency
Source: Bing Maps Hybrid 2013

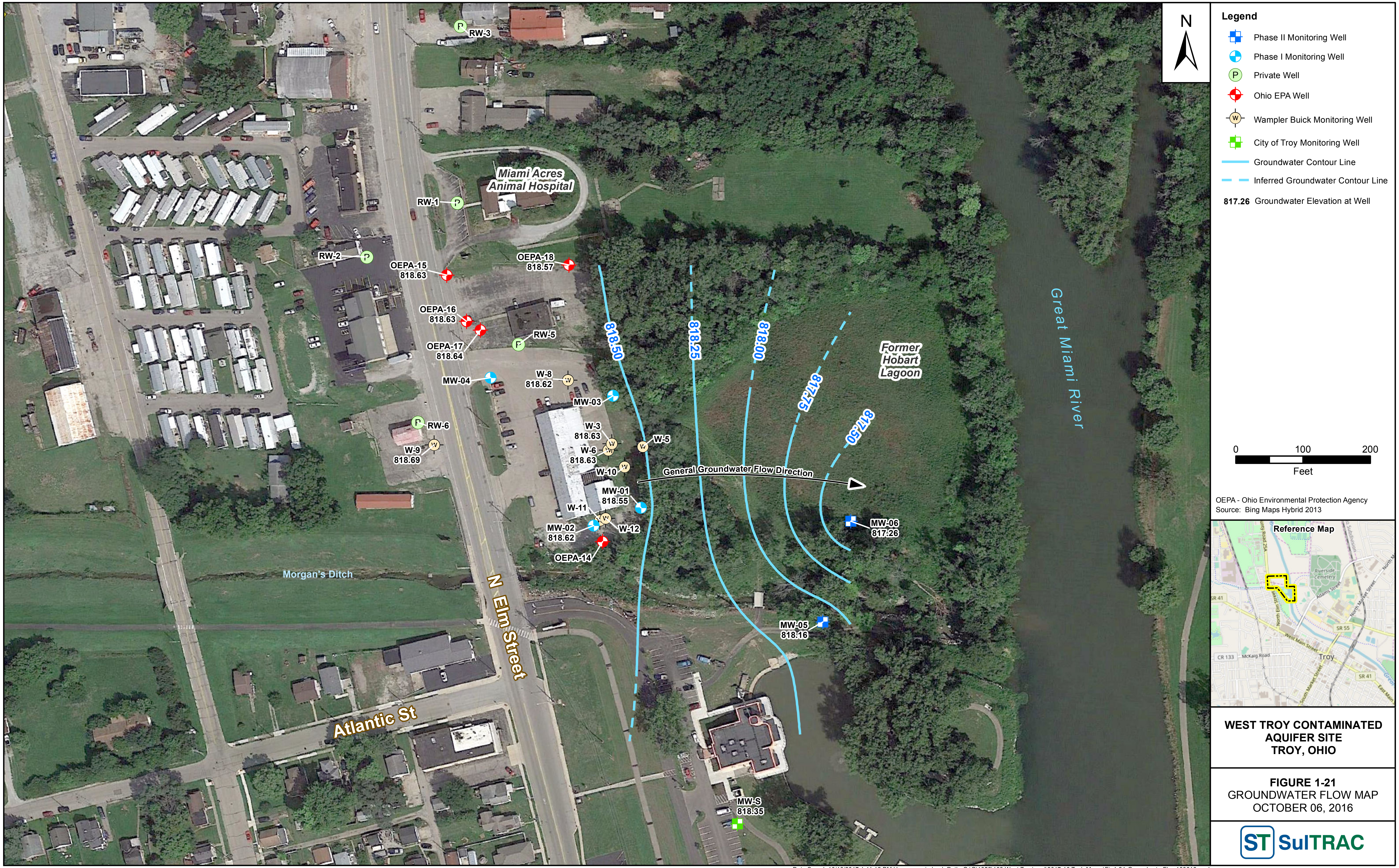


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-20
GROUNDWATER FLOW MAP
SEPTEMBER 16, 2015

SulTRAC

Date Saved: 10/18/2017 4:34:27 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-20-Phase1-GroundwaterFlow.mxd

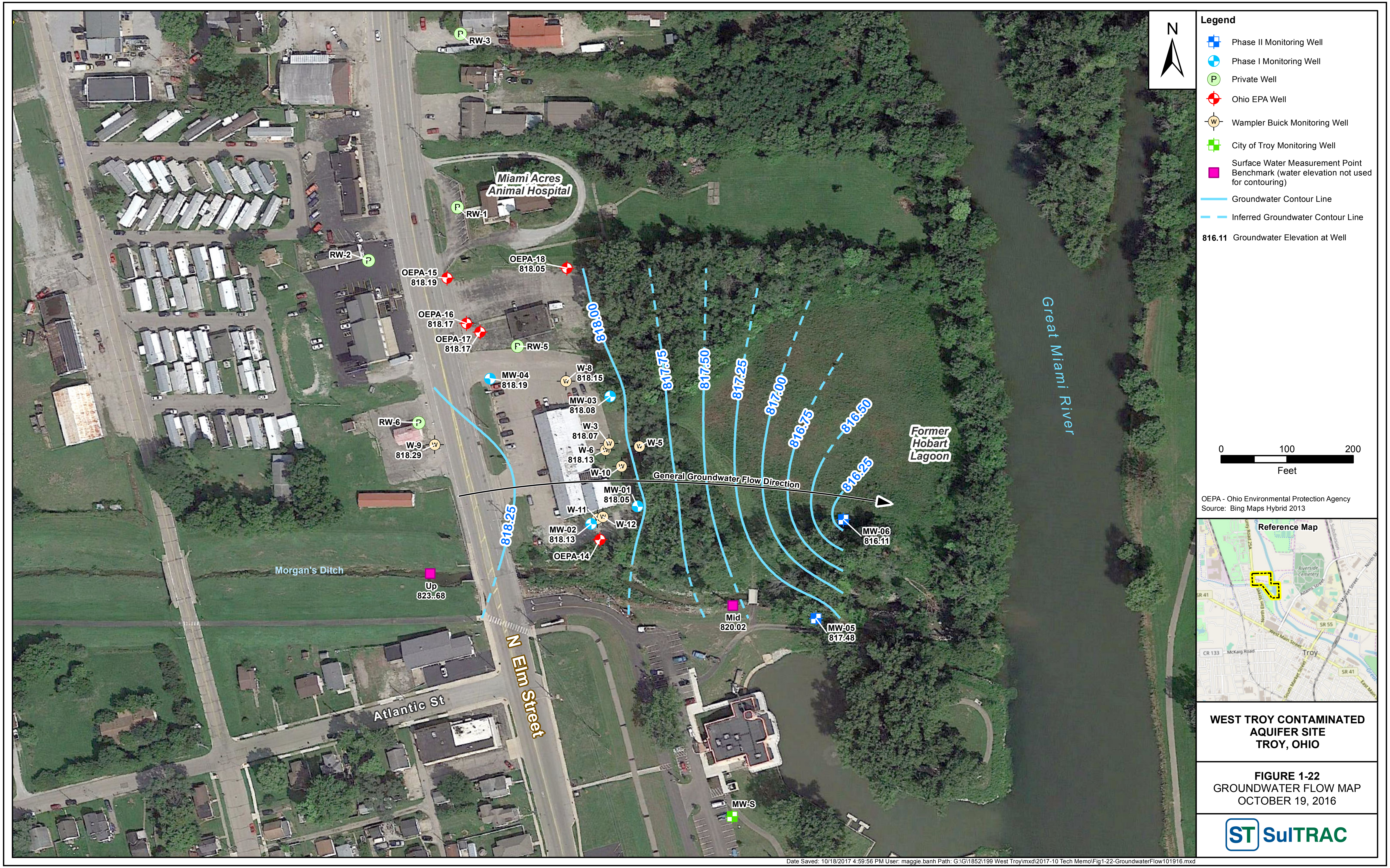


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-21
GROUNDWATER FLOW MAP
OCTOBER 06, 2016

ST SulTRAC

Date Saved: 10/18/2017 4:41:12 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-21-GroundwaterFlow100616.mxd



N
Legend
Phase II Monitoring Well
Phase I Monitoring Well
Private Well
Ohio EPA Well
Wampler Buick Monitoring Well
City of Troy Monitoring Well
Surface Water Measurement Point Benchmark (water elevation not used for contouring)
Groundwater Contour Line
Inferred Groundwater Contour Line
816.11 Groundwater Elevation at Well
0 100 200
Feet
OEPA - Ohio Environmental Protection Agency
Source: Bing Maps Hybrid 2013
Reference Map
Miami Acres Animal Hospital
RW-3
RW-1
RW-2
RW-5
RW-6
OEPA-15 818.19
OEPA-18 818.05
OEPA-16 818.17
OEPA-17 818.17
OEPA-14
MW-04 818.19
MW-03 818.08
MW-01 818.05
MW-02 818.13
MW-06 816.11
MW-05 817.48
MW-S
W-8 818.15
W-3 818.07
W-6 818.13
W-5
W-9 818.29
W-10
W-11
W-12
818.00
817.75
817.50
817.25
817.00
816.75
816.50
816.25
818.25
General Groundwater Flow Direction
Former Hobart Lagoon
Great Miami River
Morgan's Ditch
Up 823.68
Mid 820.02
N Elm Street
Atlantic St
WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO
FIGURE 1-22
GROUNDWATER FLOW MAP
OCTOBER 19, 2016
ST SulTRAC
Date Saved: 10/18/2017 4:59:56 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-22-GroundwaterFlow101916.mxd

Legend

- Phase II VAS Location
- Phase I VAS Location
- Approximate Horizontal Extent of Plume Exceeding 5 micrograms per Liter (µg/L)
- Inferred Plume Extent

Notes:

Sample depths are feet below ground surface.

Tetrachloroethene (PCE) results are in units of micrograms per Liter (µg/L). Highlighted results exceed the maximum contaminant level of 5 µg/L.

Where duplicate samples were collected the higher sample result is presented.

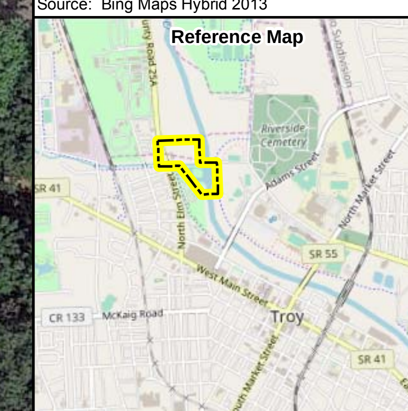
U = The analyte was not detected above the laboratory reporting limit.

J = The analyte was positively identified. The associated value is an approximate concentration.

VAS = Vertical Aquifer Sampling.

0 100 200
Feet

Source: Bing Maps Hybrid 2013



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-23
PHASE I AND II WATERLOO VERTICALAQUIFER SAMPLING (VAS) RESULTS FOR TETRACHLOROETHENE

ST SulTRAC

Date Saved: 11/30/2017 12:15:12 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-23-PCE_Results.mxd

VAS-01	
Depth	Result
15.2	1U
25.3	1U
35.2	1U
45.2	1U
55.1	1U

VAS-02	
Depth	Result
12.8	1U
23	0.61 J
33.3	1U
43	1U
50.5	1U

VAS-03	
Depth	Result
13.2	1U
23	1U
32.9	1U
43	1U
49.7	1U

VAS-04	
Depth	Result
13.2	1U
18	1U
28	1U
38	1U
48.5	1U

VAS-26	
Depth	Result
15.2	1U
25.2	1U
35.4	0.21 J
45.3	1U
49.5	1U

VAS-27	
Depth	Result
15.1	1U
25.1	0.19 J
34.9	1U
45	1U
49.17	1U

VAS-07	
Depth	Result
15	1U
25	1U
35	1U
43.5	1U

VAS-08	
Depth	Result
13.35	1U
23.25	1U
33	0.6 J
43	1U
49.5	1U

VAS-09	
Depth	Result
13.2	1U
18.5	1U
27.4	1U
35.2	1U
45.2	1U
50.4	1U

VAS-31	
Depth	Result
9.9	1U
19.9	1U
30.1	1U
40	1U
45.5	1U

VAS-25	
Depth	Result
14.9	1U
24.9	1U
34.9	0.27 J
44.9	1U
47.7	1U

VAS-05	
Depth	Result
15.4	1U
25.3	1U
35	1U
45	1U
55	1U
59.5	1U

VAS-06	
Depth	Result
15.1	1U
25	1U
35.1	1U
45.15	1U
55	1U

VAS-28	
Depth	Result
15.1	1U
24.9	1U
35	1U
45	1U
47.6	1U

VAS-10	
Depth	Result
15.2	1U
25.2	0.49 J

VAS-12	
Depth	Result
15	1U
25.1	1.19
35	1U
45.1	1U
54.8	1U

VAS-24	
Depth	Result
15.3	1U
25.3	1U
35.2	1U
45.1	1U
51.2	1U

VAS-13	
Depth	Result
15.3	1U
19.5	1U
30	1U
40	1U
50	0.47 J

VAS-23	
Depth	Result
17.8	1U
28.4	0.29 J
35	1U
44.9	1U
51.5	1U

VAS-30	
Depth	Result
17.1	1U
24.3	1U
35	0.17 J
45.1	1U
51.6	1U

VAS-29	
Depth	Result
15.4	1U
25.4	0.26 J
35.4	0.17 J
45.3	1U
47.3	1U

VAS-34	
Depth	Result
13.5	23
22.9	0.31 J
33.4	0.36 J
43.1	1U
49.8	1U

VAS-35 (35A)	
Depth	Result
13	1U
23	6.3
32.9	0.74 J
43.1	0.78 J
50.5	0.18 J

VAS-36	
Depth	Result
15.2	0.3 J
25.2	1U
35.3	0.24 J
43.5	1U

VAS-22	
Depth	Result
15	1U
24.9	1U
35.3	1U
45	1U
46.7	1U

VAS-21	
Depth	Result
13.15	1U
23.2	1.16
33	2.84
41.5	0.35 J
51.5	0.58 J
60.2	1U
66.5	1U

VAS-20	
Depth	Result
13	0.48 J
18.2	10.9

VAS-40	
Depth	Result
10.1	0.36 J
20.4	1U
30.1	1U
40	1U
44.1	1U

VAS-11	
Depth	Result
15.2	1U
25	1U
35	1U
45	1U
54.6	1U
60.4	1U

VAS-14	
Depth	Result
17.8	1U
25.65	1U

VAS-15	
Depth	Result
18	1U
25.2	1U

VAS-16	
Depth	Result
15	1U
25	0.33 J
34.1	0.72 J
44.9	1U
55	1U

VAS-17	
Depth	Result
15	1U
25	0.67 J
35	1.52
46.8	1U
55.2	1U

VAS-18	
Depth	Result
13.5	1U
20	1.14
30	0.3 J
39.9	1U
48.8	1U
58.8	1U
63.7	1U

VAS-19	
Depth	Result
12.5	1U
22.5	1U
32.5	1U
42.6	0.73 J
48.5	0.63 J

VAS-33	
Depth	Result
17.1	1U
27.1	1U
37	0.19 J
49.3	0.25 J

VAS-41	
Depth	Result
8.1	0.17 J
18.1	1U
28.1	1U
38	1U
40.5	0.19 J

VAS-42	
Depth	Result
8.15	1U
18.18	1U
23.7	1U
32.75	1U

VAS-32	
Depth	Result
15.1	0.27 J
25	0.17 J
35	1U
41.8	1U
45.3	1U

VAS-37	
Depth	Result
14.9	1U
24.8	1U
34.3	1U
44.4	0.35 J
46.5	0.34 J

VAS-38	
Depth	Result
12	1U
21.3	0.27 J
31.3	0.31 J
33.4	0.3 J
43	0.22 J
51.6	0.26 J

VAS-39	
Depth	Result
9.9	1U
24.6	1U
34	1U

Legend

Phase II VAS Location

Phase I VAS Location

Approximate Horizontal Extent of Plume Exceeding 5 micrograms per Lite (µg/L)

Notes:

Sample depths are feet below ground surfae.

Benzene results are in units of micrograms per Liter (µg/L). Highlighted results exceed the maximum contaminant level of 5 µg/L.

Where duplicate samples were collected the higher sample result is presented.

U = The analyte was not detected above the laboratory reporting limit.

J = The analyte was positively identified. The associated value is an approximate concentration.

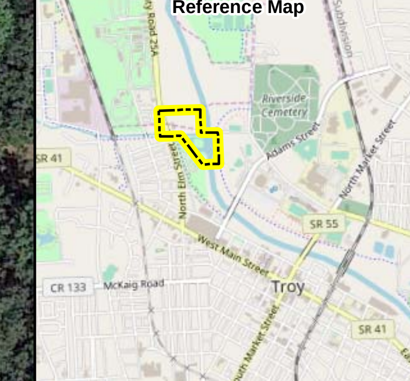
VAS = Vertical Aquifer Sampling

0 100 200

Feet

Source: Bing Maps Hybrid 2013

Reference Map



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-24
PHASE I AND II WATERLOO VERTICALAQUIFER SAMPLING (VAS) RESULTS FOR BENZENE

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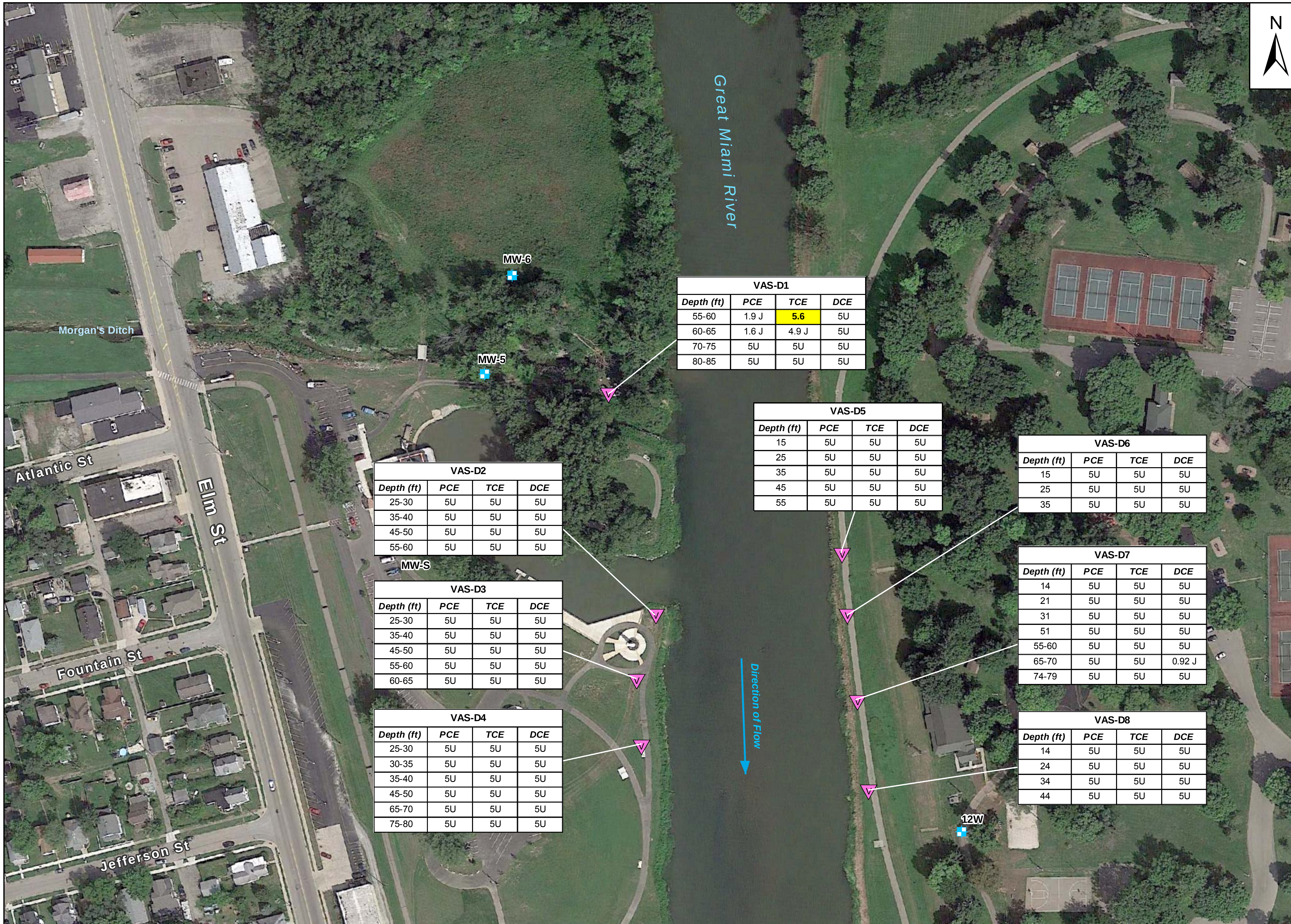
Date Saved: 11/30/2017 12:16:05 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-24-Benzene_Results.mxd



VAS-D1			
Depth (ft)	*PCE*	*TCE*	*DCE*
55-60	1.9 J	**5.6**	5U
60-65	1.6 J	4.9 J	5U
70-75	5U	5U	5U
80-85	5U	5U	5U

VAS-D2			
Depth (ft)	*PCE*	*TCE*	*DCE*
25-30	5U	5U	5U
35-40	5U	5U	5U
45-50	5U	5U	5U
55-60	5U	5U	5U

VAS-D3			
Depth (ft)	*PCE*	*TCE*	*DCE*
25-30	5U	5U	5U
35-40	5U	5U	5U
45-50	5U	5U	5U
55-60	5U	5U	5U
60-65	5U	5U	5U

VAS-D4			
Depth (ft)	*PCE*	*TCE*	*DCE*
25-30	5U	5U	5U
30-35	5U	5U	5U
35-40	5U	5U	5U
45-50	5U	5U	5U
65-70	5U	5U	5U
75-80	5U	5U	5U

VAS-D5			
Depth (ft)	*PCE*	*TCE*	*DCE*
15	5U	5U	5U
25	5U	5U	5U
35	5U	5U	5U
45	5U	5U	5U
55	5U	5U	5U

VAS-D6			
Depth (ft)	*PCE*	*TCE*	*DCE*
15	5U	5U	5U
25	5U	5U	5U
35	5U	5U	5U

VAS-D7			
Depth (ft)	*PCE*	*TCE*	*DCE*
14	5U	5U	5U
21	5U	5U	5U
31	5U	5U	5U
51	5U	5U	5U
55-60	5U	5U	5U
65-70	5U	5U	0.92 J
74-79	5U	5U	5U

VAS-D8			
Depth (ft)	*PCE*	*TCE*	*DCE*
14	5U	5U	5U
24	5U	5U	5U
34	5U	5U	5U
44	5U	5U	5U

Legend

Troy Production Well

Deep VAS Location

Sample depths are feet below ground surfae.

All results are in units of micrograms per Liter (µg/L).

Highlighted TCE result exceeds the maximum contaminant level of 5 µg/L.

PCE = Tetrachloroethene
TCE = Trichloroethene
DCE = cis-1,2-dichloroethene
ND = Non-detect

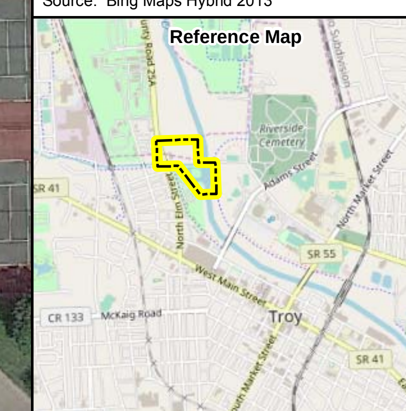
J = The analyte was positively identified. The associated value is an approximate concentration.

U = The analyte was not detected above the laboratory reporting limit.

VAS = Vertical Aquifer Sampling

0 100 200
Feet

Source: Bing Maps Hybrid 2013



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-25
DEEP VERTICAL AQUIFER SAMPLING (VAS) RESULTS

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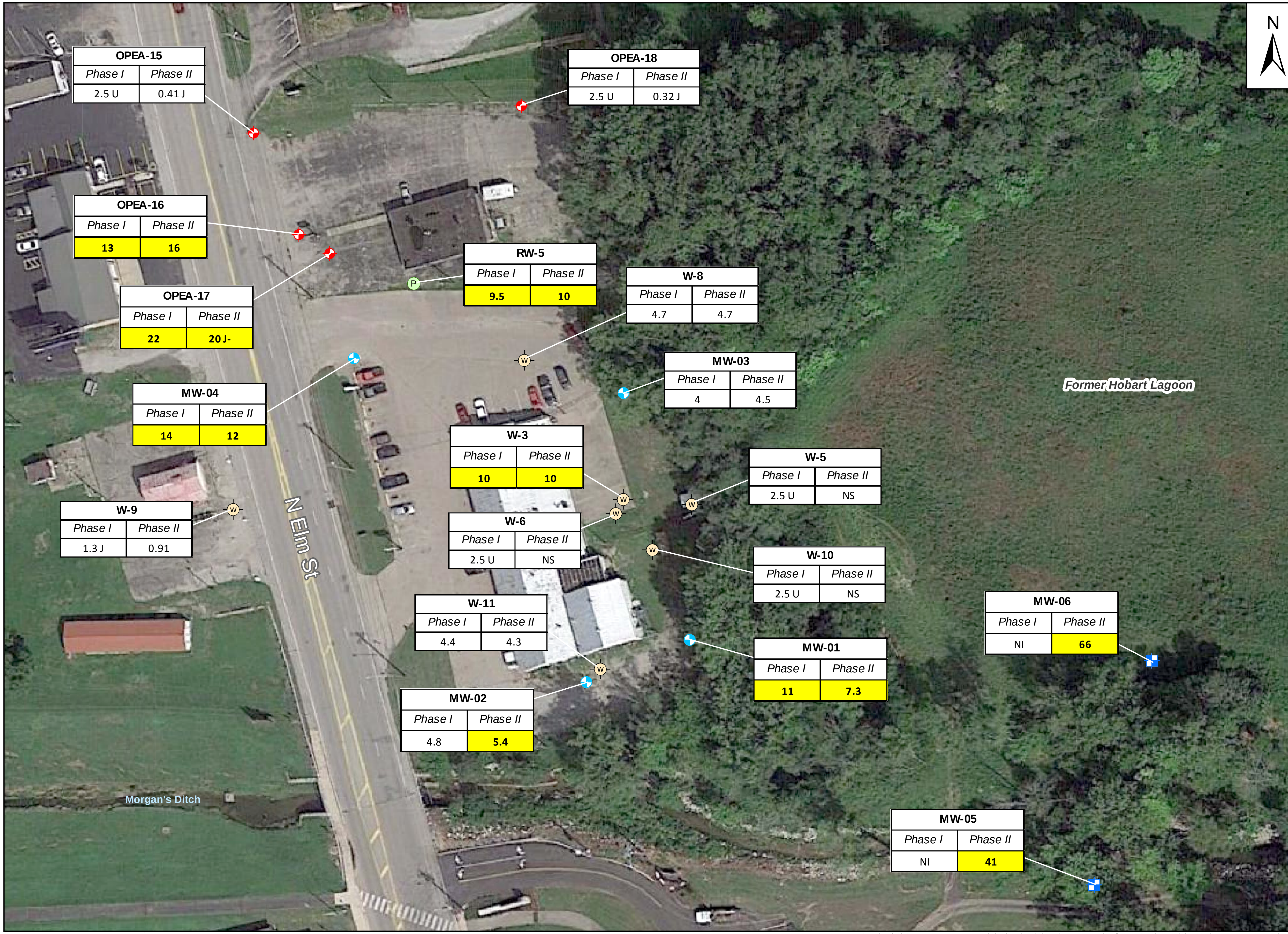
Date Saved: 10/18/2017 5:10:31 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-25-DeepVAS_Results.mxd



N

Legend

- Phase II Monitoring Well
- Phase I Monitoring Well
- Private Well
- Ohio EPA Well
- Wampler Buick Monitoring Well

Notes:

Tetrachloroethene (PCE) results are in units of micrograms per Liter (µg/L). Highlighted results exceed the maximum contaminant level of 5 µg/L.

Where duplicate samples were collected the higher sample result is presented.

U = The analyte was not detected above the laboratory reporting limit.

J = The analyte was positively identified. The associated value is an approximate concentration.

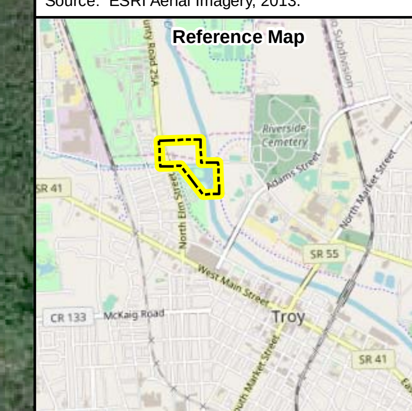
J- = The analyte was positively identified. The associated value is an approximate concentration and may be biased low.

NS = Well was not Sampled.

NI = Well was not installed.

0 50 100
Feet

Source: ESRI Aerial Imagery, 2013.



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-26
PHASE I & II - MONITORING WELL SAMPLING RESULTS FOR TETRACHLOROETHENE

ST SulTRAC

Date Saved: 10/18/2017 5:02:15 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-26-Phase1_2MW-PCEResults.mxd

Legend

- Phase II Monitoring Well
- Phase I Monitoring Well
- Private Well
- Ohio EPA Well
- Wampler Buick Monitoring Well

Notes:

Results are in units of micrograms per Liter (µg/L).

The benzene concentration at W-6 is 4.9 µg/L just below the Maximum Contaminant Level (MCL) at 5 µg/L.

Where duplicate samples were collected the higher sample result is presented.

U = The analyte was not detected above the laboratory reporting limit.

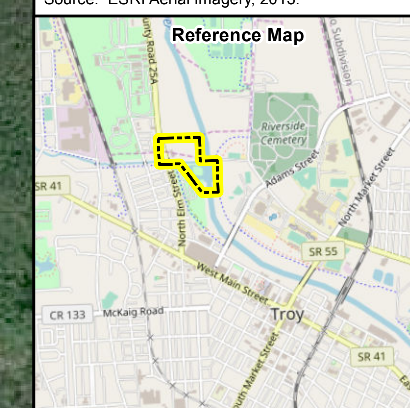
J = The analyte was positively identified. The associated value is an approximate concentration.

NS = Well was not Sampled.

NI = Well was not installed.

0 50 100
Feet

Source: ESRI Aerial Imagery, 2013.

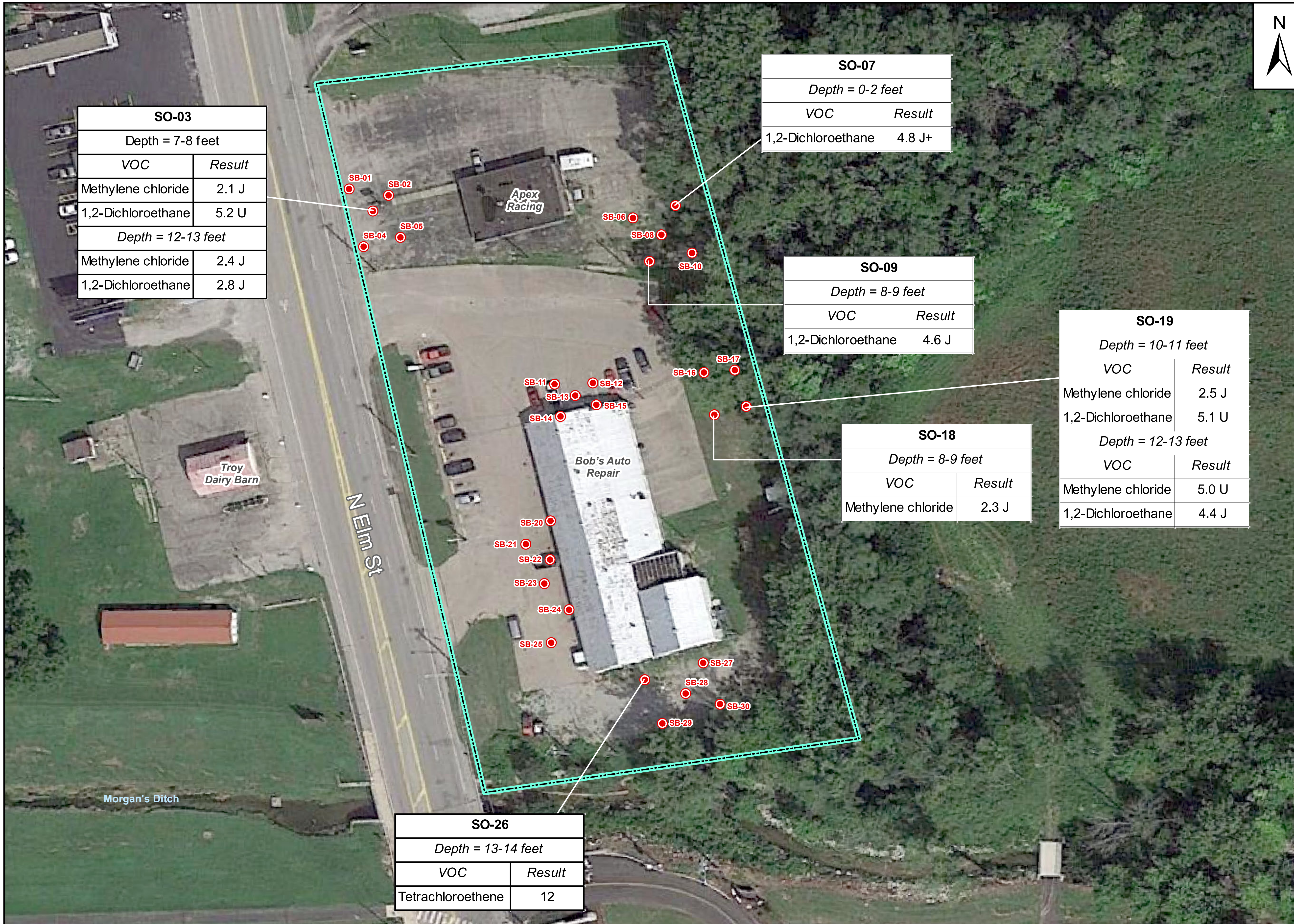


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-27
PHASE I & II - MONITORING WELL SAMPLING RESULTS FOR BENZENE

ST SulTRAC

Date Saved: 10/18/2017 5:02:57 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-27-Phase1_2MW-BenzeneResults.mxd



SO-03	
Depth = 7-8 feet	
VOC	*Result*
Methylene chloride	2.1 J
1,2-Dichloroethane	5.2 U
Depth = 12-13 feet	
Methylene chloride	2.4 J
1,2-Dichloroethane	2.8 J

SO-07	
Depth = 0-2 feet	
VOC	*Result*
1,2-Dichloroethane	4.8 J+

SO-09	
Depth = 8-9 feet	
VOC	*Result*
1,2-Dichloroethane	4.6 J

SO-19	
Depth = 10-11 feet	
VOC	*Result*
Methylene chloride	2.5 J
1,2-Dichloroethane	5.1 U
Depth = 12-13 feet	
VOC	*Result*
Methylene chloride	5.0 U
1,2-Dichloroethane	4.4 J

SO-18	
Depth = 8-9 feet	
VOC	*Result*
Methylene chloride	2.3 J

SO-26	
Depth = 13-14 feet	
VOC	*Result*
Tetrachloroethene	12

Legend

Phase II Soil Sampling Location

Geophysical Survey Area

Notes:

Results are in units of micrograms per kilogram (µg/kg).

Results shown exceed EPA Maximum Contaminant Level (MCL) - based protection of groundwater screening levels.

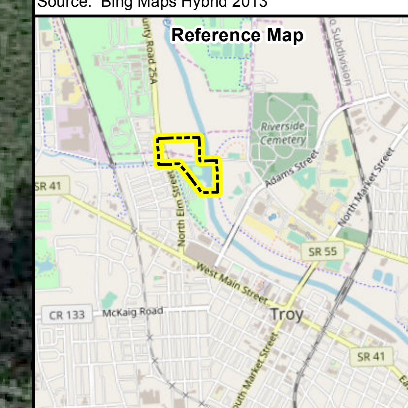
J = The analyte was positively identified. The associated value is an approximate concentration.

J+ = The analyte was positively identified. The associated value is an approximate concentration and may be biased high.

VOC = Volatile Organic Compound

0 50 100
Feet

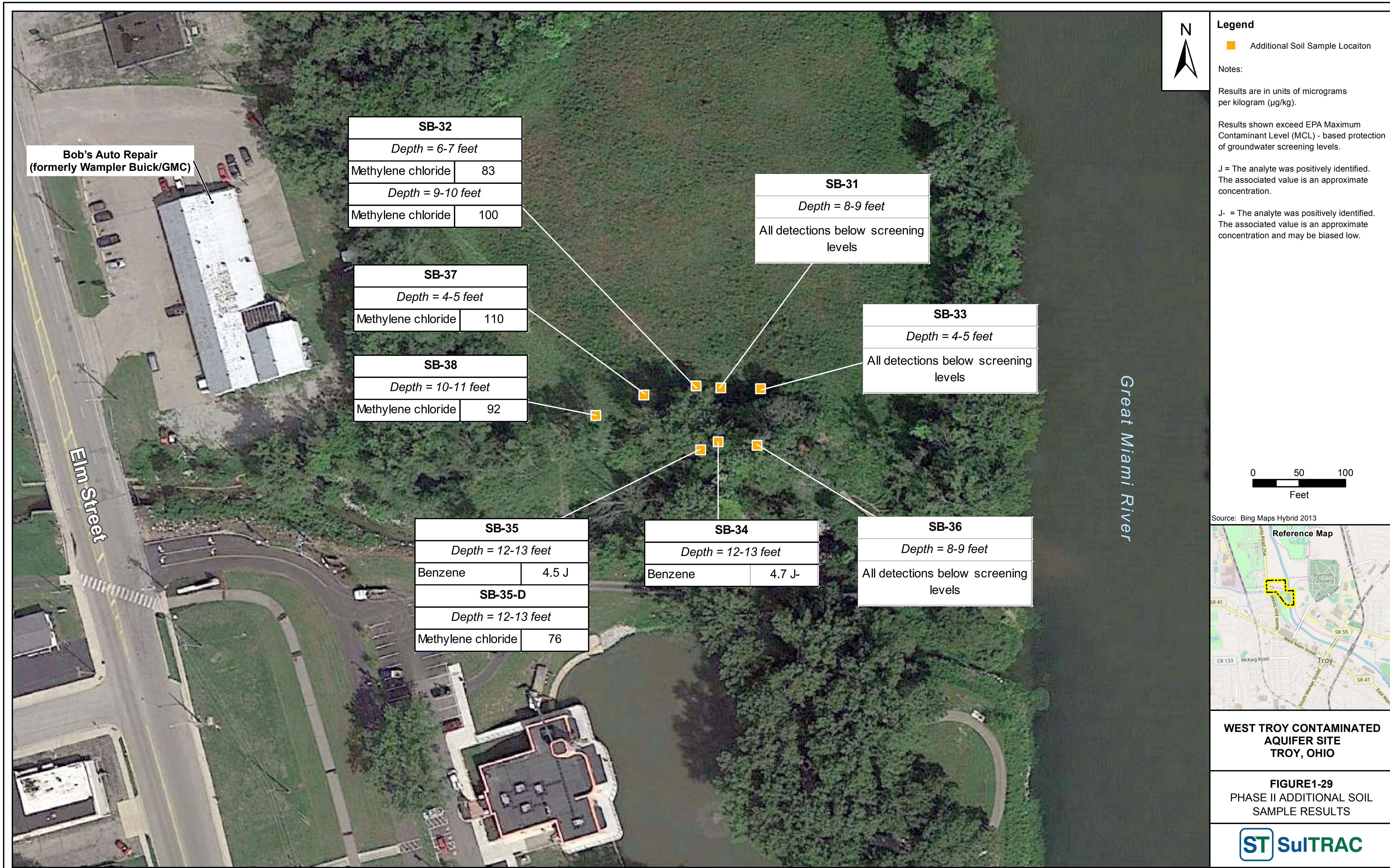
Source: Bing Maps Hybrid 2013



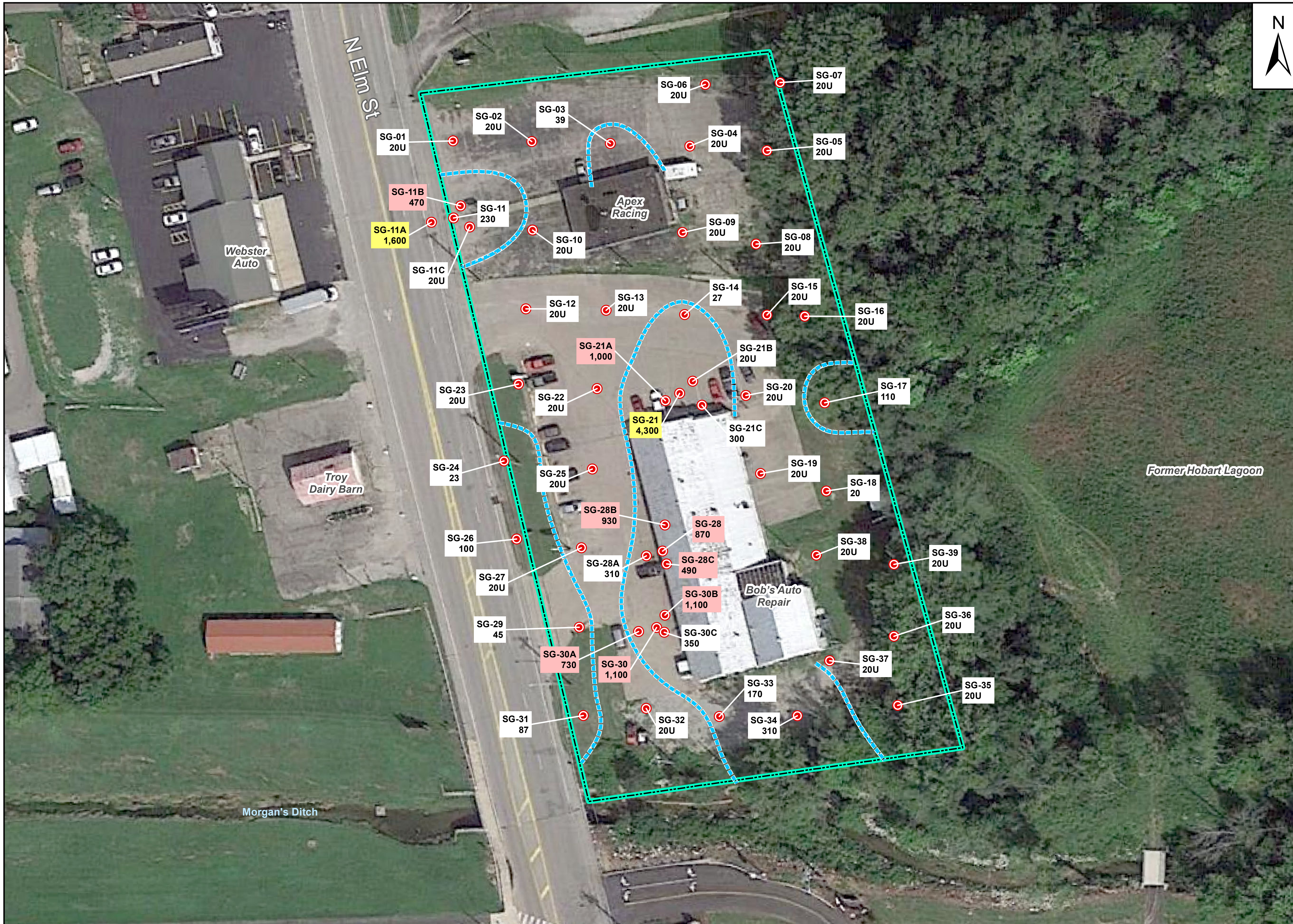
WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-28
PHASE II SOIL SAMPLE RESULTS

ST SulTRAC



Date Saved: 10/18/2017 5:05:07 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-29-Phase2SoilSampleResults.mxd



Legend

- Soil Gas Sample Location
- Approximate Areas with Tetrachloroethene Detections
- Geophysical Survey Area
- 1,100 Result Exceeds Residential Soil Gas VISL
- 1,600 Result Exceeds Commercial Soil Gas VISL

Notes:

Results are in units of micrograms per cubic meter (μg/m^3).

Where duplicate samples were collected the higher sample result is presented.

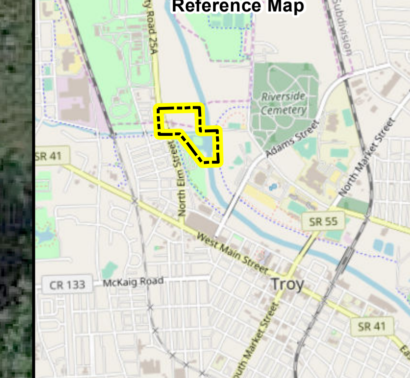
U = The analyte was not detected above the laboratory reporting limit.

VISL = Vapor Intrusion Screening Level.

0 50 100
Feet

Source: ESRI Aerial Imagery, 2013.

Reference Map



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-30
SOIL GAS RESULTS FOR TETRACHLOROETHENE

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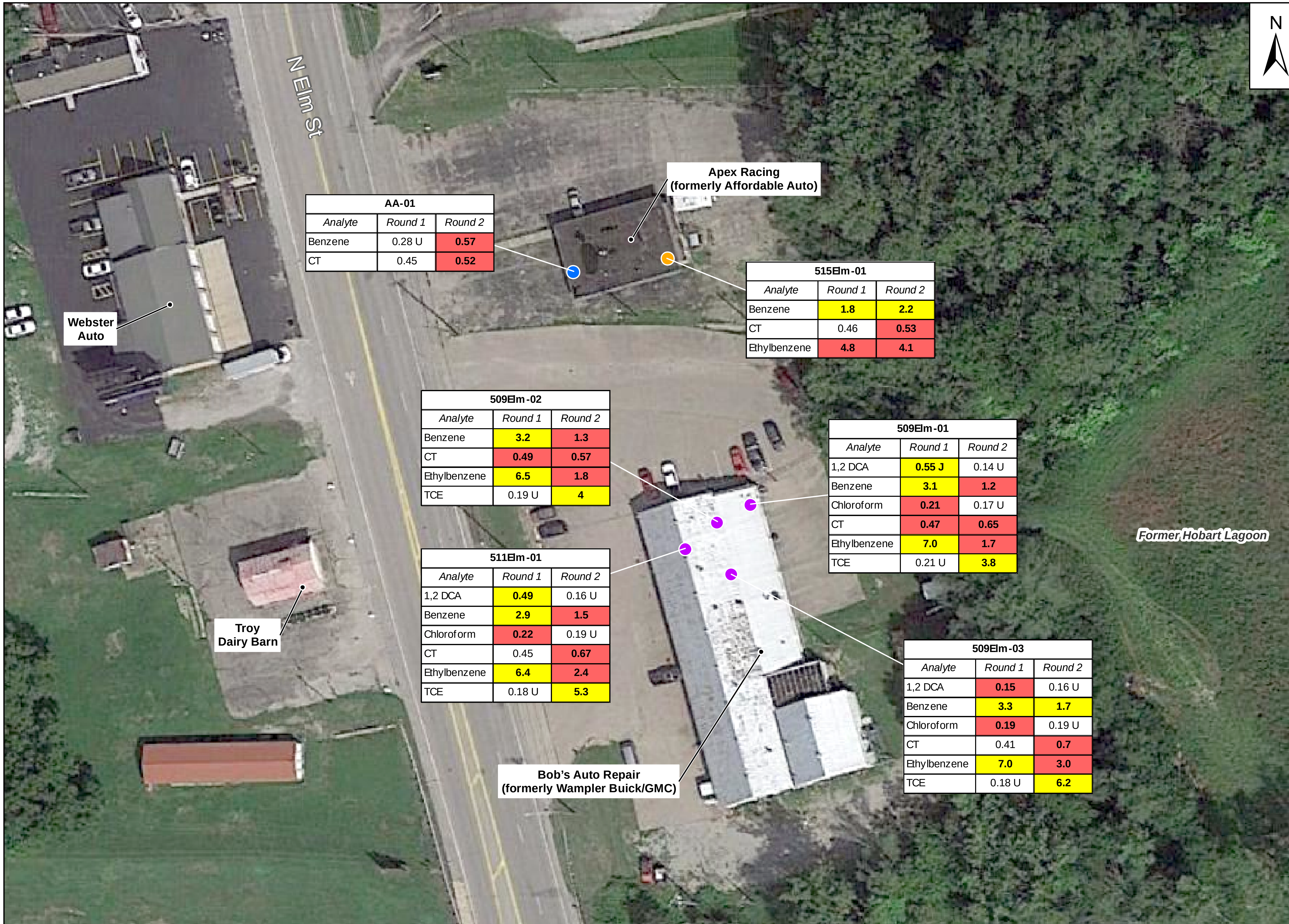
Date Saved: 10/18/2017 5:05:57 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-10 Tech Memo\Fig1-30-SoilGasPCEResults.mxd



AA-01

Analyte	Round 1	Round 2
Benzene	0.28 U	0.57
CT	0.45	0.52

515Elm-01

Analyte	Round 1	Round 2
Benzene	1.8	2.2
CT	0.46	0.53
Ethylbenzene	4.8	4.1

509Elm-02

Analyte	Round 1	Round 2
Benzene	3.2	1.3
CT	0.49	0.57
Ethylbenzene	6.5	1.8
TCE	0.19 U	4

509Elm-01

Analyte	Round 1	Round 2
1,2 DCA	0.55 J	0.14 U
Benzene	3.1	1.2
Chloroform	0.21	0.17 U
CT	0.47	0.65
Ethylbenzene	7.0	1.7
TCE	0.21 U	3.8

511Elm-01

Analyte	Round 1	Round 2
1,2 DCA	0.49	0.16 U
Benzene	2.9	1.5
Chloroform	0.22	0.19 U
CT	0.45	0.67
Ethylbenzene	6.4	2.4
TCE	0.18 U	5.3

509Elm-03

Analyte	Round 1	Round 2
1,2 DCA	0.15	0.16 U
Benzene	3.3	1.7
Chloroform	0.19	0.19 U
CT	0.41	0.7
Ethylbenzene	7.0	3.0
TCE	0.18 U	6.2

N

Legend

- Ambient Air Sampling Location
- Indoor Air Sampling
- Sub-slab and Indoor Air Sampling Location
- 0.49 Result Exceeds Commercial Indoor Air VISL
- 0.67 Result Exceeds Residential Indoor Air VISL

Notes:

Results are in units of micrograms per cubic meter (μg/m^3).

Where duplicate samples were collected the higher sample result is presented.

J = The analyte was positively identified. The associated value is an approximate concentration.

U = The analyte was not detected above the laboratory reporting limit.

VISL = Vapor Intrusion Screening Level

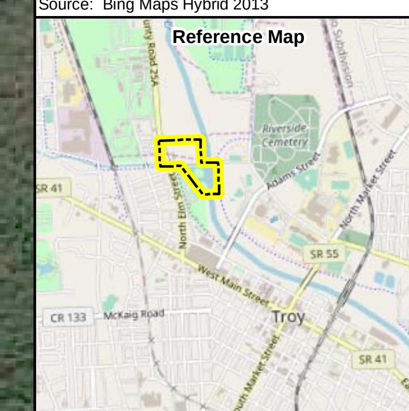
1,2 DCA = 1,2-dichloroethane

CT = Carbon tetrachloride

TCE = Trichloroethene

0 50 100
Feet

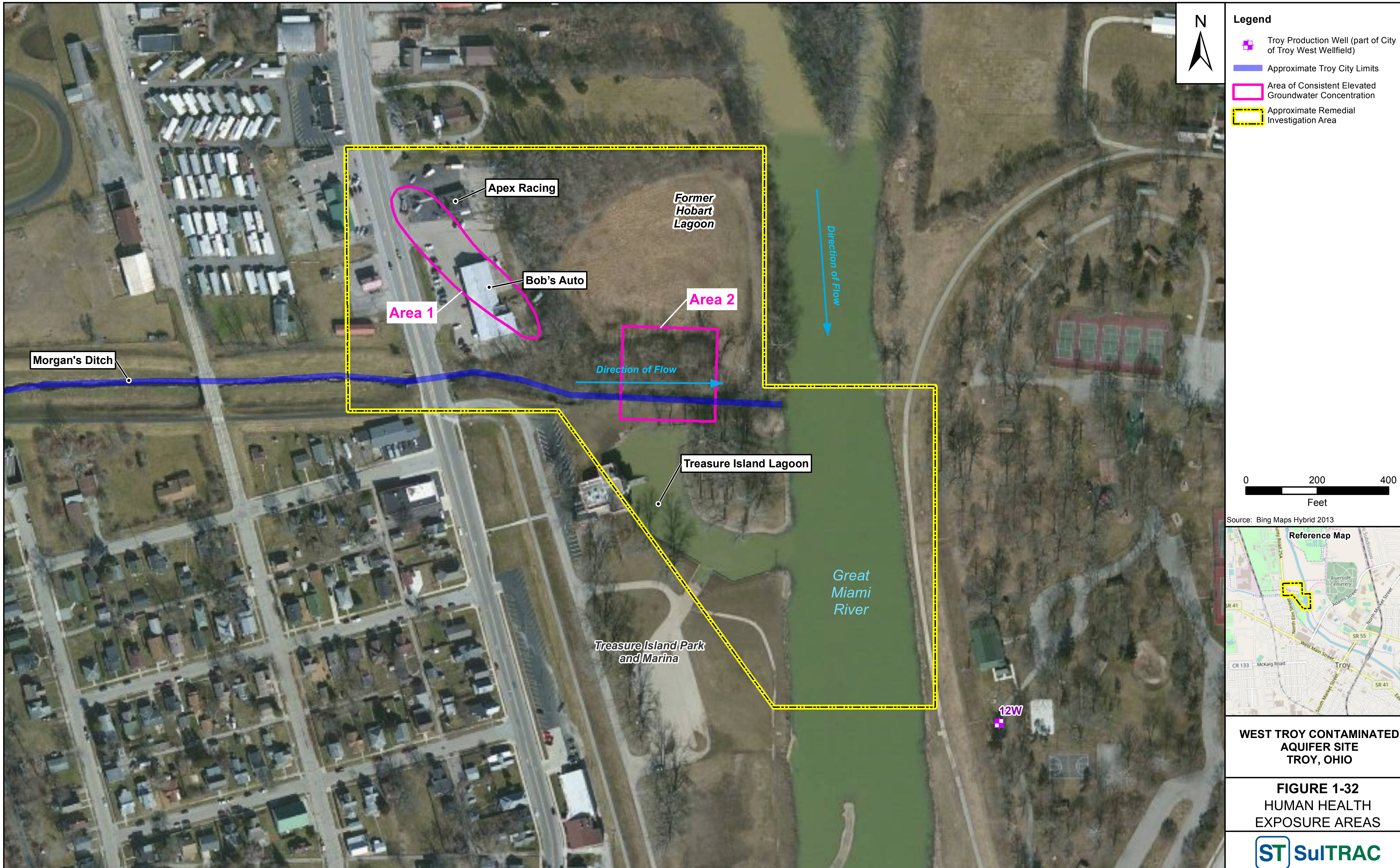
Source: Bing Maps Hybrid 2013



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-31
PHASE II SUB-SLAB, AMBIENT AIR, AND INDOOR AIR SAMPLING RESULTS - ROUNDS 1 AND 2

ST SulTRAC

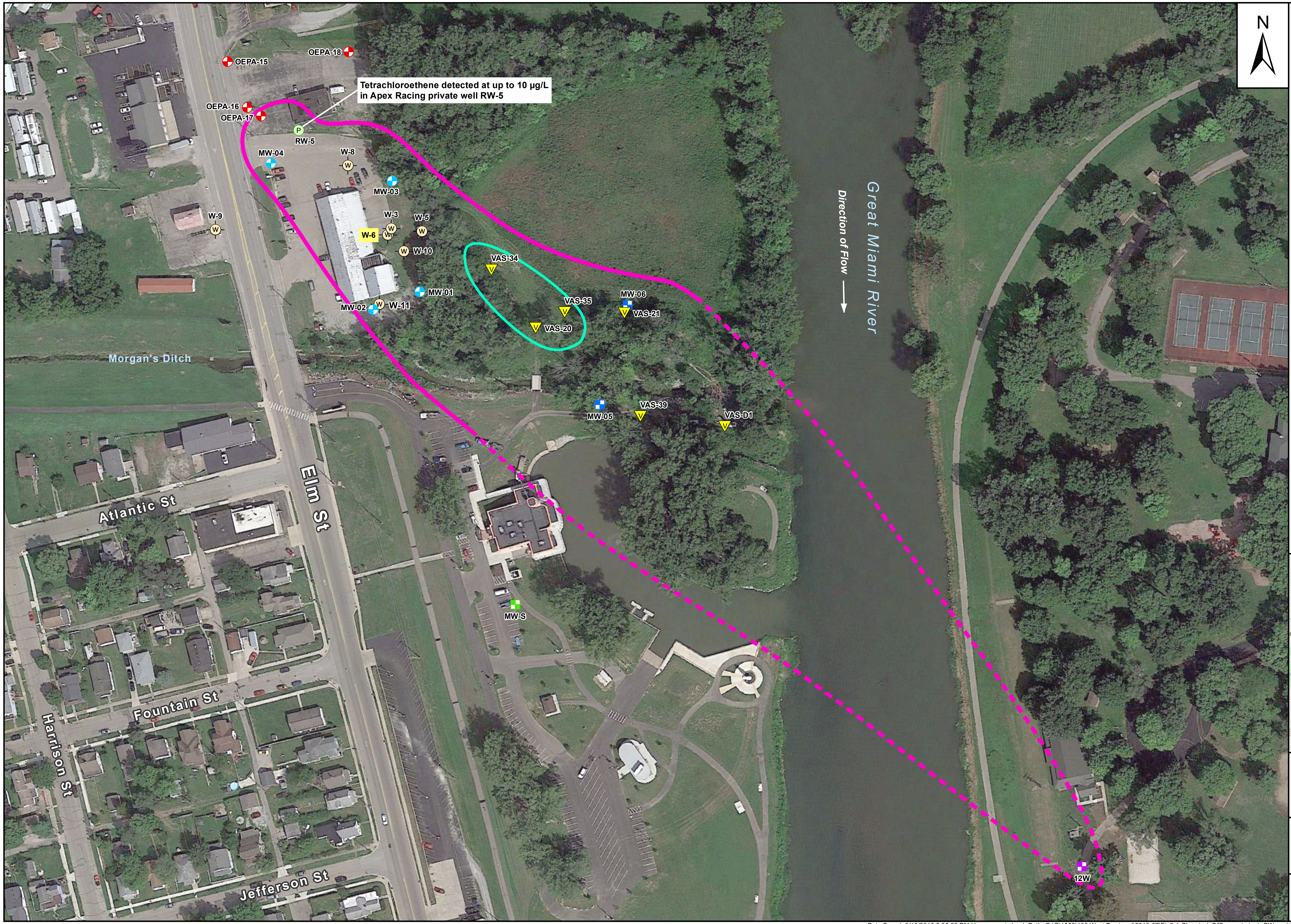


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 1-32
HUMAN HEALTH EXPOSURE AREAS

ST SulTRAC

1/11/2018 G:\G\1852\199 West Troy\mxd\2017-12\Fig1-32-HumanHealthExposureAreas.mxd



N

Legend

- VAS Location
- Private Well
- Ohio EPA Well
- Wampler Buick Monitoring Well
- Phase I Monitoring Well
- Phase II Monitoring Well
- City of Troy Monitoring Well
- City of Troy production well (effluent currently treated by city using air stripping)
- Estimated extent of Tetrachloroethene Plume greater than 5 µg/L (see Figures 1-23, 1-25, & 1-26 for PCE results)
- Inferred plume extent
- Estimated extent of Benzene area greater then 5 µg/L (see Figures 1-24 & 1-27 for Benzene results)

The only detection of 1,4-dichlorobenzene was at W-6 (11 µg/L).

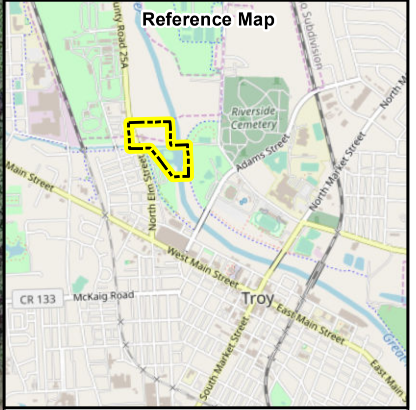
Trichloroethene was detected at concentration greater than 1 µg/L at VAS-21, VAS-35, VAS-39, MW-06, and VAS-D1. All concentrations were below 5 µg/L except VAS-01 (5.6 µg/L).

PCE = Tetrachloroethene
µg/L = micrograms per Liter
VAS = Vertical Aquifer Sampling

0 100 200
Feet

Source: Bing Maps Hybrid 2013

Reference Map

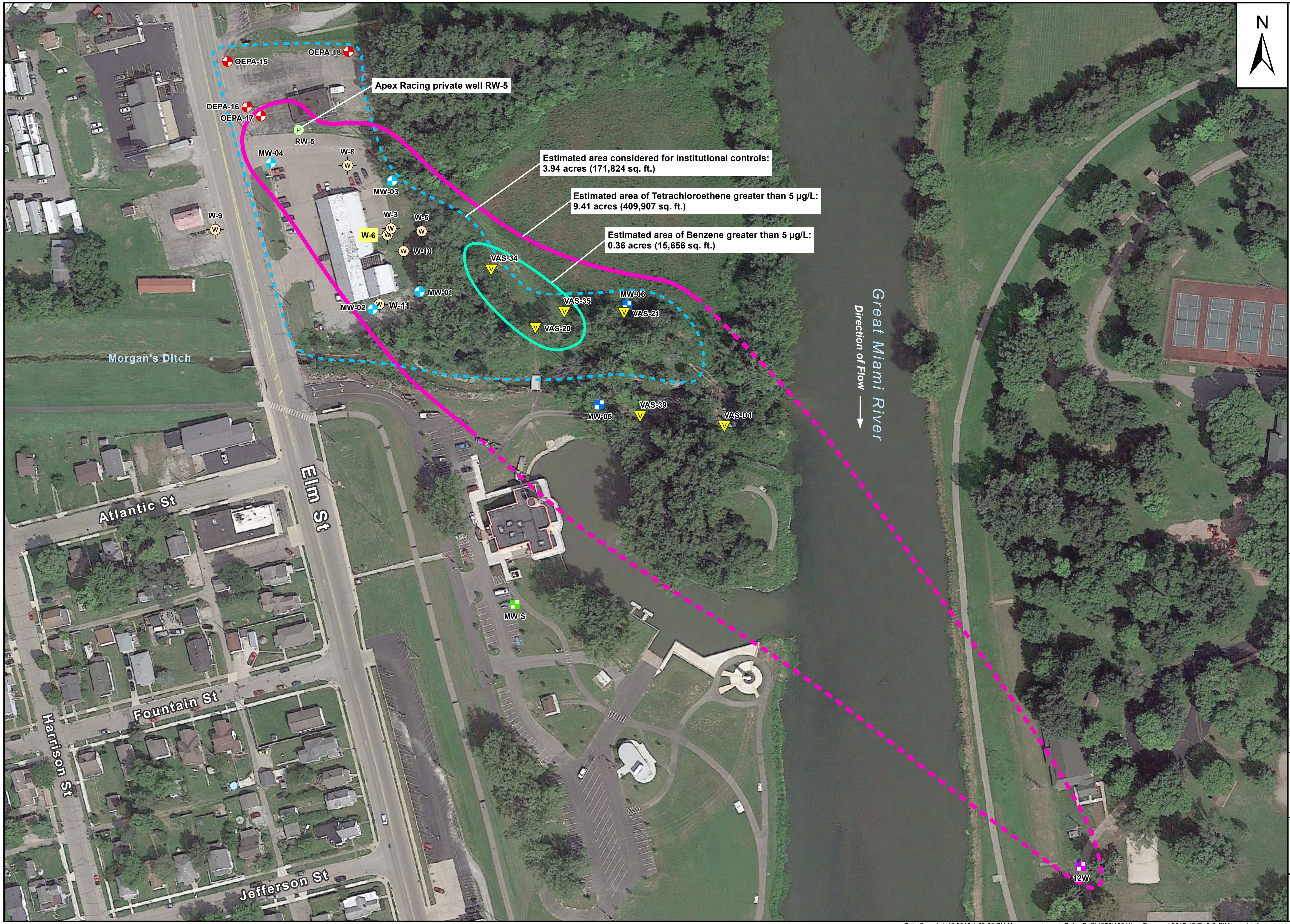


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 2-1
CHEMICALS OF CONCERN
IN GROUNDWATER

ST SulTRAC

Date Saved: 9/13/2018 5:06:02 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2018-07\Fig2-1-ChemicalsOfConcentraionInGW.mxd



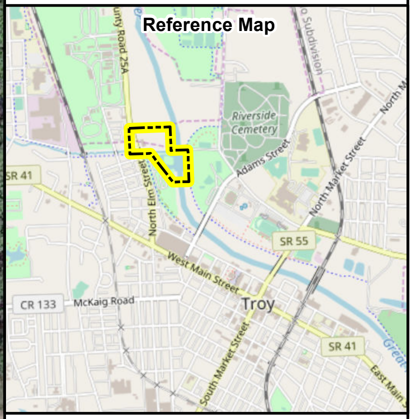
Legend

- VAS Location
- Private Well
- Ohio EPA Well
- Wampler Buick Monitoring Well
- Phase I Monitoring Well
- Phase II Monitoring Well
- City of Troy Monitoring Well
- City of Troy production well (effluent currently treated by city using air stripping)
- Area considered for groundwater and vapor intrusion institutional controls
- Estiamted extent of Benzene area greater then 5 µg/L (see Figures 1-24 & 1-27 for Benzene results)
- Estimated extent of Tetrachloroethene Plume greater than 5 µg/L (see Figures 1-23, 1-25, & 1-26 for PCE results)
- Inferred plume extent

µg/L = micrograms per Liter
VAS = Vertical Aquifer Sampling

0 100 200
Feet

Source: Bing Maps Hybrid 2013



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 2-2
ESTIMATED AREAS OF GROUNDWATER IMPACTS AND POTENTIAL VAPOR INTRUSION

ST SulTRAC

Date Saved: 1/18/2018 4:23:00 PM User: maggie.banh Path: G:\G\1852\199 West Troy\mxd\2017-12\Fig2-2-GWImpactedAreas.mxd

Groundwater GRA	Remedial Technology	Process Options	Description
No action	No action	No action	No action
Land Use Controls	Institutional Controls	Proprietary controls	Easements or restrictive covenants prohibiting specific activities that would compromise the effectiveness of the response action
		Governmental controls	Building or zoning restrictions on land use
		Enforcement and permit tools	Administrative orders, permits, etc. limiting specific site activities
		Informational devices	Recordable documents such as deed notices, property records, advisories, etc. informing future property owners contamination still remains
Monitoring	Monitoring	Groundwater monitoring	Periodic sampling and analyses of groundwater in existing monitoring wells at the site
Containment	Pumping/ barriers	Extraction wells	Installation of several wells at a site and pumping these wells at specified rates to manipulate the natural hydraulic gradient
		Slurry wall	A vertical barrier constructed of a cement-bentonite mixture sometimes mixed with native soil
		Sheet piling	A vertical barrier constructed by driving interlocking sections of steel into the ground to create an impervious wall
In Situ Treatment	Natural Attenuation	Monitored natural attenuation	Attenuation through natural physical, chemical, and biological processes
	Biological treatment	Aerobic bioremediation	Aerobic biodegradation is enhanced by delivering microbes to the subsurface to stimulate native organisms
		Enhanced reductive dechlorinization	Anaerobic biodegradation using organic carbon substrate such as vegetable oil, molasses, or sodium lactate delivered into the subsurface to stimulate native microogranisms
	Chemical treatment	In-situ chemical oxidation	Uses chemicals called "oxidants" to help change harmful contaminants into less toxic ones
		In-situ chemical reduction	Placement of reducing agents in groundwater to destroy or immobilize contaminants
	Physical treatment	Air sparging	A system of injection wells injects air into groundwater, where dissolved and adsorbed VOCs would be removed by air stripping
Removal	Pumping	Extraction wells	Installation of several wells at a site and pumping these wells at specified rates to manipulate the natural hydraulic gradient
		Interceptor trenches	A trench with a perforated pipe layed horizontally along the bottom
Ex Situ Treatment	Physical/ Chemical	Air stripping	Contaminated water in an air stripping unit is exposed to large volumes of air where VOCs are transferred from a water phase to an air phase
		Adsorption	Various techniques which concentrate contaminated solids or remove nonaqueous liquids from groundwater or other aqueous streams via physical and chemical means
		Advanced oxidation	Technology that generates the hydroxyl free radical to destroy organic contaminants
Disposal	Discharge	Injection	Treated groundwater is injected back in the formation
		Discharge to surface water	Collecting contaminated groundwater, treating groundwater to meet NPDES discharge requirements, and discharging the treated groundwater to nearby water body
		Discharge to POTW	Collecting contaminated groundwater, treating groundwater to meet POTW standards, and discharging the treated groundwater to the POTW for final treatment and disposal

Notes:

GRA = General response action
NPDES = National Pollution Discharge Elimination System
POTW = Publicly owned treatment works
VOC = Volatile organic compound

FIGURE 3-1
GRAs, TECHNOLOGIES, AND PROCESS OPTIONS FOR GROUNDWATER

ST SulTRAC

Groundwater GRA	Remedial Technology	Process Options	Description
No action	No action	No action	No action
Monitoring	Monitoring	Private well monitoring	Periodic sampling and analyses of groundwater in existing private well
Alternate Water Supply	Supplied water	Bottled water	Bottled water is provided to occupants for consumption purposes
	Install new well	Shallow upgradient	Installation of a new private well upgradient of contamination
		Deeper	Installation of a new well in a deeper aquifer (if present) below the contaminated aquifer
	Public water system	Public water supply	Residence is connected to a publicly owned (municipal) water system
Treatment	Physical	Air stripping	Removes VOCs from water via mass transfer from water phase to gaseous phase
		Activated carbon adsorption	Water is passed through activated carbon to remove VOCs
		Filtration	Removes suspended solids from water by using porous media
		Phase separation	Separates components having a specific gravity different than water

Notes:

GRA = General response action
VOC = Volatile organic compound

FIGURE 3-2
GRAs, TECHNOLOGIES, AND PROCESS OPTIONS FOR PRIVATE WELL

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Soil Vapor GRA	Remedial Technology	Process Options	Description
No Action	None	No action	No action
Land Use Controls	Institutional Controls	Proprietary controls	Easements or restrictive covenants prohibiting specific activities that would compromise the effectiveness of the response action
		Governmental controls	Building or zoning restrictions on land use
		Enforcement and permit tools	Administrative orders, permits, etc. limiting specific site activities
		Informational devices	Recordable documents such as deed notices, property records, advisories, etc. informing future property owners that contamination still remains
Monitoring	Monitoring	Soil vapor monitoring	Ongoing monitoring of soil vapors (soil gas, sub-slab, indoor air)
Containment	Physical barrier	Sheet barrier	Impermeable layer between the subsurface and concrete slab (associated with new construction)
		Poured/cured in-place barrier	Impermeable layer above the concrete slab (applied to existing structures)
		General sealing	Sealing cracks in the foundation and utility conduits (applied to existing structures)
	Venting	Passive venting	Passive sub-slab vent to passively discharge vapors
	Depressurization	Sub-slab depressurization	Uses a venting system to discharge vapors from the sub-slab
		Crawlspace depressurization	Uses a venting system to discharge vapors from the crawlspace
		Block wall depressurization	Uses a venting system to discharge vapors from the block wall
		Sub-slab ventilation	Generate airflow below the subslab to dilute vapors
	Pressurization	HVAC system	Use HVAC system to create positive pressure within the building
		Sub-slab pressurization	Use sub-slab pressurization to blow air out the opposite side of the building
Treatment	Carbon sorption	Carbon filtration	Filter indoor air through carbon filter to eliminate VOCs
	Photocatalytic oxidation	Ultraviolet oxidation	Filter indoor air through ultraviolet light filter to eliminate VOCs through a chemical reaction

Notes:

GRA = General response action
HVAC = Heating ventilation and air conditioning
SVE = Soil vapor extraction
VOC = Volatile organic compound

FIGURE 3-3
GRAs, TECHNOLOGIES, AND PROCESS OPTIONS FOR VAPOR INTRUSION

ST SulTRAC

Process Options	Effectiveness	Implementability	Cost
No action	Does not achieve RAOs	Not acceptable to state and federal agencies	None
Proprietary controls	Effective for limiting potential exposure to contaminants	Readily implementable	Negligible
Governmental controls	Effective for limiting potential exposure to contaminants	Readily implementable	Negligible
Enforcement and permit tools	Effective for limiting potential exposure to contaminants	Readily implementable	Negligible
Informational devices	Effective for informing on-site or nearby populations of remaining contamination	Readily implementable	Negligible
Groundwater monitoring	Effective for tracking contaminants	Readily implementable	Low capital and low to moderate O&M costs
Extraction wells (containment)	Effective for plume control	Readily implementable	Moderate capital and moderate to high O&M costs
Low permeability barriers (Sheet piling/slurry wall)	Effective in controlling off-site groundwater migration if keyed into a lower confining layer or coupled with hydraulic control	Difficult to implement because of urban landscape and buried utilities	High capital and low O&M costs
Monitored Natural attenuation	Effective for low level contamination	Readily implementable	Low capital and moderate O&M costs
Aerobic bioremediation	Effective for high level contamination	Moderately difficult to implement; requires treatability studies	Moderate to high capital and low to moderate O&M costs
Enhanced reductive dechlorination	Effective for high level contamination	Moderately difficult to implement; requires treatability studies	Moderate to high capital and low to moderate O&M costs
In-situ Chemical oxidation	Effective for high level contamination	Moderately difficult to implement; requires treatability studies	Moderate to high capital and low to moderate O&M costs
In-situ chemical reduction	Effective for high level contamination	Moderately difficult to implement; requires treatability studies	High capital and low to moderate O&M costs
Sparging	Effective for high level contamination	Readily implementable; requires soil vapor extraction to remove vapor-phase contaminants	Moderate capital and O&M costs
Extraction wells (removal)	Effective for groundwater cleanup	Readily implementable	Moderate capital and moderate to high O&M costs
Interceptor trenches	Effective for plume control	Difficult to implement because of urban landscape and buried utilities	High to moderate capital and low to moderate O&M costs
Air stripping	Effective for removing volatile COCs in extracted groundwater	Readily implementable	Low to moderate capital and O&M costs
Adsorption	Effective for removing organic COCs in extracted groundwater	Readily implementable	Moderate capital and O&M costs
Advanced oxidation	Effective for organic COCs in extracted groundwater	Readily implementable; system design and operation can be complex	High capital and moderate O&M costs
Discharge to Injection Wells	Effective for managing extracted and treated groundwater	Readily implementable; will require approval by state agencies	Moderate capital and O&M costs
Discharge to surface water	Effective for managing extracted and treated groundwater	Readily implementable with river nearby; will require approval by state agencies	Moderate capital and O&M costs
Discharge to POTW	Effective for managing extracted and treated groundwater	Readily implementable depending on POTW capacity; Pre-treatment standards easily attainable	Low capital and moderate O&M costs

Notes:

O&M = Operation and maintenance
POTW = Publicly owned treatment works
RAO = Remedial action objective
COC = Chemical of concern

Retained process option (*see text in Section 4.1 for screening discussion details*)

Retained (shaded) process options: No action; Proprietary controls; Governmental controls; Enforcement and permit tools; Informational devices; Groundwater monitoring; Aerobic bioremediation; In-situ Chemical oxidation; Sparging; Extraction wells (removal); Air stripping; Adsorption; Discharge to surface water.

FIGURE 4-1
SCREENING OF
PROCESS OPTIONS FOR GROUNDWATER

ST SulTRAC

Process Options	Effectiveness	Implementability	Cost
No action	Does not achieve RAOs	Not acceptable to state and federal agencies	None
Monitoring	Effective for tracking contaminants	Readily implementable	Low capital and low to moderate O&M costs
Bottled water	Effective short-term solution for eliminating potential exposure to contamination	Readily implementable	Low capital and low to moderate O&M costs
Install shallow upgradient well	Effective for eliminating potential exposure to contaminants; shallow groundwater maybe susceptible to other types of contaminants	Readily implementable	Moderate capital and O&M costs
Install deep well	Effective for eliminating potential exposure to contaminants; deeper groundwater chemistry may not be suitable water source	Moderately difficult to implement	Moderate to high capital and moderate O&M costs
Connect to public supply	Effective long-term solution for eliminating potential exposure to contaminants	Readily implementable; municipal water main already exists adjacent to Apex Racing building	Negligible
Air stripping	Effective for removing volatile COCs in groundwater	Readily implementable as a POE system	Moderate to high capital and O&M costs
Activated carbon adsorption	Effective for removing volatile COCs from groundwater	Readily implementable as a POU or POE system	Moderate capital and moderate to high O&M costs
Filtration	Effective for removing suspended solids from groundwater: may be suitable as a pre-treatment step	Readily implementable as a POE system	Moderate capital and moderate to high O&M costs
Phase separation	Effective through physical separation of components with a specific gravity different from water; not applicable to low-level VOCs present in site groundwater	Readily implementable	Moderate to high capital and O&M costs

Notes:

O&M = Operation and maintenance
POE = Point of entry
POU = Point of use
RAO = Remedial action objective
COC = Chemical of concern

Retained process option (*see text in Section 4.2 for screening discussion details*) — No action, Monitoring, Connect to public supply, Activated carbon adsorption, Filtration

FIGURE 4-2
SCREENING OF
PROCESS OPTIONS FOR PRIVATE WELL

SulTRAC

Process Options	Effectiveness	Implementability	Cost
No action	Does not achieve RAOs	Not acceptable to state and federal agencies	None
Institutional controls	Effective for reducing potential exposure to contaminants	Readily implementable	Negligible
Vapor intrusion monitoring	Effective for tracking contaminants and evaluating effectiveness of vapor intrusion mitigation systems	Readily implementable; would require installation of soil-gas and sub-slab probes	Low capital and low to moderate O&M costs
Sheet barrier	Effective for preventing vapor intrusion through the sub-slab	Difficult to implement for existing structures; requires removing and replacing existing slab	High capital and negligible O&M costs
Poured or cured in-place barrier	Effective for preventing vapor intrusion through the sub-slab	Difficult to implement; requires removing all existing features in basement until existing slab is exposed	High capital and low O&M costs
General sealing	Effective for preventing vapor intrusion through cracks and openings the sub-slab or walls	Moderately difficult to implement; requires finding and sealing conduits and cracks in basement	Low capital and low O&M costs
Passive venting	Effective for rerouting vapors from the sub-slab through vents	Difficult to implement; requires new construction to take advantage of convection currents associated with piping through the house	Moderate capital and low O&M costs
Sub-slab depressurization	Effective for actively removing vapors from the sub-slab	Moderately difficult to implement; requires installation of soil-vapor system to remove vapors from the sub-slab	Moderate capital and low O&M costs
Crawlspace depressurization	Effective for actively removing vapors from the crawlspace	Moderately difficult to implement; requires installation of soil-vapor system to remove vapors from the crawlspace	Moderate capital and low O&M costs
Block wall depressurization	Effective for actively removing vapors from the block wall	Moderately difficult to implement; requires installation of soil-vapor system to remove vapors from the block wall	Moderate capital and low O&M costs
Sub-slab ventilation	Effective for diluting VOCs within the sub-slab	Moderately difficult to implement; requires installation of soil-vapor system to blow air beneath the sub-slab	Moderate capital and low O&M costs
HVAC system	Effective for creating positive pressure within the building to prevent vapors from entering the building	Readily implementable; uses existing HVAC system	Low capital and moderate O&M costs
Sub-slab pressurization	Effective for blowing vapors out of the sub-slab to the other side of building	Moderately difficult to implement; requires installation of soil-vapor system to blow air out from underneath the sub-slab	Moderate capital and moderate O&M costs
Carbon filter	Effective for removing specific VOCs from a single room	Readily implementable; requires purchase of room filters	Low capital and moderate O&M costs
Ultraviolet oxidation	Effective for removing specific VOCs from a single room or entire house	Readily implementable; requires purchase of room filter or HVAC filter	Low capital and moderate O&M costs

Notes:

HVAC = Heating ventilation and air conditioning
O&M = Operation and maintenance
RAO = Remedial action objective
VOC = Volatile organic compound

Retained process option (*see text in Section 4.3 for screening discussion details*) [No action; Institutional controls]

FIGURE 4-3
SCREENING OF
PROCESS OPTIONS FOR VAPOR INTRUSION

ST SulTRAC

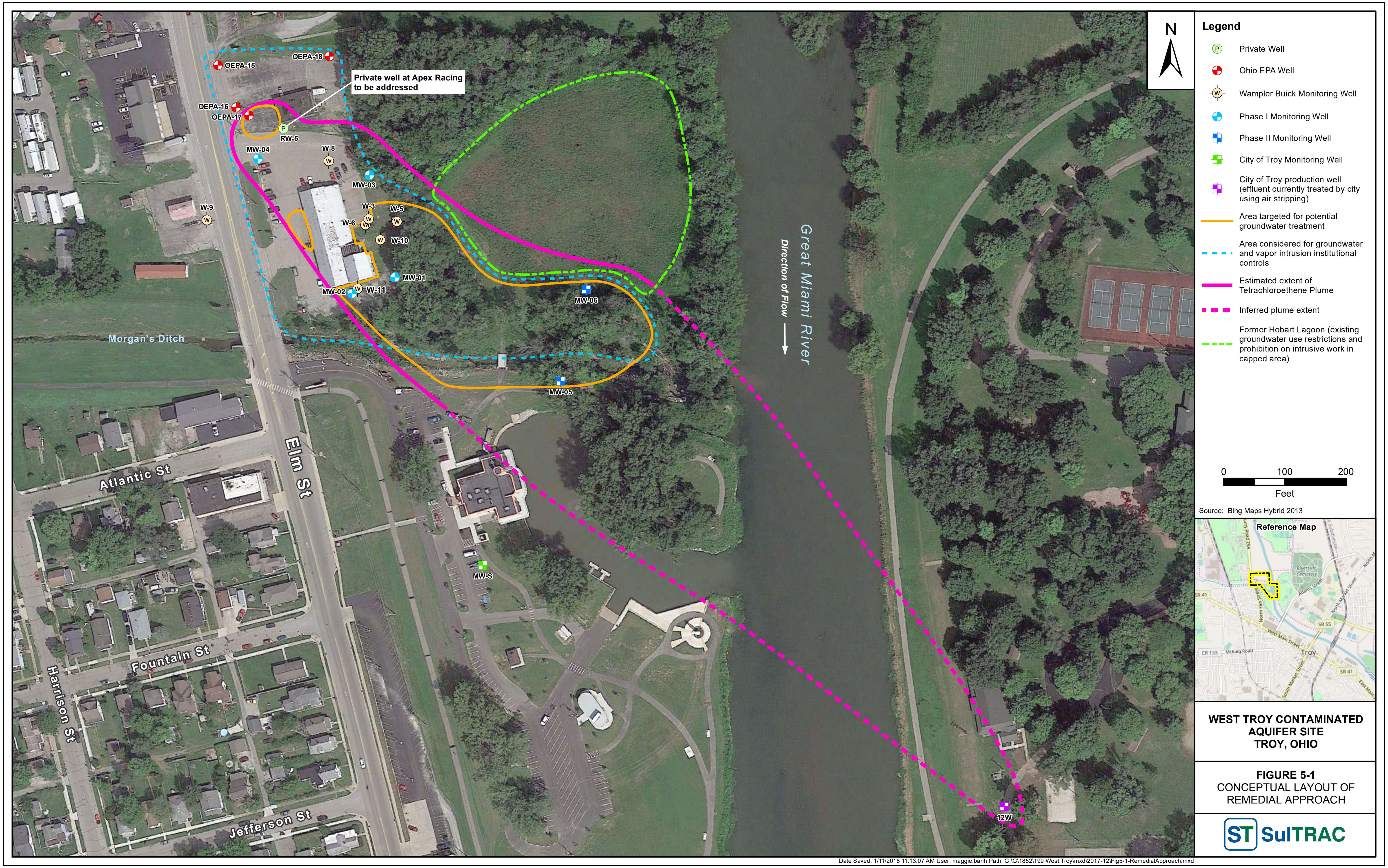
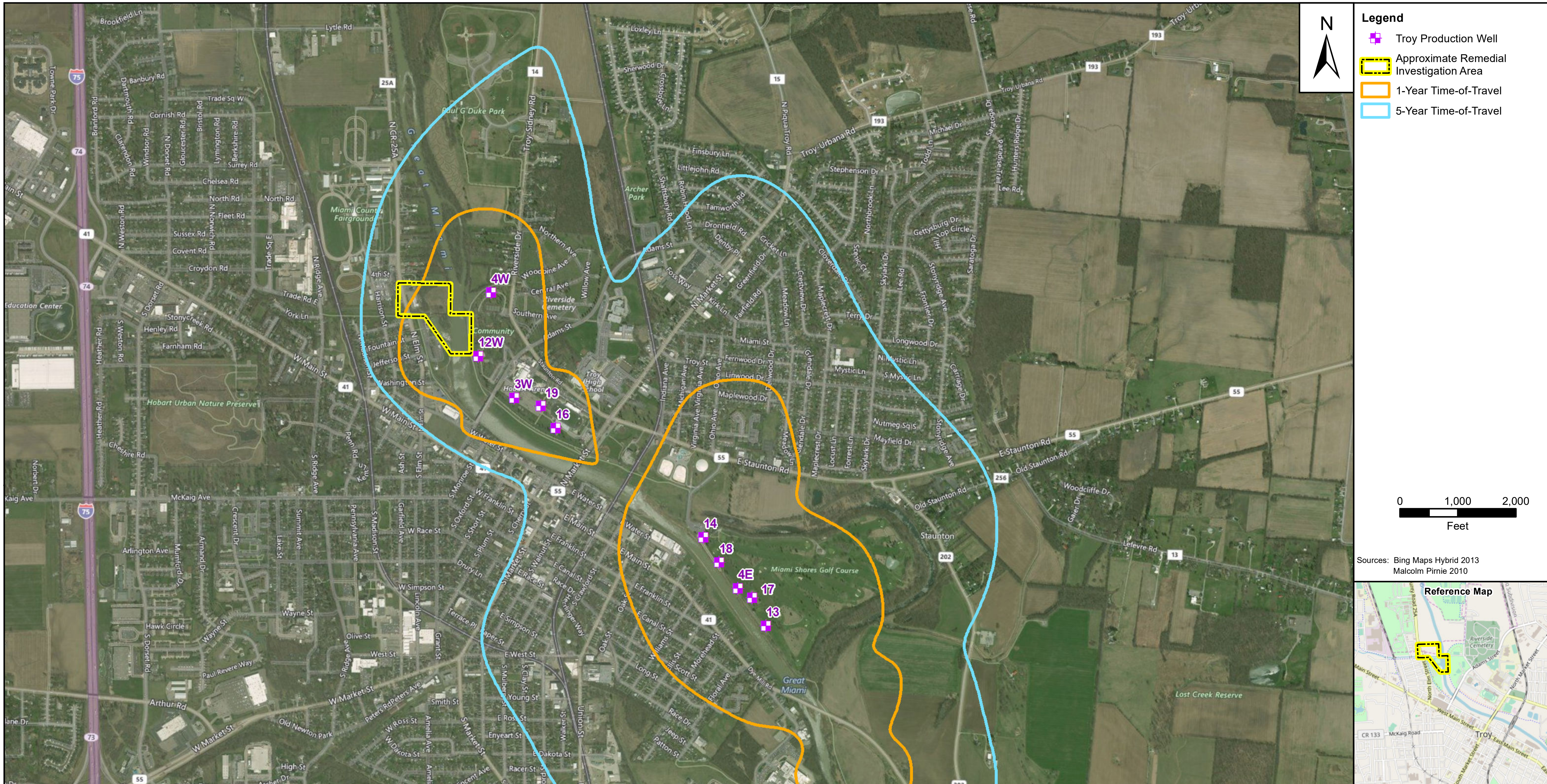


FIGURE 5-1
CONCEPTUAL LAYOUT OF REMEDIAL APPROACH

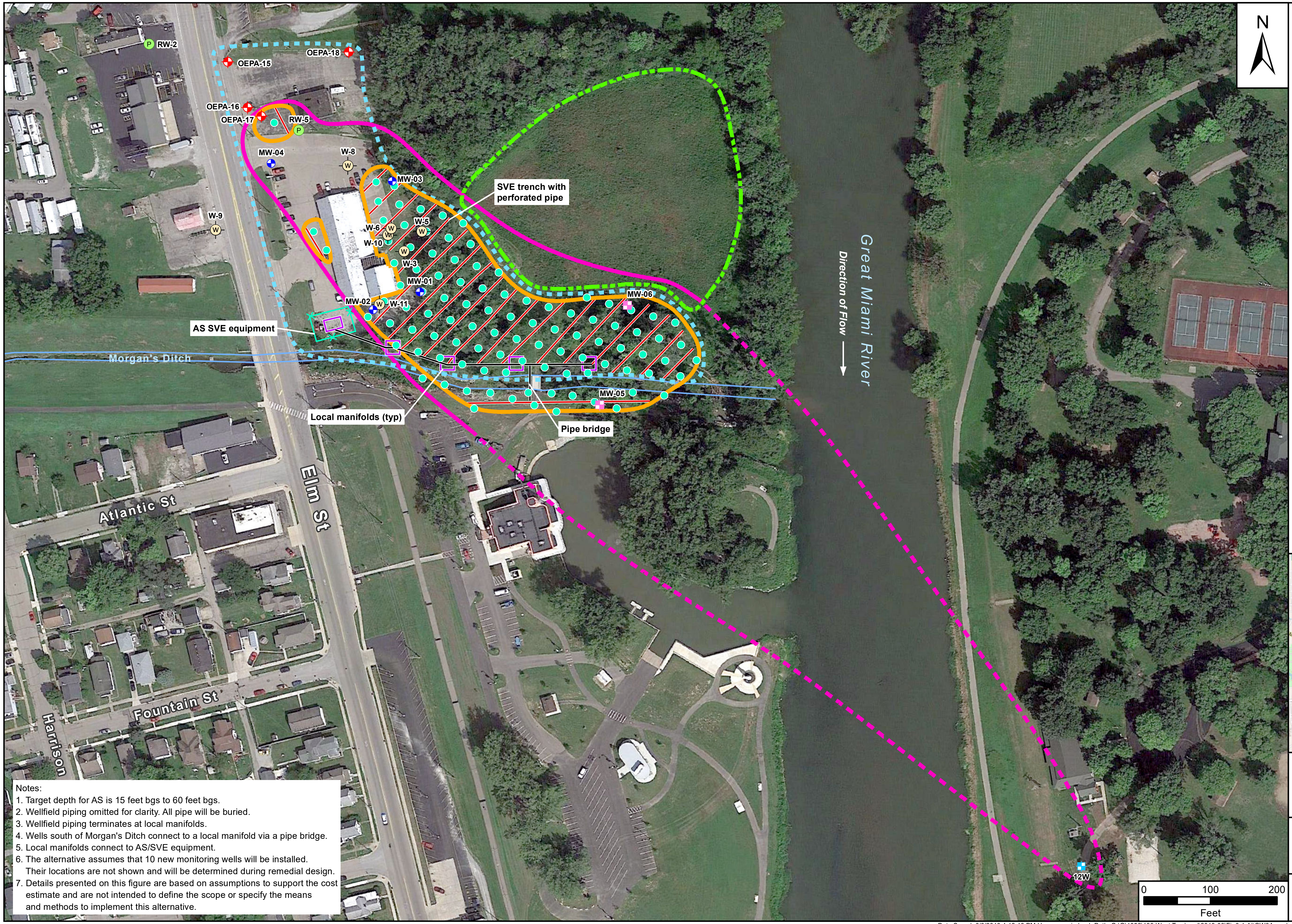


WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

FIGURE 5-2
ONE AND FIVE YEAR TIME-OF-TRAVEL BOUNDARIES

ST SulTRAC

9/10/2018 G:\G\1852\199 West Troy\mxd\2018-07\Fig5-2-TimeTravelBoundaries.mxd

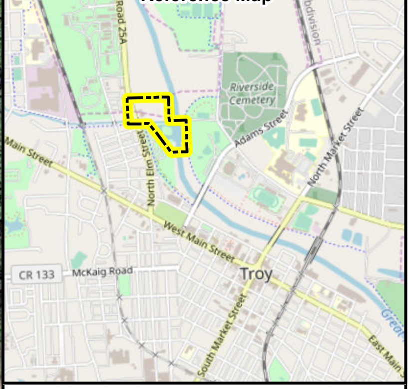


Legend

- 102 Sparge Points (20 feet ROI)
- SVE trench with perforated pipe
- Troy Municipal Well
- Phase I Monitoring Well
- Private Well
- Ohio EPA Well
- Wampler Buick Monitoring Well
- Phase II Monitoring Well Location
- Area targeted for potential groundwater treatment
- Area considered for groundwater and vapor intrusion institutional controls
- Estimated extent of Tetrachloroethene Plume
- Inferred plume extent
- Former Hobart Lagoon (existing groundwater use restrictions and prohibition on intrusive work in capped area)
- Morgan's Ditch

AS = Air sparging
bgs = Below ground surface
PCE = Tetrachloroethene
PVC = Polyvinylchloride
ROI = Radius of Influence
SVE = Soil Vapor Extraction

Reference Map



Notes:
1. Target depth for AS is 15 feet bgs to 60 feet bgs.
2. Wellfield piping omitted for clarity. All pipe will be buried.
3. Wellfield piping terminates at local manifolds.
4. Wells south of Morgan's Ditch connect to a local manifold via a pipe bridge.
5. Local manifolds connect to AS/SVE equipment.
6. The alternative assumes that 10 new monitoring wells will be installed. Their locations are not shown and will be determined during remedial design.
7. Details presented on this figure are based on assumptions to support the cost estimate and are not intended to define the scope or specify the means and methods to implement this alternative.

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

Figure 6-1
Conceptual Layout of Alternative GW-3A
Air Sparging/Soil Vapor Extraction, Institutional Controls, and Monitoring

SulTRAC

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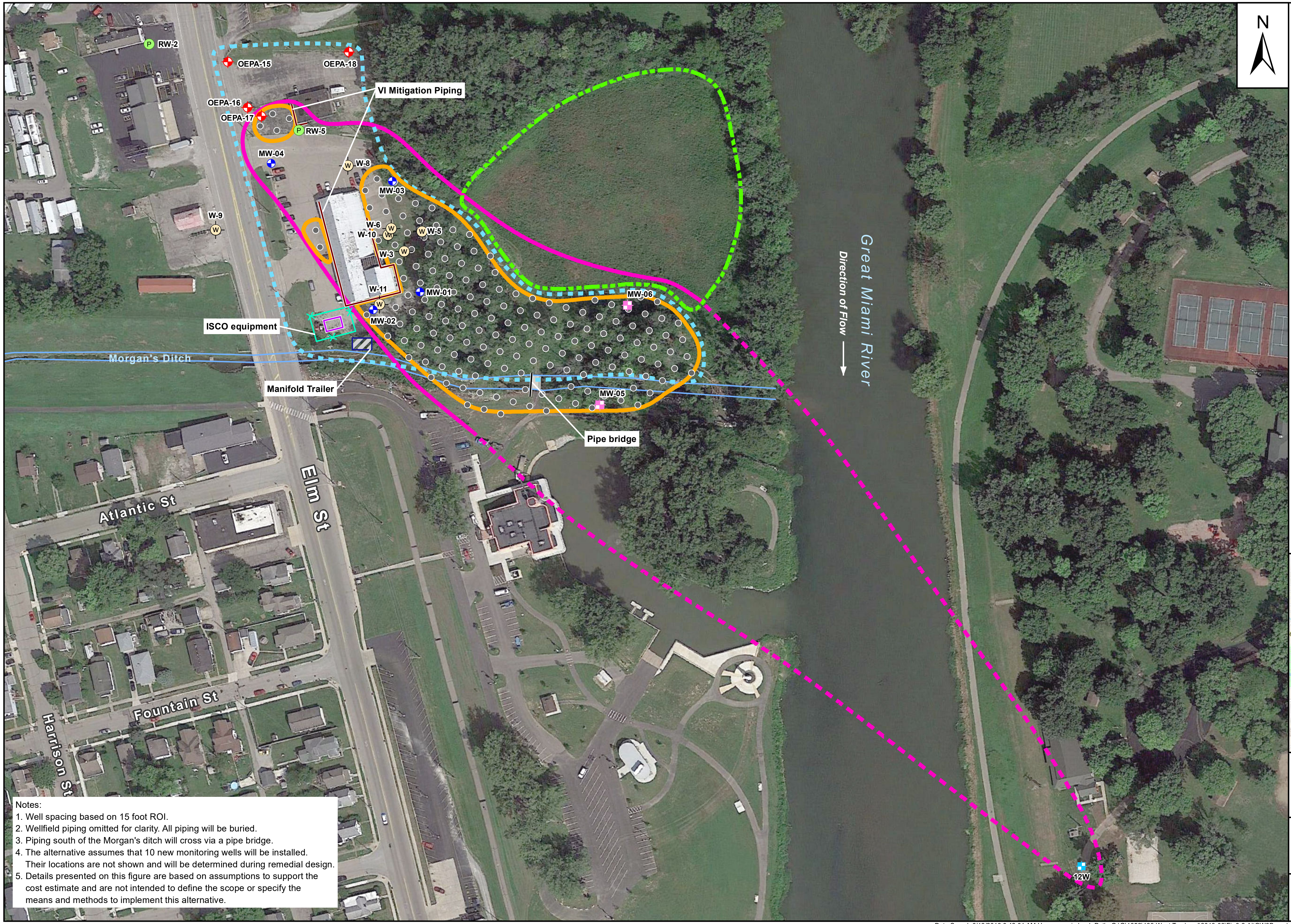
Source: Bing Maps Hybrid 2013



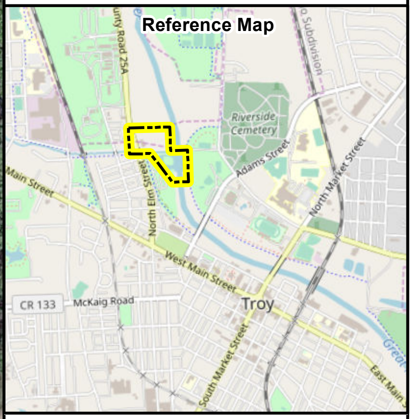
Legend

- 167 ISCO Wells (15 feet ROI)
- Troy Municipal Well
- Phase I Monitoring Well
- Private Well
- Ohio EPA Well
- Wampler Buick Monitoring Well
- Phase II Monitoring Well Location
- Area targeted for potential groundwater treatment
- Area considered for groundwater and vapor intrusion institutional controls
- Estimated extent of Tetrachloroethene Plume
- Inferred plume extent
- Former Hobart Lagoon (existing groundwater use restrictions and prohibition on intrusive work in capped area)
- Morgan's Ditch

ISCO = In Situ Chemical Oxidation
ROI = Radius of influence
VI = Vapor intrusion

0 100 200
Feet

Source: Bing Maps Hybrid 2013



Notes:
1. Well spacing based on 15 foot ROI.
2. Wellfield piping omitted for clarity. All piping will be buried.
3. Piping south of the Morgan's ditch will cross via a pipe bridge.
4. The alternative assumes that 10 new monitoring wells will be installed. Their locations are not shown and will be determined during remedial design.
5. Details presented on this figure are based on assumptions to support the cost estimate and are not intended to define the scope or specify the means and methods to implement this alternative.

WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

Figure 6-2
Conceptual Layout of Alternative GW-3B
In Situ Chemical Oxidation,
Institutional Controls, and Monitoring

ST SulTRAC

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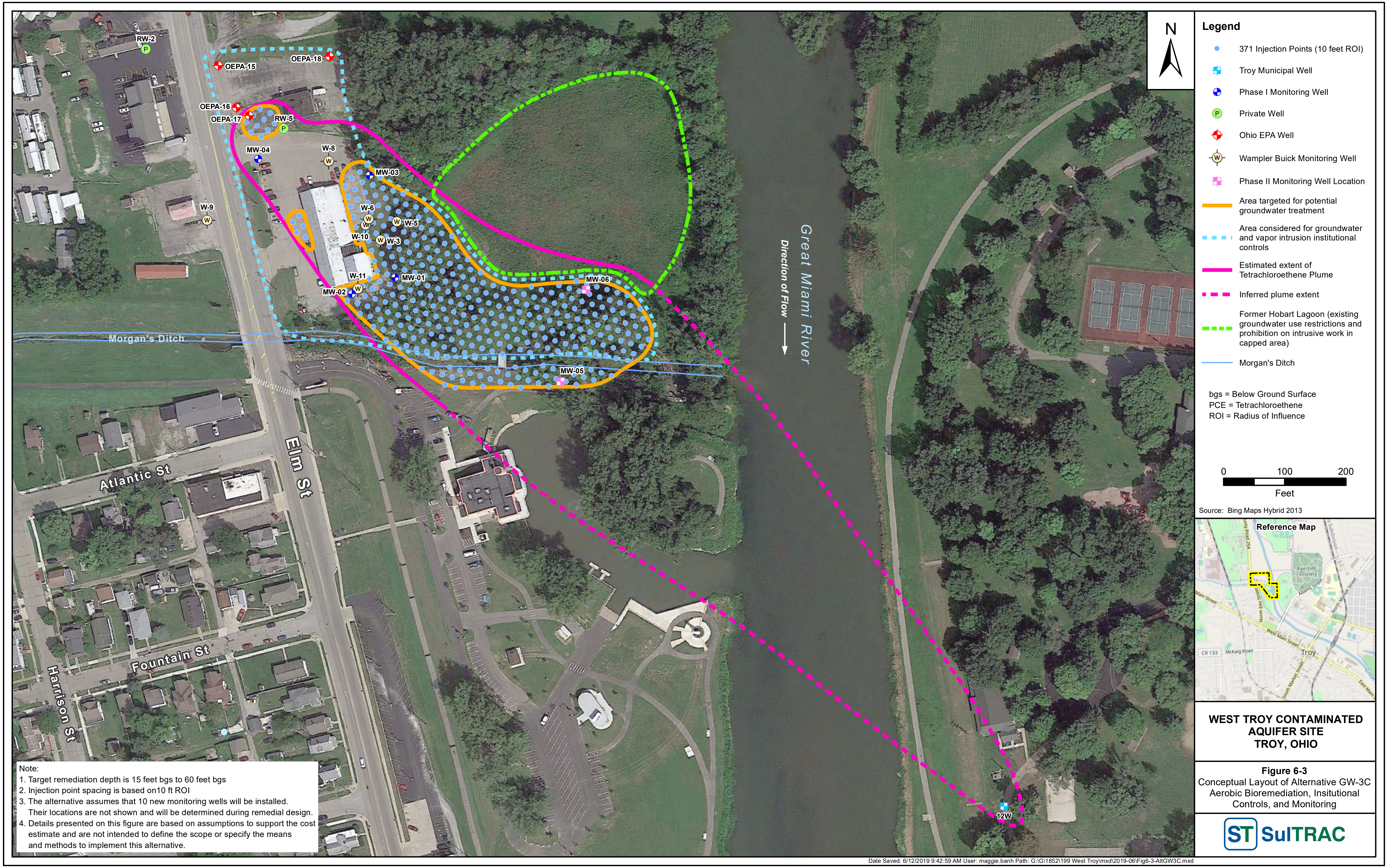
N
Legend
371 Injection Points (10 feet ROI)
Troy Municipal Well
Phase I Monitoring Well
Private Well
Ohio EPA Well
Wampler Buick Monitoring Well
Phase II Monitoring Well Location
Area targeted for potential groundwater treatment
Area considered for groundwater and vapor intrusion institutional controls
Estimated extent of Tetrachloroethene Plume
Inferred plume extent
Former Hobart Lagoon (existing groundwater use restrictions and prohibition on intrusive work in capped area)
Morgan's Ditch
bgs = Below Ground Surface
PCE = Tetrachloroethene
ROI = Radius of Influence
0 100 200
Feet
Source: Bing Maps Hybrid 2013
Reference Map
Troy
RW-2
OEPA-15
OEPA-18
OEPA-16
OEPA-17
RW-5
MW-04
W-8
MW-03
W-9
W-6
W-5
W-10
W-3
W-11
MW-01
MW-02
MW-06
MW-05
Morgan's Ditch
Great Miami River
Direction of Flow
Atlantic St
Elm St
Fountain St
Harrison St
12W
Note:
1. Target remediation depth is 15 feet bgs to 60 feet bgs
2. Injection point spacing is based on10 ft ROI
3. The alternative assumes that 10 new monitoring wells will be installed. Their locations are not shown and will be determined during remedial design.
4. Details presented on this figure are based on assumptions to support the cost estimate and are not intended to define the scope or specify the means and methods to implement this alternative.
WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO
Figure 6-3
Conceptual Layout of Alternative GW-3C
Aerobic Bioremediation, Insitutional Controls, and Monitoring
ST SulTRAC
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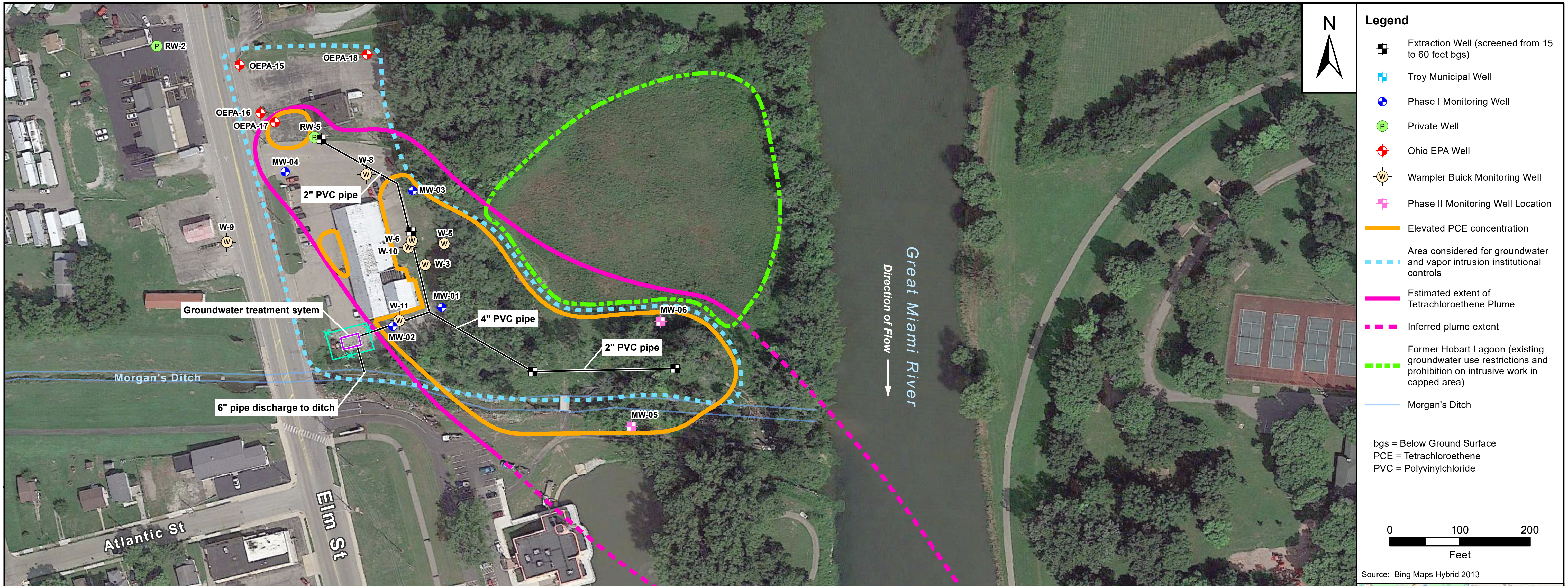
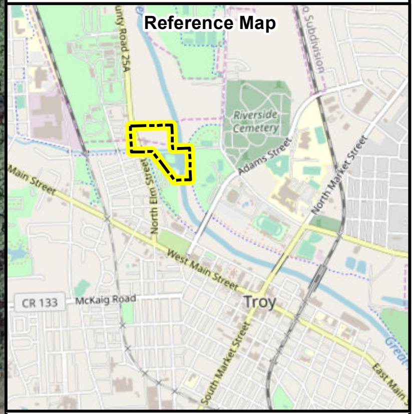


Notes:
1. The alternative assumes that 10 new monitoring wells will be installed. Their locations are not shown and will be determined during remedial design.
2. Details presented on this figure are based on assumptions to support the cost estimate and are not intended to define the scope or specify the means and methods to implement this alternative.



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

Figure 6-4
Conceptual Layout of Alternative GW4 Groundwater Extraction Treatment and Discharge, Institutional Controls, and Monitoring

ST SulTRAC

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N

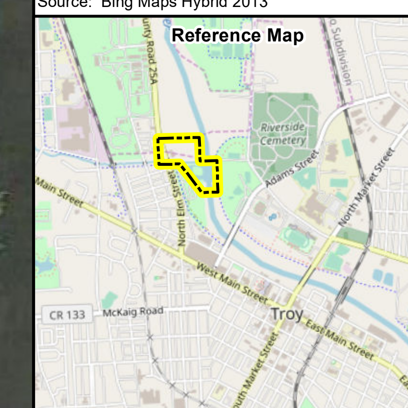
Legend

- Existing Sewer Line
- Existing Water Main
- New Public Water Service Lateral
- Existing Private Well to be abandoned

Note:
Details presented on this figure are merely assumptions to support the cost estimate and are not intended to define the scope or specify the means and methods to implement this alternative.

0 50 100
Feet

Source: Bing Maps Hybrid 2013



WEST TROY CONTAMINATED AQUIFER SITE
TROY, OHIO

Figure 6-5
Conceptual Layout of Alternative PR-3
Connection to City Water and
Abandoned Private Well

ST SulTRAC

TABLE 1-1

SUMMARY OF 2016-2018 ANALYTICAL RESULTS FOR PCE, TCE, AND cis-DCE TROY WEST WELLFIELD PRODUCTION WELLS AND MW-S

Well	Date	PCE (µg/L)	TCE (µg/L)	cis-DCE (µg/L)
P-4W	7/12/18	ND	ND	ND
	6/7/18	ND	ND	ND
	5/16/18	ND	ND	ND
	4/16/18	ND	ND	ND
	3/15/18*	ND	ND	ND
	2/15/18	ND	ND	ND
	11/9/17	ND	ND	ND
	10/19/17	ND	ND	ND
	9/7/17	ND	ND	ND
	8/10/17	ND	ND	ND
	7/5/17	ND	ND	ND
	6/8/17	ND	ND	ND
	5/4/17	ND	ND	ND
	4/5/17	ND	ND	ND
	3/19/17	ND	ND	ND
	2/9/17	ND	ND	ND
	1/12/17	ND	ND	ND
	12/8/16	ND	ND	ND
	11/10/16	ND	ND	ND
	10/12/16	ND	ND	ND
	8/11/16	ND	ND	ND
	5/11/16	ND	ND	ND
	4/6/16	ND	ND	ND
	3/17/16	ND	ND	ND
	2/10/16	ND	ND	ND
	1/14/16	ND	ND	ND
P-12W	7/12/18	**2.1**	**0.4**	**0.7**
	6/7/18	**2.0**	**0.5**	**0.8**
	5/16/18	**2.4**	**0.6**	**1.0**
	4/16/18	**5.3**	**1.2**	**1.7**
	3/15/18*	**4.2**	**1.0**	**1.2**
	2/15/18	**3.9**	**1.0**	**1.3**
	1/11/18	**4.2**	ND	**1.1**
	12/7/17	**2.0**	ND	ND
	11/9/17	**2.5**	ND	ND
	10/19/17	**4.6**	ND	**1.27**
	9/7/17	**3.4**	ND	**1.0**
	8/23/17	**3.4**	ND	**1.1**
	7/5/17	**1.8**	ND	ND
	6/8/17	**2.1**	ND	ND
	5/4/17	**2.3**	ND	ND
	4/5/17	**2.7**	**1.2**	**1.0**
	3/19/17	**4.0**	**1.7**	**1.2**
	2/9/17	**4.3**	ND	**1.5**
	1/12/17	**3.6**	ND	**1.0**
	12/8/16	**2.4**	ND	ND

TABLE 1-1

SUMMARY OF 2016-2018 ANALYTICAL RESULTS FOR PCE, TCE, AND cis-DCE TROY WEST WELLFIELD PRODUCTION WELLS AND MW-S

Well	Date	PCE (µg/L)	TCE (µg/L)	cis-DCE (µg/L)
P-12W Continued	11/10/16	**2.4**	ND	ND
	10/12/16	**2.8**	ND	**1.0**
	9/8/16	**2.4**	ND	ND
	8/11/16	**3.3**	ND	ND
	7/6/16	**2.0**	**1.7**	ND
	6/9/16	**2.1**	ND	ND
	5/11/16	**2.6**	ND	ND
	4/6/16	**5.8**	ND	**1.2**
	3/17/16	ND	ND	**1.0**
	2/10/16	**5.1**	ND	**1.0**
	1/14/16	**2.8**	ND	ND
P-3W	7/12/18	ND	ND	ND
	6/7/18	ND	ND	**0.2**
	5/16/18	ND	ND	**0.4**
	4/16/18	ND	ND	**0.6**
	3/15/18*	ND	ND	ND
	2/15/18	ND	ND	ND
	1/11/18	ND	ND	ND
	12/7/17	ND	ND	ND
	11/9/17	ND	ND	ND
	10/19/17	ND	ND	ND
	9/7/17	ND	ND	ND
	8/10/17	ND	ND	ND
	7/5/17	ND	ND	ND
	6/8/17	ND	ND	ND
	5/4/17	ND	ND	ND
	4/5/17	ND	ND	ND
	3/19/17	ND	ND	ND
	2/9/17	ND	ND	ND
	1/12/17	ND	ND	ND
	12/8/16	ND	ND	ND
	11/10/16	ND	ND	ND
	10/12/16	ND	ND	ND
	8/11/16	ND	ND	ND
	5/11/16	ND	ND	ND
	4/6/16	ND	ND	ND
	3/16/16	ND	ND	ND
	2/10/16	ND	ND	ND
	1/14/16	ND	ND	ND
P-19W	7/12/18	ND	ND	ND
	6/7/18	ND	ND	ND
	4/16/18*	ND	ND	ND
	11/9/17	ND	ND	ND
	10/19/17	ND	ND	ND
	9/7/17	ND	ND	ND
	8/23/17	ND	ND	ND

TABLE 1-1

SUMMARY OF 2016-2018 ANALYTICAL RESULTS FOR PCE, TCE, AND cis-DCE TROY WEST WELLFIELD PRODUCTION WELLS AND MW-S

Well	Date	PCE (µg/L)	TCE (µg/L)	cis-DCE (µg/L)
P-19W Continued	7/5/17	ND	ND	ND
	6/8/17	ND	ND	ND
	5/4/17	ND	ND	ND
	4/5/17	ND	ND	ND
	11/10/16	ND	ND	ND
	10/12/16	ND	ND	ND
	8/11/16	ND	ND	ND
	5/11/16	ND	ND	ND
	4/6/16	ND	ND	ND
P-16	7/12/18	ND	ND	ND
	6/7/18	**2.0**	**0.4**	**0.8**
	5/16/18	ND	ND	ND
	4/16/18	ND	ND	ND
	3/15/18*	ND	ND	ND
	1/11/18	ND	ND	ND
	12/7/17	ND	ND	ND
	11/9/17	ND	ND	ND
	10/19/17	ND	ND	ND
	9/7/17	ND	ND	ND
	8/10/17	ND	ND	ND
	7/5/17	ND	ND	ND
	6/8/17	ND	ND	ND
	5/4/17	ND	ND	ND
	4/5/17	ND	ND	ND
	3/19/17	ND	ND	ND
	2/9/17	ND	ND	ND
	1/12/17	ND	ND	ND
	12/8/16	ND	ND	ND
	11/10/16	ND	ND	ND
	10/12/16	ND	ND	ND
	8/11/16	ND	ND	ND
	6/9/16	ND	ND	ND
MW-S	10/5/16	ND	ND	ND

Notes:

Data provided by City of Troy (Troy) 2018
Bold represents detected analyte
Bold and Highlight represent analyte detection above its Maximum Contaminant Level (MCL)

* Laboratory began reporting raw data at less than the Reporting Limit (RL) and above the Method Detection Limit (MDL).
RL for PCE = 1.0 µg/L; MDL for PCE = 0.2 µg/L; EPA MCL for PCE = 5.0 ppb
RL for TCE = 1.0 µg/L; MDL for TCE = 0.2 µg/L; EPA MCL for TCE = 5.0 ppb
RL for cis-DCE = 1.0 µg/L; MDL for cis-DCE = 0.2 µg/L; EPA MCL for cis-DCE = 70 ppb

µg/L Micrograms per liter
cis-DCE cis-1,2-Dichloroethene
ND Not detected
PCE Tetrachloroethene
TCE Trichloroethene

TABLE 1-2A

HUMAN HEALTH RISK AND HAZARD SUMMARY
WEST TROY CONTAMINATED AQUIFER SITE
TROY, MIAMI COUNTY, OHIO

Exposure Area	Medium	Receptor	Land Use	Exposure Pathway	Risk	Risk COCs	HI	HI COCs
Area 1 -- Apex	Soil	--		--	--	--	--	--
	Groundwater	Industrial/ Commercial Worker	Current	VI	**3E-06**	Benzene	0.09	NA
			Future	Potable uses	**8.1E-06**	**1,4-DCB; benzene**	0.1	NA
				VI	**2.7E-06**	Benzene	0.09	NA
					1E-05		0.2	
		Construction Worker	Current/future	Dermal and inhalation	2E-08	NA	0.1	NA
		Utility Worker	Current/future	Dermal and inhalation	1E-07	NA	0.03	NA
		Resident	Future	Potable uses	**3.5E-05**	**1,4-DCB; benzene; PCE**	0.5	NA
				VI	**1.2E-05**	Benzene; CT; EB	0.3	NA
					5E-05		0.8	NA
Area 1 -- Bob's Auto	Soil	--		--	--	--	--	--
	Groundwater	Industrial/ Commercial Worker	Current	VI	**7E-06**	Benzene; 1,2-DCA; EB; **TCE**	0.9	NA
			Future	Potable uses	**8.1E-06**	**1,4-DCB; benzene**	0.1	NA
				VI	**7.3E-06**	Benzene; 1,2-DCA; EB; **TCE**	0.9	NA
					2E-05		1	
		Construction Worker	Current/future	Dermal and inhalation	5E-07	NA	0.1	NA
		Utility Worker	Current/future	Dermal and inhalation	**4E-06**	**1,4-DCB; benzene**	0.03	NA
		Resident	Future	Potable uses	**3.5E-05**	**1,4-DCB; benzene; PCE**	0.5	NA
				VI	**3.6E-05**	Benzene; 1,2-DCA; CT; EB; **TCE**	**3.6**	**TCE**
					7E-05		**4**	
Area 2	Soil	--		--	--	--	--	--
	Groundwater	Industrial/ Commercial Worker	Future	Potable uses	**1.8E-06**	**PCE**	0.4	NA
				VI	9.3E-07	NA	0.3	NA
					3E-06		0.7	
		Construction Worker	Current/future	Dermal and inhalation	7E-08	NA	0.5	NA
		Utility Worker	Current/future	Dermal and inhalation	5E-07	NA	0.1	NA
		Resident	Future	Potable uses	**6.9E-06**	**PCE; TCE**	**1.6**	**PCE**
				VI	**4.3E-06**	**PCE**	**1.1**	NA
					1E-05		**3**	

Notes:
Risk and hazard results presented in this table were summarized from exposure area-specific risk and hazad summary tables presented in the risk assessment (see Appendix I to the Remedial Investigation report).

Number	Risk ≥ 1E-06 and/or HI > 1		
PCE	**Bolded** COCs are those judged to be site-related; unbolded COCs are judged to be related largely or entirely to indoor, on-going industrial/commercial operations.		
--	No soil COPCs identified		
COC	Chemical of concern (risk ≥ 1E-06 or HI > 1)	HI	Hazard index
COPC	Chemical of potential concern	NA	Not applicable
CT	Carbon tetrachloride	PCE	Tetrachloroethene
1,4-DCB	1,4-Dichlorobenzene	TCE	Trichloroethene
EB	Ethylbenzene	VI	Vapor intrusion

TABLE 1-2B

HUMAN HEALTH RISK AND HAZARD SUMMARY -- CURRENT LAND USE
WEST TROY CONTAMINATED AQUIFER SITE
TROY, MIAMI COUNTY, OHIO

Exposure Area	Medium	Receptor	Exposure Pathway	Risk	Risk COCs	HI	HI COCs
Area 1 -- Apex	Soil	--	--	--	--	--	--
	Groundwater	Industrial/Commercial Worker	VI	**3E-06**	Benzene	0.09	NA
		Construction Worker	Dermal and inhalation	2E-08	NA	0.1	NA
		Utility Worker	Dermal and inhalation	1E-07	NA	0.03	NA
Area 1 -- Bob's Auto	Soil	--	--	--	--	--	--
	Groundwater	Industrial/Commercial Worker	VI	**7E-06**	Benzene; 1,2-DCA; EB; **TCE**	0.9	NA
		Construction Worker	Dermal and inhalation	5E-07	NA	0.1	NA
		Utility Worker	Dermal and inhalation	**4E-06**	**1,4-DCB**; **benzene**	0.03	NA
Area 2	Soil	--	--	--	--	--	--
		Construction Worker	Dermal and inhalation	7E-08	NA	0.5	NA
		Utility Worker	Dermal and inhalation	5E-07	NA	0.1	NA

Notes:

Risk and hazard results presented in this table were summarized from exposure area-specific risk and hazad summary tables presented in the risk assessment (see Appendix I to the Remedial Investigation report).

Number Risk ≥ 1E-06 and/or HI > 1

PCE **Bolded** COCs are those judged to be site-related; unbolded COCs are judged to be related largely or entirely to indoor, on-going industrial/commercial operations.

--	No soil COPCs identified	
COC	Chemical of concern (risk ≥ 1E-06 or HI > 1)	Hazard index
COPC	Chemical of potential concern	Not applicable
CT	Carbon tetrachloride	Tetrachloroethene
1,4-DCB	1,4-Dichlorobenzene	Trichloroethene
EB	Ethylbenzene	Vapor intrusion

TABLE 1-2C

HUMAN HEALTH RISK AND HAZARD SUMMARY -- FUTURE LAND USE
WEST TROY CONTAMINATED AQUIFER SITE
TROY, MIAMI COUNTY, OHIO

Exposure Area	Medium	Receptor	Exposure Pathway	Risk	Risk COCs	HI	HI COCs
Area 1 -- Apex	Soil	--	--	--	--	--	--
	Groundwater	Industrial/Commercial Worker	Potable uses	**8.1E-06**	**1,4-DCB; benzene**	0.1	NA
			VI	**2.7E-06**	Benzene	0.09	NA
				1E-05		0.2	
		Construction Worker	Dermal and inhalation	2E-08	NA	0.1	NA
		Utility Worker	Dermal and inhalation	1E-07	NA	0.03	NA
		Resident	Potable uses	**3.5E-05**	**1,4-DCB; benzene; PCE**	0.5	NA
			VI	**1.2E-05**	Benzene; CT; EB	0.3	NA
				5E-05		0.8	NA
Area 1 -- Bob's Auto	Soil	--	--	--	--	--	--
	Groundwater	Industrial/Commercial Worker	Potable uses	**8.1E-06**	**1,4-DCB; benzene**	0.1	NA
			VI	**7.3E-06**	Benzene; 1,2-DCA; EB; **TCE**	0.9	NA
				2E-05		1	
		Construction Worker	Dermal and inhalation	5E-07	NA	0.1	NA
		Utility Worker	Dermal and inhalation	**4E-06**	**1,4-DCB; benzene**	0.03	NA
		Resident	Potable uses	**3.5E-05**	**1,4-DCB; benzene; PCE**	0.5	NA
			VI	**3.6E-05**	Benzene; 1,2-DCA; CT; EB; **TCE**	**3.6**	**TCE**
				7E-05		**4**	
Area 2	Soil	--	--	--	--	--	--
	Groundwater	Industrial/Commercial Worker	Potable uses	**1.8E-06**	**PCE**	0.4	NA
			VI	9.3E-07	NA	0.3	NA
				3E-06		0.7	
		Construction Worker	Dermal and inhalation	7E-08	NA	0.5	NA
		Utility Worker	Dermal and inhalation	5E-07	NA	0.1	NA
		Resident	Potable uses	**6.9E-06**	**PCE; TCE**	**1.6**	**PCE**
			VI	**4.3E-06**	**PCE**	**1.1**	NA
				1E-05		**3**	

Notes:

Risk and hazard results presented in this table were summarized from exposure area-specific risk and hazad summary tables presented in the risk assessment (see Appendix I to the Remedial Investigation report).

Number	Risk ≥ 1E-06 and/or HI > 1	
PCE	**Bolded** COCs are those judged to be site-related; unbolded COCs are judged to be related largely or entirely to indoor, on-going industrial/commercial operations.	
--	No soil COPCs identified	
COC	Chemical of concern (risk ≥ 1E-06 or HI > 1)	Hazard index
COPC	Chemical of potential concern	Not applicable
CT	Carbon tetrachloride	Tetrachloroethene
1,4-DCB	1,4-Dichlorobenzene	Trichloroethene
EB	Ethylbenzene	Vapor intrusion

TABLE 6-1
GROUNDWATER REMEDIAL ALTERNATIVES - DETAILED ANALYSIS SUMMARY

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume (TMV) Through Treatment	Short-Term Effectiveness	Implementability	Cost	Sustainability
GW-1: No Action	Not protective.	Does not comply	Not an effective or permanent remedy. Relies on perpetual operation of existing municipal well air stripper to deliver clean water to the public. Does not protect private well users. Does not protect potential future residents from vapor intrusion.	Does not reduce TMV through treatment.	Does not pose new risks to workers, community, or environment, although existing risk would continue.	Easy to implement physically because no action would be taken; however, not administratively implementable because it is not protective.	$0	Does not consume energy or resources but does not restore a degraded natural resource.
GW-3A: In Situ Treatment Using AS/SVE, ICs, and Monitoring	Is protective. The combination of in situ groundwater treatment and ICs adequately addresses site-related groundwater risks. Groundwater cleanup challenged by fine-grained soils. Poses no significant threat to municipal wells.	Complies	Removes contaminants from groundwater. AS is more effective for coarse-grained soils than fine-grained soils and its effectiveness would be limited in fine-grained soils. Contaminants remaining in fine-grained soils could re-contaminate groundwater after treatment. Fine-grained soils in the vadose zone may also limit recovery of sparged vapors. Extracted vapors would be safely released to the atmosphere. ICs and monitoring would prevent exposure to contaminants and track remedial progress until MCLs have been attained.	Does not reduce TMV of chlorinated VOC contaminants through treatment. Chlorinated VOCs would be transferred from groundwater to the atmosphere where they would slowly degrade naturally. Some in situ aerobic destruction of benzene would occur through treatment.	Controllable risk to workers from construction and chemical hazards. Minimal risk to workers and community from contaminants. AS/SVE has minimal effect on geochemistry and is unlikely to negatively impact municipal wells. SVE would reduce vapor intrusion risk and risk from exhausting untreated vapors to the atmosphere would be insignificant. Groundwater mounding caused by sparging within treatment areas could temporarily affect localized groundwater flow.	Moderately difficult to implement. Requires many permanent remediation wells, buried piping, and process equipment. Also requires access to properties for construction of system infrastructure, O&M, and long-term monitoring.	$4.67 M	Consumes energy but aids in the restoration of a natural resource. May ultimately conserve energy by eventually removing the need for pre-treatment of municipal water.
GW-3B: In Situ Treatment Using ISCO, ICs, and Monitoring	Is protective. The combination of in situ groundwater treatment and ICs adequately addresses site-related groundwater risks. Controllable risk from physical and chemical hazards to workers and community.	Complies	Destroys contaminants. ISCO is highly effective in coarse-grained soils and somewhat effective in fine-grained soils. Un-oxidized contaminants remaining in fine-grained soil could re-contaminate groundwater after treatment. Naturally occurring organic matter could increase oxidant demand. ISCO may form oxidation byproducts that could be controlled. Potential vapor intrusion generated by some ISCO methods may require vapor monitoring and possibly mitigation. ICs and monitoring would prevent exposure to contaminants and track remedial progress until cleanup objectives have been attained.	Reduces toxicity and volume through treatment. Destroys contaminants in place.	Controllable risk to workers from construction and chemical hazards. Minimal risk to workers from contaminants. No risk to community from contaminants. Some risk of spills on public property if liquid oxidants transported to site. Controllable risk of ozone intrusion into indoor air during remediation. Localized groundwater mounding may occur but is not expected to be significant because of low and intermittent air flow rates.	Moderately difficult to implement. Requires many permanent injection wells, buried piping, process equipment, and automation. Also requires access to properties for construction of system infrastructure, O&M, and long-term monitoring. Expected to receive administrative approval.	$6.06 M	Consumes energy but aids in the restoration of a natural resource. May ultimately conserve energy by eventually removing the need for pre-treatment of municipal water.

TABLE 6-1
GROUNDWATER REMEDIAL ALTERNATIVES - DETAILED ANALYSIS SUMMARY

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume (TMV) Through Treatment	Short-Term Effectiveness	Implementability	Cost	Sustainability
GW-3C: In Situ Treatment Using Aerobic Bioremediation, ICs, and Monitoring	Is protective. The combination of in situ groundwater treatment and ICs adequately addresses site-related groundwater risks. Controllable risk to workers and community during implementation.	Complies	Destroys contaminants. Effective in both permeable and low-permeability soils. Targets contamination using a dense injection grid (horizontally and vertically). Residual contamination remaining after treatment would decline over time. Slight reduction in formation permeability may occur if solid peroxides are used as oxygen source. Treatment intermediates are not expected to migrate to municipal wells. Any changes in groundwater geochemistry resulting from treatment would occur locally (within the treatment area) and are not expected to adversely impact the municipal wells. Potential harmful effects could be controlled proactively because of limitations of contingency actions. ICs and monitoring would prevent exposure to contaminants and track remedial progress until cleanup objectives have been attained.	Reduces toxicity and volume through treatment. Biodegrades contaminants in place.	Controllable risk to workers from construction and chemical hazards. Minimal risk to workers from contaminants. No risk to community from contaminants. Some risk of spills on public property if solid peroxide amendments transported to site. Potential spills of other remediation amendments not a significant concern.	Uses direct push injection which would require no infrastructure. Injection methods requiring infrastructure, such as biosparging, are optional. Injection would take significant effort because of multiple events targeting many injection points. Also requires access to properties for implementation, O&M, and long-term monitoring.	$5.93 M	Consumes energy but aids in the restoration of a natural resource. May ultimately conserve energy by eventually removing the need for pre-treatment of municipal water.
GW-4: Extraction, Treatment and Discharge, ICs, and Monitoring	Is protective. The combination of groundwater extraction and ex situ treatment and ICs adequately addresses site-related groundwater risks.	Complies	Effectively captures groundwater and removes VOCs using ex situ treatment. Hydraulic control would prevent migration of contaminated groundwater to municipal wells. Groundwater may not be cleaned up in a reasonable duration. Would not target contamination in low-permeability soils. ICs and monitoring would prevent exposure to contaminants and track remedial progress until remediation goals have been attained.	Does not reduce TMV through treatment. Contaminants are transferred from liquid to vapor phase and discharged to the atmosphere without treatment. Reduces plume mobility through hydraulic control.	Controllable risk to workers from construction hazards. Minimal risk to workers and community from contaminants. No risk to municipal wells. Air stripper treating extracted groundwater would discharge contaminants to the atmosphere without treatment; no significant risk from such discharge.	Fairly easy to implement, and requires minimal infrastructure. Also requires access to properties for construction of system infrastructure, O&M, and long-term monitoring.	$4.62 M	Consumes energy but aids in the restoration of a natural resource. May offset energy required for pre-treatment of municipal water.

Notes:

ARAR Applicable or relevant and appropriate requirement
AS Air sparging
DCE Dichloroethene
IC Institutional control
ISCO In situ chemical oxidation
M Million
MCL Maximum contaminant level
O&M Operation and maintenance
SVE Soil vapor extraction
TMV Toxicity, mobility, or volume
VOC Volatile organic compound

TABLE 6-2
PRIVATE WELL REMEDIAL ALTERNATIVES - DETAILED ANALYSIS SUMMARY

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume (TMV) Through Treatment	Short-Term Effectiveness	Implementability	Cost	Sustainability
PR-1: No Action	Not protective	Does not comply	Would not prevent consumption of contaminated groundwater; some risk would continue although water is not used for drinking. Risk will persist until groundwater remediation is complete.	Does not reduce TMV	Would not pose new risk although existing risk will persist until groundwater remediation is complete.	Easily implementable physically because no action would be taken; however, not administratively implementable because it is not protective.	$0	Does not consume energy or resources but does not protect human health.
PR-2: Treatment and Monitoring	Protects human health if water filter is monitored and maintained. Protects environment because contaminated water would not be discharged into sewers.	Complies	Effective if water filter is monitored and maintained until groundwater remediation is complete. ICs and monitoring would also help prevent exposure to contaminants by ensuring that filter is effectively removing contaminants from water.	Permanently reduces contaminant mobility through sorption to treatment media.	Minimal risk to workers from contamination during installation and maintenance of water filter.	Fairly easy to implement. Can only be implemented with groundwater remedies that do not alter geochemistry.	$55,000	Moderately sustainable because it expends resources while protecting human health
PR-3: Connect to City Water and Abandon Private Well	Protects human health by providing a source of clean water. Protects environment because contaminated water would not be used or discharged into sewers.	Complies	Permanently prevents use of contaminated groundwater without monitoring or maintenance.	Does not reduce TMV	Minimal risk to workers from construction activities and contaminated groundwater.	Moderately easy to implement physically. Would require trenching or horizontal drilling beneath a street to connect to city water main. Apex Racing property is outside of the city limits. So administratively implement would require annexation of property into city limits and owner consent.	$47,000	Highly sustainable because fewer resources expended to protect human health.

Notes:

ARAR Applicable or relevant and appropriate requirement
IC Institutional control
TMV Toxicity, mobility, or volume

TABLE 6-3
VAPOR INTRUSION REMEDIAL ALTERNATIVES - DETAILED ANALYSIS SUMMARY

Alternative	Overall Protection of Human Health and Environment	Compliance with ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume (TMV) Through Treatment	Short-Term Effectiveness	Implementability	Cost	Sustainability
VI-1: No Action	Not protective of future hypothetical residents.	Does not comply	Not an effective or permanent remedy. There is no current VI risk; however, it does not protect potential future residents from VI if groundwater remains contaminated.	Does not reduce TMV.	Does not pose a short-term risk to workers, community, or environment.	Physically implementable because no action would be taken; however, not administratively feasible because it is not protective of potential future residents.	$0	Does not consume energy or resources but is not sustainable because it does not protect human health.
VI-2: ICs and Monitoring	Protective of future hypothetical residents because ICs would protect future building occupants at risk and monitoring would ensure occupant safety.	Complies	Effective because ICs would require VI risk to be mitigated if it exists. However, effectiveness would be subject to enforcement of ICs and proper operation and maintenance of VI mitigation systems installed. Monitoring would ensure that measures are effective.	Not likely to reduce TMV because treatment is not anticipated.	Does not pose a short-term risk to workers, community, or environment because ICs are administrative and do not involve remedial activities or construction.	ICs could be implemented easily. Also requires access to properties for long-term monitoring.	$105,000	ICs do not consume energy or resources; therefore, it is sustainable because it protects human health with minimal effort.

Notes:

ARAR Applicable or relevant and appropriate requirement
IC Institutional control
TMV Toxicity, mobility, or volume
VI Vapor intrusion