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From: Clark, Lisa <LClark@trccompanies.com>
Sent: Thursday, December 9, 2021 3:04 PM
To: Kuhn, Kimberly M. <kuhnkm@dhec.sc.gov>
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Subject: Revised Focused Feasibility Study Report - former WestPoint Home Site, Clemson, South Carolina - DHEC File #20395

Kimberly,

The Ad Hoc link below will direct you to the revised Focused Feasibility Study Report for the former WestPoint Home Site in Clemson, South Carolina. The report cover letter is attached as a PDF. If you have any problems accessing the file, please let me know.

https://adhocftp.trccompanies.com:443/AHT/AHT_UI/public/#/password?package=G%2f8BGH0JxH6OunJnfs7T%2bsF0nawMRTrJsgRKWE%2fm7U3rFwzZ105POk4HROjpiCYKB%2bRCkJeq1%2fXt%2fqb%2bElhRSChtektgcgWDP5P7epABABY%3d

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WESTPOINT
HOME

December 9, 2021

Ms. Kimberly M. Kuhn
Project Manager
State Voluntary Clean-up Program
Bureau of Land and Waste Management
South Carolina Department of Health and Environmental Control
2600 Bull Street
Columbia, South Carolina 29201

Subject: Revised Focused Feasibility Study
WestPoint Home Inc., Former Clemson, South Carolina Site
Oconee County
File #20395

Dear Ms. Kuhn:

Attached is the revised Focused Feasibility Study Report prepared for the WestPoint Home, Inc. former Clemson, South Carolina facility. This report has been revised to address comments issued by the South Carolina Department of Health and Environmental Control dated October 28, 2021.

We look forward to concluding the FFS and moving forward with the next steps in the regulatory process of identifying and certifying a suitable and appropriate site remedy.

Sincerely,

WestPoint Home LLC

Julie A. Seel

Julie Seel
Director/Environmental Department

Attachments: Revised FFS

cc: Steve W. Webb, TRC
Lucas Berresford, BLWM
Chris McCluskey, Upstate Region BEHS Office
Lisa Clark, TRC

Focused Feasibility Study Report

For Remediation of VOC-Affected Groundwater

WestPoint Home, Inc.
Former Clemson, South Carolina, Facility

August 2017, Revised December 2021

Joyce E. Peterson, P.E.
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List of Acronyms

AOC	Administrative Order by Consent
ARARs	applicable or relevant and appropriate requirements
AST	Aboveground storage tank
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituent of concern
COPC	constituent of potential concern
CSM	Conceptual site model
DPT	direct push technology
ERD	Enhanced Reductive Dechlorination
ESA	Environmental site assessment
FFS	Focused Feasibility Study
FS	Feasibility Study
HI	hazard index
ISCO	*In situ* Chemical Oxidation
MCL	Maximum Contaminant Level
MNA	monitored natural attenuation
msl	mean sea level
NCP	National Contingency Plan
NPL	National Priority List
NPV	Net Present Value
OBC	Oxygen Bio Chem
O&M	operations and maintenance
PPE	personnel protection equipment
PRB	Permeable reactive barrier
PRP	potentially responsible party
psi	pounds per square inch
RA	Remedial Action
RAO	remedial action objective

RD	Remedial Design
REC	Recognized environmental condition
RGO	remedial goal option
RI	Remedial Investigation
SC DHEC	South Carolina Department of Health and Environmental Control
SCS	Soil Conservation Service
SI	site inspection
SMCL	South Carolina Maximum Contaminant Level
SOW	Statement of Work
TBC	to-be-considered
UIC	underground injection control
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
UST	Underground storage tank
VCC	Voluntary Clean-up Contract
VOC	volatile organic compound
WWTP	Wastewater treatment plant
ZVI	Zero valent iron

Section 1
Introduction

The former WestPoint Home (WPH) textile manufacturing facility (Site) is located on West Cherry Road in Oconee County, southeast of and across Hartwell Lake from the city of Clemson, South Carolina. The Site address is 679 Edinburgh Way, Seneca, South Carolina 29678. The Site location is shown on Figure 1-1. During its period of active operation, the textile facility was primarily used for the manufacturing of sheeting fabric. The facility was closed in April 2006 and subsequently purchased by a consortium of local business entrepreneurs having an interest in redeveloping the former industrial property as a State-approved Brownfield Redevelopment Project. Ongoing Site development activities have included construction of a number of large apartment complexes for students enrolled in Clemson University's "Bridge Program" (situated along the northern side of West Cherry Road) and a mixed-use assortment of various residential houses, duplexes and town homes along the southern side of West Cherry Road. To date, construction has been limited to areas outside the footprint of the tetrachloroethene (PCE)-affected groundwater. However, with development nearly complete in the other areas of the property, the site owners have recently expressed their interest and desire to further expand development efforts into PCE-affected groundwater areas.

The ongoing Site investigation and remediation work at the former WPH textile facility has been conducted under the review and oversight of the South Carolina Department of Health and Environmental Control (SC DHEC). These Site investigation and remediation activities have been conducted under the terms and conditions of Consent Agreement 06-163-W, which is overseen by SC DHEC's Bureau of Land and Waste Management - State Remediation Section (reference File #20395 - former Site #00895). The property redevelopment team is also working with SC DHEC staff under the terms of a separate Brownfield Redevelopment Agreement (also referred to as a Voluntary Clean-Up Contract [VCC]).

1.1 Background

The Site was originally designed and constructed as a major textile production facility in 1951 by the J.P. Stevens Company. The facility was subsequently acquired by WestPoint Pepperell in 1989, a company that later changed its corporate name to WestPoint Stevens. The original building footprint was constructed in 1951, with several additional plant expansions occurring in 1955, 1959, 1962, 1974, and 1990. The Clemson manufacturing complex was operated as an integrated textile manufacturing facility that produced a wide variety of finished textile fabrics, including flat and fitted sheets and pillowcases. On-site production operations include a greige mill, a dyeing and finishing plant, and a fabricating plant. Operations conducted at the plant included making cloth fabric from cotton and polyester fibers, dyeing and printing of the cloth, finishing the cloth, and fabricating bedding from the finished cloth fabrics.

Following more than 50 years of active production operations, the Clemson site was closed in 2006. In preparation for the sale of the site, a Phase I Environmental Assessment was prepared that designated several areas of possible environmental concern. A Phase II investigation was performed in these areas, and also included the former coal pile storage area (used to fire the on-site boilers). Groundwater sampling conducted at the Site revealed the presence of PCE in groundwater. Expanded sampling was conducted across the Site to locate the source of the groundwater contamination. During these sampling activities, laboratory analyses also identified the presence of ethylbenzene and xylene in the soils and groundwater samples collected adjacent to the former mill building. Upon review of historical records and employee interviews, it was determined that an aboveground Varsol tank had been removed from an upgradient location as part of a prior building expansion.

Once this area was identified and the soil contamination confirmed (March 2006), WPH initiated a removal action to excavate and properly dispose of the contaminated soil. During this soil removal action, the contractor encountered residual evidence of underground storage tank (UST) saddles, at depth, within the area of concern. These UST saddles were previously installed to support prior USTs that had also been removed at some time in the past. There was also evidence that sand had been used for backfill, presumably as the USTs were removed. These concrete saddles were identified at a depth of approximately 18 feet below ground surface (bgs).

Laboratory analysis of the soil and groundwater samples from this area identified the presence of ethylbenzene and xylene. However, PCE was not detected in the subsurface soils of this area, occurring only within the groundwater samples. The analytical data didn’t appear to indicate that the PCE observed in the Site groundwater was sourced from these former USTs.

These findings initiated a series of Site investigations and interim remedial measures that are more fully described in Section 2 of this Focused Feasibility Study (FFS). Ultimately, four areas of the Site were identified as possible source areas for the observed release of PCE to the groundwater. These possible source areas were identified through review of plant records and employee interviews of staff familiar with historical textile production operations. More details on these sources of the Site constituents of concern (COC) into the underlying Site groundwater are provided later in this FFS.

This Focused Feasibility Study has been developed to provide SC DHEC with a detailed summary and evaluation of various remedial technologies that have been identified as best suited and applicable to address observed Site conditions, taking into account the current/future land-use applications that are anticipated for the property. The technical details and discussion that follow have been prepared to provide the Department with a suitable basis upon which to develop a regulatory strategy for selecting a treatment alternative that will suitably address groundwater impacts that have been identified and documented within the underlying groundwater of the former WPH facility.

1.2 Report Organization

This FFS report for the Site was developed in general accordance with *USEPA RI/FS Guidance* (USEPA, 1988). The contents of this report are organized as follows:

- **Section 1: Introduction** – provides a general overview of Site history and facility details**.**
- **Section 2: Existing Conditions** — provides a summary of the previous groundwater and soil investigations conducted at the Site and provides a summary of the affected media and constituents of concern.
- **Section 3: Site Conceptual Model** – summarizes the conceptual Site model that has been developed to describe transport and migration of constituents of concern (COCs) and potential exposure identified at the Site.
- **Section 4: Identification of Applicable or Relevant and Appropriate Requirements** — contains a summary of chemical-specific, location-specific, and action-specific ARARs identified for the Site.
- **Section 5: Development of Remedial Action Objectives** — summarizes the constituents of concern, discusses allowable exposures reflective of risk-based considerations and the relevant state and federal ARARs. The site RAOs, representing refined and numerical remediation target concentrations for the various affected media, are presented.
- **Section 6: Identification and Screening of Remedial Technologies** — identifies and screens a range of different remediation techniques and methods that could potentially be applied for use in the remediation of the affected media and COCs detected at the site.
- **Section 7: Development and Evaluation of Remedial Alternatives** — assembles the remediation techniques/methods that are more suitable for existing Site conditions into remedial alternatives that could be reasonably implemented to address the affected media and COCs. These remedial alternatives are then evaluated with respect to the various threshold and balancing criteria established by USEPA guidance.
- **Section 8: Comparative Analysis of Remedial Action Alternatives** —contains a comparison of the alternatives that were evaluated in Section 7, including statutory requirements, as well as, effectiveness, implementability, and cost. This Section compares the remedial alternatives using the balancing criteria set forth by the USEPA guidance documents.
- **Section 9: References** — provides reference citations for documents and reports discussed in this FFS.

BASE MAP FROM USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE SERIES.

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1 " = 3,000 '
1:36,000

0 1,100 2,200
FEET

TRC

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Patewood Plaza Three
Greenville, SC 29615
Phone: 864.281.0030

TRC - GIS

PROJECT:

WESTPOINT HOME, INC.
CLEMSON, SOUTH CAROLINA

TITLE:

LOCATION OF FORMER
WESTPOINT HOME SITE

DRAWN BY:	RWIXON
CHECKED BY:	LCLARK
APPROVED BY:	LCLARK
DATE:	AUGUST 2021
PROJ. NO.:	450113.0000.0000
FILE:	Fig 1-1_Site location_2021.mxd

Figure 1-1

Section 2
Existing Conditions

The following narrative presents a summary of the current conditions that have been documented at the Site. The Site conditions described in this section of the FFS have been compiled from numerous field investigations and sampling events that have been conducted at the Site since 2008 and extending forward to the present day.

2.1 Site Location, Setting and Land Use

The Site is located on a peninsula of land that extends along the western shore of Hartwell Lake just south of West Cherry Road, which crosses Hartwell Lake about 2 miles south of the city of Clemson. During the time of WPH's ownership, the Site encompassed approximately 384 acres. This property has subsequently been subdivided for ongoing redevelopment. Of this total acreage, the portion of the Site relevant to this FFS encompasses approximately 191.7 acres. Of this total, approximately 16 acres have been determined to be underlain by VOC-affected groundwater.

The Site is currently in the process of redevelopment activities involving construction of student housing and mixed-use residential communities. The property development team has entered into a Brownfield Agreement (Voluntary Cleanup Contract 07-4895-NRP) with SC DHEC. Recognizing the possible environmental and health consequences of conducting residential development activities within the VOC plume areas, the site developer had previously delayed active development activities within the footprint of the property underlain by VOC-affected groundwater.

As Site redevelopment has continued and been completed outside the VOC-affected groundwater area, the property owner has recently expressed a desire to begin construction activities within the VOC plume area. Figure 2-1 provides a site map showing the planned extent of recent Site redevelopment activities and the underlying zone of the VOC-affected groundwater plume areas.

Within the immediate vicinity of the VOC-affected groundwater area, the Site exhibits approximately 25 feet of topographic relief, extending from the footprint of the former textile manufacturing complex for a distance of about 1400 feet (in a southeasterly direction) to the shoreline of Hartwell Lake. The former WPH facility was constructed on a topographic high that generally slopes to the east-southeast, towards Hartwell Lake. The land surface elevation at the former manufacturing building is approximately 685 feet above mean sea level (msl). The elevation of Hartwell Lake at full pool level is 660 feet above msl.

Hartwell Lake is a reservoir constructed by the US Army Corps of Engineers (USACE) between 1955 and 1963 for flood control and hydropower. The lake encompasses approximately 56,000 acres and has a shoreline of about 962 miles. In addition to its flood control and hydropower uses, the lake also provides recreational use for local communities, municipal and industrial water supply, and fish and wildlife habitat.

2.2 Surrounding Areas

The area immediately surrounding the Site can be seen on the Site Location Map (Figure 1-1). Figure 2-1a shows the immediate surrounding area in greater detail. The Site is located in a rural/wooded area surrounded on three sides (i.e., east, south, and west) by Hartwell Lake. Along the lakefront on the west side of the Site lies Martin Creek, an inlet characterized by low-density, lake-front residential housing. The property north of West Cherry Road (also part of the former WPH Site) has already been developed into mixed-use apartment housing generally targeted for students enrolled in Clemson University's Bridge Program. To the north and west of this developed area, there is low-density residential housing development. The shoreline along Hartwell Lake opposite the Site is generally undeveloped or low-density residential development.

Jacabb Utilities currently owns and conducts wastewater treatment operations on a 7.6-acre parcel that is completely surrounded by the Site. This area contains the wastewater treatment plant (WWTP) that was formerly operated by WPH. The wastewater treatment equipment has been repurposed to address treatment of wastewater generated by the various Site developments. The permitted NPDES discharge outfall for the WWTP is located at the southernmost end of the Site, making use of the same NPDES outfall structure that was previously utilized by WPH during its period of textile manufacturing operations.

2.3 Geologic and Hydrogeologic Conditions

The Site is located within the Piedmont Physiographic Province of South Carolina and, as such, is generally underlain by massive, crystalline bedrock. Bedrock in this area consists of igneous and metamorphic rocks with low permeability, and is generally characterized by moderate relief and gently sloping topographic features.

The Wickham Series sandy loam soil association underlies the immediate Site area. The soil is generally deep, well drained, and developed in old alluvium on second bottoms or low terraces along larger streams. According to the Soil Conversation Service (SCS), the surface layer commonly is brown to dark-brown, friable sandy loam and the subsoil is red to dark-red clay loam.

Based on the soil boring logs prepared during installation of Site groundwater monitoring wells, four lithostratigraphic units were identified beneath the site, including the following:

- ***Fill or disturbed material*** – predominately silt, clay and sand associated with the former building structures and grading activities.
- ***Saprolite*** – a highly weathered, disintegrating rock containing a high percentage of silt and clay and retaining evidence of former rock structure and fabric.
- ***Transition Zone*** – a somewhat less weathered rock containing a higher percentage of sand and gravel.
- ***Shallow Bedrock*** – which predominately occurred as a biotite gneiss, exhibiting an abundance of shallow fractures.

Groundwater beneath the Site generally occurs under unconfined conditions. Groundwater present within each of the three lithostratigraphic units (*i.e.*, saprolite, transition zone, and shallow bedrock) is considered to be hydraulically interconnected. Based upon these observations, each of these four units is considered to comprise a single unconfined aquifer beneath the Site.

The calculated hydraulic gradient of the Site water table was observed to range from approximately 0.007 to 0.01 feet/foot, becoming steeper as the groundwater flow approaches Hartwell Lake. Similar conditions were observed within the potentiometric surface of the intermediate zone, where hydraulic gradients also ranged from approximately 0.007 to 0.01 feet/foot. The hydraulic gradients observed within the top of competent rock and shallow bedrock zone wells were generally consistent across the Site, with values ranging from 0.007 to 0.009 feet/foot.

Hydraulic conductivity values were determined through the performance of slug testing procedures at selected monitoring wells located within each zone. Effective porosity values were estimated based on the consistency of the soil materials encountered during well installation. Preliminary estimates for groundwater flow rates range from 25 to 150 ft/year within the shallow saprolite, 25 to 50 ft/year within the intermediate saprolite, 4 to 6 ft/year within the transition zone and shallow bedrock. Due to the nature of slug testing on wells screened across the water table, groundwater flow estimates for the shallow saprolite unit may be biased high.

Vertical gradients have also been calculated within the VOC-affected groundwater plume areas. Downward flow gradients were observed within the upland areas. These flow gradients gradually shift to upward flow gradients, as groundwater approaches and discharges into Hartwell Lake. Figures 2-2 and 2-3 are geological cross-sections along the upgradient and downgradient plumes that also include details regarding vertical flow gradients.

2.4 Summary of Site Investigations and Interim Measures

A Phase 1 Environmental Site Assessment (ESA) was conducted by RMT, Inc., (RMT) in March 2005, at the request of WPH, to identify and document recognized environmental conditions (RECs) at the Site. A Phase 2 ESA was conducted by PSC Industrial Outsourcing L.P. (PSC) in November 2005 to evaluate the

Recognized Environmental Conditions (RECs) documented in the Phase 1 ESA. The Phase 2 ESA identified three additional RECs, including a former UST, a former Varsol aboveground storage tank (AST), and a facility storage area initially suspected as a potential source of PCE detected in the groundwater. Field activities conducted during the period of February through August 2006 investigated these areas. During this timeframe, PSC installed numerous groundwater monitoring wells across the Site.

While PSC was investigating the presence of ethylbenzene and xylene in the area near the site of the former Varsol AST (March 2006), laboratory analysis of soil samples identified the presence of other COCs that were determined to be residuals from a previously removed/closed UST. PSC conducted a removal action, during which approximately 1,877 tons of VOC-affected soil materials were excavated from the former UST area and transported off-site for disposal. The resulting excavation from this removal effort extended to a depth of about 21 feet, approximately the uppermost extent of the Site groundwater table. Prior to backfilling the excavation, PSC introduced approximately 1,925 pounds of a commercially available bioremediation compound known as OBC (Oxygen Bio Chem). The OBC was placed along the base of the excavation, ostensibly to address treatment of residual organic contaminants that might be present in the groundwater.

In September 2008, surface water and underlying sediment pore water samples were collected by RMT (later acquired by TRC Environmental Corporation [TRC]) from 11 locations along the shoreline of Hartwell Lake. PCE was detected in four of these pore water samples. Trichloroethene (TCE) was detected in two of these four pore water samples and *cis*-1,2-Dichloroethene (DCE) was detected in one of these four pore water samples. The PCE concentrations observed in the pore water samples ranged from 0.00062 mg/L to 0.0047 mg/L. PCE was the only VOC detected in any of the surface water samples. It was detected in five of the near-shore surface water samples at concentrations ranging from 0.00047 mg/L to 0.0034 mg/L. PCE was not detected in any of the offshore surface water samples.

Also in September 2008, RMT conducted an expanded Site investigation using membrane interface probe (MIP) technology to provide enhanced delineation of the VOC-affected groundwater areas and to determine whether there was a meaningful source of vadose zone source materials. This January 2009 MIP study, applied in conjunction with groundwater monitoring data collected using direct-push technology (DPT), provided refined delineations of the extent of VOCs in groundwater. The findings of this field effort suggested the presence of what appeared to be two VOC plumes emanating from two different source areas. The findings of these MIP studies provided support to the hypothesis that historical releases from process sewer lines associated with former WPH facility operations represent the likely source of the VOCs observed within the groundwater. Over the years, this observation has received further support, as vadose zone COCs have never been detected at the Site and elevated VOC levels are consistently encountered at depths at or below the observed water table (approximately 20 ft bgs).

Expanded soil sampling was conducted in February 2009 within targeted areas of process sewer lines to investigate whether these areas represented possible VOC source areas for the elevated VOCs observed in the Site groundwater. In July 2009, a number of test pits were installed at key junctions of the process sewer lines to access the underground piping and collect representative samples of the nearby soils and sludge residuals. While a few of these test pit locations were found to exhibit elevated VOC readings in soil gas samples, VOC-affected soils were not encountered at levels that would represent a meaningful vadose zone source area.

In 2010, the Site property owner advised WPH of its intent to expand Site redevelopment activities into closer proximity of the two VOC plume areas. Site drawings were shared that revealed the property development team would soon be installing roadways and various infrastructure improvements that, based on their proposed locations, would pose a risk of damage or destruction to a number of existing WPH monitoring wells. In January 2011, WPH conducted an abandonment of 28 Site monitoring wells in anticipation of these pending Site redevelopment activities.

Additional soil samples were collected in August 2013 in an attempt to locate and delineate possible VOC source areas to the groundwater. The results of these field efforts continued to indicate that the source of VOC releases occurred at depths at or below the observed groundwater table. The underground process sewer lines of the former WPH Site continue to represent the most compelling and logical point of release for these observed COCs. Within each of the two VOC plume areas (now designated as Upgradient and Downgradient VOC plume areas), TRC has been able to identify sections) of former process sewer piping that are situated along the upgradient end of these two VOC plume areas. Historical releases from former Site process piping continues to represent the most likely source of PCE into the groundwater of these areas.

During the period of April 1 through June 17, 2014, WPH installed 17 new wells to replace wells that had previously been abandoned for Site redevelopment. During this same timeframe, 36 new monitoring wells were installed to help address horizontal and vertical data gaps that were identified within the Upgradient and Downgradient VOC plume areas. These monitoring wells were generally installed at four designated depth intervals, including wells bracketing the water table, across the intermediate saprolite zone, along the top of bedrock (transition zone), and within shallow bedrock.

Groundwater samples were collected from the monitoring well network in July 2014. In addition, pore water and surface water samples were collected from the shoreline of Hartwell Lake. The results of the investigation revealed additional data gaps in the delineation of the VOC-affected groundwater areas. Ten additional monitoring wells were installed in May 2015 and sampled in June 2015. The resulting Site delineation was provided to SC DHEC in a report titled *Addendum to October 2014 Groundwater and Surface Water Investigation Report for WestPoint Home (WPH) Clemson Site, Site ID #00895* (TRC, August 2015).

The locations of the wells comprising the current groundwater monitoring system are shown on Figure 2-4. Table 2-1 provides a listing of the current performance monitoring well network, along with key well construction details.

2.5 ABC+ Pilot Studies

In 2015, a pilot study was proposed to SC DHEC as a means of evaluating an emerging treatment technology that was identified by TRC as reasonable and appropriate for addressing Site conditions. A pilot study was suggested because SC DHEC staff were not familiar with the proposed treatment technology and because the implementability of the treatment technology was uncertain given the subsurface/geological conditions of the Site.

The pilot study was developed to evaluate a treatment technology developed by Redox Tech, LLC, (Redox Tech) that utilizes an innovative treatment product that is commercially available under the trade name of ABC+® (ABC+), which is an acronym for "Anaerobic BioChem Plus." This treatment formulation involves a combination of Redox Tech's standard Enhanced Reductive Dechlorination (ERD) treatment formulation (ABC®), that has been supplemented with finely milled zero valent iron (ZVI) particles. Thus, ABC+ represents a treatment technology that effectively embodies both a robust means of stimulating anaerobic ERD activity in the subsurface groundwater and a reactive ZVI component that provides an ongoing, supplemental physical-chemical treatment aide.

TRC has had prior experience with the efficacy of ABC+ treatment, but was interested in determining whether the ABC+ treatment media could be successfully introduced into the subsurface of the Site via DPT injection. TRC's prior work within the fractured rock environments of the South Carolina Upstate has revealed technical challenges with attempting to advance DPT borings to depths greater than 30-40 feet. If DPT could be conducted to depths greater than 50 feet at the Site, ABC+ could be applied to depths representing the highest PCE concentrations within the Upgradient and Downgradient VOC plumes.

2.5.1 2016 ABC+ Pilot Study

The initial ABC+ pilot study was conducted at the Site between June 2016 and March 2017. The pilot study was conducted at two locations; one injection area situated near the head of the Upgradient VOC plume and the other injection area located near the head of the Downgradient VOC plume. A key objective of the pilot study was to evaluate the maximum depth to which direct-push injection could extend at the Site, as the ability to deliver treatment chemicals to the appropriate depths in the aquifer was identified as an important key to the potential success of this treatment technology. At both targeted pilot study injection areas, TRC was able to successfully deploy DPT treatment across the entire extent of the saprolite zone (i.e., 70 to 76 feet bgs). This was a significant achievement because it indicated that the more highly impacted aquifer zones could be treated directly using DPT technology. Treatment injections at depths greater than 50 feet bls would also be expected to disperse and migrate into deeper aquifer zones. This pilot study finding has significance not only for the ABC+ treatment alternative, but for the other in-situ treatment alternatives including In-situ Chemical Oxidation (ISCO) and ERD.

During the 2016 pilot study, ABC$^+$ injections were conducted via three injection points at each of the two pilot study areas. 200-gallon injections were made at 5-foot intervals from depths of 55 feet bls and extending upward to 15 feet bls. The injection pressures were generally 200 pounds per square inch (psi), but some locations/depths were injected at lower pressures to mitigate "daylighting" of the ABC$^+$ injectate in some nearby monitoring wells. Once the pilot study injections were completed, performance monitoring was conducted at nearby observation wells on an approximately monthly basis for six monitoring events.

In addition to the permanent monitoring and observation wells that were used during the 2016 pilot study, the final monitoring round included collection of groundwater samples using DPT. Permanent observation well locations were selected based on the presumed direction of overall groundwater movement from the injection points, but the added DPT sampling points were needed to fill in groundwater quality data based on actual migration within the subsurface. The pilot study demonstrated that localized variations in flow patterns were present at the site and influence the distribution of applied treatment chemicals.

The 2016 ABC$^+$ pilot study effectively demonstrated that DPT injections could be used to deliver the ERD- and ZVI-based treatment additives to prescribed depths across the Site and promote, over time, *in situ* dechlorination of the target VOCs using both biological and physiochemical treatment pathways. After nearly five years, treatment influences from the 2016 pilot study injections continue to be observed.

During the ABC$^+$ pilot study, geochemical conditions within the treatment zone of the pilot study area transitioned from high dissolved oxygen (DO)/high oxidation-reduction potential (ORP) conditions to low DO/low ORP conditions, geochemical conditions more conducive to ERD. Multiple lines of evidence were observed during the pilot study that demonstrated the distribution and treatment efficacy of the ABC$^+$ treatment chemicals.

"Lessons learned" during the pilot study included the importance of moderating injection pressures and maintaining a sufficient distance from monitoring wells to minimize "daylighting" of the ABC$^+$ injectate at performance monitoring wells near the ABC$^+$ injection points. Groundwater sampling two years after the completion of the 2016 ABC+ pilot study (see Section 2.5.1) also demonstrated that the long-lasting treatment effects of ABC+ take time to distribute and to become apparent in the observed plume configurations.

The findings and conclusions of the 2016 ABC+ pilot study were submitted to SC DHEC for review in May 2017. The regulators deemed the pilot study results to be inconclusive and expressed a desire to see more compelling evidence that a significant reduction in COC levels had occurred.

2.5.2 Expanded ABC+ Pilot Study

Upon consideration of SC DHEC's comments regarding the 2016 pilot study, TRC and WPH concluded that the expectation for compelling differences in the VOC plume configuration could not reasonably be provided in the timeframe of a pilot study without significantly expanding the scope of pilot-study treatment injections. To address these concerns, an Expanded ABC+ Pilot Study was proposed and conducted that increased the amount of ABC+ injected into the subsurface from about 22,000 pounds in the 2016 pilot study to about 255,400 pounds in the expanded pilot study. By expanding the scope of the ABC+ pilot study, TRC specifically conducted what amounted to a full-scale ABC+ treatment event within the 0.10 mg/L isoconcentration line of the Upgradient VOC plume area.

Prior to conducting the expanded pilot study, a site-wide round of groundwater sampling was conducted in January and February 2019 to establish baseline conditions. In addition to the existing permanent groundwater monitoring wells in the area, 8 multi-depth DPT sampling locations were established in the injection area to monitor changes in water quality closer to the injection locations, thus sooner in time following the injections. The pre-injection sampling round occurred about two years after the final sampling round of the 2016 pilot study and provided evidence of continued treatment effects from the relatively small amount of ABC+ injected during that pilot study.

The Expanded ABC+ Pilot Study included injections at 80 locations with 2-foot vertical spacings. These 80 locations consisted of an array of seven transects perpendicular to the groundwater flow direction within the Upgradient VOC plume. Based on lessons learned from the 2016 pilot studies, injection pressures were lower during the Expanded ABC+ Pilot Study and closely monitored. Injection locations were at least 30 feet from the nearest permanent groundwater monitoring well to minimize daylighting. Injections were conducted between May 14 and July 10, 2019.

Performance monitoring was intended to include two semiannual events including field and laboratory indicator parameters, VOCs, and dissolved gases. Samples were also collected from three locations for DHC census and functional gene panel evaluation for dechlorinating bacteria. The onset of the Covid-19 pandemic resulted in schedule disruptions of the pilot study monitoring activities. The first semi-annual performance monitoring event was conducted as intended in March 2020, then the evaluation of the data and collection of subsequent monitoring data was placed on hold, as communicated to SC DHEC in correspondence dated April 14, 2020. As the Covid-19 quarantines and shut-downs were relaxed, work on the project was able to resume in late 2020. A final performance monitoring event was conducted in March 2021. The postponement of the second "semiannual" sampling event provided an additional six months for the distribution and treatment effects of the ABC+ injections to be observed.

Field indicator parameters were used to evaluate changes in ERD conditions that occurred over time within the treatment area. PCE and cis-1,2-dichloroethene concentrations were used to evaluate the changes in the plume configuration between the baseline sampling event in January/February 2019 to the final monitoring event in March 2021. To account for differences in constituent migration within zones of the aquifer, performance monitoring results were evaluated separately for shallow (water table) wells, intermediate zone wells, and transition zone wells. Attachment A includes figures from the Expanded ABC+ Pilot Study Report (TRC June 2021) showing pre- and post-injection conditions in the Expanded ABC+ Pilot Study area.

In Appendix A, Figures 4-13, 4-14, and 4-15 from the Pilot Study Report compare the extent of robust ERD conditions between the 2019 pre-injection conditions and the 2021 conditions for the three groundwater zones. The continuing effects from the 2016 pilot study, with injections near RMW-27 for the upgradient plume and near RMW-23 for the downgradient plume, can be seen in the 2019 data. With an expanding area of robust ERD conditions, improvement of groundwater quality observed during the 2019 pilot study is anticipated to continue.

In Appendix A, Figures 4-1, 4-2, and 4-3 from the Pilot Study Report show changes in PCE concentrations for the three groundwater zones. Figure 4-4 from the Pilot Study Report provides a vertical profile of PCE concentrations through the Upgradient VOC plume. The most pronounced reductions in PCE concentrations are at the upgradient end of the upgradient plume, where minimal PCE migration from upgradient locations occurs. It is likely that PCE destruction is similar at locations further downgradient, but PCE concentrations also reflect the continuing movement of affected groundwater from upgradient locations that has yet to achieve treatment. The high volume of ABC+ injections is also expected to have resulted in some displacement and transport of PCE and its daughter products.

In Appendix A, Figures 4-6, 4-7, and 4-8 show changes in cis-1,2-DCE concentrations for the three groundwater zones. These figures show the expanding areas of ERD activity between the two sampling events, as daughter products formed abiotically by ZVI treatment are usually too short-lived to be observed in ordinary groundwater monitoring. The 2019 baseline cis-1,2-DCE figure clearly shows the effects of the 2016 pilot study.

In June 2021, TRC submitted the findings and conclusions of the expanded ABC+ pilot study to SC DHEC for the Department's review and consideration. Based on the compelling and conclusive nature of the performance monitoring data set forth in this report, the Department has requested that WPH revise and update the 2017 FFS and resubmit it for Department review and approval.

2.6 Nature and Extent of Constituents of Concern

Based on the results of prior investigations conducted at the Site, four discrete VOC plumes have been identified and delineated. These affected groundwater areas are shown in Figure 2-5.

- The Upgradient VOC plume is the largest of the VOC plumes and is composed primarily of PCE. It appears to originate from a source area within and beneath the footprint of the former manufacturing complex. This plume is migrating in a southeastwardly direction toward Hartwell Lake. Based on prior investigations conducted in this area summarized in Section 2.4, this plume appears to originate near the southern end of the manufacturing building constructed in 1959. Underground process sewer lines associated with the facility were excavated in 2009 along with associated affected soil. Based on performance monitoring results collected in March 2021, substantial diminishment of the upgradient VOC plume has already occurred.
- The Downgradient VOC plume is smaller in areal extent than the Upgradient VOC plume, but it is similarly composed primarily of PCE. This plume appears to originate from a different source area (most likely another process sewer identified at the upper end of the plume) and migrates toward Hartwell Lake. Another potential source (or partial source) for the Downgradient VOC plume may be related to a possible preferential flow pathways that may link the Upgradient and Downgradient plumes. TRC has observed curious field conditions that cause us to suspect that there may be some manner of hydraulic connection between these two VOC plume areas. During the Expanded ABC+ Pilot Study, TRC introduced bromide tracer into several wells to evaluate this possible interconnectivity between the Upgradient and Downgradient VOC plume. However, these efforts did not provide supportive results, possibly because the extended shutdown from COV-19 quarantine occurred during the time that the water-soluble bromide tracer would have been most likely detected. TRC still considers the hydrogeologic connectivity possible and will continue to look for supporting evidence within performance monitoring data. The pilot study data revealed evidence of continued treatment effects within the Downgradient VOC plume from the 2016 pilot study injections. There is also a possibility that, given sufficient time for migration, ABC+ treatment effects from the Upgradient VOC plume pilot injections would be observable within the Downgradient VOC plume.
- A third VOC plume, located near the southwest corner of the former manufacturing building, is centered around the former location of a used-oil underground storage tank (UST) that was closed/removed in 1992. This plume has historically been referred to as the "UST plume" and has dimensions of approximately 200 feet long by 100 feet wide. PSC previously installed five monitoring wells to evaluate the groundwater quality in this area. These wells have since been abandoned. During groundwater sampling conducted in 2009, five VOCs were detected in the groundwater of this area. Of these detected VOCs, only PCE exceeded its MCL, exhibiting concentrations ranging from <0.001 mg/L to 0.0247 mg/L.

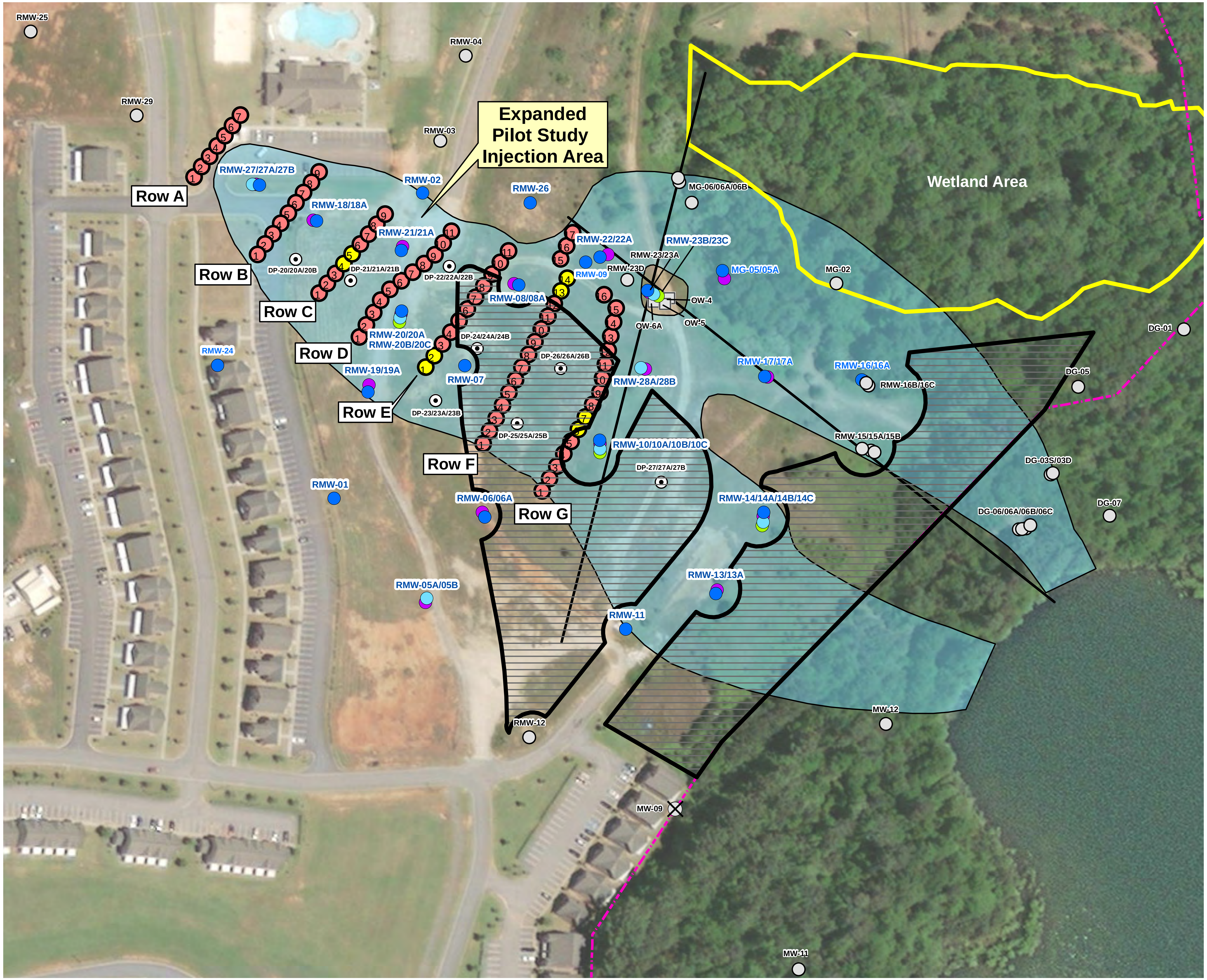
- The fourth VOC plume identified at the site is located near the southeastern edge of the former manufacturing building and is centered around the location of the aboveground Varsol tank that was removed prior to WPH's acquisition of the Site in 1989. The associated VOC plume from this area, referred to as the "Varsol tank plume," measures approximately 100 feet in diameter. The VOCs identified at this area of the facility have consisted primarily of ethylbenzene and xylene. While PCE was detected within this plume area, it was identified at concentrations below its MCL. The Varsol tank plume overlaps and eventually comingles with the northern edge of the upgradient VOC plume. Ethylbenzene and xylene concentrations at RMW-02, which monitors the Varsol tank location, have decreased significantly during the recent two ABC+ pilot studies. Ethylbenzene declined from 17 mg/L in May 2016 to 0.35mg/L in March 2021, while xylenes declined from 51 mg/L in May 2016 to 1.1 mg/L in March 2021. Neither of these constituents currently exceeds its MCL within the former Varsol tank area.

The Upgradient and Downgradient VOC plumes flow parallel with each other and migrate toward Hartwell Lake; they appear to comingle before discharging into the lake. The concentrations of PCE observed in the Upgradient plume (as of March 2021) range from below analytical detection limits to an upper bound of 9 mg/L (a concentration observed in the transition zone at RMW-28B). Other constituents that exceed their Maximum Contaminant Levels (MCLs) within the Upgradient plume include benzene (0.0094 mg/L at RMW-24 and 0.0064 at RMW-26), cis-1,2-DCE (ranging from less than detection to 2.6 mg/L at RMW-20A), TCE (ranging from less than detection to 0.12 mg/L at RMW-27), and vinyl chloride (ranging from less than detection to 0.016 at RMW-20A). Detections of PCE daughter products (cis-1,2-DCE and vinyl chloride) have increased substantially during the pilot studies, but are expected to diminish as treatment continues.

The concentrations of PCE observed in the Downgradient VOC plume range from less than the analytical detection limit to an upper bound of 10 mg/L (which was observed in the intermediate aquifer zone at RMW-16A [note: the duplicate result was 8.9 mg/L]). Other constituents that exceed their Maximum Contaminant Levels (MCLs) within the downgradient plume include cis-1,2-DCE (ranging from less than detection to 0.82 mg/L at RMW-23C), TCE (ranging from less than detection to 0.014 mg/L at RMW-16), and vinyl chloride (ranging from less than detection to 0.0026 at RMW-23C).

PCE concentrations observed within the sediment pore water along the shore of Hartwell Lake in August 2014 ranged from below the analytical detection limit to an upper bound of 0.32 mg/L. PCE was detected in several of the near-shore surface water samples, but always at concentrations less than the MCL. VOCs have not been detected in offshore samples collected approximately 40 feet from the lake shoreline.

Based on prior field work conducted at the Site, TRC can find no evidence of continuing VOC sources within the vadose zone soils that might constitute an ongoing release of VOCs to groundwater. Rather, the field data seems to indicate that the release of VOCs has occurred at a depth that correlates with underground process sewer lines of the former WPH facility. Figures depicting the horizontal and vertical extent of PCE in the Upgradient and Downgradient VOC plumes are provided in Appendix A.



LEGEND

- Water Table Aquifer Monitoring Well
- Intermediate Aquifer Monitoring Well
- Transition Zone Aquifer Monitoring Well
- Bedrock Aquifer Monitoring Well
- Observation Well (Previous Pilot Study)
- Direct-Push Groundwater Sample Location
- Destroyed Water Table Monitoring Well
- Pilot Study Injection Point
- Pilot Study Injection Point with Bromide Tracer
- Property Boundary (Approximate)
- Inferred Fracture
- Proposed Development 2021

NOTES

Aerial Photograph Source: ESRI World Imagery. (Aquisition Date: 5/11/2020).

The groundwater treatment target area is based on the extent of PCE concentrations in groundwater greater than 0.1 mg/L.

Monitoring wells shown in gray are not included in the performance monitoring network.

N

0 120 240 Feet

1 " = 133 '

1:1,600

PROJECT:

FORMER WESTPOINT HOME
CLEMSON, SOUTH CAROLINA

TITLE:

ABC+ PERFORMANCE MONITORING NETWORK

DRAWN BY:	WIXON S	PROJ. NO.:	300688.0.0.10
CHECKED BY:	CLARK L		
APPROVED BY:	WEBB S		**FIGURE 2-1**
DATE:	AUGUST 2021		

TRC

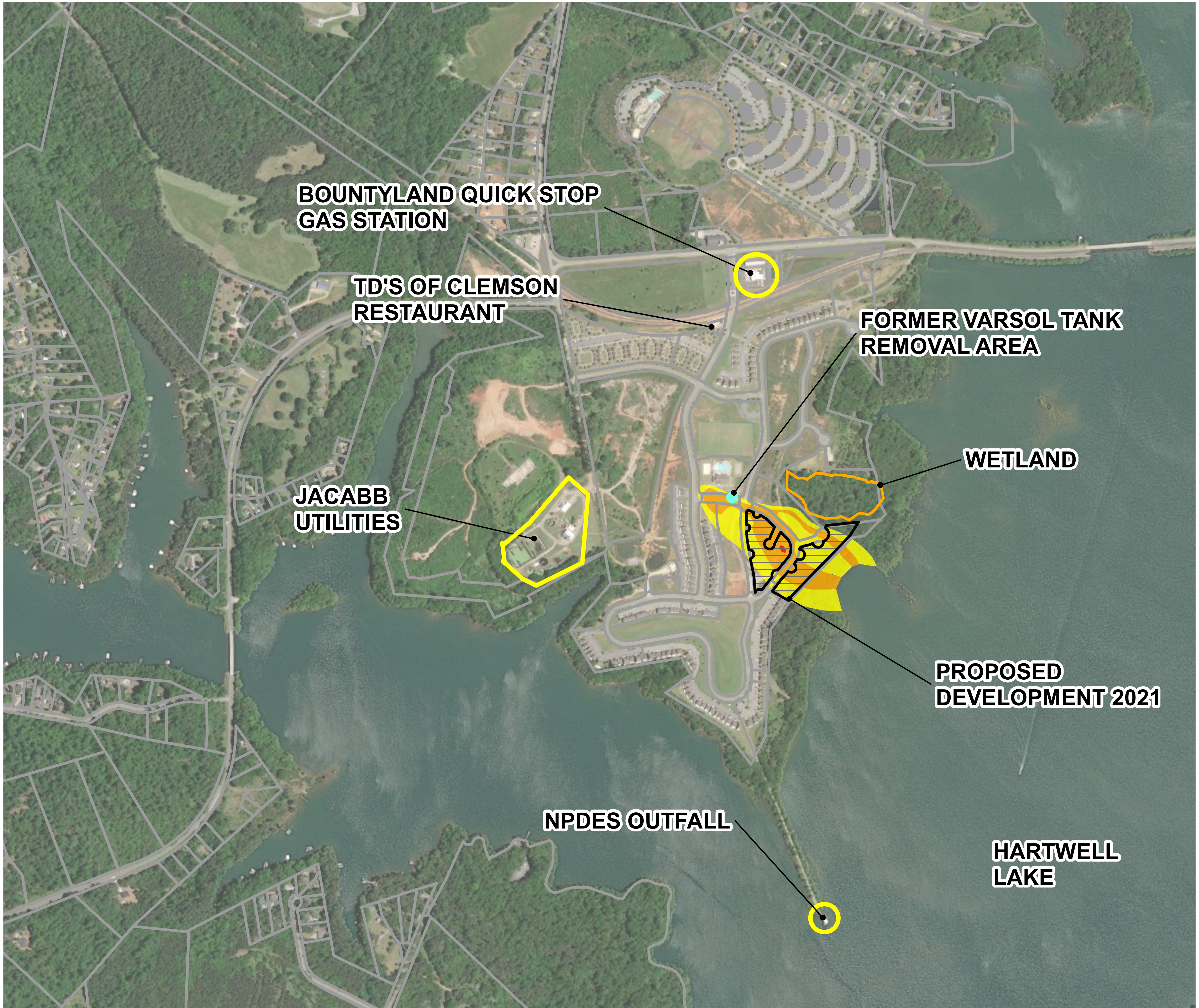
50 International Drive, Suite 150
Patewood Plaza Three
Greenville, SC 29615
Phone: 864.281.0030
www.TRCcompanies.com

FILE NO.: Fig 2-1_Site Map.mxd

TRC - GIS

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

Plot Date: 8/18/2021, 14:43:38 PM by RWIXON -- LAYOUT: ANSI B(11"x17")
Path: V:\1-PROJECTS\West Point Home\Clemson SC\GIS\450113\FFS Revised\Fig 2-1_Site Map.mxd



LEGEND

- Oconee County Parcels
- Proposed Development 2021
- Wetland Outland_Approx
- Former Varsol Tank Removal Area

PCE Concentration Key

- > 0.005 to 0.1 mg/L
- > 0.1 to 1.0 mg/L
- > 1.0 mg/L

NOTES

1) Aerial Image from ESRI World Imagery dated May 2021
2) Oconee County Parcels from Oconee County GIS File downloaded on November 8th, 2021 https://oconeesc.com/departments/gis
3) PCE Plume Shown - Shallow Groundwater March 2021
4) PCE - Tetrachloroethene

N

0 0.25 0.5 Miles

1 " = 800 '
1:9,600

PROJECT: WESTPOINT HOME, INC. CLEMSON, SOUTH CAROLINA			
SHEET TITLE: SITE AND SURROUNDING AREA			
DRAWN BY: DS	SCALE: 1: 9,600	PROJ. NO. 300688	
CHECKED BY: JP		FILE NO. UIC Permit.mxd	
APPROVED BY: JP	DATE PRINTED:	FIGURE 2-1A	
DATE: MARCH 2015			

TRC

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Greenville, SC 29615
Phone: 864.281.0030
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Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0
Saved By: DSZYNAL on 11/9/2021, 13:13:45 PM
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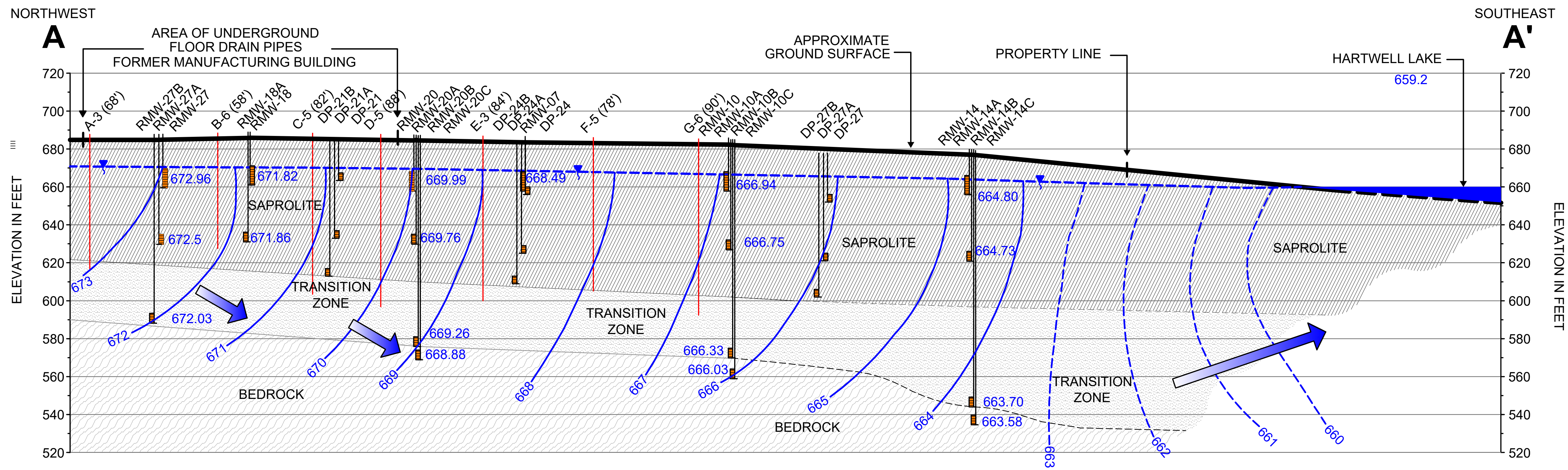
TRC - GIS



CROSS SECTION A - A'

LEGEND

SAPROLITE

TRANSITION ZONE

BEDROCK

WELL

WELL SCREEN

WATER TABLE (MARCH 8, 2021)

TEMPORARY DIRECT PUSH DP WELL

WELL SCREEN

ABC+ INJECTION LOCATION

VERTICAL FLOW CONTOUR

GROUNDWATER FLOW DIRECTION

NOTES

A-3 (68') - MAXIMUM DEPTH OF ABC+ INJECTION AT LOCATION A-3 PROVIDED IN FEET BELOW GRADE.

672.03 - WATER ELEVATION AT DESIGNATED WELL IN FEET MSL.

WATER LEVELS NOT AVAILABLE AT DP LOCATIONS.

PROFILE SCALE:

VERTICAL SCALE: 1" = 60' (0 – 60)

HORIZONTAL SCALE: 1" = 120' (0 – 120)

VERTICAL EXAGGERATION = 2X

PROJECT:
WESTPOINT HOME, INC
CLEMSON, SOUTH CAROLINA

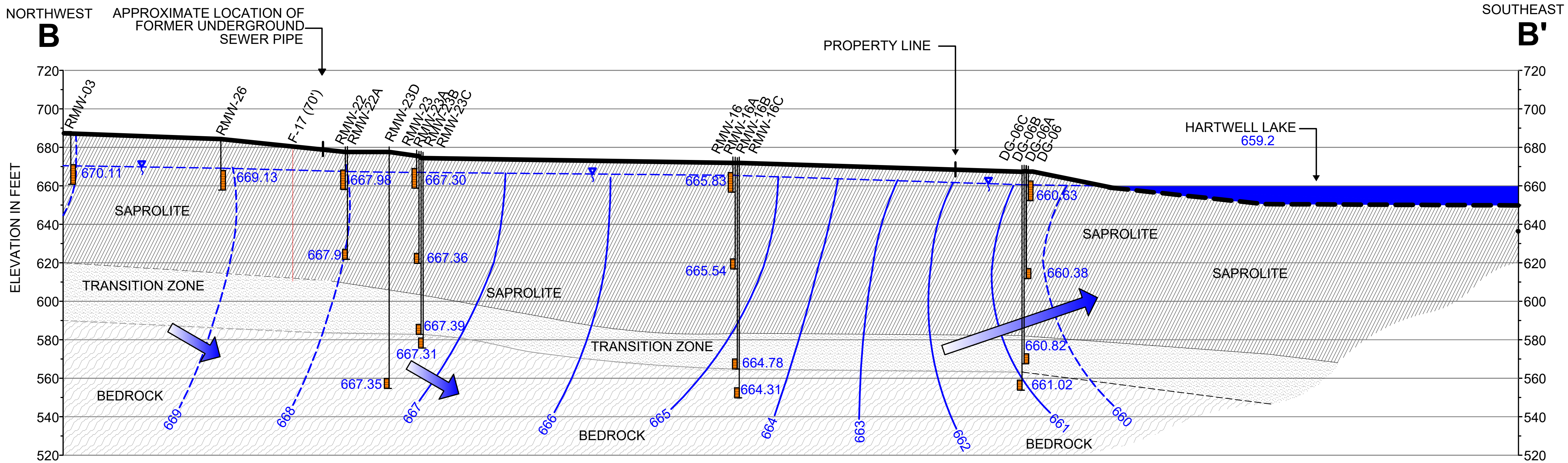
TITLE:
GEOLOGIC CROSS SECTION WITH VERTICAL FLOW GRADIENTS - UPGRADIENT PLUME

DRAWN BY:	S. HAMWAY	PROJ NO.:	450113.0000.0000
CHECKED BY:	L. CLARK	**FIGURE 2-2**	
APPROVED BY:	S. WEBB		
DATE:	AUGUST 2021		

TRC
650 Suffolk Street
Suite 200
Lowell, MA 01854
Phone: 978.970.5600

FILE NO.: 450113 - FIG 2-2 VERTICAL FLOW GRADIENT MAP.dwg

DRAWING NAME: J:\CAD\WPH Clemson\450113\0000\450113 - FIG 2-2 VERTICAL FLOW GRADIENT MAP.dwg -- PLOT DATE: August 23, 2021 - 1:16PM -- LAYOUT: FIGURE 2-2
Version: 2017-10-21



CROSS SECTION B - B'

LEGEND

SAPROLITE

TRANSITION ZONE

BEDROCK

WELL

WELL SCREEN

WATER TABLE (MARCH 8, 2021)

ABC+ INJECTION LOCATION

VERTICAL FLOW CONTOUR

GROUNDWATER FLOW DIRECTION

NOTES

F-17 (70') - MAXIMUM DEPTH OF ABC+ INJECTION AT LOCATION F-17 PROVIDED IN FEET BELOW GRADE.

667.31 - WATER ELEVATION AT DESIGNATED WELL IN FEET MSL.

PROFILE SCALE:

VERTICAL 60 0 SCALE: 1" = 60'

HORIZONTAL 0 120 SCALE: 1" = 120'

VERTICAL EXAGGERATION = 2X

PROJECT:	WESTPOINT HOME, INC CLEMSON, SOUTH CAROLINA
TITLE:	GEOLOGIC CROSS SECTION WITH VERTICAL FLOW GRADIENTS - DOWNGRADIENT PLUME
DRAWN BY: S. HAMWAY	PROJ NO.: 450113.0000.0000
CHECKED BY: L. CLARK	FIGURE 2-3
APPROVED BY: S. WEBB	
DATE: AUGUST 2021	

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Suite 200
Lowell, MA 01854
Phone: 978.970.5600

FILE NO.: 450113 - FIG 2-3 VERTICAL FLOW GRADIENT MAP.dwg

LEGEND

- Water Table Aquifer Monitoring Well
- Intermediate Aquifer Monitoring Well
- Transition Zone Aquifer Monitoring Well
- Bedrock Aquifer Monitoring Well
- Observation Well (Previous Pilot Study)
- Destroyed Water Table Monitoring Well
- Property Boundary (Approximate)

NOTES

Aerial Photograph Source: ESRI World Imagery (Aquisition Date: 5/11/2020).

N

0 120 240 Feet

1 " = 133 '

1:1,600

PROJECT:	FORMER WESTPOINT HOME CLEMSON, SOUTH CAROLINA
TITLE:	WELL LOCATION MAP
DRAWN BY: WIXON S	PROJ. NO.: 450113.0000.0000
CHECKED BY: CLARK L	FIGURE 2-4
APPROVED BY: WEBB S	
DATE: AUGUST 2021	

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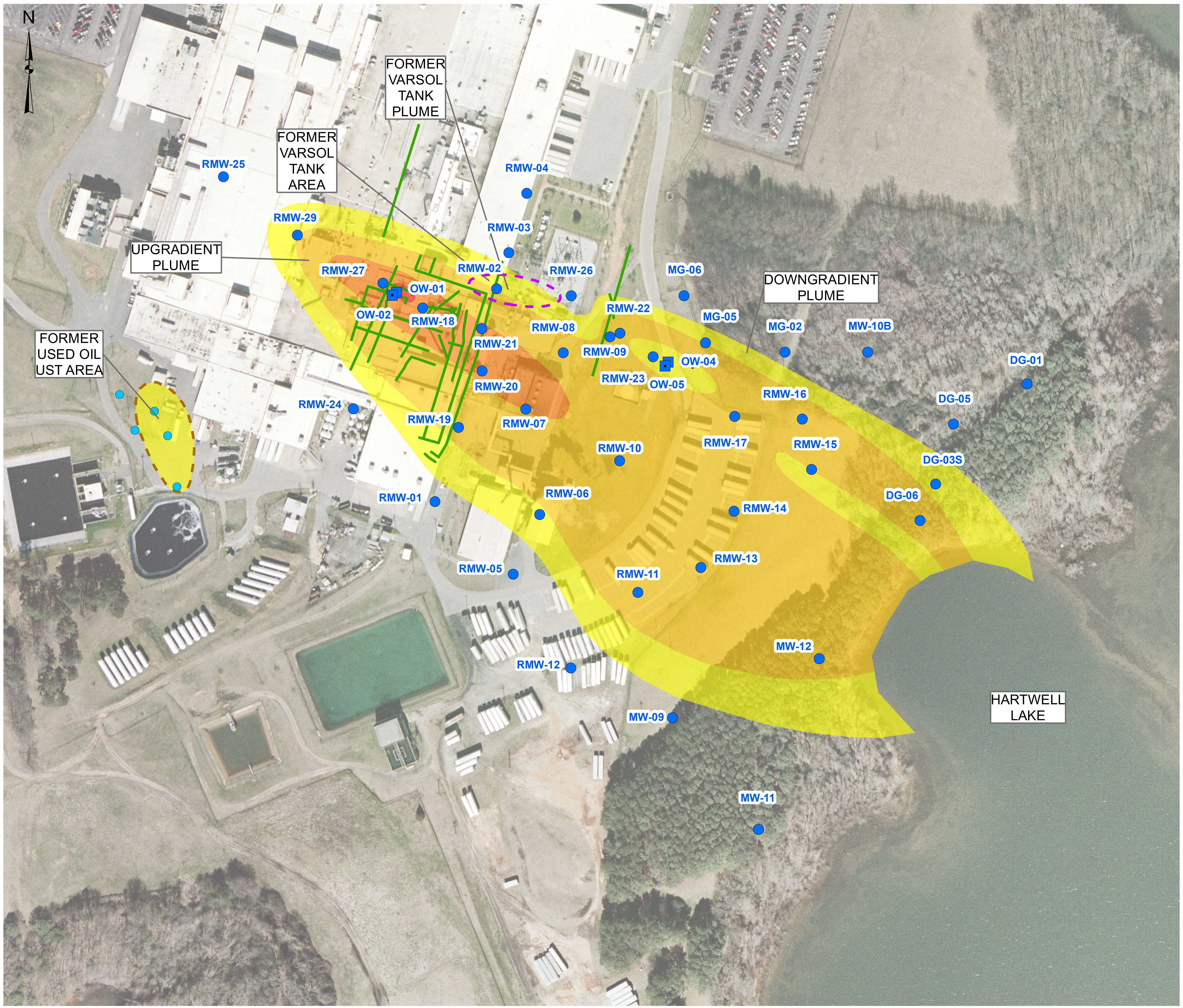
FILE NO.: Fig 2-4_Well Location Map_2021.mxd

TRC - GIS

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

Plot Date: 8/18/2021, 14:43:01 PM by RWIXON -- LAYOUT: ANSI B(11"x17")
Path: V:\1-PROJECTS\West Point Home\Clemson SC\GIS\450113\FFS Revised\Fig 2-4_Well Location Map_2021.mxd



LEGEND

- WATER TABLE MONITORING WELL
- OBSERVATION WELL
- ABANONDONED WELL FORMER UST AREA
- UST PLUME APPROXIMATE AFFECCTED GROUNDWATER BOUNDARY. BASED ON 2009 GROUNDWATER DATA.
- VARSOL TANK PLUME APPROXIMATE AFFECTED GROUNDWATER BOUNDARY,

GROUNDWATER SAMPLES COLLECTED JULY 2014 THROUGH FEBRUARY 2017 (mg/L) BASED ON WATER TABLE MONITORING WELLS

- >0.005 - 0.05 mg/L
- >0.05 - 0.5 mg/L
- >0.5 - 5 mg/L
- >5 mg/L

NOTES

AERIAL PHOTOGRAPHY FROM GOOGLE EARTH PRO OCTOBER 2015

LOCATIONS OF PIPING AND OTHER STRUCTURES (GREEN LINES) ARE FOR REFERENCE ONLY. FACILITY WAS DEMOLISHED 2008-2009.

PCE - TETRACHLOROETHENE

0 200 400 Feet

1 " = 200 '

1:2,400

PROJECT: WESTPOINT HOME, INC. CLEMSON, SOUTH CAROLINA			
SHEET TITLE: FIGURE 2-5 AFFECTED GROUNDWATER AREAS			
DRAWN BY: DSZYNAL	SCALE: 1: 2,400	PROJ. NO. 226253.0.0.6	
CHECKED BY: CLARK L		FILE NO. Figure 2-5 - PCE - WaterTable.mxd	
APPROVED BY: WEBB S	DATE PRINTED:		
DATE: AUGUST 2017			

TRC

TRC - GIS

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

Saved By: DSZYNAL on 8/9/2017, 08:17:19 AM
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Table 2-1
Monitoring Well System

WELL ID	MONITORED INTERVAL	WELL DIAMETER (inches)	NORTHING	EASTING	GROUND SURFACE ELEVATION (feet msl)	TOP OF WELL CASING ELEVATION (feet msl)	TOTAL WELL DEPTH (feet bgs)	WELL SCREEN INTERVAL (feet bgs)
DG-01	Water Table	1	1028846.921	1441353.601	666.30	666.23	20.00	10-20
DG-03D	Intermediate	1	1028643.597	1441166.833	670.50	670.26	38.50	33.5-38.5
DG-03S	Water Table	1	1028645.455	1441170.111	670.40	670.13	20.00	10-20
DG-05	Water Table	1	1028766.057	1441205.755	669.51	669.35	15.00	5-15
DG-06	Water Table	2	1028572.355	1441138.486	667.41	670.26	20.00	20-Oct
DG-06A	Intermediate	2	1028568.180	1441132.230	667.60	670.50	55.20	50-55
DG-06B	Top of Rock	2	1028567.335	1441126.898	667.60	670.73	103.20	98-103
DG-06C	Bedrock	2	1028566.824	1441122.638	667.55	670.54	113.30	108.3-113.3
DG-07	Intermediate	2	1028586.007	1441249.615	664.86	667.43	38.00	33-38
MG-02	Water Table	1	1028911.176	1440866.859	667.27	666.59	20.00	10-20
MG-05	Water Table	1	1028929.331	1440706.873	670.03	669.77	20.00	10-20
MG-05A	Intermediate	2	1028918.168	1440709.553	670.23	673.18	55.30	50.2-55.2
MG-06	Water Table	1	1029024.159	1440663.970	669.66	669.26	20.00	10-20
MG-06A	Intermediate	2	1029052.95	1440646.64	670.35	673.34	55.1	50.1 to 55.1
MG-06B	Top of Rock	2	1029058.82	1440644.84	670.12	673.19	80.7	75.7 to 80.7
MW-11	Water Table	1	1027950.688	1440813.914	665.91	665.69	15.00	5-15
MW-12	Water Table	1	1028294.367	1440936.126	665.91	665.75	15.00	5-15
RMW-01	Water Table	2	1028610.550	1440162.880	683.07	686.01	23.70	13.5-23.5
RMW-02	Water Table	2	1029038.558	1440286.920	687.05	686.99	28.90	18.7-28.7
RMW-03	Water Table	2	1029110.729	1440311.907	687.28	687.28	26.00	15.9-25.9
RMW-04	Water Table	2	1029230.121	1440347.654	686.69	686.41	25.10	14.9-24.9
RMW-05A	Intermediate	2	1028464.99	1440290.78	683.11	685.89	55.2	50.2 to 55.2
RMW-05B	Top of Rock	2	1028470.51	1440292.39	682.98	685.96	136.1	131.1 to 136.1

Table 2-1
Monitoring Well System

WELL ID	MONITORED INTERVAL	WELL DIAMETER (inches)	NORTHING	EASTING	GROUND SURFACE ELEVATION (feet msl)	TOP OF WELL CASING ELEVATION (feet msl)	TOTAL WELL DEPTH (feet bgs)	WELL SCREEN INTERVAL (feet bgs)
RMW-06	Water Table	2	1028584.436	1440373.681	681.77	684.56	23.90	13.7-23.7
RMW-06A	Intermediate	2	1028591.295	1440370.090	681.74	684.62	55.20	49.6-54.6
RMW-07	Water Table	2	1028796.459	1440345.889	683.55	686.61	25.10	15-25
RMW-08	Water Table	2	1028909.298	1440421.223	680.59	683.68	21.00	10.9-20.9
RMW-08A	Intermediate	2	1028911.330	1440414.925	680.57	683.49	75.60	65.4-75.4
RMW-09	Water Table	2	1028941.255	1440515.400	676.68	679.95	19.10	8.9-18.9
RMW-10	Water Table	2	1028692.186	1440534.661	682.29	685.15	25.00	14.8-24.8
RMW-10A	Intermediate	2	1028687.040	1440535.423	682.25	684.96	55.50	50.3-55.3
RMW-10B	Top of Rock	2	1028680.061	1440535.324	682.20	685.04	112.00	106.8-111.8
RMW-10C	Bedrock	2	1028674.501	1440535.071	682.02	684.97	123.00	118-123
RMW-11	Water Table	2	1028427.396	1440571.125	676.31	679.47	21.20	11.1-21.1
RMW-12	Water Table	2	1028275.287	1440436.454	677.86	680.98	22.40	12.2-22.2
RMW-13	Water Table	2	1028477.539	1440697.535	676.15	679.18	18.70	8.5-18.5
RMW-13A	Intermediate	2	1028482.191	1440699.214	675.96	678.96	55.50	50.3-55.3
RMW-14	Water Table	2	1028591.034	1440764.739	678.10	681.12	21.20	11-21
RMW-14A	Intermediate	2	1028585.679	1440763.670	677.77	680.74	55.30	50.2-55.2
RMW-14B	Top of Rock	2	1028577.332	1440763.544	677.70	680.63	132.00	126.8-131.8
RMW-14C	Bedrock	2	1028572.418	1440762.328	677.76	681.16	142.80	137.8-142.8
RMW-15	Water Table	2	1028674.905	1440920.341	675.07	678.23	18.00	7.9-17.9
RMW-15A	Intermediate	2	1028676.740	1440915.254	675.05	678.09	74.90	64.8-74.8
RMW-15B	Top of Rock	2	1028679.677	1440902.676	675.33	678.15	150.00	144.8-149.8
RMW-16	Water Table	2	1028776.515	1440902.082	671.92	674.99	15.10	5-15
RMW-16A	Intermediate	2	1028774.560	1440905.068	671.79	674.90	55.00	49.8-54.8
RMW-16B	Top of Rock	2	1028771.464	1440908.769	671.90	674.62	107.00	101.8-106.8

Table 2-1
Monitoring Well System

WELL ID	MONITORED INTERVAL	WELL DIAMETER (inches)	NORTHING	EASTING	GROUND SURFACE ELEVATION (feet msl)	TOP OF WELL CASING ELEVATION (feet msl)	TOTAL WELL DEPTH (feet bgs)	WELL SCREEN INTERVAL (feet bgs)
RMW-16C	Bedrock	2	1028767.880	1440911.638	671.76	674.88	126.80	116.8-126.8
RMW-17	Water Table	2	1028781.464	1440765.901	674.16	676.99	17.00	6.8-16.8
RMW-17A	Intermediate	2	1028780.534	1440769.918	674.09	676.94	56.20	51-56
RMW-18	Water Table	2	1028999.353	1440138.400	685.95	688.96	25.20	15-25
RMW-18A	Intermediate	2	1029000.245	1440133.515	685.86	688.96	55.20	50-55
RMW-19	Water Table	2	1028759.696	1440210.184	685.35	688.23	26.10	15.9-25.9
RMW-19A	Intermediate	2	1028769.533	1440211.815	685.19	688.09	55.00	49.9-54.9
RMW-20	Water Table	2	1028872.996	1440257.536	684.53	687.45	23.20	13-23
RMW-20A	Intermediate	2	1028869.054	1440256.479	684.80	687.35	55.30	50.2-55.2
RMW-20B	Top of Rock	2	1028863.852	1440255.100	684.50	687.10	108.20	103-108
RMW-20C	Bedrock	2	1028857.563	1440254.491	687.26	687.26	118.80	113.8-118.8
RMW-21	Water Table	2	1028957.931	1440257.111	688.52	688.52	24.20	14-24
RMW-21A	Intermediate	2	1028963.108	1440258.520	688.56	688.56	55.20	50-55
RMW-22	Water Table	2	1028948.731	1440535.042	677.31	680.23	18.80	8.6-18.6
RMW-22A	Intermediate	2	1028952.199	1440546.337	677.68	680.53	55.20	50.1-55.1
RMW-23	Water Table	2	1028901.862	1440601.755	675.47	678.49	16.10	6-16
RMW-23A	Intermediate	2	1028899.181	1440604.209	675.06	677.94	55.30	50.1-55.1
RMW-23B	Top of Rock	2	1028896.445	1440610.401	674.50	677.88	92.00	86.8-91.8
RMW-23C	Bedrock	2	1028893.709	1440616.455	674.45	677.44	97.80	92.8-97.8
RMW-23D	Bedrock	2	1028915.91	1440573.78	677.6	680.23	122.7	117.7 to 122.7
RMW-24	Water Table	2	1028796.827	1439999.369	683.04	686.14	26.00	15.1-25.1
RMW-25	Water Table	2	1029263.731	1439738.092	683.66	686.59	18.10	7.9-17.9
RMW-26	Water Table	2	1029024.434	1440437.373	682.52	685.19	24.40	14.2-24.2
RMW-27	Water Table	2	1029049.48	1440058.33	684.96	687.91	25.3	15.3 to 25.3

Table 2-1
Monitoring Well System

WELL ID	MONITORED INTERVAL	WELL DIAMETER (inches)	NORTHING	EASTING	GROUND SURFACE ELEVATION (feet msl)	TOP OF WELL CASING ELEVATION (feet msl)	TOTAL WELL DEPTH (feet bgs)	WELL SCREEN INTERVAL (feet bgs)
RMW-27A	Intermediate	2	1029050.23	1440053.17	684.91	687.79	55	50 to 55
RMW-27B	Top of Rock	2	1029050.45	1440048.49	684.85	687.83	96.5	91.5 to 96.5
RMW-28A	Intermediate	2	1028791.41	1440598.85	678.42	681.5	55.2	50.2 to 55.2
RMW-28B	Top of Rock	2	1028793.26	1440592.44	678.4	681.19	97.8	92.8 to 97.8
RMW-29	Water Table	2	1439886.71	1029146.25	684.87	688	25	15 - 25

Indicates a water table well

Indicates an intermediate zone well

Indicates a top of rock well

Indicates a bedrock well

Section 3
Conceptual Site Model

This Section of the FFS provides TRC's interpretation of the origin, migration, and potential exposure for the VOC-affected groundwater areas observed across the Site. This Conceptual Site Model (CSM) is supported by the distribution of groundwater COCs described in Subsection 2.6. The CSM developed for the Site is illustrated in Figure 3-1 and Figure 3-2. Figure 3-1 is a schematic representation of the CSM illustrating sources, migration and exposure pathways, and potential exposure points as determined during the Site investigations described in Subsection 2.4. Figure 3-2 is a representation of this same CSM as a flow diagram, communicating the various sources and release mechanisms that were considered and exposure pathways that are completed or could potentially be completed.

3.1 Contaminant Sources

The known sources of the VOCs identified within the soils and groundwater of the Site appear to have occurred as result of historical releases from the following source areas:

- Underground process sewer lines underlying the southern end of the former manufacturing building.
- Underground process sewer line near the former electrical switchyard area.
- Former aboveground Varsol tank and historical USTs located near the southern end of the manufacturing building.
- Former used oil UST located at the southwest end of the former manufacturing building.

As discussed in Section 2.4, each of these source areas has been thoroughly investigated. The following remedial activities have been conducted to address these source areas:

- During closure of the former Varsol tank area in 2008, approximately 1,877 tons of VOC-affected soils were removed and approximately 1,925 pounds of OBC was applied to the excavation prior to backfilling.
- The former used oil UST was closed/removed circa 1992.

Extensive MIP sampling was conducted in September 2008 and soil sampling was conducted in February 2009 and August 2013 to determine if there were ongoing VOC source areas within vadose zone soils. These investigations failed to reveal evidence of remaining VOC source areas present in vadose zone soils. The only evidence of residual VOCs in subsurface soils was found within the capillary fringe and smear zone of the fluctuating water table surface within the footprint of each VOC groundwater plume area.

3.2 Fate and Transport

The potential constituent transport pathways for this site are anticipated to include the following key elements for the upgradient and downgradient VOC plumes:

- Historic subsurface migration of VOC-affected process water from underground pipes and tankage, over an extended time frame, through the underlying soils and into the underlying groundwater.
- Downgradient flow and transport of these VOCs (predominantly PCE) via the groundwater of the upgradient and downgradient plumes toward the nearby surface water body (Hartwell Lake).
- Limited natural, biotransformation of PCE to its daughter products TCE, cis-1,2-DCE, and vinyl chloride, predominately in areas where BTEX constituents are also present.
- Transport of VOCs into the nearby surface water body through the groundwater-surface water interface at Hartwell Lake.

Analytical results confirm that VOCs are present in the groundwater within the saprolite, transition zone, and shallow portions of the underlying bedrock. The highest concentrations of PCE were detected in wells screened within the intermediate saprolite zone (*i.e.*, 50 to 55 feet bgs). Much lower concentrations of PCE were detected in shallow, water table wells and wells screened within the transition zone and shallow bedrock.

The shape and observed distribution of PCE in groundwater are influenced by the hydrogeologic characteristics of the Site aquifer. Vertical hydraulic gradients within the aquifer are downward across most of the site, promoting downward migration of PCE from the Upgradient and Downgradient areas. The horizontal rate of groundwater flow within the saprolite is significantly higher than that of the transition zone and upper bedrock zones, allowing for elongation of the VOC plumes within the lower to intermediate saprolite zones. As groundwater flows downgradient, toward Hartwell Lake, vertical flow gradients eventually become upward, promoting discharge of groundwater into the surface water of the lake. Data collected during the 2016 ABC^+ pilot study revealed evidence of potential fracture flow within the saprolite in directions that are otherwise contrary to observed groundwater flow. While fracture flow may have some influence on VOC distribution and plume transport, the configuration of the VOC plumes suggests that seepage flow is the primary transport mechanism. However, further evaluation of data from the two pilot studies suggests preferential flow mechanisms may contribute to the intermingling of the Upgradient plume into the Downgradient plume.

Potential constituent fate and transport considerations for the UST plume will be similar, given that the constituent of concern (PCE) is the same. If other constituents associated with this used oil storage area were also released from the former UST, the concentrations have since degraded/attenuated to concentrations below detection limits. The UST plume occupies a much smaller area than the Upgradient and Downgradient plumes and does not appear to extend towards Hartwell Lake.

Potential constituent fate and transport associated with the Varsol plume may differ from the other plume areas, given the observed constituent make-up. The primary constituents associated with the Varsol plume are non-chlorinated organics (*i.e.*, ethylbenzene and xylene), which would be expected to respond differently in the subsurface environment than chlorinated organics. OBC had previously been added to the excavation area as an interim remedial response prior to backfilling. This occurred when the affected soil in the Varsol plume area was excavated to the water table in 2008. Groundwater samples collected downgradient from the Varsol tank excavation prior to the ABC+ pilot studies provided evidence of ongoing treatment effects from the OBC addition. Ethylbenzene and xylene concentrations in the Varsol tank area have decreased dramatically following the 2016 ABC+ pilot study.

3.3 Potential Exposure Pathways

An exposure pathway is a means by which a Site constituent of concern might reasonably move from a source zone area to a potential receptor. An exposure pathway must exhibit the following key elements in order to be considered a completed pathway:

- A confirmed constituent source area;
- A reasonable mechanism for constituent release and environmental transport; and
- A feasible route for potential exposure to the receptor.

Suspected sources areas for the observed VOC releases and the most likely VOC transport media and pathways were addressed earlier in this Section. VOCs in groundwater present the possibility of two subsequent media pathways to completed or potentially completed exposure routes. These include groundwater migration to surface water and volatile emissions from groundwater to dwellings constructed on the land surface above the VOC-affected groundwater area.

The Site remains the ongoing focus of property redevelopment activities including construction of various student-related apartment complexes, residential community housing, and multi-use commercial structures have been constructed. Thus, the potentially exposed population at the site would reasonably include Site construction workers and community residents. As indicated earlier, neither commercial nor residential development activities have been conducted within the immediate area of the upgradient and downgradient VOC plumes. However, the developer is currently contemplating construction activities within these areas of VOC-affected groundwater.

Groundwater occurs at a depth of approximately 15-20 feet bgs throughout most of the VOC-affected groundwater area, with shallower depths to groundwater encountered near the lake (which is USACE property not subject to development) and on the northern edge of the downgradient plume along a low-lying wooded area. The groundwater in these areas is unlikely to be subject to direct contact either by current site workers or current/future residents of the Site.

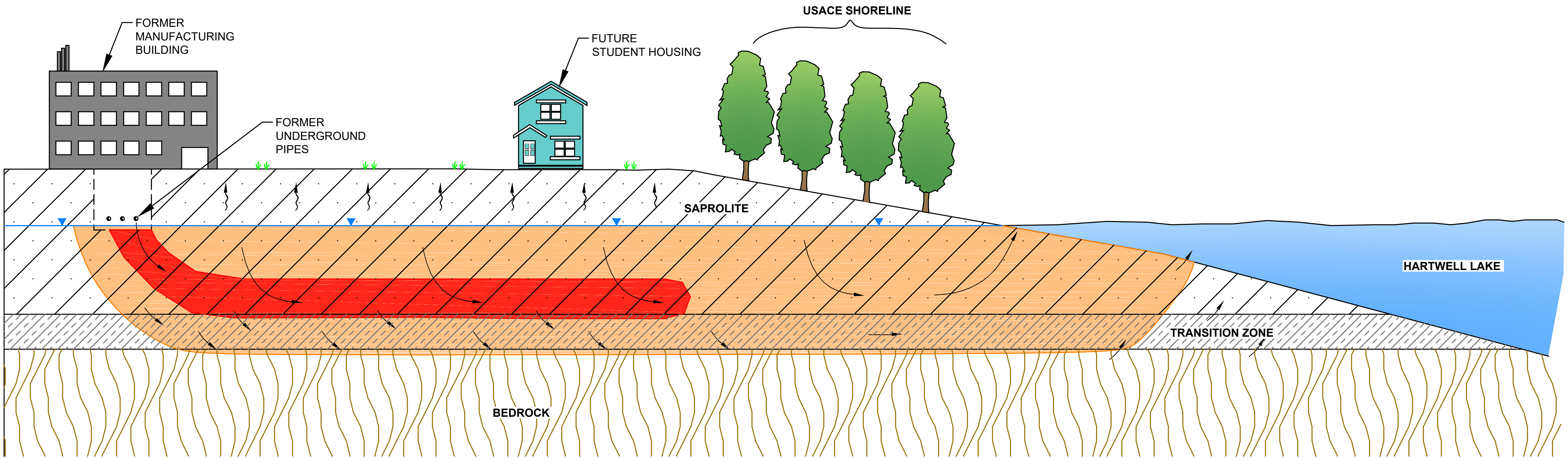
At the request of SC DHEC, vapor intrusion calculations were conducted for the site. Based on the observed depth and concentration of VOCs in the underlying groundwater, there appears to be potential for VOC vapors to accumulate to concentrations above acceptable levels for indoor air if a building were constructed above the VOC plume areas without vapor intrusion mitigations. The VCC currently requires the property owner to include vapor intrusion design considerations for construction above the VOC-affected groundwater areas. Absent a building, there does not appear to be a significant potential for release of VOC vapors from the subsurface plume areas to the land surface at levels of concern for human health. The Site development also makes exclusive use of available public water supply, so use of the Site groundwater is not anticipated for any manner of industrial/domestic use or consumption.

Since several pore water and near-shore surface water samples exhibited detectable levels of PCE, with two near-shore surface water samples exceeding the drinking water standard for PCE, a potential exposure pathway might reasonably include recreational boaters or persons wading along the near-shore environment. This scenario does not appear likely, given the silty/clay consistency of the shoreline in this area. However, this scenario constitutes the only reasonably anticipated route of exposure for PCE under current or future land-use scenarios. For this reason, we have considered PCE in the surface water at the lake shore to be subject to possible incidental ingestion and/or dermal exposure.

Groundwater use within the broader context of Site redevelopment and the area of concern is not currently contemplated as a source of future potable use. Public water is readily available along West Cherry Road and has been utilized since the J. P. Stevens plant was originally constructed. The site development team are already incorporating publicly available water supplies for the residential dwellings that are being constructed or anticipated. There do not appear to be any future plans for utilizing groundwater as a potential potable water source. Site development includes installation of public water lines that will provide a sustained and suitable source of potable water for the community residents. Therefore, the potential for groundwater ingestion is **not** considered to represent a potential or complete pathway for receptors that might reasonably be present under current and future land-use considerations.

During active industrial operations and prior to residential development, the Site was surrounded by security fencing and access was controlled by security guards. Following demolition of the former textile plant and the onset of Site redevelopment activities, security measures were relaxed, and the VOC-affected areas of the Site are currently accessible by Site construction workers and community residents. Since VOC-affected soil is not present at the ground surface and the observed depth to the VOCs in groundwater is approximately 15-20 feet bgs, there are no significant pathways for human exposure to these COCs under current conditions.

The construction of residences at the Site has previously been limited to property areas outside the VOC-affected groundwater area. However, over time, construction activities continue to advance toward the Upgradient and Downgradient VOC plume areas.



LEGEND

	SAPROLITE
	TRANSITION ZONE
	BEDROCK
	GROUNDWATER FLOW
	DISSOLVED PCE - HIGHER CONCENTRATIONS
	DISSOLVED PCE - LOWER CONCENTRATIONS
	WATER TABLE SURFACE (APPROXIMATE)

SCALE: NOT TO SCALE

PROJECT:
WESTPOINT HOME FFS
CLEMSON, SOUTH CAROLINA

TITLE:
SITE CONCEPTUAL MODEL SCHEMATIC

DRAWN BY:	C. NEWELL	PROJ NO.:	450113.0000.0000
CHECKED BY:	L. CLARK	**FIGURE 3-1**	
APPROVED BY:	L.CLARK		
DATE:	MAY 2017		

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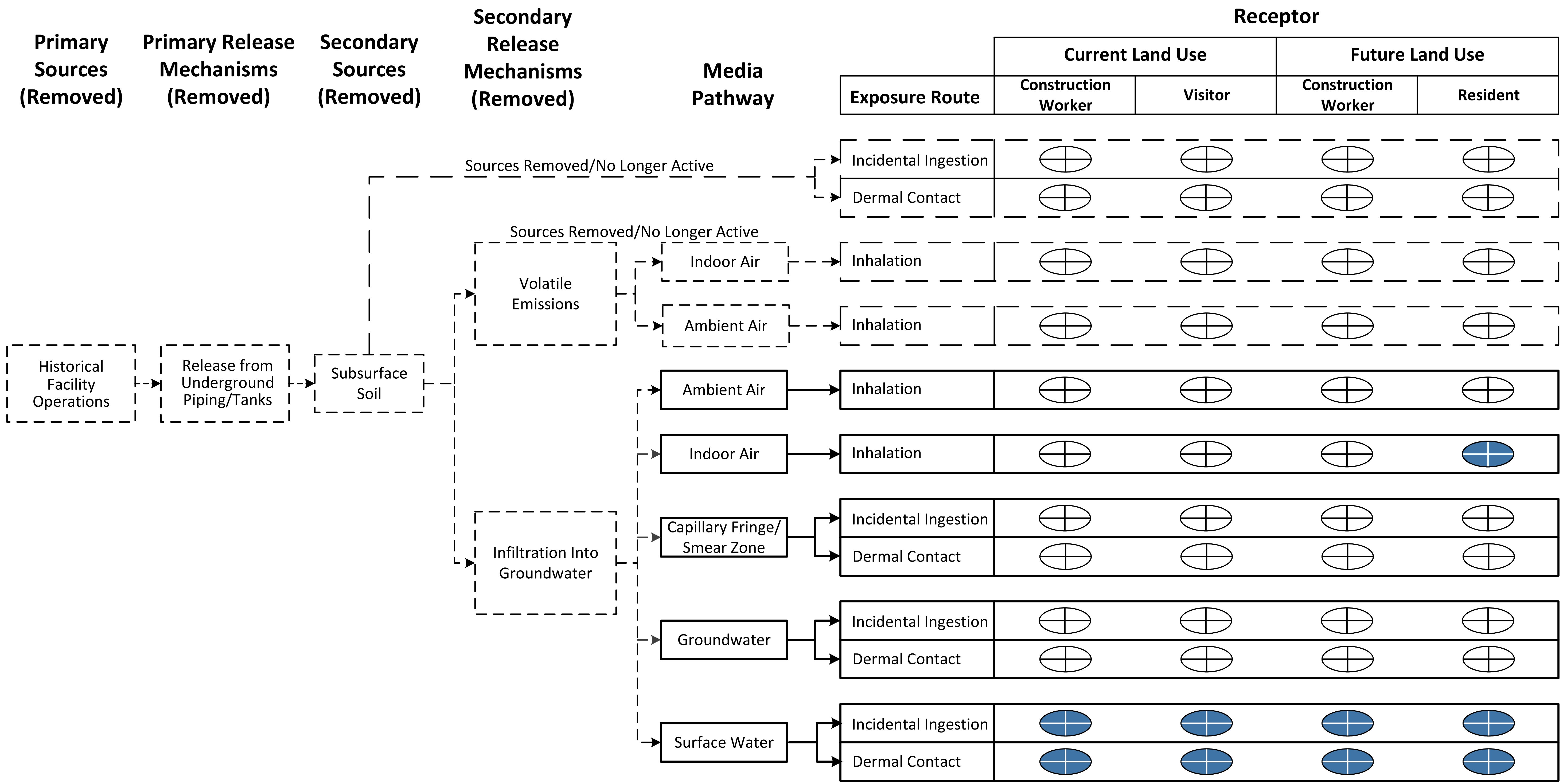

Pathway incomplete

Pathway potentially complete

NOTE:

Dashed lines and boxes indicate sources were removed and exposure route no longer exists.

WESTPOINT HOME
CLEMSON, SC

SITE CONCEPTUAL MIGRATION AND EXPOSURE MODEL

DRAWN BY: RSW rev JEP	FIGURE NO: 3-2	PROJECT NO: 450113.0.0
CHECKED BY: LMC		DATE: AUGUST 2021
APPROVED BY: SWW		

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P:_West Point Home\Clemson SC\226253 – Remedial Action Work Planning\FFS\Site Conceptual Migration and Exposure Model_2017.vsd

Section 4
Identification of Applicable or Relevant and Appropriate Requirements

The evaluation of potential remedial alternatives for the Site requires consideration of the following three categories of ARARs: chemical-specific, location-specific, and action-specific. These ARAR categories are not always mutually exclusive and may often overlap. Chemical-specific ARARs are numeric requirements that are typically human health– or risk-based criteria for a specific chemical and are potentially applicable as remediation goals. The potential chemical-specific ARARs for the Site are primarily associated with groundwater or groundwater treatment. Location-specific ARARs are requirements or limitations that reflect the physical setting of the site. The location-specific ARARs for the Site are associated with protection of Hartwell Lake and the wetlands in the vicinity of the VOC-affected areas of the Site. Action-specific ARARs are usually technology- or activity-based requirements or limitations on particular activities related to the RA selected to manage the hazardous substances, pollutants, or contaminants. A summary of potential ARARs and “to-be-considered” values (TBCs) appears in Table 4-1 through Table 4-3. The identification of ARARs will continue to be refined and updated throughout the remedial design/remedial action (RD/RA) process.

Other requirements that may be used in the FFS process include various guidelines and criteria that are identified within applicable TBC references and considerations. TBCs are typically non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the same regulatory status of ARARs.

4.1 Chemical-specific Applicable or Relevant and Appropriate Requirements

Chemical-specific ARARs are Federal and State requirements that define/establish acceptable exposure levels and are useful in establishing remediation goals. Chemical-specific ARARs are available for the Site-related COCs that are present in the soil, groundwater, and surface water media. A brief discussion of potential chemical-specific ARARs relative to Site COCs follows:

Groundwater Applicable or Relevant and Appropriate Requirements

Promulgated USEPA MCLs for drinking water have been previously applied as chemical-specific ARARs for the Site COCs detected in groundwater. MCLs are concentration limits applied to public drinking water systems in consideration of human health and technical practicality concerns. MCLs exist for most of the site-related COCs. The chemical-specific groundwater ARARs are listed in Table 4-1.

Surface Water Applicable or Relevant and Appropriate Requirements

For Site COCs present in the surface water of the Site, the chemical-specific ARARs are the South Carolina Water Classifications and Standards (South Carolina Regulations 61-68 Appendix). These criteria are based solely on human health and environmental considerations, without any allowance for economic or technical considerations. Table 4-1 includes a listing of the chemical-specific ARARs for site-related COCs detected in surface water.

4.2 Location-specific Applicable or Relevant and Appropriate Requirements

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely on the basis of location. Examples of location-specific ARARs include state and federal requirements to protect floodplains, critical habitats, and wetlands. Remedial measures that involve remedial activity within the adjacent USACE shoreline of Hartwell Lake or in the lake itself would require a Corps permit. The range of alternatives potentially applicable for groundwater may be subject to potential location-specific ARARs presented in Table 4-2.

4.3 Action-specific Applicable or Relevant and Appropriate Requirements

Action-specific ARARs are technology-based or activity-based requirements or limitations on actions taken with respect to solid and/or hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy. Since there are usually several alternative treatment measures for any remedial site, various requirements can be ARARs; not all will be relevant to each potential remedy. Table 4-3 lists potential action-specific ARARs.

Table 4-1
Chemical-Specific ARARs

MEDIA	SOURCE	LAW/REGULATION	SUMMARY OF REQUIREMENT	ARAR/TBC STATUS
Soil (federal)	USEPA RSL Table 2014	Protection of groundwater risk-based soil screening levels	Provides non-enforceable, generic screening levels for constituents in soil based on potential migration to groundwater.	TBC – non-promulgated risk-based guidance levels for constituents
	USEPA RSL Table 2014	Protection of Groundwater MCL-based soil screening levels	Provides non-enforceable, generic screening levels for constituents in soil based on potential migration to groundwater.	TBC – non-promulgated MCL-based guidance levels for constituents
	USEPA Soil Screening Guidance (SSG) 1996	Migration to groundwater dilution attenuation factor 20 (DAF 20) soil screening levels	Provides non-enforceable, generic screening levels for constituents in soil based on potential migration to groundwater.	TBC – non-promulgated MCL-based guidance levels for constituents
Groundwater (federal)	40 CFR Part 141.61(a)	Safe Drinking Water Act, National Primary Drinking Water Regulations, MCLs	Specifies the maximum permissible concentration of contaminants in public drinking water supplies. Federally enforceable standards based, in part, on health effects and on the availability and cost of treatment techniques.	ARAR – Relevant and appropriate for groundwater that is or may be used for drinking water
Surface Water and Groundwater (South Carolina)	R.61-68	Water Classifications and Standards	Establishes a system and rules for managing and protecting the quality of South Carolina's surface and groundwater. ▪ Maintain and improve surface waters to provide for the survival and propagation of a balanced indigenous aquatic community of flora and fauna and to provide for recreation in and on the water. ▪ Maintain or restore groundwater quality so it is suitable as a drinking water source without any treatment.	ARAR – Relevant and appropriate for any surface water or groundwater within South Carolina

Table 4-1
Chemical-Specific ARARs

MEDIA	SOURCE	LAW/REGULATION	SUMMARY OF REQUIREMENT	ARAR/TBC STATUS
Maximum Contaminant Levels in Surface Water (South Carolina)	R.61-68 Appendix	Water Classifications and Standards	Surface water rules cite these numerical standards for Site COCs detected in surface water samples: Tetrachloroethene – 0.00069 mg/L	ARAR – Surface water standards are applicable for Hartwell Lake.
Maximum Contaminant Levels in Drinking Water (South Carolina)	R.61-58.8	Numerical levels for contaminants in drinking water.	Groundwater rules cite these numerical standards 1,1-Dichloroethene – 0.007 mg/L 1,2-Dichlorobenzene – 0.6 mg/L 1,2-Dichloroethane – 0.005 mg/L 1,2-Dichloropropane – 0.005 mg/L Benzene – 0.005 mg/L Bromodichloromethane – 0.080 mg/L Chloroform – 0.080 mg/L *cis*–1,2-Dichloroethene – 0.070 mg/L Ethylbenzene – 10 mg/L Methylene chloride – 0.005 mg/L Tetrachloroethene – 0.005 mg/L Trichloroethene – 0.005 mg/L Vinyl chloride – 0.002 mg/L Xylenes – 10 mg/L	ARAR – Primary MCLs are applicable for groundwater.
Maximum Contaminant Levels in Drinking Water (South Carolina)	R.61-58.8	Numerical levels for contaminants in drinking water.	Groundwater rules cite these numerical standards Sulfate – 250 mg/L pH – 6.5 – 8.5 s.u.	TBC - Secondary standards are TBC for groundwater.

Table 4-2
Location-Specific ARARs

LOCATION	LAW/REGULATION	SUMMARY OF REQUIREMENT	ARAR/TBC STATUS
Floodplains	Executive Order No. 11988, Section 2(a)(2)	▪ Avoid, to the extent possible, or minimize long- and short-term adverse impacts associated with the occupancy and modification of floodplains and avoid direct or indirect support of floodplain development if a practicable alternative exists. ▪ Provide leadership and take action to reduce the risk of flood loss, to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains. ▪ Evaluate potential effects of actions that may be taken in floodplains and ensure that planning and budgeting reflect consideration of flood hazardous and floodplain management.	TBC – To be considered for activities conducted with in a 100-year floodplain
Wetlands	Executive Order No. 11990, Section 2(a)	▪ Avoid, to the extent possible, or minimize long- and short-term adverse impacts associated with the destruction, loss or modification of wetlands and avoid direct or indirect support of new construction in wetlands if a practicable alternative exists. ▪ Provide leadership and take action to minimize destruction, loss, or degradation of wetlands, and to preserve and enhance the natural and beneficial values of wetlands.	TBC – To be considered for activities conducted with in a wetland
Within floodplain	Federal 40 CFR 6, Appendix A Fish and Wildlife Coordination Act 40 CFR 6.302	Requires action to avoid adverse effects, minimize potential harm, restore and preserve natural and beneficial values if action will occur in a floodplain.	ARAR – Applicable for activities within a 100-year floodplain
Near Significant Artifacts	National Historic Preservations Action, Section 106, 36 CFR Part 65	Requires action to recover and preserve artifacts if alteration of terrain threatens significant scientific, prehistorical, historical, or archaeological data.	ARAR – Applicable for activities near significant artifacts
Near Historic Projects	National Historic Preservations Action, Section 106, 36 CFR Part 800	Requires action to preserve historic properties and planning of action to minimize harm to National Historic Landmarks if action is on property included in or eligible for the National Register of Historic Places.	ARAR – Applicable for activities near historic projects owned or controlled by a federal or state agency

Table 4-2
Location-Specific ARARs

LOCATION	LAW/REGULATION	SUMMARY OF REQUIREMENT	ARAR/TBC STATUS
USACE Hartwell Lake Shoreline	Section 460D, Title 16, US Code Section 9701. Title 31, US Code NEPA of 1969 Sect. 404 of CWA (33 USC 1344) Sect. 1134(d) Water Resources Development Act Sect. 10 of Rivers and Harbors Act Flood Control Act of 1944 Section 6, Public Law 97-140 Title 36, Chapter III, Part 327 CFR Title 33, Chapter II, Part 323 CFR Executive Order 12088 Executive Order 11644	USACE Shoreline Management Plan for Hartwell Lake requires permits for activities along the Hartwell Lake shoreline. Shoreline Use Permits and Licenses apply to routine issues such as docks, underbrushing, and bank stabilization. Specified Acts or Letter Permits are required for activities not specifically outlined in the Shoreline Management Plan, which would include groundwater monitoring installations and remediation activities within the USACE shoreline.	ARAR – Applicable for activities within the USACE shoreline boundary.
Near Critical Habitats	Endangered Species Act of 1973 50 CFR Part 200 50 CFR Part 402 Fish and Wildlife Coordination Act 33 CFR Parts 320-330	Requires action to conserve endangered species or threatened species, including consultation with the Department of Interior if it is determined that endangered or threatened species are present.	ARAR – Applicable for activities near critical habitats for endangered species
Wetlands	Fish and Wildlife Coordination Act 40 CFR 6.302 CWA, Section 401 CWA Section 404 Rivers and Harbors Act, Section 10	40 CFR Part 6 Subpart A sets forth USEPA policy for carrying out the provisions of Executive Orders 11988 (Floodplain Management) and 11990 (Protection of Wetlands). Executive orders are binding on the level (*e.g.,* federal, state) of government for which they were issued. Requires actions to avoid adverse effects, minimize potential harm, and preserve and enhance wetlands to the extent possible.	ARAR – Applicable for activities within a wetland
Area affecting stream or river	Wild and Scenic Rivers Act Fish and Wildlife Coordination Act 40 CFR 6.302	Requires avoiding actions that would have a direct adverse effect on a scenic river. Requires action to protect fish or wildlife if an activity modifies a stream or river	ARAR – Applicable for activities potentially affecting a wild or scenic river or modifying a stream or river.

Table 4-3
Action-Specific ARARs

GENERAL ACTION CATEGORY	LAW/REGULATION	SUMMARY OF REQUIREMENT	ARAR/TBC STATUS
Characterization of Solid Waste	40 CFR 262.11 and R.61-79.262.11	Requires determination if solid waste is hazardous waste	ARAR – Applicable for material excavated during RAs
	40 CFR 268.7 and .9 and R.61-79.268. 7 and .9)	For hazardous wastes to be land disposed, requires determination if underlying hazardous constituents are present above regulatory limits	ARAR – Applicable if material excavated during RA is hazardous waste
Management of Remediation Wastes On-Site	40 CFR 264.552	Establishes Corrective Action Management Units (CAMUs) – land based units where hazardous waste may be placed without meeting land disposal restriction treatment standards. Hazardous waste may be treated *ex situ* and placed in a CAMU	ARAR – Relevant and appropriate if excavated soil meets the definition of hazardous waste.
Transportation of hazardous waste on-site	40 CFR 262.20(f) and R.61-79.262.20(f)	Generator manifesting requirements do not apply for transportation on-site. Generator or transporter must comply with the requirements set forth in in 40 CFR 263.30 and .31 in the event of a discharge of hazardous waste on a private or public right-of-way	ARAR – Applicable if material excavated during RA is hazardous waste
Transportation of hazardous materials	49 CFR 171.1(c)	Requires compliance with all applicable provision of the HMTA and DOT HMR at 49 CFR 171-180 for persons who transport a hazardous material in commerce or who cause hazardous materials to be transported in commerce	ARAR – Applicable for materials that meet the definition of "hazardous material."
Excavation	South Carolina Erosion and Sediment Control Regulations (R.61-72 Article 3)	Storm water management and sediment control plan approvals are necessary prior to engaging in any land-disturbing activity related to residential, commercial, industrial or institutional land use which are not specifically exempted or waived by these regulations	ARAR – Applicable for excavations meeting the requirements of the regulation

Table 4-3
Action-Specific ARARs

GENERAL ACTION CATEGORY	LAW/REGULATION	SUMMARY OF REQUIREMENT	ARAR/TBC STATUS
Land Clearing	South Carolina Erosion and Sediment Control Regulations (R.61-72 Article 3)	Storm water management and sediment control plan approvals are necessary prior to engaging in any land-disturbing activity related to residential, commercial, industrial or institutional land use which are not specifically exempted or waived by these regulations	ARAR – Applicable for land clearing activities meeting the requirements of the regulation
Managing Storm Water	South Carolina Erosion and Sediment Control Regulations (R.61-72 Article 3)	Storm water management and sediment control plan approvals are necessary prior to engaging in any land-disturbing activity related to residential, commercial, industrial or institutional land use which are not specifically exempted or waived by these regulations	ARAR – Applicable for land clearing activities meeting the requirements of the regulation
Underground injection	South Carolina Underground Injection Control Regulations (R.61-87)	Specific requirements for controlling underground injection in the State and provisions for: the classification and regulation of injection wells; prohibiting unauthorized injection; and, requirements for abandonment, monitoring, and reporting for existing injection wells used to inject wastes or contaminants.	ARAR – Applicable for underground injections
Installation of monitoring wells	South Carolina Well Standards (R.61-71)	Establishes minimum standards for the construction, maintenance, and operation of monitoring wells (including non-standard installations) and boreholes to ensure that underground sources of drinking water are not contaminated and public health is protected.	ARAR – Applicable for installation of monitoring wells
Land use controls	Voluntary Clean-up Program – Model Contract	Establishes guidelines for institutional controls.	TBC – To be considered for land use controls

Section 5
Development of Remedial Action Objectives

This section presents remedial action objectives (RAOs) developed for the Site groundwater, based on interim corrective measures that have been previously conducted at the Site, the Site conceptual model presented in Section 3 of this FFS, and the current Site groundwater monitoring data.

The purpose of a remedial action is to implement a remedy that removes, treats, or isolates contaminant mass to the extent that residual COC concentrations are protective of the public health, community safety and the overall environment. Specifically, RAOs are employed to define the goals for ensuring protection of human health and the environment and formulate a defensible basis for identifying remedial alternatives development and comparison of various management options to reduce risk, and to maintain acceptable levels of risk exposure at the Site. The RAOs for the former WPH Clemson Site were developed from the results of previous soil and groundwater investigations that have been conducted at the Site.

5.1 Constituents of Potential Concern

Constituents of potential concern are those constituents in groundwater that are present above background concentrations and have established state or federal maximum contaminant limits. The primary COCs for the Site include various chlorinated ethenes/ethanes, such as PCE, TCE, and their associated daughter products.

5.2 Remedial Action Objectives

The RAOs for the WPH Clemson Site include goals for the protection of human health and the environment and for the management of contaminant migration potential. These RAOs are presented and further discussed below.

- Minimize future human exposure (i.e., dermal contact, ingestion, and inhalation) to groundwater with contaminants above levels that are protective of beneficial use.
- Treat or remove chlorinated VOCs present in the groundwater to the extent practicable, or suitably contain chlorinated VOCs when treatment or removal is not technically practicable.
- Minimize future migration of chlorinated VOCs into Hartwell Lake, to the extent reasonable and practicable.

5.3 Remediation Target Concentrations

To achieve the RAOs of reducing potential risk and migration at the site, target concentrations are established for use in reviewing the various remedial alternatives described in this FFS. Target concentrations are based on groundwater and surface water ARARs, as presented below. Proposed clean-up targets for groundwater are listed in Table 5-2.

5.4 Estimated Volume of Materials Addressed in the Focused Feasibility Study

The area of VOC-affected groundwater area addressed within the scope of this FFS is shown in Figure 2-1. Calculating the four aquifer zones separately with thickness and porosity estimates applicable to the individual zones, the volume of potentially affected groundwater, as delineated in Figure 2-1, is estimated to range from a lower bound of 50 million gallons to an upper bound of 100 million gallons.

Table 5-1
Remedial Action Objectives and General Response Actions

OBJECTIVE	COMMENTS	GENERAL RESPONSE ACTIONS
Prevent future human exposure (dermal contact, ingestion, and inhalation) to groundwater with contaminants above levels that are protective of beneficial groundwater use	Future residential development is planned in the plume area, but public water will be provided. Several constituents are currently present in site groundwater at concentrations that would result in risks or hazards greater than USEPA's acceptable range if groundwater were contacted or ingested. Groundwater COCs present a potential vapor intrusion issue if residences are constructed w/o suitable engineering controls within the immediate vicinity of the affected groundwater.	▪ Institutional controls will prevent future groundwater use. ▪ Directly treating or removing constituents that exceed MCLs or contribute significantly to risk will improve groundwater quality and mitigate the risk of vapor intrusion when residences are constructed in the affected groundwater area. ▪ Engineering controls to mitigate accumulation of possible VOC vapors within residential housing units.
Treat or remove chlorinated VOCs present in the groundwater to the extent practicable, or suitably contain chlorinated VOCs when treatment or removal is not technically practicable.	Known sources of constituents to groundwater have been addressed.	▪ Directly treating or removing constituents that exceed MCLs will improve groundwater quality. ▪ Groundwater treatment or containment strategies would serve to reduce migration within the groundwater and to Hartwell Lake.
Minimize future migration of chlorinated VOCs into the Hartwell Lake, to the extent reasonable and practicable.	Under current conditions, the migration of site groundwater to Hartwell Lake results in surface water at the shoreline having detectable concentrations of some site COCs.	▪ Improvements in groundwater quality will serve to reduce migration to Hartwell Lake. ▪ Groundwater containment strategies would serve to reduce migration to Hartwell Lake.

Table 5-2
Proposed Remedial Target Concentrations – Groundwater

CONSTITUENT	MAXIMUM OBSERVED[1] (mg/L)	REMEDIATION GOAL (mg/L)	BASIS FOR REMEDIATION GOAL
Benzene	0.02 (RMW-24, 7/2014)	0.005	Primary MCL
Bromodichloromethane	0.004 (DG-06B; 7/2014)	0.08[2]	Primary MCL
Chloroform	0.04 (DG-06B; 7/2014)	0.08[2]	Primary MCL
1,1-Dichloroethene	0.007 (DG-07; 7/2014)	0.007	Primary MCL
1,2-Dichlorobenzene	0.006 (RMW-24; 7/2014)	0.6	Primary MCL
1,2-Dichloroethane	0.004 (RMW-24; 7/2014)	0.005	Primary MCL
1,2-Dichloropropane	0.0004 (RMW-24; 7/2014)	0.005	Primary MCL
1,4-Dichlorobenzene	0.0005 (RMW-24; 3/2021)	0.075	Primary MCL
cis-1,2-Dichloroethene	2.6 (RMW-20A; 3/2021)	0.07	Primary MCL
Chloroform (THM)	0.012 (RMW-05B;3/2021)	0.1	Primary MCL
Ethylbenzene	0.35 (RMW-02; 3/2021)	0.7	Primary MCL
Methylene chloride	0.0021 (RMW-02; 3/2021)	0.005	Primary MCL
Styrene	0.0011 (RMW-24; 3/2021	0.1	Primary MCL
Tetrachloroethene	10 (RMW-18A and RMW-23A; 7/2014)	0.005	Primary MCL
Toluene	0.01 (RMW-23D and MG-06B; 6/2016)	1.0	Primary MCL
trans-1,2-Dichloroethene	0.0026 (RMW-23C; 3/2021)	0.1	Primary MCL
Trichloroethene	0.26 (RMW-17A; 3/2021)	0.005	Primary MCL
Vinyl chloride	0.016 (RMW-20A; 3/2021)	0.002	Primary MCL
Xylenes	1.1 (RMW-02; 3/2021)	10	Primary MCL

(1) Based on July 2014 sampling round supplemented by pilot study groundwater monitoring in 2017 and 2021.

Section 6
Identification and Screening of Remedial Technologies

This section of the FFS summarizes and screens an array of different remedial treatment methods that have been considered to address the VOC-affected groundwater at the Site. A tabular summary of these potential remedial technologies is presented in Table 6-1. These treatment methods have been evaluated and screened to focus on those remedial technologies that are believed to be most feasible and/or technically practical for implementation at the Site. The screening process is intended to remove from further consideration remedial technologies that can be demonstrated to be ineffective in addressing site-specific conditions and/or unable to achieve remedial action objectives or effectively treat the site-specific COCs.

A generalized cost comparison has also been provided to assess the relative cost requirements necessary to implement these potential remedial technologies. These should not be misconstrued as detailed construction cost estimates, but rather an added consideration that has been developed for the technology evaluation and screening process. Table 6.1 includes a column in which there is commentary specifying whether or not a particular remediation technology was retained during the screening process and carried forward in the FFS for further consideration and evaluation. The remedial technologies that have been retained will be the subject of more detailed review as site-specific RA alternatives in Section 7.

6.1 Description of the Screening Process

The screening process for the various remedial technologies was performed in consideration of each treatment technology's relative technical merits, including construction implementability, treatment effectiveness, appropriateness to site conditions, and general cost implications. The general types of response measures considered in Table 6.1 can be categorized by their overall approach to addressing the VOC-affected media at the site, including: institutional controls, containment strategies, and active treatment methods. It is possible, even likely, that several of these general response measures could be combined into a more integrated and comprehensive set of remedial alternatives. Such alternatives would be focused on efficiently and cost effectively achieving the RAOs and complying with ARARs.

The remedial response methods that were considered and screened in Table 6.1 were identified and selected based on the following resources and information:

- USEPA guidance documents
- Current/recent technical literature

- Site-specific considerations and community-related factors
- Prior TRC/WPH experience, including the ABC+ pilot studies (which are summarized in Section 2.5)

Various site characteristics and the nature of the affected media were considered during the evaluation and screening the remediation alternatives. Many technical benefits and limitations associated with each treatment technology were also considered. Some of the specific considerations addressed during the screening process are described below:

- ***Site characteristics*** – The available Site data were evaluated to identify conditions that may limit or promote the application of certain remediation techniques or methods. The remediation methods that were not expected to be effective and/or implementable, based on our general knowledge and understanding of Site characteristics, were eliminated from further consideration. A review of these Site-specific conditions and potential constraints was addressed during the review and evaluation of the various remedial alternatives.
- ***Characteristics of COC-affected media*** – The Site groundwater regime exhibits characteristics that may limit or reduce the effectiveness of a given remediation treatment method. Where a given remedial alternative was determined to be constrained or otherwise limited by these Site-specific characteristics, the remedial alternative was subject to elimination from further consideration.
- ***Technology limitations*** – During the screening process, the following considerations were reviewed and evaluated for each remedial treatment measure, including: current level of technology development; long-term performance history; documented instances of failure and its implications; and prior issues associated with constructability, operations, monitoring and/or maintenance. In this manner, remedial treatment methods that have been previously applied at other sites and have been shown to be ineffective, performed poorly, or have not successfully achieved RAOs during field performance testing were eliminated from further consideration.
- ***Regulatory considerations -*** State and federal regulations that may limit or otherwise preclude the implementation of a specific remedial treatment method were considered.

TRC's rationale for applying general screening ratings for evaluating the relative implementability, treatment effectiveness, and relative overall cost of a particular remedial alternative follows:

- ***Implementability***
  - **Implementable** – In order to be considered implementable, a remedial technology should have a documented history of prior and successful field implementation at sites exhibiting similar COCs and affected media characteristics. The technology would be considered implementable if Site characteristics or affected media characteristics suggest that minor to no modifications for the remedial technology are needed in order for it to be suitable for implementation at the site.
  - **Moderately implementable** – Site or affected media characteristics suggest that significant modifications and/or enhancements would be required to the technology in order for it to be implemented at the site.
  - **Low implementability** – Site or affected media characteristics suggest that there would be major significant challenges to successfully implementing the technology at the Site. Those

remedial technologies determined to exhibit a limited potential for successful application at the Site were given a low rating.

- ***Effectiveness***
  - **Effective** – In order for a remedial treatment method to be considered effective, it must have a prior history of having consistently achieved RAOs at other sites with similar site and affected media characteristics. Effective remedial treatment methods would be expected to exhibit a high probability for successful attainment of RAOs for this Site, considering the characteristics of the Site, the affected media, and the COCs being addressed.
  - **Partially effective** –Remedial treatment methods that exhibit the potential to partially achieve the RAOs, or may require significant engineering or design modifications to address site or affected media characteristics, would be considered partially effective.
  - **Not effective** – Remedial treatment methods may be categorized as not effective if technology limitations are identified that would preclude the remedial treatment method from effectively achieving the RAOs.
- ***Relative Cost***
  - ***Low*** – A low cost rating would be applied to a remedial treatment method that has been implemented at other similar sites at a capital and O&M total net present value of less than $1,000,000.
  - ***Moderate*** – A moderate cost rating would be applied to a remedial treatment method that has been implemented at other similar sites at capital and O&M total net present value cost in the range of $1,000,000 to $2,000,000.
  - ***High*** – A high cost rating would be applied to a remedial treatment method that has been implemented at other similar sites at a capital and O&M total net present value cost in excess of $2,000,000.

6.2 Potential Groundwater Remedial Technologies

A number of potential general remedial strategies and specific remedial technologies have been identified and screened for groundwater remediation at the Site. These strategies and technologies are presented on Table 6-1 and include No Action, Institutional Controls, Hydraulic Containment and Control, and *In situ* Treatment Measures. General descriptions of the potential treatment remedies considered within these broader categories are outlined below. The overall intent and focus of the groundwater treatment remedies considered for the Site is to reduce the observed levels of chlorinated VOCs from Site groundwater, minimize migration of these chlorinated VOCs to Hartwell Lake, and restore the underlying groundwater quality of the Site.

- ***No Action*** – This remedial alternative has been included as a specific requirement of the National Contingency Plan (NCP; 40 CFR 300). Under this alternative, no active remediation or regulatory controls would be imposed to address VOC-affected groundwater at the site beyond measures already conducted or in place.

- ***Institutional Controls and Site Access Restrictions*** – In accordance with USEPA guidance, institutional controls may include various land-use restrictions (*e.g.,* deed restrictions, conservation easements) to limit human/environmental exposure to site COCs. Deed restrictions could be enacted to reduce the potential for future exposure to the groundwater at the Site. Institutional controls represent a meaningful consideration for minimizing human exposure.
- ***Monitored Natural Attenuation*** – Monitored Natural Attenuation (MNA) has become more widely utilized as a term of art that has both regulatory and technical implications and draws upon a number of naturally occurring environmental processes. Over time, MNA treatment processes can reduce constituent concentrations in groundwater. In addition to natural advective dispersion effects, some aquifers exhibit natural groundwater quality conditions that are conducive to varying levels of physical, chemical, or biological treatment processes, which can facilitate long-term reductions in contaminant mass. Additionally, some aquifer geochemistry (after receiving artificial stimulation and/or enhancements) can achieve/maintain MNA treatment conditions at sustainable levels that are conducive to long-term reductions in contaminant mass. At the former WPH Site, MNA is expected to ultimately result in COC reductions. Thus, MNA can represent a useful and appropriate closure strategy for a particular site, following completion of active treatment measures to reduce the COC mass to more suitable levels appropriate for MNA use and application.
- ***Hydraulic containment –***Hydraulic containment can encompass a wide variety of remedial options ranging from physical barriers (such as slurry walls) to hydraulic capture and control of groundwater plumes via active groundwater pumping methods or phytoremediation techniques. A slurry wall could be installed to present a barrier to the flow of VOC-affected groundwater. An important consideration for any barrier wall would reside in its ability to form an effective barrier to groundwater flow. For most barrier walls, this is achieved by "keying" the barrier wall into low permeability geologic strata. The fractured bedrock that underlies the former WPH site presents a significant challenge/obstacle, in this regard.

  Groundwater pumping and treatment would entail the construction and installation of an extensive network of groundwater recovery wells, piping, instrumentation, and a centralized treatment system and discharge outfall. This extensive infrastructure would not be consistent with the ongoing and pending residential development activities at the Site.

  Phytoremediation represents an innovative remedial technique, providing a more subtle form of hydraulic control via rhizofiltration (i.e., uptake of water and COC adsorption by selected plant species). As the VOC-affected groundwater is taken up by the plant roots, plant-based processes (like phytovolatilization) can result in the uptake and release of groundwater via transpiration through leaves and diffusion through plant stem|trunk. Phytodegradation treatment (i.e., contaminant sorption/accumulation or degradation within the plant tissue) occur and can reduce observed VOC mass over time. While it is conceivable that active groundwater pumping/treatment and/or phytoremediation could be applied to exert hydraulic containment controls at the Site (*i.e.*, reduce COC mass migrating toward Hartwell Lake), neither of these treatment strategies are amenable to current and future land-uses anticipated for the Site.
- ***In situ treatment*** – There are several i*n situ* treatment methods available to treat chlorinated VOCs in groundwater, including chemical oxidation, enhanced reductive dechlorination (ERD), and zerovalent iron (ZVI). *In situ* chemical oxidation (ISCO) involves introduction of an aggressive

chemical oxidant into the VOC-affected groundwater, where the oxidant makes direct contact with the contaminant and chemically degrades the organic mass. With direct contact, this oxidative treatment reaction can occur in a relatively short time period. ERD is a biologically based treatment alternative that is designed to enhance the growth of indigenous anaerobes (or artificially bioaugmented microbes) present in soils that possess a unique and highly specialized capacity to respire and degrade various chlorinated VOC groundwater contaminants. In order to degrade chlorinated VOCs, these anaerobic soil microbes must be provided with suitable anoxic and reducing environmental conditions to facilitate their population growth and expanded Site presence. Under proper treatment conditions, these anaerobic organisms are capable of degrading chlorinated organics, like PCE and TCE, to by-products like ethene, ethane, and carbon dioxide. Zero valent iron (ZVI) is another *in situ* remedial technology that can degrade chlorinated ethenes via a physical/chemical reaction that effectively reduces the chlorinated VOCs to nontoxic end products. ZVI is typically introduced into the subsurface via direct injection or applied as a permeable reactive barrier (PRB), through which the VOC-affected groundwater flows through the treatment zone.

Another potential *in situ* treatment technology involves air sparging. Air sparging typically involves injection of air into targeted treatment zones within a VOC-affected aquifer. As the injected air traverses horizontally and vertically through the soil column, the inherent volatility of the VOCs results in what amounts to an underground air stripper. The VOCs are effectively desorbed from the soil column and flushed from the aquifer's saturated zone. Typically, a soil vacuum is applied to capture and collect VOCs that have been removed from the groundwater within the unsaturated (vadose) zone soils. where the desorbed VOCs are captured and removed from the subsurface. Similar to the groundwater pump and treatment alternative, air sparging and SVE treatment systems would require construction of considerable Site infrastructure (i.e., air sparging/SVE wells, treatment equipment, pumps and piping) that would not be compatible with the current and future land-use activities that are anticipated for the property.

Groundwater performance monitoring is considered to represent an essential component f for each of the remedial strategies considered in Table 6.1 (with the exception of the No Action treatment strategy).

6.3 Discussion of Potential Groundwater Remedies

As indicated earlier, a wide variety of remedial technologies is potentially applicable to the Site. Of this larger array of available remedial technologies, a subset of the treatment alternatives is consistent with overall Site needs, requirements, and RAOs. Within this FFS, these remedial technologies have been categorized into a shortlist of potential groundwater treatment measures for more detailed consideration and evaluation. The various categories of remedial alternatives that are considered in Section 6 include:

- **The No Action alternative** - This alternative has been retained for further evaluation as a point of comparison for the other active treatment remedies, as required by USEPA guidance.
- **Institutional Controls and Land Use Restrictions** – After careful consideration, this alternative was not retained for more detailed evaluation, primarily because it does not represent a stand-alone remedy that would be appropriate to Site conditions (existing and future). Because the Site is

currently under active redevelopment as a residential community, institutional controls and land-use restrictions would not provide the active treatment response that is required to achieve RAOs in a meaningful timeframe. The use and application of institutional controls and land-use restrictions does represent a reasonable path for mitigating human use and exposure to the underlying, VOC-affected groundwater in a manner that is protective of human health and the environment. In many ways, such considerations have already been contemplated and incorporated into the VCC that exists between the property owner/developer and SC DHEC.

- **Monitored Natural Attenuation** – MNA has been retained for further evaluation, since MNA represents a logical and useful transition between an active treatment measure for the VOC-affected groundwater and achieving final Site closure. Although the current VOC plume concentrations and contaminant mass distribution do not meet established MNA guidance criteria, there exists a high likelihood that MNA could be applied as a supplemental remedial response measure, upon completion of a more suitable active treatment measures to reduce the VOC contaminant mass. At reduced contaminant mass levels, MNA could then be applied to achieve final Site closure as a polishing, clean-up step across the VOC-affected groundwater area.
- **Hydraulic Containment** - The application of possible hydraulic barriers, air sparging and/or groundwater pumping and treatment systems is not viewed as consistent and compatible with the ongoing site redevelopment activities and the long-term land-use focus of the property owner. While there may be various hydraulic containment technologies available and capable of achieving some of the Site remedial action objectives, existing Site conditions (*i.e.*, fractured bedrock environment) and ongoing Site redevelopment activities preclude any meaningful consideration of barrier walls, air-sparging systems and/or groundwater pump and treatment systems. It is for these reasons that hydraulic containment alternatives have not been retained for further evaluation.
- ***In Situ* Treatment** - The *in situ* treatment of VOC-affected groundwater is a treatment alternative that has received wide-spread use and application at Sites like the former WPH Clemson facility. *In situ* treatment technologies are appropriate to observed Site conditions and consistent with the current/future land-use and redevelopment activities. *In situ* treatment alternatives can be applied at the Site in parallel with ongoing site redevelopment. It is for these reasons that *in situ* treatment measures have been retained for further evaluation in this FFS.

Table 6-1
Identification and Screening of Remedial Technologies

GENERAL RESPONSE STRATEGY	REMEDIAL TECHNOLOGY	DESCRIPTION	IMPLEMENTABILITY	EFFECTIVENESS	RELATIVE COST	ACCEPTABLE FOR FURTHER CONSIDERATION
No Action	No Action	Reliance upon naturally occurring physical, biological and chemical processes to reduce COC concentrations over time. As this option involves no action, groundwater monitoring is not included.	Implementable	Not Effective ▪ No treatment of COCs ▪ Migration of groundwater COCs is unchanged ▪ VOC discharge to Hartwell Lake	Not Applicable	Yes - Required by Guidance
Institutional Controls	Land Use Restrictions	Involves permanent assignment of a notice or restriction on the property deed to limit/reduce the potential for future exposure to the underlying VOC-affected groundwater.	Implementable	Partially effective ▪ Effective in limiting future exposure to VOC affected groundwater ▪ Groundwater exposure is already minimal due to current availability of public water service and current/reasonably anticipated future land use. ▪ Not effective in restoring groundwater quality conditions to levels consistent with MCLs ▪ Not effective in reducing downgradient migration of groundwater COCs.	Low	Yes, but only as a supplemental measure for other active treatment remedies
Natural Attenuation	Monitored Natural Attenuation	Reliance upon naturally occurring physical, chemical, and biological processes to reduce COC concentrations over time. Periodic groundwater monitoring will be required to verify long-term effectiveness.	Low Implementability ▪ Current groundwater concentrations within the plume zone areas generally exceed concentrations considered amenable to MNA as a stand-alone remedy. ▪ Current groundwater conditions are not amenable to VOC degradation without treatment amendments or enhancements.	Partially effective ▪ Limited risk of groundwater exposure due to current availability of public water service. ▪ Natural attenuation will require extended time-frame to achieve RAOs. ▪ VOC-affected groundwater will continue to migrate downgradient from site toward Hartwell Lake	Low	Yes, but only as a supplemental measure to other active treatment remedies
Hydraulic Containment	Slurry Wall and Capping	Includes installation of a slurry wall surrounding the VOC-affected groundwater plume area. A cap to limit infiltration and groundwater pumping wells/treatment system would be necessary to manage groundwater levels within the enclosed plume zone area.	Low implementability ▪ Site characteristics such as fractured bedrock and aquifer depth limit technical feasibility of slurry wall. ▪ Areal extent of affected groundwater may affect technical feasibility. ▪ Will require significant ongoing O&M (*i.e.,* treatment of groundwater mounded behind slurry wall. ▪ Will limit future redevelopment of the treatment area for residential use.	Partially effective ▪ Will limit downgradient migration of groundwater COCS. ▪ Underlying saprolite and weathered bedrock will not provide a suitable confining unit for keying in a slurry wall. ▪ Could potentially promote creation of new lateral and vertical contaminant migration pathways. ▪ Not consistent with future land-use requirements.	High	No

Table 6-1
Identification and Screening of Remedial Technologies

GENERAL RESPONSE STRATEGY	REMEDIAL TECHNOLOGY	DESCRIPTION	IMPLEMENTABILITY	EFFECTIVENESS	RELATIVE COST	ACCEPTABLE FOR FURTHER CONSIDERATION
Hydraulic Containment (continued)	Groundwater Pumping and Treatment	Includes extracting VOC-affected groundwater using an array of extraction wells and piping for treatment at centralized treatment system for reduction of COC levels suitable for discharge to Hartwell Lake via NPDES outfall.	Low implementability ▪ Extracted groundwater will require treatment. ▪ Will require significant ongoing O&M ▪ Groundwater pumping may induce recharge from Hartwell Lake. ▪ Obtaining NPDES permit for discharge of treated water could be challenging.	Potentially effective ▪ Effectiveness of treatment system is dependent upon the ability to achieve hydraulic control of VOC affected groundwater. ▪ Hydrogeology of site (low permeability) limits influence and extraction rate of wells. ▪ Fractured bedrock environment represents challenge. ▪ Extended timeframe to achieve site closure.	High	No
	Phytoremediation	Suitable plants and microorganisms are available to capture, remove or limit further migration of COCs in groundwater.	Implementable ▪ Technology available and feasible for hydraulic containment and COC treatment. ▪ Can be monitored/maintained. ▪ If implemented on the USACE Shoreline, a Shoreline permit would be required.	Partially effective ▪ Plants can provide hydraulic control of groundwater, but only during the growing season. ▪ Long-term care and sustainability of plants questionable ▪ Removal of chlorinated VOCs via rhizofiltration, phytodegradation, and phytovolatilization. ▪ Limited to no impact on groundwater quality at deeper depths. ▪ Will limit future site redevelopment.	High	No
In situ treatment	Chemical Oxidation	Chemical oxidation involves introduction of reactant into the subsurface that chemically converts COCs. The oxidizing agents most commonly applied include hydrogen peroxide, catalyzed hydrogen peroxide, potassium permanganate, sodium permanganate, sodium persulfate, and ozone.	Implementable ▪ Technically and administratively feasible. ▪ Technology is generally reliable. ▪ Can be monitored/maintained. ▪ UIC permit required. ▪ Can achieve closure objectives in an expedited timeframe.	Effective ▪ Can effectively degrade COCs within the treatment area. ▪ Extent of treatment influence can be limited by the physical characteristics of the soil and aquifer materials. ▪ Direct contact between oxidant and COC is necessary. ▪ Repeated treatments may be required	High	Yes
	Zero Valent Iron	ZVI is a reactive iron powder/particulate that is capable of inducing effective chemical reduction of chlorinated VOCs. Can be installed as a physical treatment wall through which groundwater passes and undergo abiotic reactions that dechlorinate VOCs in groundwater. Can also be introduced by direct injection into the subsurface.	Low implementability ▪ Site characteristics such as fractured bedrock and aquifer depth limit technical feasibility of installing ZVI treatment wall. ▪ Areal extent of affected groundwater affects technical feasibility. ▪ Can be injected into subsurface under pressure. ▪ Will treat site COCs.	Effective ▪ Effectively limits downgradient migration of chlorinated VOCs. ▪ Has no impact on groundwater quality upgradient of treatment zone and does not migrate with groundwater ▪ Effectiveness may be constrained by the lack of a competent confining unit for keying in a PRB. ▪ Extended residence time and treatment life. ▪ Documented performance success with VOCs	High	No, but ZVI has been retained as a supplemental treatment additive for ABC+ (see below)

Table 6-1
Identification and Screening of Remedial Technologies

GENERAL RESPONSE STRATEGY	REMEDIAL TECHNOLOGY	DESCRIPTION	IMPLEMENTABILITY	EFFECTIVENESS	RELATIVE COST	ACCEPTABLE FOR FURTHER CONSIDERATION
` *In situ* treatment, continued	Enhanced Reductive Dechlorination	Biologically mediated dechlorination process facilitated by soil microbes under anaerobic/low ORP conditions. Natural process can be enhanced by creating conducive hydrogeologic conditions and providing microbes with suitable electron donor substrate and nutrients.	Implementable ▪ Existing site conditions are aerobic/high ORP, requiring enhancements. ▪ Pilot study testing revealed multiple lines of evidence that ERD was occurring after treatment.	Effective ▪ Effectively degrades COCs within the treatment area into daughter products. ▪ Under conducive treatment conditions, naturally occurring microbes can extend the ERD treatment area beyond the location of the treatment chemical injections. ▪ Indigenous microbes can be augmented with lab-cultured anaerobes.	Moderate	Yes
	ABC^+ Treatment	ABC^+ is an acronym for “Anaerobic BioChem plus” and is a proprietary formulation of different treatment additives designed to enhance standard ERD treatment processes. ABC+ has been enhanced with the addition of ZVI. This integrated treatment method effectively combines the biological treatment effects of ERD and the physical/chemical treatment of ZVI.	Implementable ▪ Existing site conditions are aerobic/high ORP, requiring enhancements. ▪ Pilot study showed ABC^+ can be applied via direct push injection. ▪ Pilot study showed multiple lines of evidence that ERD/ZVI treatment was occurring. ▪ ZVI can be introduced into subsurface under pressure.	Effective ▪ Effectively degrades COCs within the treatment area ▪ ERD conducive conditions and naturally occurring microbes can extend the treatment area beyond the location of the treatment chemical injections. ▪ The ZVI enhances and extends the longevity of applied treatment.	High	Yes

Section 7
Development and Evaluation of Remedial Action Alternatives

The purpose of Section 7 is to assemble a set of remedial technologies (previously identified and retained by the screening process conducted in Section 6) and arrange them into coherent remedial alternatives that could be suitable for future Site remediation. These remedial alternatives will then be evaluated according to USEPA guidance using the baseline, balancing, and modifying criteria described in Section 7.1. The remedial alternatives that are addressed in Section 7 were identified as response measures deemed most suitable to address the COCs observed within the Site groundwater and the ongoing-future land-use applications of the property owner.

The remedial alternatives addressed in Section 7 of this FFS include a range of general response strategies, as required by the NCP. These remedial alternatives include active treatment components and considerations that are further described in Table 7-1.

Consistent with the site RAOs, the remedial alternatives presented in Section 7 have been developed to minimize human exposure to VOC-affected groundwater with contaminants at levels above regulatory thresholds developed to be protective of beneficial use, to treat or remove chlorinated VOCs present in the groundwater to the extent practicable, and to minimize future migration of chlorinated VOCs into Hartwell Lake (again, to the extent reasonable and practicable). Clean-up target concentrations used for the evaluations conducted in Section 7 were developed based on ARARs considerations and assessments previously discussed in Section 4 and summarized on Table 5-2.

Because of prior interim corrective measures and the two ABC+ pilot studies that have been conducted at the Site, a considerable level of remedial treatment has already been applied to the Site. Thus, for the purposes of this FFS, the baseline conditions upon which TRC's evaluation of the various Remedial Action Alternatives will be based will be the environmental conditions that were observed/documented by the March 2021 performance monitoring event of the Expanded ABC+ Pilot Study. As such, there are currently considerable portions of the VOC-affected groundwater areas – both in the Upgradient and Downgradient VOC plumes - that currently exhibit robust ERD/ZVI treatment influences. TRC anticipates that these pilot study areas will exhibit continued reductions in PCE concentrations over time. We expect that these ongoing COC reductions will continue as a consequence of biotic and abiotic reductive dechlorination influences that were set into motion during the Expanded ABC+ Pilot Study. These treatment influences are anticipated to continue for many months and/or years.

7.1 Criteria for Evaluation of Remedial Alternatives

Analysis of the various remedial action alternatives presented in this section of the FFS was conducted to address the various technical and regulatory considerations that are most relevant to the site-specific conditions. Each of the remedial alternatives was evaluated in terms of seven key criteria, which include two threshold criteria and five balancing criteria.

The two baseline or threshold criteria include the following:

1. ***Overall protectiveness of the public health and the environment.*** Evaluates the ability of each alternative to protect public health and the environment.
2. ***Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)*** – Assesses the compliance of an alternative with state and federal requirements or provides grounds for invoking a waiver.

The five balancing criteria include the following considerations:

1. ***Long-term Effectiveness and Permanence*** – Examines the protection of human health and the environment after construction and implementation of the remedial alternative. This criterion addresses the long-term adequacy, reliability, and permanence of the remedial action alternative.
2. ***Reduction of Toxicity, Mobility, and Volume through Treatment*** – Examines the extent to which the remedial alternative achieves the statutory preference for corrective action that permanently and significantly reduces the toxicity, mobility, and volume of contaminants.
3. ***Short-term Effectiveness*** – Examines the protection of the community, employee health, and environment during construction and implementation of the corrective action alternative. This criterion also evaluates the time required to achieve corrective action objectives.
4. ***Implementability*** – Considers the technical and administrative feasibility of each alternative, as well as availability of required resources. Factors considered include ease of construction; reliability; O&M of the corrective action alternative; potential problems which may be encountered during the implementation of an alternative; required approvals and permits from regulatory agencies; availability of required off-site treatment or disposal services; and availability of necessary equipment, materials, and personnel.
5. ***Cost*** – Involves development and evaluation of the capital cost of construction, equipment, land, buildings, engineering services, and project administration. O&M costs of labor, spare parts, materials, and administration are also addressed. The level of detail employed in developing these estimates is considered appropriate for making comparisons between alternatives, but the estimates are not intended for budgetary planning. Total present worth calculations are based on a 6 percent rate of return.

Two modifying criteria include State acceptance and community acceptance, which reflect apparent preferences or concerns by the state of South Carolina and the community about the alternatives. These two criteria are not evaluated in this FFS, but may be evaluated by SC DHEC if a determination is reached that would suggest public review/comment is necessary.

7.2 Remedial Alternative 1 – No Action

The "No Action" alternative is prescribed by USEPA guidance and represents an important benchmarking tool for the FFS. The purpose of this alternative is to provide a baseline for comparison with the other remedial alternatives. Under this remedial alternative, there would be no groundwater monitoring or any further active remedial treatment measures employed to assess, treat, or otherwise mitigate the site-related COCs present in groundwater and surface water.

7.2.1 Description

Under this remedial alternative, no further groundwater monitoring or active remedial treatment measures would occur to assess or treat the remaining concentrations and migration pathways of the site-related VOCs. The "No Action" alternative is a required element of the USEPA's feasibility study guidance for comparison to other remedial alternatives. Under this alternative, WPH would cease existing monitoring and treatment activities at the site. The current property owner/developer would maintain access and control of the portion of the site affected by VOCs in groundwater under the terms of their Voluntary Cleanup Contract with SC DHEC.

7.2.2 Overall Protection of Human Health and the Environment

The No Action alternative would not provide overall protection of human health and the environment. Although site groundwater is not anticipated to be consumed or contacted under current land use (residential development with public water supplied), there is a potential for some level of exposure to COCs by the vapor pathway if residences are constructed immediately above the VOC-affected groundwater portion of the site at current VOC concentrations. The VCC currently calls for design and installation of suitable engineering controls to mitigate accumulation of VOC vapors.

VOC-affected groundwater will also continue to migrate downgradient in a direction toward Hartwell Lake. Although detected VOC concentrations along the shoreline of the lake have been shown to be very limited and localized, possible contact by human and environmental receptors would be uncontrolled.

7.2.3 Compliance with Applicable or Relevant and Appropriate Requirements

Site groundwater remediation target levels will not be met in the short term, but may eventually be achieved in the long term. This would only occur following an extended period of natural attenuation of the residual VOCs observed in groundwater. The natural geochemical conditions of the underlying aquifer are not supportive or otherwise conducive to biodegradation processes without intervention.

On its own merits, it is unlikely that the No Action alternative will be able to achieve sufficient reductions in PCE concentrations to achieve the Remedial Action Objectives established for the Site. With no active or ongoing groundwater monitoring component for this alternative, the relative reduction of site groundwater contaminant levels and the extent of VOC migration could not be readily discerned, documented, and/or communicated to project stakeholders.

7.2.4 Long-term Effectiveness and Permanence

The long-term effectiveness and permanence of the No Action alternative for addressing the VOC-affected groundwater of the site is largely dependent upon the extent and ability of natural attenuation processes to degrade and reduce observed concentrations of VOCs over time. It is expected that VOCs would continue to exceed remediation target concentrations for an extended period of time under the No Action alternative. This extended timeframe would not be deemed acceptable, either by SC DHEC or the property owner.

7.2.5 Reduction of Toxicity, Mobility, and Volume

Over time, natural attenuation processes would reduce the toxicity, mobility, and volume of site-related VOCs present in the groundwater. Under the No Action alternative, such reductions could not be adequately tracked and reported because a groundwater monitoring program is not considered to be a part of this treatment alternative.

7.2.6 Short-term Effectiveness

The extent of short-term improvements in groundwater quality under this scenario would likely be minimal within the downgradient plume. We would not anticipate any meaningful decline in VOC levels migrating toward Hartwell Lake in the short-term. Similarly, the potential vapor intrusion into residential structures within the plume footprint would not decrease substantially in the short term and engineering controls would need to be incorporated into residential structures built above the VOC-affected groundwater area to mitigate the possibility of accumulated VOC vapors.

7.2.7 Implementability

The No Action alternative would not require any special implementation measures. The ongoing Site redevelopment activities already include provisions for public drinking water service. This would preclude the future use of Site groundwater, even though specific land-use restrictions or easements are not currently in place.

7.2.8 Opinion of Probable Cost

Alternative 1 does not include provision for any active remedial treatment or performance monitoring activities. As a result, no additional response costs will be incurred as a consequence of remedy implementation of this alternative.

7.3 Remedial Alternative 2 – Monitored Natural Attenuation

For this remedial alternative, there would be no provisions for containment or active treatment of the VOC-affected groundwater. MNA at the Site would make use of the various physical, chemical, and biological processes that facilitate natural attenuation of a given contaminant mass in the environment, including degradation, dispersion, dilution, volatilization, and sorption. Routine groundwater monitoring would be continued as an important and necessary performance assessment tool for evaluating the overall effectiveness of the MNA remedy over time. The existing monitoring well network at the Site would be utilized and maintained to address the monitoring requirements anticipated for an MNA site remedy. The Site groundwater monitoring program would include periodic sampling of the groundwater for VOCs and basic indicator parameters.

During the period of ongoing MNA, the property owner/developer would be allowed to proceed with redevelopment of the Site within the requirements set forth in their Voluntary Cleanup Contract. Because the VOC-affected groundwater generally occurs at depths at or below 15 feet below ground surface, there would be no existing or future plans for Site access control features (such as security fencing) in or around the VOC-affected areas of the Site.

Because Site COCs would remain in the groundwater at levels above RAOs for an undefined period of time, this remedial alternative would necessarily include provision for periodic regulatory reviews, as may be required by SC DHEC. During these regulatory reviews, attention would be given towards whether or not MNA is achieving desired RAOs in a timely and appropriate manner.

Under current aquifer conditions and existing VOC concentrations, natural attenuation processes would be expected to require an extended period of time (likely exceeding the USEPA's established MNA guidelines) to restore the groundwater quality of the underlying aquifer to the desired remedial target concentrations (i.e., MCLs). Despite this apparent limitation, MNA is still viewed as an important and necessary consideration for achieving final Site closure. Insofar as MNA can be implemented as a supplemental polishing step to achieve groundwater quality clean-up criteria, the most appropriate application of MNA would occur following completion of active groundwater treatment measure(s). To the extent that the existing groundwater quality can be improved, the effectiveness of subsequent MNA-based treatment measures could be enhanced. Thus, the use of MNA to achieve final remedial target concentrations (i.e., MCLs) across the areas of VOC-affected groundwater is a reasonable and appropriate application of this treatment alternative.

7.3.1 Remedy Description

The primary mechanisms of a natural attenuation remedy consist of many physical, chemical, and biological processes that are generally present and active in nature. MNA processes include degradation, dispersion, dilution, volatilization, and adsorption of organic materials onto underlying soils are ongoing in the natural environment.

In accordance with the USEPA's MNA guidance, this remedial alternative would need to include a detailed and systematic program of periodic groundwater and surface water monitoring to assess the site-wide distribution of VOC concentrations, evaluate potential contaminant migration pathways, and develop a better understanding of the role that MNA processes are playing at the Site. For the purposes of this FFS, TRC has assumed that the MNA groundwater monitoring network would generally consist of the existing groundwater monitoring well network that has been installed across the areas of VOC-affected groundwater.

TRC has also assumed that the property owner/developer would continue to retain responsibility for the ongoing maintenance and repair of key features within the VOC-affected groundwater zone (*i.e.*, mowing, utilities, roadways, *etc.*) and WPH would be responsible for inspection and maintenance of the monitoring well network. In addition, because VOCs would remain in the groundwater at levels above site remedial target concentrations for an extended period of time, this remedial alternative anticipates periodic 5-year performance reviews, as required by CERCLA guidance.

7.3.2 Overall Protection of Human Health and the Environment

Site controls would remain in place to provide protection of human health and the environment from potential exposure risks to on-site groundwater while groundwater concentrations remain above target remediation levels. The availability of public water service throughout the Site represents one of the most important of these site controls. Deed restrictions could also be established to prohibit the future use of site groundwater as a potable water source or for other uses (*i.e.,* irrigation, cooling water, etc.).

As a remedial alternative, MNA would not be expected to impart any short-term impacts or adverse effects on the local community, construction workers, or the overall environment. No groundwater receptors are currently identified at locations on or near the Site. Without active treatment measures, VOC-affected groundwater would continue to migrate downgradient in a direction toward Hartwell Lake. While detectable concentrations of PCE have been observed at near-shore monitoring locations along Hartwell Lake, these sampling locations represent the only potential exposure points for either human and/or ecological receptors.

Residential development activities have been ongoing at the Site. Currently, no residential construction activities are occurring within the VOC-affected groundwater areas. However, the property owner has recently expressed an interest in expanding construction into these areas. Presently, the recreation center and swimming pool area, located along the upper terminus of the Upgradient VOC plume, is the only development near the plume area. This facility is in active operation and used by residents of the property development. Ordinary use of the recreation center, pool area, and the adjacent parking lot is not expected to result in potential exposure to the VOC-affected groundwater, as the underlying aquifer is located approximately 20 feet bgs.

A systematic monitoring program involving periodic sampling and testing of the groundwater and surface water monitoring would provide a mechanism for conducting ongoing monitoring and evaluation of groundwater quality and flow conditions. A 5-year review process would provide an additional level of regulatory oversight and assurance that human health and the environment are being protected.

7.3.3 Compliance with Applicable or Relevant and Appropriate Requirements

As a stand-alone remedy, MNA would not be expected to achieve Site groundwater remediation target levels in a reasonable timeframe. However, in conjunction with a more robust and active treatment remedy, MNA could represent a useful polishing step to achieve remediation target levels in a reasonable timeframe. The groundwater monitoring component for the MNA alternative would make discernment and documentation of COC reductions and groundwater quality improvements more readily available to share and communicate with project stakeholders.

7.3.4 Long-term Effectiveness and Permanence

The long-term effectiveness and permanence of MNA as a suitable remedial alternative for VOC-affected groundwater is largely dependent upon the extent and ability of naturally occurring physical/chemical mechanisms to continue to reduce observed concentrations of VOCs in groundwater over time.

If considering MNA from the standpoint of a polishing step following active remedial measures presented in Sections 7.4, 7.5, and 7.6 of this FFS, the long-term effectiveness of MNA is anticipated to vary depending on the active treatment method selected. Based on observations from the two ABC+ pilot studies, natural attenuation by degradation is expected to persist for an extended period. Natural attenuation by degradation following ERD treatment without the ZVI component would persist for a shorter duration, and natural attenuation by degradation following ISCO treatment would be short-lived. While MNA may not currently be viewed as a stand-alone means of achieving Site RAOs, there is clearly a future role and consideration for MNA. MNA is better suited to serve as a supplemental treatment measure, following completion of a more active and aggressive treatment response.

7.3.5 Reduction of Toxicity, Mobility, and Volume

Over time, natural attenuation processes would be expected to reduce the observed toxicity, mobility, and volume of site-related VOCs present in the groundwater. With no further active treatment component, MNA would likely require an unreasonable timeframe to achieve target clean-up levels. Ongoing performance monitoring would represent the primary means of tracking the required timeframe, treatment rate and duration requirements of MNA. This ongoing monitoring would form the basis for periodic progress reports and communications with regulators and local stakeholders.

7.3.6 Short-term Effectiveness

While the Upgradient VOC plume has received a robust dose of ABC+ treatment media, the expected extent of short-term improvements within the groundwater quality of the Downgradient VOC plume would likely be minimal. In view of the existing VOC levels within the Downgradient VOC plume area, we would not anticipate observing any meaningful declines in VOC levels that are migrating toward Hartwell Lake in the short-term. Similarly, the potential for vapor intrusion to occur within residential structures constructed within the VOC plume footprint would not be expected to decrease substantially without some manner of active treatment. In the short term, engineering controls would need to be incorporated into residential structures built above the VOC-affected groundwater areas to provide suitable levels of protection and assurance that Site conditions would remain protective of human health and the environment.

7.3.7 Implementability

The MNA alternative would not require any special implementation measures. The availability of public water service within the Site development obviates the need for, use of, or exposure to the VOC-affected groundwater. Monitoring of the groundwater and surface water quality can be implemented using existing monitoring wells, sampling techniques, and sampling locations. All sampling equipment, materials, and subcontractors necessary to implement this remedial alternative are readily available.

7.3.8 Opinion of Probable Cost

Because an adequate groundwater monitoring system is already in place, no additional capital costs have been ascribed to Remedial Alternative 2 (MNA). The estimated annual cost to implement MNA at the site would be approximately $80,000 (2021 dollars). For purposes of this FFS, TRC has assumed that MNA would continue for a minimum required timeframe of 30 years. This timeframe may extend over a longer period, depending upon many Site environmental variables. Based on these assumptions, the 30-year net present value of this remedial alternative would be $959,000.

A detailed summary of the assumptions and cost estimates utilized to arrive at these costs are presented in Appendix B (Cost Estimate Basis) and Appendix C (Cost Estimate Calculations).

7.4 Remedial Alternative 3 – *In situ* Chemical Oxidation

For this remedial alternative, the VOC-affected groundwater would receive treatment by direct injection of a strong and aggressive chemical oxidant using direct push technology. Strong and aggressive chemical oxidants do not discriminate between organic contaminants and naturally occurring oxidizable constituents in the groundwater and geologic strata of the aquifer. When introduced into the subsurface, *in situ* Chemical Oxidation (ISCO) treatment media will aggressively oxidize and degrade chlorinated and non-chlorinated organic constituents, as well as the naturally occurring geochemistry. These types of indiscriminate chemical oxidation reactions can frequently result in a chemical oxidant demand that is considerably greater than the measured contaminant mass present in the subsurface. Chemical oxidation is generally regarded as a fast and efficient means of degrading the targeted COCs into less hazardous byproducts.

The hazardous nature of the chemical oxidants makes handling and injection of these chemicals a matter that should only be conducted by trained and experienced professionals. Even with the involvement of skilled and trained professional workers, risks and uncertainties are still present during the course of a treatment remedy. More details regarding the specifics of ISCO as a treatment alternative are provided, below.

7.4.1 Remedy Description

ISCO technology is a well-established and proven technical approach that is known to effectively remediate a wide range of organic materials, including the suite of VOCs observed at the Site. A variety of ISCO treatment chemicals are commercially available, including gaseous-phase oxidants (i.e., ozone) and many liquid–phase oxidants (i.e., Fenton's reagent, permanganates, persulfates, and peroxides). TRC has prior experience with conducting pilot studies in the Upstate of South Carolina that have evaluated the use and application of each of these chemical oxidants.

Gaseous phase ozone is anticipated to be a very effective, albeit short-lived, chemical oxidant within the subsurface. The downside of ozone treatment is the capital cost of acquiring the treatment equipment and the long-term cost of operations and maintenance (O&M). The aggressive nature of the ozone gas continually oxidizes and degrades the equipment parts and piping, necessitating constant and ongoing repairs.

Fenton's reagent and acid-catalyzed peroxides are also aggressive and effective chemical oxidants. However, the aggressive nature of the chemical reactions generates exothermic conditions that can result in the formation of underground steam pressures and melted injection well piping. These types of chemical reactions were considered and deemed inappropriate for Site conditions.

The use and application of permanganate as a possible ISCO injectate was also considered. While permanganate has been found to exhibit excellent chemical oxidation effects in the subsurface and good longevity of treatment performance, this chemical oxidant has a very distinctive purple hue at the treatment doses typical for ISCO. TRC has observed purple discoloration at seepage faces or other areas where the permanganate-treated injectate might daylight (resurface).

Of the various chemical oxidants considered and evaluated, current Site conditions and the existing/future land-use plans for the Site suggest that the use and application of sodium persulfate chemistry would be the most likely and appropriate oxidant. Sodium persulfate is a widely applied chemical oxidant that has a documented history of effectively reducing elevated VOC levels. For this FFS, TRC has assumed that a NaOH-catalyzed sodium persulfate would be applied as the ISCO treatment of choice.

Due to the robust and aggressive nature of ISCO treatment, health and safety concerns are a paramount consideration, particularly when conducting chemical oxidation in proximity to nearby residents. Considerable attention to health and safety protocols must be a constant consideration and priority when transporting, handling, injecting, and monitoring all ISCO treatment materials.

To effectively degrade an organic contaminant, it is crucial to bring a sufficient concentration of the chemical oxidant into direct contact with the contaminants. The application of ISCO as a VOC treatment remedy is often related the sports analogy of it being a "contact" sport. For the chemical oxidation reaction to be optimized, the contaminant mass must intermingle and come into direct contact with the chemical oxidant. Thus, the key to successfully implementing ISCO will include selection of a reliable delivery technique, understanding the oxidative demands of the subsurface soils, and selecting a chemical oxidant chemistry appropriate to the VOCs.

The type of chemical oxidant and the mode of delivery may vary based on site-specific considerations and desired performance objectives. During the ABC$^+$ pilot study, DPT was confirmed to be a suitable method for delivering liquid-phase and slurried treatment media into the subsurface and achieve the required treatment depths to ensure suitable treatment results.

This remedial alternative consists of a treatment strategy involving targeted treatment of higher concentration VOC areas using ISCO (*i.e.*, sodium persulfate). The ISCO treatments would be utilized to aggressively target and treat these higher concentration areas of VOCs and reduce the contaminant mass to an extent where MNA processes could then be relied upon to yield ongoing improvements to groundwater quality. This remedial strategy would involve a period of active ISCO treatment, that would eventually be followed by a period of passive MNA treatment. Over time, this is a treatment strategy that could reasonably expected to achieve Site RAOs.

As with the other treatment alternatives, ongoing performance monitoring of the groundwater quality will be important to determine when VOCs levels within the VOC-affected areas of the groundwater have been degraded to the point where active ISCO treatment could be discontinued and a transition to the more passive MNA could occur. Depending upon Site conditions and aquifer response, it is expected that multiple ISCO treatment events may be required to achieve the desired level of VOC mass reduction. Only ongoing performance monitoring will reveal when this milestone has been achieved.

During ISCO treatment, it would be possible for ongoing Site redevelopment activities to continue. However, the health and safety of workers and nearby residents would need to be carefully monitored and protected. As experienced during the 2016 ABC+ pilot study, it is possible for injected ISCO treatment media to “daylight” into unexpected locations. This phenomenon could occur as a result of heterogenous site geology, injection pressures or faulty well constructions. In any event, inadvertent exposure to ISCO treatment media can be very hazardous to workers and nearby residents, particularly without suitable personal protective equipment. If Site development activities occur on the ground surface above targeted treatment areas, the locations for injection will be limited by accessibility.

Although public drinking water supplies are currently available across the Site and all ISCO treatment activities would occur at depths greater than 20 feet bgs, deed restrictions would still need to be instituted to formally prohibit current/future use of Site groundwater as a potable water or irrigation water source. There would also need to be some manner to exert temporary access controls or restrictions to the ISCO treatment areas during ongoing treatment work. This is necessary to ensure workers and residents are not exposed to chemical treatment agents that may “daylight” in any areas or other potentially dangerous Site conditions. ISCO treatment media can remain active and aggressive in the subsurface for a period of several weeks following injection. After several weeks in the subsurface the chemical oxidant demands of the contaminant mass and the native soils will eventually exhaust the treatment media. For sodium persulfate treatment activities, the observed levels of sulfate present in the groundwater will tend to increase over time.

The current monitoring well network would be maintained for performance monitoring of the treatment effects and observed extent of the ISCO remedy. In addition, because VOCs would likely remain in the groundwater at levels above site clean-up goals for some period of time, this alternative would also include a provision for the performance of 5-year reviews, as required under CERCLA. Similar to the other active treatment alternatives that are considered in Section 7, ongoing groundwater performance monitoring will be used as an important tool to assess the treatment effectiveness of ISCO, over time.

7.4.2 Overall Protection of Human Health and the Environment

ISCO is considered to be capable of protecting human health and the environment by quickly and effectively reducing the mass and concentration of chlorinated and non-chlorinated VOCs in the groundwater. Although the actual ISCO treatment will occur at depths greater than 20 feet bgs, temporary Site controls to control/limit entry and egress into the ISCO treatment areas would be needed in case daylighting were to occur. Site controls would be problematic in the event the property owner should decide to build residential housing units within and around targeted ISCO treatment zones prior to completion of treatment. In this event, temporary exclusion barriers would need to be erected and ongoing site inspections conducted to ensure there is no “daylighting” of the ISCO injectate. Such precautions would necessarily extend for a period of weeks in preparation for and following ISCO treatment. These measures would be needed to ensure the protection and safety of nearby workers and property residents. Structures constructed above the targeted treatment areas would limit access for future ISCO injections.

There are currently no completed exposure pathways associated with the VOC-affected groundwater plume areas. Public water supplies are already available across the Site. Deed restrictions will need to be instituted to legally prohibit use of site groundwater resources for drinking water or irrigation purposes.

The aggressive nature of ISCO treatment chemicals can pose serious health and safety concerns for the workers involved in preparing and introducing these chemical oxidant solutions into the subsurface. Special precautions will need to be implemented during each treatment event to protect workers from accident or injury. The *in situ* nature of ISCO treatment activities should not present an immediate concern for the health and safety of nearby residents and the local community, but special precautions are necessary to provide adequate oversight during treatment activities and ongoing Site inspections would need to be conducted to look for daylighted ISCO treatment chemicals.

7.4.3 Compliance with Applicable or Relevant and Appropriate Requirements

ISCO is a remedial technology that is capable of achieving ARARs for groundwater at the Site. When implemented in concert with a comprehensive groundwater monitoring program, the observed reduction of VOC contaminant mass and the improvement in site groundwater quality should be readily discerned, documented, and/or communicated to project stakeholders.

The injection of a chemical oxidant solution into the subsurface will require submission of an Underground Injection Control (UIC) permit application to SC DHEC. The State's UIC permit will regulate the manner and approach that ISCO is conducted at the site. For the ISCO remedy, Site compliance with the existing ARARs can be both feasible and practical when ISCO is applied in a safe and prescribed manner.

7.4.4 Long-term Effectiveness and Permanence

When ISCO is safely and appropriately applied, this treatment remedy can provide an effective and permanent treatment solution for a VOC site. The long-term effectiveness of this treatment alternative within site groundwater is dependent upon the success with which the oxidant can be brought into direct contact with the contaminant.

ISCO treatment agents are strong chemical oxidants and largely non-discriminatory with regards to the substrate that the oxidant can react with. Chemical oxidants will react with any available and receptive material that is present within the subsurface. Thus, it is important to understand the immediate chemical oxidant demand of the native soils before initiating any ISCO treatment operations.

In order for ISCO treatment to be optimized, the effective concentration of the chemical oxidant demand applied by the underlying native soils must be anticipated and taken into account. Subsurface soil samples within the treatment area are collected (prior to ISCO treatment) to calculate a threshold level for the chemical oxidant demands of these native soils. The dosing requirements for the estimated mass of the groundwater contaminants and any other readily oxidizable material can then be properly accounted for.

During the Expanded ABC+ Pilot Study, TRC injected large quantities of organic materials (ABC) into the subsurface of the Upgradient VOC plume. These organic materials are currently in-place and would represent a noncontaminant-related source of chemical oxidant demand. In order to offset the reducing effects of these ERD treatment additives, it would also be necessary to introduce an excess amount of the chemical oxidant to properly account for and address the chemical oxidant demand of the ERD treatment materials. This would result in the need for excess volumes of chemical oxidant and increased treatment cost within the Upgradient plume area.

Once the ISCO treatment media is introduced into the subsurface, the chemical oxidation reaction is fast and irreversible. The ISCO treatment media will react, indiscriminately, with all readily available and amenable materials (organic or otherwise), until the applied levels of chemical oxidants have been exhausted. In the event there is untreated VOC mass remaining, it is possible that contaminant concentrations may rebound into the groundwater through a process known as back-diffusion. Back-diffusion occurs when VOC residuals present in lower permeability aquifer soils are slowly released (by diffusion) into the groundwater. Back-diffusion is frequently exhibited during initial ISCO treatment events and is manifested as rebounding concentrations of VOC levels in the groundwater. Over time and continued treatment, back-diffusion effects subside and VOC concentration declines become more persistent.

ISCO involves application of strong oxidizing chemicals that would cause the oxidation/reduction potential (ORP) of the underlying aquifer to become strongly positive. The naturally occurring ORP condition of the Site aquifer is variable, but generally positive. The two ABC+ pilot studies have transformed large areas of the Upgradient and Downgradient VOC plumes to negative ORP conditions. Negative ORP conditions are more favorable to long-term MNA conditions, while positive ORP conditions are more conducive to the faster acting ISCO treatment effects.

As with the other remedial treatment alternatives discussed in this section, groundwater and surface water quality monitoring would be used as an important tool to track remedy performance and document the long-term effectiveness of the ISCO treatment remedy and subsequent transition/progress of the eventual, supplemental treatment remedy, MNA.

7.4.5 Reduction of Toxicity, Mobility, and Volume

ISCO involves application of strongly oxidizing chemicals that are capable of degrading the site COCs and reducing the toxicity, mobility, and volume of both the chlorinated and non-chlorinated VOCs present in the affected groundwater at the Site. Oxidation of the VOCs requires direct contact with the injected oxidant.

7.4.6 Short-term Effectiveness

Implementation of the ISCO alternative should have limited to no discernible impact on the local community and nearby residents, given the *in situ* nature of the treatment process. However, since it is possible for Site workers to be exposed to short-term hazards and dangers during the preparation and application of these aggressive chemical treatment agents, all Site workers involved with implementation of an ISCO treatment remedy must be subject to a requirement for specialized training and personal protective equipment (PPE) to prevent exposure to the treatment chemicals and Site VOCs. During treatment events, temporary barriers would also need to be erected to prevent the nearby community or Site trespassers from entering the treatment area for the duration of the ISCO injection event and subsequent oxidation treatment.

Because ISCO involves the application of aggressive chemical oxidants, it is a treatment alternative with the greatest potential to achieve site groundwater remediation target levels in a relatively short period of time. Many similar sites have achieved site closure in a matter of a few years. This expedited treatment potential is offset by the possibility of adverse health and safety effects to nearby workers and residents. An active performance groundwater monitoring component will be conducted during this remedial alternative to track the observed reduction in contaminant mass and determine when transition to more passive MNA treatment makes the most sense. These observed changes and improvements to the site groundwater quality and the associated reduction in contaminant mass levels will be closely evaluated, documented, and communicated to project stakeholders.

7.4.7 Implementability

ISCO treatment technology, equipment, and materials are available from a select number of subcontractors and vendors. TRC has had prior working experience with a number of these subcontractors and vendors and is experienced with the required expertise, field techniques and performance monitoring necessary to implement ISCO injections and the related groundwater treatment activities required by this remedial alternative. The ABC^+ pilot studies have successfully demonstrated the feasibility of using DPT as a field technique to inject ISCO treatment agents into the subsurface at depths extending through the shallow aquifer and intermediate aquifer zones.

7.4.8 Opinion of Probable Cost

The injection techniques anticipated for Remedial Alternative 3 (ISCO) would not require construction of permanent infrastructure. DPT would be used to introduce the chemical oxidant into the appropriate target locations. For this reason, there would be no direct capital costs associated with implementation of an ISCO-based treatment alternative.

Based on communications with remediation contractors, several assumptions have been applied to generate the estimated costs for implementing ISCO injections at the former WPH facility. The major assumption is that the ISCO treatment program would involve four rounds of discrete treatment events. The first two would be full scale to address the highest VOC concentration areas based on the March 2021 groundwater sampling event. The second two injection events are estimated as half-scale to target areas experiencing back diffusion and areas not directly contacted by the previous injection events. This treatment strategy is designed to be conservative, but also appropriate to Site conditions.

The estimated cost of the most extensive ISCO injection events would be expected to require a budget of approximately $1,637,000. The first two ISCO treatment events (years 1 and 3) would be focused on the more highly concentrated VOC mass that is present within the Upgradient and Downgradient VOC plume areas. The initial treatment events would then be followed up by two half-scale ISCO injection events occurring in years 6 and 8 (estimated cost $818,500. The half-scale ISCO injection events would be targeted to areas experiencing VOC concentration rebounds or lack of apparent VOC decreases. The injection program assumptions represent a phased and targeted treatment strategy to address residual VOC mass. The estimated costs developed for this remedial alternative include the required level of effort necessary to plan and implement each of the four rounds of ISCO injections.

The annual cost for conducting performance monitoring for the ISCO treatment alternative is the same as previously calculated for the MNA alternative at a value of approximately $80,000 per year. The total calculated net present value of Alternative 3 was developed by assuming an eight-year period of targeted ISCO injections, followed by a four-year period of MNA. Following this 12-year time frame, TRC projects that a No Further Action status could be reasonably anticipated for the site. These costs yield a total net present value of $4,321,000.

The assumptions and cost basis that TRC applied to derive these estimated treatment costs are presented in Appendix B and Appendix C.

7.5 Remedial Alternative 4 – Enhanced Reductive Dechlorination

Enhanced reductive dechlorination (ERD) is a widely accepted, biologically based treatment process in which many chlorinated and non-chlorinated hydrocarbons can be degraded by indigenous and bioaugmented soil microbes. Reductive dechlorination most readily occurs when aquifer conditions exhibit low dissolve oxygen levels and the ORP of the groundwater is negative. Under these aquifer conditions, the growth of the anaerobic microbes can be optimized and effectively focused on degrading chlorinated ethenes (*i,e.*, PCE and TCE). Under anaerobic and reducing treatment conditions, ERD is capable of degrading chlorinated ethenes (like TCE and PCE) to end-products of ethane, ethene and carbon dioxide.

As a stand-alone treatment alternative, ERD typically involves the introduction of a prescribed mix of nutrients and treatment additives suitable for optimizing the growth of these highly specialized, dehalogenating-microbes into the VOC-affected groundwater. The treatment additives most often employed with ERD include a suitable carbon source (*i.e.*, lactate, vegetable oil, etc.), various nutrient amendments (*i.e.*, potassium, phosphate, etc.), a chemical buffer to maintain suitable alkalinity and stable pH, and an oxygen scavenger to reduce dissolved oxygen levels. In certain cases, it may also be advantageous to supplement the indigenous aquifer microbes with the addition of lab-grown culture of anaerobes (*i.e.*, bioaugmentation). During each of the prior ABC+ pilot studies, TRC conducted bioaugmentation of the applied treatment media.

These various treatment amendments can then be introduced into the subsurface using direct-push technology. When properly applied, ERD injectates can create suitable geochemical conditions within the VOC-affected aquifer that are supportive of reducing conditions and more effectively degrade chlorinated VOCs to their more nontoxic byproducts.

7.5.1 Remedy Description

ERD is a well-established and field-documented treatment strategy that has been previously demonstrated to effectively remediate a wide range of organic compounds, including the chlorinated VOCs observed at the Site. In order to stimulate the growth of indigenous anaerobic microbes, it is necessary to adjust the groundwater quality of the aquifer to maintain anaerobic/negative ORP conditions within an acceptable pH range (5.5 to 8 s.u.). Within these prescribed environmental conditions, naturally occurring anaerobic microbes (*i.e.*, dehalogenators) exhibit a specialized ability to respire chlorinated organic materials by substituting hydrogen (H) for chlorine (Cl) on various chlorinated ethene compounds. By effectively dechlorinating the targeted contaminant mass, ERD can reduce the observed concentration and toxicity of the VOCs present at the Site. ERD treatment represents the biotic treatment component of the previous ABC+ pilot studies that were conducted at the Site.

A number of commercially available carbon substrates are available to facilitate effective ERD treatment. For the purposes of this FFS, TRC has assumed the use and application of a lactate-based carbon substrate. The treatment formulation anticipated for the Site is specifically blended to address many site-specific characteristics and involves a combination of various organic substrates, including lactate esters, glycerin, and emulsified fatty acids. When introduced into the subsurface, this lactate-based substrate can serve as the functional electron donor material for the anaerobic microbes responsible for ERD treatment.

In order to effectively degrade the site VOCs, a sufficient concentration of the carbon substrate is needed to provide the required electron donor necessary to facilitate this biochemical reaction. Once conducive aquifer conditions are established, the zone of ERD treatment will tend to disperse from the injection points, thereby expanding and self-sustaining over an extended period of time. Since the purpose of the ERD injection is to establish a suitable population of anaerobic microbes within the aquifer, direct contact between the injectate and the contaminant mass is not as critical as with ISCO treatment. Once the growth of the appropriate anaerobes is established and begins to expand, a reduction in chlorinated VOC concentrations would be expected to occur and continue over an extended period of time. The key to ERD treatment performance is establishing and sustaining suitable anaerobic conditions and providing an electron donor and nutrients for the biochemical process.

It is also possible for naturally occurring soil microbes, under appropriate site conditions, to degrade many non-chlorinated VOCs, such as ethylbenzene and xylenes as a carbon source. While reductive dichlorination is typically not the biotreatment pathway associated with these types of constituents, the soil microbes are opportunistic and treatment synergies are common. The organic constituents previously identified within the former Varsol tank area could be amenable to biotreatment and similar treatment would be expected, coincidental to the applied ERD biotreatment of TCE and PCE. Significant reductions in the observed concentrations of ethylbenzene and xylenes have been observed within the former Varsol tank area following the 2016 pilot study. During the March 2021 sampling event, there were no observed MCL exceedences for either ethylbenzene or xylene.

Similar to the treatment strategy for ISCO, TRC has assumed that targeted ERD treatment would focus on the higher concentration VOC plume areas. Using DPT, ERD treatment could be reasonably deployed to target and treat higher concentration areas of VOC detected within the Upgradient and Downgradient VOC plume areas. ERD treatment would continue until VOC levels have declined to the extent where active treatment measures could transition to passive MNA treatment. Depending upon Site conditions and aquifer response, it is expected that multiple ERD treatment events may be required to achieve the desired level of VOC mass reduction. Only ongoing performance monitoring will reveal when this milestone has been achieved. During the MNA phase, site-wide monitoring would continue to track and document that natural attenuation processes are active, on-going, and able to achieve desired remediation levels across the Site.

Since the overall Site is undergoing residential redevelopment efforts, this *in situ* treatment approach would be consistent with the current and future property land-use needs and requirements. Public drinking water service is available throughout the Site, so usage of the underlying groundwater resource is not anticipated. Deed restrictions should also be considered and instituted to formally prohibit use of site groundwater. There are presently no institutional controls to limit access to the area of concern, but there are also no potential exposure pathways that are considered completed within the VOC-affected groundwater area. Site controls within the immediate vicinity of DPT injection points would be established and enforced during treatment activities to ensure that the health and safety of the local community is protected. The treatment materials involved with ERD generally make use of food-grade additives and do not present risk or exposure hazards to the nearby populace. Active treatment will occur at depths in excess of 20 feet bgs, so temporary access controls would be utilized and then discontinued after ERD injections have been completed. If Site development activities occur on the ground surface above targeted treatment areas, the locations for injection will be limited by accessibility.

The current monitoring well network would be retained for ongoing performance monitoring activities. Such performance monitoring would be conducted to assess and evaluate the effect and influence of ERD treatments on the VOC-affected portion of the groundwater. Because VOCs would remain in groundwater at levels above site clean-up goals for some period of time, this remedial alternative includes the performance of 5-year regulatory reviews, as required under CERCLA. Similar to the other remedial alternatives considered in this section, groundwater performance monitoring would be used as an important tool to assess the overall treatment effectiveness of ERD over time.

7.5.2 Overall Protection of Human Health and the Environment

The ERD treatment alternative would be protective of human health and the environment by reducing the mass and concentration of chlorinated VOCs in the groundwater. Only temporary Site controls are anticipated during remedy implementation, as no exposure pathways are currently identified as being completed. ERD treatment media are basically food-grade materials that do not represent a health and safety concern to workers or nearby residents. Public water services are readily available throughout the Site. Deed restrictions would be instituted to legally prohibit the use of site groundwater for future industrial or potable drinking water purposes.

7.5.3 Compliance with Applicable or Relevant and Appropriate Requirements

The ERD treatment alternative is capable of achieving ARARs for groundwater at the Site. With the groundwater monitoring component for this alternative, reductions of site groundwater contaminant levels and the extent of VOC migration can be readily discerned, documented, and/or communicated to project stakeholders.

The introduction of ERD treatment additives (*e.g.*, carbon substrate, nutrient amendments, and bioaugmentation cultures) into the subsurface would require a UIC permit from SC DHEC. The two ABC+ pilot studies were conducted under the terms of SC DHEC UIC permits, so permitting of this treatment alternative should not present any problems. Site compliance with the existing ARARs is both feasible and practical using the ERD treatment alternative in an appropriate and prescribed manner.

7.5.4 Long-term Effectiveness and Permanence

When applied under the appropriate environmental conditions, ERD can provide an effective and permanent treatment remedy for observed levels of VOCs present at the Site. The long-term effectiveness of this remedial alternative is largely dependent upon maintaining strongly reducing conditions in the subsurface environment and sustaining an adequate concentration of carbon substrate to facilitate the required biochemical reactions. Biologically mediated reductive dechlorination does not occur instantaneously, so an extended period of treatment time will likely be required to establish suitable geochemical conditions, optimize the growth of a sufficient population of dehalogenating microbes and achieve the target clean-up levels. However, once the appropriate conditions are established and suitable nutrients are introduced, the indigenous aquifer microbes are generally capable of sustaining contaminant metabolism for an extended period of time. If needed, there are commercially available bioaugmentation cultures available to supplement/amend the existing population indigenous microbes.

The natural geochemical conditions of the site aquifer are variable, but were observed to be generally oxidizing and exhibit positive ORP. The ABC+ pilot studies have converted large areas of the two VOC plumes to reducing conditions and negative ORP. During each of the ABC+ pilot studies, geochemical conditions favorable to ERD were quickly established and sustained for the duration of the pilot studies and beyond. Field data collected during these pilot studies has suggested that ERD conditions and evidence of ERD treatment response could be expected to extend and expand over a longer period. The lactate-based carbon substrate applied during the pilot studies has been appropriate to Site conditions and the suite of VOCs detected at the Site.

As with the other treatment alternatives discussed in this section, groundwater and surface water quality monitoring would represent an important tool to track remedy performance, document treatment influence/extent, and assure that the long-term effectiveness of the ERD treatment remedy is proceeding in a steady and appropriate manner. Performance monitoring will also be utilized to determine when active ERD treatment can be transitioned to the more passive MNA treatment.

7.5.5 Reduction of Toxicity, Mobility, and Volume

ERD represents a treatment alternative that is suitable and capable of reducing the toxicity, mobility, and volume of the contaminant mass that has been detected within the VOC-affected groundwater plume areas of the Site. While not as aggressive and fast reacting as ISCO, ERD presents fewer health and safety concerns and reduced risks to the nearby workers and residents.

7.5.6 Short-term Effectiveness

Implementation of the ERD alternative would have no discernible impact on the local community and nearby residents, given the *in-situ* nature of this treatment alternative. Site workers would not be exposed to aggressive treatment chemicals during ERD injection events, as most ERD treatment additives are food-grade and much safer to handle than chemical oxidants. Temporary barriers would be erected to keep nearby residents and trespassers from inadvertently entering the treatment areas during a treatment event. The possible health effects and safety concerns associated with "daylighting" of ERD treatment materials would be greatly reduced from ISCO.

ERD represents a proven and effective remedial treatment alternative that can be reasonably implemented at the Site to achieve groundwater remediation target levels, within a reasonable period of time. While not as aggressive as ISCO, many VOC sites have been successfully remediated using ERD. The conduct of ongoing groundwater performance monitoring can be used to track the rate and extent of observed improvements to the groundwater quality and the decline of the site groundwater contaminant mass. In this manner, the progress of VOC treatment efforts can be readily discerned, documented, and communicated to interested project stakeholders.

7.5.7 Implementability

ERD treatment technology, equipment, and materials are readily available from many commercial vendors to support successful implementation of all aspects of this remedial alternative. TRC has had prior experience with a number of these contractors and vendors and is experienced with the required techniques necessary to successfully conduct the required nutrient injection and groundwater treatment activities required of this remedy. The ABC^{+} pilot studies successfully demonstrated the feasibility of conducting ERD at the Site by confirming the utility of DPT to inject the required treatment additives into suitable aquifer depths and establish/sustain appropriate biotreatment zones within the subsurface across the shallow and intermediate aquifer zones and beyond.

7.5.8 Opinion of Probable Costs

The required implementation strategy for ERD treatment at the site would not require construction/installation of any permanent infrastructure. Therefore, no direct capital costs are associated with this remedial alternative.

Based on communications with remediation contractors, several assumptions have been applied to generate the estimated costs for implementing ERD injections at the former WPH facility. Similar to the ISCO remedy, treatment events would occur in a phased and sequential manner.

Treatment injections are assumed to be conducted in five events over a period of 13 years (Year 1, Year 4, Year 7, Year 10, and Year 13). Based on this assumed approach, the estimated cost for the first three injection events would be approximately $680,400. An extended period of performance monitoring time would then be allowed between injection events to facilitate *in situ* biotreatment. Follow-up injection events assumed to occur in Year 10 and Year 13 are assumed to be half the scale on the initial injections, costing an estimated $340,200 each. These cost estimates are based on a declining extent of injections targeted to areas experiencing VOC concentration rebounds or lack of apparent VOC decreases.

The annual cost of conducting ongoing performance monitoring at the site during ERD treatment was calculated to be approximately $80,000 per year. The total estimated cost for Alternative 4 (ERD) was developed by assuming that there would be a thirteen-year period of active ERD injections, followed by a seven-year period of MNA. At the end of this 20-year timeframe, TRC has assumed that the site would attain groundwater levels suitable for a regulatory determination of No Further Action. These cost assumptions yield a total net present worth cost of $2,347,000.

A detailed summary of the assumptions and costs applied to derive the net present value of this treatment remedy are presented in Appendix B and Appendix C.

7.6 Remedial Alternative 5 – ABC+ Treatment

ABC^+ is a hybrid between two *in situ* treatment alternatives, ERD and ZVI. There are many useful and beneficial treatment synergies available when the standard ERD treatment formulation is enhanced by addition of a finely milled ZVI particulate, as demonstrated in the Expanded ABC+ Pilot Study (discussed in Section 2.5 of this FFS). This innovative treatment strategy results in a treatment process that embraces both biological and physio-chemical treatment attributes. Together, ERD and ZVI exert synergistic treatment influences in the natural environment that further extends the utility and application of both treatment alternatives.

Individually, both ERD and ZVI treatment techniques are widely accepted and documented in the scientific literature and in successful field applications. The combination of ERD/ZVI treatment and the ability to introduce this treatment alternative into the subsurface via DPT represents an exciting break-through in remedial technology.

This remedial alternative assumes that the VOC-affected groundwater will receive *in situ* treatment in much the same manner as has been previously presented for ISCO and ERD. The treatment media will be delivered into the subsurface using DPT. For the full-scale injections of ABC+, the injection pressures of the applied treatment media (via DPT) will be carefully monitored and maintained within a range of approximately 50 to 100 psi. The pressure is required to inject both the ERD nutrients and the finely milled ZVI slurry into the underlying strata. By injecting the ABC+ under slight pressure, the treatment media can more readily disperse into the aquifer and begin to create a broader zone exhibiting suitable geochemical conditions within the aquifer. In this manner, the ABC+ will be able to promote and facilitate both biologically mediated reductive dechlorination via ERD and the physio-chemically induced reduction reactions of ZVI.

The more water-soluble components of the ERD treatment components will tend to disperse and migrate with the advective flow of the underlying groundwater. The ZVI treatment component, on the other hand, remains in proximity to the point of injection. Once in place, the ZVI component will help further promote and establish reducing conditions, thereby better facilitating reductive dechlorination of the VOCs by both physical/chemical and biochemical means. This "symbiotic" benefit between the two remedial technologies occurs because the presence of ZVI treatment media tends to establish reducing conditions wherever it is placed, and the byproducts of the ZVI treatment reaction also tend to enhance the growth and metabolism of the ERD treatment microbes. By integrating these treatment strategies into a single remedial treatment process, chlorinated VOC levels can be reduced by two different mechanisms and more quickly achieve the Site RAOs.

7.6.1 Remedy Description

As stated above, ABC^+ treatment represents an innovative combination of two established and proven remedial techniques, both capable of effectively addressing a wide range of organic compounds, including the chlorinated VOCs observed at the Site. The "ABC" designation of this commercial designation is an acronym for the term "anaerobic biochem", denoting the standard lactate based ERD formulation that was described in Remedial Alternative 4 (ERD). As discussed for Remedial Alternative 4, the lactate-based ABC components promote ERD treatment when geochemical conditions are adjusted to the point whereby indigenous anaerobic microbes (dehalogenators) begin to substitute hydrogen (H) for chlorine (Cl) on the chlorinated ethene compounds of concern. The ERD reaction effectively dechlorinates the target organic contaminant mass, altering its chemical composition and reducing its apparent toxicity.

The "**+**" designation of the ABC+ nomenclature denotes that finely milled ZVI has been included in the treatment formulation as an abiotic treatment component. The presence of ZVI in the treatment mix is innovative and useful, as it can also facilitate the redox reaction responsible for physio-chemical dechlorination of VOCs. The major difference between a generalized ERD treatment material and ABC+ treatment is that the presence of the ZVI necessitates injection of the ABC+ treatment additives under moderate pressure (approximately 50 - 100 psi). This pressure is necessary to force the ZVI particles out into the subsurface formation to the greatest extent possible.

In situ treatment using ABC+ is generally no different than application of ERD, in that a sufficient concentration of the carbon substrate (lactate) is still required to provide the necessary electron donor for the anaerobic, redox biochemical reaction to occur. The presence of the ZVI treatment media further reinforces and amplifies the reducing conditions and affords an additional physio-chemical treatment pathway to augment the biological treatment process. While the ERD treatment components tend to enhance the growth of the anaerobic microbes present within the aquifer, the ZVI treatment components tend to enhance reducing conditions present within the aquifer. ZVI also directly dechlorinates VOCs in groundwater that passes through the injected ZVI locations.

Depending upon aquifer response, it is expected that multiple ABC+ treatment events could be required to achieve the desired level of VOC mass reduction. Ongoing performance monitoring will reveal when this milestone has been achieved. Together, ERD and ZVI represent an innovative treatment strategy for enhancing reducing conditions within the aquifer and inducing biotic and abiotic treatment effects to reduce the observed concentration of chlorinated VOCs in groundwater, over time.

As previously discussed, the Site is currently involved in a series of ongoing and extensive residential developments. The property owner has recently expressed an interest in conducting future development activities within the VOC-affected groundwater plume areas. The use and application of an *in situ* treatment technology like ABC+ would be consistent with the anticipated future uses of the property, insofar as the initial phase of ABC+ injections can be completed prior to construction of residential units. Subsequent phases of ABC+ treatment could be conducted as targeted injection events, using DPT injections in and around new housing units, but construction of buildings above the affected groundwater area will limit accessibility for conducting the injections.

Public drinking water is available throughout the Site, so concern for public consumption of the underlying groundwater is effectively negated. However, deed restrictions should be considered and instituted to legally restrict future use of the site groundwater as a resource. There are no institutional controls restricting access to the area of concern, primarily because the only potential for exposure occurs at a depth of over 20 feet bgs. Thus, no completed exposure pathways are reasonably anticipated to the VOC-affected groundwater area. Site access controls within the immediate vicinity of the ABC+ injection locations would be established during any injection event, but such measures would be temporary and discontinued once the treatment event is completed. Like ERD treatment activities, the ABC+ treatment media present considerably lower hazard than ISCO treatment.

The current monitoring well network would be maintained for performance monitoring of the extent and influence of the remedy. In addition, because VOCs would remain in groundwater at levels above site clean-up goals for some period of time, this alternative includes the periodic conduct of a 5-year regulatory review, as required under CERCLA. Similar to the other remedial alternatives discussed in this section, groundwater performance monitoring would be used as an important tool to assess treatment performance and effectiveness, over time. At some point in the remedy, performance monitoring would be used to determine that active treatment measures may be transitioned to passive MNA treatment.

7.6.2 Overall Protection of Human Health and the Environment

An ABC$^+$ treatment alternative would be protective of human health and the environment by reducing the mass and concentration of chlorinated VOCs in groundwater. No Site institutional controls are in place, but there are also no completed exposure pathways. Public water is available throughout the Site, greatly reducing any concern for human consumption of the underlying groundwater. Deed restrictions should be considered and instituted to legally restrict the use of site groundwater for future industrial and/or potable drinking water purposes.

7.6.3 Compliance with Applicable or Relevant and Appropriate Requirements

The ABC$^+$ alternative is capable of achieving ARARs for groundwater at the Site. With the groundwater monitoring component for this alternative, the reduction of site groundwater contaminant levels and the extent of VOC migration can be readily discerned, documented, and communicated to project stakeholders.

The injection of ABC$^+$ treatment chemicals (*e.g.*, carbon substrate, nutrient amendments, bioaugmentation microbes and ZVI) into the subsurface would require issuance of a UIC permit from SC DHEC. Site compliance with the existing ARARs is both feasible and practical using the ABC$^+$ treatment alternative in accordance with established practice and in the prescribed manner set forth by the treatment vendor.

7.6.4 Long-term Effectiveness and Permanence

Under the appropriate environmental conditions, ABC$^+$ can provide an effective and permanent treatment remedy for observed levels of VOCs present at the site. The long-term effectiveness of the ERD component of this remedial alternative is largely dependent upon maintaining strongly reducing and anaerobic conditions in the subsurface environment. Effective ERD treatment will also require a sustained and adequate supply of suitable carbon substrate (lactate) for the desired biochemical reactions to occur. As with ERD, the biological treatment components of the ABC$^+$ treatment process will not occur instantaneously. A sufficient period of time will be required to establish appropriate geochemical conditions and to optimize the growth of an adequate population of dehalogenating microbes. The presence of ZVI in the treatment additives will assist in ensuring that appropriate geochemical conditions are sustained over an extended period of time.

The natural condition of the site aquifer is variable, but was previously observed to be primarily an oxidizing environment with positive ORP. The two ABC+ pilot studies have already transformed large areas of the two VOC plume areas to reducing conditions with negative ORP. During the ABC+ pilot studies, geochemical conditions favoring ERD treatment have been established and sustained since the implementation of these pilot studies. Recent data collected during the March 2021 performance monitoring event indicated that ABC^+ can be successfully implemented at the Site and geochemical conditions suitable for long-term ERD treatment can be established and sustained. The carbon substrate (lactate) evaluated during the pilot study appears suitable for Site conditions and appropriate to the anaerobic (indigenous and bioaugmented) microbes that are present. Similarly, the ZVI additive has also demonstrated its utility as a useful treatment media that is capable of further enhancing VOC dechlorination and sustaining reducing conditions across the site for an extended period of time.

As with the other treatment alternatives discussed in this section, groundwater and surface water quality monitoring will be applied as an important tool to document and ensure the long-term effectiveness of the ABC^+ treatment remedy. Upon completion of active treatment measures, performance monitoring will also be used to monitor and verify the progress of MNA.

7.6.5 Reduction of Toxicity, Mobility, and Volume

ABC^+ is capable of reducing the toxicity, mobility, and volume of chlorinated VOCs in the affected groundwater at the Site. The possible health effects and safety concerns associated with “daylighting” of ABC+ treatment materials would be on a par with ERD treatment and greatly reduced from that of ISCO treatment.

7.6.6 Short-term Effectiveness

Implementation of the ABC^+ alternative would have no discernible impact on the local community and nearby residents, given the *in situ* nature of the treatment. This is an important feature of this remedial alternative and one that is consistent with the anticipated future-use of the site. Site workers and nearby residents would not be exposed to aggressive or hazardous treatment chemicals during injection events, because much of the material comprised in the ERD nutrient mix are derived from food-grade products and ZVI is basically just a highly processed and reduced form of scrap iron. When handled with appropriate PPE and precautions, ABC+ treatment chemicals are safe to handle. For the treatment application anticipated at this Site, ABC+ would be supplied in pre-mixed batches, shipped in chemical totes for easy handling. Temporary barriers would be installed to restrict nearby residents and trespassers from the area of treatment activity, for the duration of an injection event.

ABC+ represents an effective treatment alternative by which Site groundwater remediation target levels could be achieved within a reasonable period of years. With the groundwater monitoring component for this alternative, the observed improvements in Site groundwater quality could be readily discerned, documented, and communicated to project stakeholders.

7.6.7 Implementability

ABC+ treatment technology, equipment, and materials are readily available to successfully conduct all aspects of this remedial alternative. The ABC+ pilot study has demonstrated the feasibility and efficacy conducting ABC+ treatment at the Site. The pilot studies have also confirmed the utility of using DPT to inject ABC+ treatment amendments into the subsurface through the shallow and intermediate aquifer zones.

7.6.8 Opinion of Probable Cost

The requirements for implementing Remedial Alternative 5 (ABC+ treatment) would not require construction or installation of permanent infrastructure. This is an important feature of this treatment alternative and is consistent with the anticipated future-use of the property. For these reasons, there are no direct capital costs are associated with this alternative.

Based on communications with remediation contractors, several assumptions have been applied to generate the estimated costs for implementing ERD injections at the former WPH facility. Similar to the ERD treatment alternative, the remedy would be implemented in a series of several treatment events, spread over a seven-year timeframe. The initial ABC+ treatment event would occur in Year 1, followed by an extended period of performance monitoring to observe and document the extent and influence of the applied treatment. Subsequent smaller, targeted treatment events are assumed to occur in Years 4 and 7, during which the residual VOC mass would receive further treatment. Assumptions used for this opinion of probable cost are derived from the results of the Expanded ABC+ Pilot Study, which saw increasingly robust ERD conditions during the semiannual sampling events and significant short-term treatment effects from the ZVI component.

The estimated cost to conduct the initial Year 1 injection event for Alternative 5 has been calculated at a value of $914,300. The estimated cost of the follow-up injection events occurring in Year 4 ($457,000) and Year 7 ($229,000), assume a declining level of effort and material to address remediation of VOC residuals. These costs include the required costs to plan and conduct each of the three rounds of ABC^+ injections.

The annual cost for conducting ongoing performance monitoring of the groundwater for this treatment alternative was calculated to be approximately $80,000 per year. The total estimated cost for implementing Alternative 5 (ABC^+) was developed by assuming a seven-year period for the ABC^+ treatment injections, followed by an eight-year period of MNA. At the end of this 15-year timeframe, TRC has assumed that the site would be appropriate for a regulatory determination of No Further Action. These cost assumptions yield a total net present worth cost of $1,793,000.

A more detailed summary of these costs and the assumptions and estimates that were used to derive them are presented in Appendix B and Appendix C.

Section 8
Comparative Analysis of Remedial Action Alternatives

In this section, the five remedial alternatives that received detailed consideration and evaluation in Section 7 are now compared to each other. The basis for this comparison resides in various statutory criteria, including overall protection of human health and the environment, compliance with ARARs and the five balancing criteria (i.e., long-term effectiveness; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost). Through this comparative analysis, it is possible to establish rankings between the alternatives for the various criteria. The results of these comparisons are tabulated and ranked to highlight the remedial technologies that best address the selection criteria and would represent treatment alternatives deemed most suitable and appropriate for achieving Site RAOs.

8.1 Basis for Comparative Analysis

The primary purpose for the comparative analyses conducted in this section is to compare and contrast the various strengths, weaknesses and overall performance characteristics of each remedial alternative and provide a rational basis for ultimately selecting a reasonable and appropriate treatment remedy. A brief summary of comparisons between Remedial Alternatives 1 through 5 is presented in Table 8-1.

CERCLA guidance requires that the selected remedial alternatives for a site must meet the following two threshold criteria:

- The proposed remedy must provide overall protection of human health and the environment, and
- Achieve compliance with ARARs.

Remedial alternatives that meet these threshold criteria must then strike a reasonable, site-specific balance among the remaining selection criteria (i.e., long-term effectiveness; reduction of toxicity, mobility and volume; short-term effectiveness; implementability; and cost). A number of site-specific considerations must also be taken into account when comparing the various remedial alternatives for the site, including:

- VOC-affected groundwater continues to migrate from the Site in a downgradient direction toward Hartwell Lake, where there is evidence of VOC discharge to this surface water body.
- The property owner is actively engaged in extensive Site redevelopment activities involving construction of residential housing units. The property owner has recently expressed a desire and intention to begin new development activities within the Upgradient and Downgradient VOC plume

areas. Thus, the selected site remedy must be appropriate and compatible with the anticipated future-use of the property (*i.e.*, residential development).

- The selected site remedy must also be able to achieve site RAOs in a timely manner that is consistent and compatible with the property owner's anticipated timeline for site redevelopment and SC DHEC's expectations/guidelines for suitable remedy completion.
- Remedial alternatives requiring extensive utility infrastructure (*i.e.*, excavation/trenching, in-ground piping/power, permanent support structures, and/or treatment facilities) would not be well suited and/or compatible with ongoing site redevelopment activities.
- *In situ* treatment alternatives (*i.e.*, ISCO, ERD and ABC^{+}) afford more flexibility with regards to treatment and monitoring and a reduced likelihood of interference/delay with ongoing site redevelopment work.
- Two pilot studies (using ABC+) have been successfully conducted at the site. The results of these treatment efforts have converted large portions of the VOC-affected aquifer to reducing conditions. Consideration of ISCO as a possible treatment alternative must bear in mind that excess treatment measures would be required to overcome the previously applied electron donor materials, reverse the reducing effects imparted by the ABC+ pilot studies and restore positive ORP conditions.
- Monitored natural attenuation represents an important and necessary polishing step towards achieving site RAOs. Future implementation of MNA would best occur following completion of an active Site treatment components to reduce the observed concentrations of the VOC contaminants to levels more amenable to ongoing MNA treatment. While it is possible that groundwater MCLs will ultimately be achieved with MNA only, it is likely that an extended period of time will be required before MNA alone achieves this Site RAO.

Table 8-1
Comparison of Alternatives

CRITERIA		ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5
THRESHOLD CRITERIA	**Description**	**No Action** 30-year timeframe[1]	**Monitored Natural Attenuation** 30-year timeframe[1]	***In Situ* Chemical Oxidation** 12-year timeframe	**Enhanced Reductive Dechlorination** 20-year timeframe	**ABC⁺® Treatment** 15-year timeframe
THRESHOLD CRITERIA	**Overall Protection of Human Health and the Environment**	Does not reduce potential exposure to COCs or potential migration of COCs to surface water in an acceptable timeframe.	Does not reduce potential exposure to COCs or potential migration of COCs to surface water in an acceptable time frame.	Reduces potential exposure to COCs and controls downgradient migration of COCs with aggressive reduction of COC concentrations. Requires injection of strongly oxidizing and dangerous chemicals.	Reduces potential exposure to COCs and controls downgradient migration of COCs with enhanced biological reduction of COC concentrations.	Reduces potential exposure to COCs and controls downgradient migration of COCs with a combination of biological and physical/chemical treatment of COC concentrations.
BALANCING CRITERIA	**Compliance with ARARs**	Does not comply with ARARs.	Does not comply with ARARs in acceptable time frame under current conditions	Will comply with ARARs.	Will comply with ARARs.	Will comply with ARARs.
BALANCING CRITERIA	**Long-Term Effectiveness and Permanence**	Low effectiveness for COC exposure and migration	Low effectiveness for COC exposure and migration	Effective for exposure and migration	Effective for exposure and migration	Effective for exposure and migration
BALANCING CRITERIA	**Reduction of Toxicity, Mobility, and Volume**	No reduction of toxicity, mobility, or volume.	Slow, limited reduction of toxicity, mobility, or volume under current conditions.	Rapidly reduces toxicity, mobility, and volume of VOCs in groundwater; limited expectation for MNA following treatment.	Reduces toxicity, mobility, and volume of VOCs in groundwater; MNA following treatment subject to conducive geochemical conditions, may require subsequent treatment to sustain MNA conditions.	Reduces toxicity, mobility, and volume of VOCs in groundwater; residual ZVI presence provides sustaining ongoing MNA treatment processes following completion of active ABC+ treatment.

Table 8-1
Comparison of Alternatives

CRITERIA		ALTERNATIVE 1	ALTERNATIVE 2	ALTERNATIVE 3	ALTERNATIVE 4	ALTERNATIVE 5
BALANCING CRITERIA	**Short-Term Effectiveness**	No short-term effects	No short-term effects	High short-term effects associated with injection of strongly oxidizing and dangerous chemicals.	Moderate short-term effects associated with injecting ERD chemicals.	Moderate short-term effects associated with injecting ERD and ZVI reactants (ABC+).
	Implementability	Not applicable	Low implementability – limited MNA mechanisms, extended time frame before Site can achieve final closure.	Implementability issues are resolvable, but ISCO chemicals require careful handling and are dangerous due to their aggressive, reactive nature. Shortest timeframe for Site to achieve final closure. Reducing effects of the two ABC+ pilot studies would have to be reversed using additional treatment chemicals and time.	Implementability issues easily resolved using food-grade treatment media to facilitate anaerobic microbial activity	Implementability issues easily resolved. ERD and ZVI treatment media that create mutually beneficial treatment environments. Quite suitable for long-term MNA application.
	Estimated Cost	Capital Costs: $0 Annual OM&M: $0 Net Present Worth: $0[2]	Capital Costs: $0 Annual Monitoring: $80,000 Net Present Worth: $959,000[2]	Injection Costs: $9,822,000 Annual Monitoring: $80,000 Net Present Worth: $4,321,000[2]	Injection Costs: $2,722,000 Annual Monitoring: $80,000 Net Present Worth: $2,347,000[2]	Injection Costs: $1,600,000 Annual Monitoring: $80,000 Net Present Worth: $1,793,000[2]

[1] Limited to the 30-year Net Present Value timeframe; actual time to achieve RAOs expected to be longer.
[2] Net Present Worth calculated at a discount rate of 7 percent (2020)

8.2 Comparison of Remedial Alternatives

In this section, the remedial alternatives will be compared to each other on the basis of the two statutory criteria (*i.e.*, overall protection of human health and the environment and compliance with ARARs) and the five balancing criteria (*i.e.*, long-term effectiveness; reduction of toxicity, mobility, and volume; short-term effectiveness; implementability; and cost).

8.2.1 Overall Protection of Human Health and the Environment

Site institutional controls (*i.e.*, restrictions preventing human consumption or use of the Site groundwater) will need to be implemented and enforced for each of the five remedial alternatives until such time as attainment of MCLs in the underlying groundwater can be demonstrated. Because VOCs will remain in the groundwater until MCLs are achieved, each of the four active remedial alternatives assumes periodic (5-year) SC DHEC reviews will be conducted. The 5-year review process will allow SC DHEC to evaluate the overall effectiveness of the selected remedy in achieving site clean-up goals and ensuring protection of human health and the environment.

Since Alternatives 1 (No Action) and 2 (MNA) do not incorporate provisions for further active treatment of the observed site VOCs, they are both considered to represent the lowest levels of protectiveness towards human health and the environment. Primarily, these two alternatives are viewed this way because neither will provide VOC migration controls or active COC reduction. VOC-affected groundwater will also continue to migrate downgradient toward Hartwell Lake without active treatment measures. Residual VOC contaminants present in the Upgradient and Downgradient plume areas will continue to source the ongoing flow and transport of VOCs in groundwater. Alternative 2 (MNA) differs from Alternative 1 (No Action) in that MNA includes provisions for ongoing Site monitoring activities. This would facilitate the periodic assessment and evaluation of Site groundwater quality and environmental conditions. With no active treatment of the VOC source areas, the primary treatment mechanisms available for MNA would consist of dispersion, dilution, and some amount of naturally occurring bioremediation. The potential for continued bioremediation is benefitted by the two ABC+ pilot studies that were conducted at the Site. Ongoing MNA monitoring would provide a means for evaluating Site conditions and determining whether or not active treatment measures should be considered for use at the Site.

Alternatives 3 through 5 each represent active treatment remedies that could be reasonably implemented at the Site.

Alternative 3 (ISCO) represents the most aggressive and time-sensitive of these active treatment measures. While ISCO provides an aggressive means of degrading VOC concentrations present in the Site groundwater, it also requires the use of dangerous and expensive chemical formulations that could present hazards and challenges to handle, inject and monitor. ISCO could also represent a hazard if ISCO treatment media were found to "daylight" during treatment activities, thereby exposing Site workers and nearby residents to potential risks and exposure hazards. These concerns make it an imperative that ISCO treatments receive proper planning and execution, precision delivery within the appropriate locations/depths of targeted VOCs, and ongoing oversight and inspection to quickly identify and respond to any observed instances of "daylighting". Since strong chemical oxidants are not selective and will oxidize any naturally occurring material present in the subsurface, targeted delivery of ISCO to the VOC-affected groundwater is essential to avoid waste of costly treatment media and missed treatment opportunity. After a period of weeks, the applied ISCO treatment media is anticipated to become exhausted. After adequate time for the treatment effects to distribute and be monitored, additional ISCO injection events will be necessary to address active treatment of areas of VOCs insufficiently treated by previous injections. ISCO treatment would not be expected to provide an extended period of treatment influence and limited longevity.

The two ABC+ pilot studies have already created reducing conditions and introduced lactate-based carbon source materials across broad portions of the VOC plume areas. In order for ISCO to be implemented at the Site, it would first be necessary to reverse the reducing conditions that have been imposed on the Site by applying additional oxidant, which will add cost in time, materials and labor. The application of ISCO is viewed as a counter-productive step towards achieving Site RAOs, particularly when considered in terms of the progress and performance recently identified in the June 2021 ABC+ Pilot Study Report.

ISCO carries a higher level of potential concern for both on-site and off-site exposure risks, as well as greater potential health and safety concerns for nearby workers and residents. The risk of strong oxidants "daylighting" from a well or remnant geologic structure, thereby exposing nearby residents to potential exposure risk must be considered. While ISCO is more likely to quickly reduce the observed levels of chlorinated and non-chlorinated VOCs in groundwater, ERD and ABC^+ treatment measures appear to be more compatible with the current and future use of the property. ISCO treatment is also dependent upon achieving direct contact (at a sufficient concentration) between the chemical oxidant and the targeted COCs. Once the chemical oxidant is exhausted, no further treatment will occur until supplemental ISCO treatment measures are implemented. Thus, the subsequent role of MNA "polishing" of the residual VOCs in groundwater would be largely limited to groundwater flow mechanisms like advective dispersion and dilution.

Alternative 4 (ERD) has a long history of providing effective and reliable treatment for reducing VOC levels in groundwater. Sites are currently applying ERD treatment across the Upstate area of South Carolina and regionally across the South. In comparison to ISCO, the treatment additives associated with ERD are typically food-grade additives, neither chemically aggressive nor reactive, and would not present significant health and safety concerns to Site workers and nearby residents.

DPT would be used as the delivery mode for introducing the ERD nutrients into the subsurface. The applied ERD treatment media is water soluble and able to migrate along with the VOC-affected groundwater to facilitate ongoing ERD treatment. The two pilot studies have demonstrated that an extended period of continuing treatment can be expected at the site for ERD, and VOC reductions can be expected to occur over an extended period of time. The primary focus of a biologically mediated ERD treatment process is to establish a suitable treatment environment (*i.e.*, anaerobic and negative ORP) for the indigenous dehalogenators (anaerobic soil microbes) and providing them with a suitable carbon substrate (*i.e.*, lactate). When implemented properly, suitable ERD conditions can persist within an aquifer for many months to years. This type of sustainable environment would facilitate ongoing ERD treatment effects through a subsequent MNA period. As an active treatment measure, ERD would provide an enhanced level of protection of human health and the environment compared to Alternatives 1 (No Action) and 2 (MNA).

While not as aggressive or time sensitive as ISCO treatments, ERD would provide long-term reduction of the chlorinated VOCs, but require a longer period of time to achieve reduction of groundwater VOCs to target clean-up levels. However, ERD will achieve RAOs in a manner that is more protective of Site workers and the nearby residents. It will also achieve Site RAOs in a manner more conducive and suitable to the current and future land-use plans of the property owner. The use and application of ERD treatment is likely to exert a longer lasting influence effect on groundwater conditions, as the project transitions from active treatment to passive MNA treatment, the final polishing step for achieving RAOs.

Alternative 5 (ABC$^+$ treatment) represents an innovative, hybrid technology that integrates the treatment benefits of the microbial-based ERD treatment process with the physio-chemical treatment benefits and reducing characteristics of ZVI treatment. Like ERD, the treatment chemistry of ABC$^+$ would present lower levels of health and safety concern for Site workers and the nearby community compared to ISCO. The treatment chemistry of ABC+ would be similar to ERD treatment, but include a ZVI treatment supplement. The addition of ZVI to the ABC$^+$ treatment mix not only enhances VOC reduction via a physio-chemical pathway, but it also helps maintain a strongly reducing environment that is helpful and supportive of the ERD treatment process. ERD and ZVI function well together and provide synergistic treatment attributes to achieve an overall reduction in the observed VOC contaminant mass using biotic and abiotic means.

Once injected into the subsurface, ZVI can be expected to remain active and effective in dechlorinating VOCs for many years. This extended period of active treatment represents an element of longevity that provides a significant benefit towards sustaining MNA influence during the polishing stages of the Site remedy.

Alternative 5 is likely to exert the longest lasting effect on groundwater quality conditions, as the ZVI will continue to enhance reducing conditions within the aquifer that are compatible with long-term application of MNA. ABC+ represents a treatment alternative that is suitable and aligned with the current and future land-use needs and requirements for the Site.

8.2.2 Compliance with Applicable or Relevant and Appropriate Requirements

The chemical-specific ARARs developed for the site were predicated upon Federal drinking water MCLs. While each of the five remedial alternatives can be expected to eventually achieve compliance with ARARs, each will do so within different treatment process constraints and timeframes. Location-specific and action-specific ARARs can be achieved by proper design and planning of the remedial action.

While Alternatives 1 (No Action) and 2 (MNA) will eventually achieve the remediation target levels established for groundwater, Site conditions suggest that it is more likely that natural attenuation processes, alone, will require considerably more time to achieve chemical-specific ARARs than the active treatment remedies (*i.e.*, Alternatives 3, 4, and 5). For each of the active treatment alternatives, an extended period of MNA is assumed following completion of the active treatment. Thus, MNA has been incorporated into each of the active treatment alternatives as a polishing measure to achieve ARARs within the VOC-affected groundwater areas.

Alternative 3 (ISCO) will create more oxidative conditions within the underlying aquifer, which does not create Site conditions conducive for most MNA processes. MNA treatment attributable to the ISCO treatment alternative would more likely occur as a result of dispersion and/or dilution effects. Alternatives 4 (ERD) and 5 (ABC$^+$ treatment) would be expected to establish a more suitable environment for sustaining and promoting effective MNA conditions. The ongoing benefits of ERD plus ZVI treatment would further help support and augment MNA via the hydrogeologic influences of contaminant dispersion and dilution.

8.2.3 Long-term Effectiveness

Each of the various remedial alternatives can be expected to achieve some level of contaminant reduction and effectiveness, but over widely varying timeframes. The anticipated timeframe for Alternative 1 (No Action) and 2 (MNA) would be significantly greater than for the other active treatment alternatives. For the purposes of this FFS, TRC has assumed that Alternatives 1 and 2 would require a minimum duration of 30 years to achieve RAOs, recognizing that the actual time requirement might be even greater. Because neither Alternative 1 nor 2 involves an active treatment component, they are both viewed as exhibiting poor long-term effectiveness.

Alternatives 3 (ISCO), 4 (ERD), and 5 (ABC^+) each involve some manner of active treatment. For this reason, they would each be expected to provide for long-term effectiveness, within a considerably shorter timeframe than would be possible for either Alternatives 1 or 2. Treatment of the VOC-affected groundwater by chemical oxidation (ISCO) represents an aggressive approach to achieving Site clean-up levels. The application of ERD treatment chemicals to achieve reducing conditions suitable for biologically mediated reductive dechlorination and/or the addition of ZVI to promote an added physio-chemical reduction reaction are also viewed as exhibiting good long-term effectiveness for the Site.

8.2.4 Reduction of Toxicity, Mobility, and Volume

Because Remedial Alternatives 1 (No Action) and 2 (MNA) do not involve active treatment components, they will not facilitate further reductions (following the Expanded ABC+ Pilot Study) in the overall mobility of the VOCs that are present in the Site groundwater over a reasonable timeframe. Over time, natural attenuation processes could reduce the overall toxicity and volume of the site-related VOCs in groundwater. However, it is likely that this reduction would occur over an unreasonably long period of time, a period better measured in decades than years. Thus, Alternatives 1 and 2 are not viewed in a favorable manner for this important balancing criterion.

As active treatment measures, Remedial Alternatives 3 (ISCO), 4 (ERD), and 5 (ABC+) each would facilitate dechlorination of the COCs present in the Site groundwater. By continued and long-term degradation and dechlorination of the Site VOCs, it is reasonable to anticipate that each of these treatment alternatives would effectively reduce the toxicity and volume of the contaminant mass. The distinguishing characteristics for each of these active treatment remedies ranges from the faster-acting and indiscriminate ISCO treatment alternative to the slower-paced and steady, longer acting treatment influences of ERD and ABC+.

Based upon its aggressive and non-specific oxidative properties, Alternative 3 (ISCO) would be expected to address a more comprehensive number of chlorinated and non-chlorinated VOCs.

However, for the Site VOC plumes areas, the observed listing of chlorinated and non-chlorinated COCs is not extensive. Targeted treatment of the VOC contaminant plume areas using any of these three active treatment alternatives would result in a decline of contaminant mass in the Site groundwater. The reduction in the mass of VOCs present in the two plume areas will reduce the migration of COC mass moving downgradient toward Hartwell Lake. Thus, Treatment Alternatives 3 (ISCO), 4 (ERD), and 5 (ABC+) will each improve groundwater quality conditions by degrading/attenuating the COCs present in the groundwater, thereby reducing the potential for contaminant migration into Hartwell Lake.

While the treatment mechanisms of Alternatives 3, 4, and 5 can effectively treat COC-affected groundwater, removal of contaminants can also create diffusion gradients. Diffusion gradients will occur when COCs, previously sorbed onto underlying soils, begin to desorb from these same soils and solubilize into the previously treated groundwater. Back-diffusion can occur as a consequence of active treatment processes and can result in a rebound of VOC concentrations within the aquifer. Depending upon the rate and concentration of observed back-diffusion, MNA may or may not be able to provide an adequate means for address the observed VOC rebound. Ongoing performance monitoring is an important tool to recognize and respond to the possible need for additional, targeted active treatment measures during remedy implementation. As previously indicated, Alternative 5 (ABC^+) would be expected to provide the highest level of residual MNA treatment potential in the event a back-diffusion concern is identified. Similarly, Alternative 3 (ISCO) would be expected to exhibit the lowest potential for addressing VOC back-diffusion concerns, since ISCO treatment would not tend to enhance reductive conditions within the aquifer.

8.2.5 Short-term Effectiveness

Two potentially completed exposure pathways for the Site COCs have been identified. The first of these exposure pathways has been addressed within the requirements set forth by SC DHEC in the property owner's Voluntary Clean-Up Contract. The VCC recognizes there is a possibility of VOC vapors emanating from the subsurface environment and accumulating within the basements or crawlspaces of residential housing units that might be constructed in or around the footprint of the VOC-affected groundwater. The property owner is currently responsible for design and installation of suitable engineering controls to abate accumulated VOC vapors that might occur within the basements or crawlspaces of residential housing units contemplated for the VOC-affected groundwater plume areas.

The second exposure pathway would involve the possibility for direct human contact with VOCs that might be present within the near-shore sediments and surface waters of Hartwell Lake. Sampling conducted along the shoreline area of Hartwell Lake has previously revealed intermittent VOC concentrations that exceed ARARs. The shoreline within this area of the Site is not readily accessible to residents, and does not present a particularly attractive or appealing beach area for recreational users on Hartwell Lake. However, as the pace of residential development activities increase, this area might become more frequently visited.

As indicated earlier, the property owner has recently expressed an interest in further expanding the construction of residential housing units into the areas exhibiting VOC-affected groundwater. Because the property owner/developer has previously agreed to a VCC with SC DHEC, it falls upon the Department to provide regulatory oversight and direction of these future development activities and ensure that the appropriate requirements and provisions of the VCC are addressed.

As active treatment measures are implemented across the Site, VOC levels in groundwater will decline and vapor intrusion concerns will similarly begin to decline. This would also apply to the possible risk of human exposures to VOCs along the Hartwell Lake shoreline. The entire residential development across the former WPH facility already makes use of public drinking water supplies, and there are no plans for future use of the underlying groundwater. On this basis, there are no completed exposure pathways associated with groundwater ingestion.

Alternative 3 (ISCO) presents the greatest potential of short-term risk or impact to Site workers and nearby residents. Because of the robust and aggressive nature of the chemical oxidants utilized with ISCO, it is possible that Site workers or nearby residents could experience exposure to dangerous treatment chemicals. The workers directly responsible for remedy implementation and monitoring will all receive job-specific training and be provided appropriate PPE to properly handle the ISCO-related chemicals and conduct their assigned work. However, Site workers associated with property redevelopment and nearby residents would not have access to such training or PPE. If chemical oxidants should “daylight” (*i.e.,* seep up to the ground surface) during ISCO injection activities, these individuals could be exposed to a hazard. During active ISCO treatment events, the targeted treatment areas would need to have temporary barricades erected, cautionary placarding posted, and ongoing inspection and monitoring to identify possible hazards, limit unauthorized access, and minimize potential exposure risks. These concerns reduce the short-term effectiveness of Alternative 3 (ISCO) at this Site.

While the required timeframe for achievement of remedy completion is likely the shortest with Alternative 3 (ISCO), the Expanded ABC+ Pilot Study has already made excellent progress towards transforming aquifer conditions within the Upgradient plume to reducing conditions and conducting full-scale ABC+ treatment within the pilot study area (the VOC plume area encompassing the 0.1 mg/L PCE isocontour). Reversing the effects of the pilot study injections would add significantly to the cost and timeframe of ISCO. Therefore, the short-term effectiveness is better for Alternative 4 (ERD) or Alternative 5 (ABC+).

Considering the combined treatment influences of ERD and ZVI, the use and application of Alternative 5 (ABC^+) appears to represent a more favorable means of achieving Site RAOs in a reduced timeframe relative to Alternative 4 (ERD). The actual extent to which this timing difference would manifest itself under full-scale field conditions is difficult to quantify. During the Expanded ABC+ Pilot Study, the short-term treatment influences of the ERD and the ZVI components of ABC+ were discernable during performance monitoring. This suggests to TRC that ABC+ would result in a faster, more thorough treatment of the VOC plume areas than would be expected of ERD treatment alone.

8.2.6 Implementability

The equipment and resources necessary to implement Remedial Alternatives 1 through 5 are readily available and reasonably available from multiple sources. Currently, Alternative 5 (ABC^+) would involve procurement of the proprietary ABC+ treatment formulation is available from a single source. However, other vendors are beginning to offer similar ERD/ZVI-based formulations. The required/available quantity of treatment materials would not be expected to represent a limitation for implementation of any of the five remedial treatment alternatives.

The ABC^+ pilot studies conducted at the site have successfully demonstrated both the efficacy of advancing DPT to depths greater than 55 feet bgs and the feasibility of injecting the required ERD and ZVI treatment media into targeted depth intervals. During the Expanded ABC+ pilot study, ABC^+ injections were successfully completed from the top of the water table (approximately 20 feet bgs) to the bottom of the transition zone (at depths up to 90 feet bgs). During both the initial and the expanded pilot studies, TRC was able to document migration of the ABC^+ treatment chemicals and confirm ongoing treatment and degradation of the VOCs.

8.2.7 Remedial Cost Considerations

Cost estimates have been developed for each of the five remedial alternatives. A summary of Net Present Value (NPV) calculations for each treatment alternative is presented in Table 8-2. The NPV values were prepared for each remedial alternative using simplifying assumptions and technical criteria intended to best facilitate a direct cost comparison between each of the remedial alternatives. Thus, the cost estimates provided in this section represent TRC's opinion of the probable cost to implement each of the treatment alternatives, as well as conduct performance monitoring during the active treatment phase and subsequent MNA period. These cost figures are intended to provide the Department with a meaningful basis upon which to conduct a review, evaluation, and selection of a treatment remedy that is best suited for the Site. The assumptions and cost considerations set forth in this section should be regarded as a useful "comparative tool" and not for use as a basis for establishing budget estimates for funding future Site work.

Once a Site remedy has been selected, site-specific field conditions and detailed vendor bids should be applied to generate more detailed cost estimates that are representative of work scopes and budgets that are reflective of a future construction-level remedial response costs.

A general discussion of the assumptions, technical details and resulting Net Present Worth values provided in Table 8-2 follows.

Alternative 1 No Action – this alternative clearly represents the least costly of the five remedial alternatives under consideration. As required by regulatory guidance, the No Action alternative is intended to provide a basis from which the other treatment alternatives can be compared and contrasted. There are no significant costs associated with the implementation of Alternative 1 (No Action).

Alternative 2 (MNA) includes cost considerations for establishing and maintaining institutional controls, as well as conducting periodic groundwater and surface water monitoring events. Specific USEPA MNA guidance was applied to generate the details and technical protocols for conducting an MNA program that would be considered appropriate from a regulatory perspective. These considerations have been integrated into Alternative 2 (MNA).

Alternatives 3 (ISCO), 4 (ERD) and 5 (ABC$^+$ treatment) each embody many of the same considerations and assumptions regarding the need for institutional controls, applied treatment strategies and performance monitoring criteria (similar to those used for Alternative 2). Each of these remedial alternatives were then further expanded to address the site-specific information and details regarding what would be required to implement a full-scale version of each active treatment alternative.

Perhaps the most important consideration that was applied during these cost evaluations was that each of the three active treatment alternatives would be starting at a point in the project life cycle where there has been a measure of contaminant reduction resulting from the two ABC+ Pilot Studies. The current Site groundwater conditions can no longer be characterized by pre-ABC+ baseline monitoring results. Since 2016, the cumulative treatment influences of the two ABC+ pilot studies must now be considered, since these pilot studies have essentially transformed the aquifer from an oxidizing environment with positive ORP conditions into an aquifer that currently exhibits reducing conditions and negative ORP over much of the VOC-affected plume areas. Lactate-based organic treatment media and finely milled ZVI particulate are also currently in-place across much of the Upgradient VOC plume area and some of the Downgradient VOC plume area. While the aquifer adjustments and treatment influences that occurred during the ABC+ pilot studies are compatible with Alternatives 4 (ERD) and 5 (ABC+), technical and financial considerations involving implementation of Alternative 3 (ISCO) will now require reversing the reducing conditions and low ORP of the Site. These adjustments have been applied to the cost considerations associated with Alternative 3 (ISCO).

Several fundamental, simplifying assumptions were incorporated into the development of the cost estimates for each treatment alternative. Many of these assumptions were predicated on knowledge and understanding of prior Site history, the current groundwater quality conditions, and/or generalized "rules of thumb" for implementation of these various *in situ* treatment measures. A more detailed summary of these costs and the associated assumptions used to derive the estimated costs are presented in Appendix B and Appendix C.

Net present values were calculated for each remedial alternative and are summarized in Table 8-2.

Table 8-2
Summary of Net Present Worth Calculations

REMEDIAL ALTERNATIVE	ACTIVE TREATMENT PERIOD (YEARS)	MNA PERIOD (YEARS)	TOTAL REMEDY DURATION (YEARS)	NET PRESENT WORTH
Alternative 1: No Further Action	0	0	0	$0
Alternative 2: MNA	0	30	30	$959,000
Alternative 3: ISCO	8	4	12	$4,321,000
Alternative 4: ERD	13	7	20	$2,347,000
Alternative 5: ABC$^+$	7	8	15	$1,793,000

8.3 Results of Comparative Analysis

A points-based ranking system was developed as a tool to provide a useful evaluation and tabulation of the results of the comparative analyses presented on Table 8-1. For each of the analysis criteria, a ranking number has been assigned to represent the relative strengths and weaknesses of the five treatment alternatives. Ranking points were assigned by applying a sliding-scale that applied the following rationale:

- Low – 1 point
- Medium – 3 points

- High – 5 points

The ranking criteria associated with the relative cost for each treatment alternative were assigned points by applying the following rationale:

- Zero to Low cost – 5 points
- Moderate cost – 3 points
- High cost – 1 point

Based on this points-based ranking system, the treatment remedies that most appropriately reflect and achieve the ranking criteria will also reflect the highest cumulative point totals. Table 8-3 summarizes the results of these points-based comparative analyses.

Alternatives 1 (No Action) and 2 (MNA) fail to meet the threshold criteria of addressing Site RAOs in a reasonable time frame.

Alternatives 4 and 5 have higher overall rankings as compared to Alternative 3. All three active remedial alternatives are expected to ultimately comply with ARARs and manifest long-term effectiveness and permanence. ABC+ is ranked higher than ISCO and ERD for short-term effectiveness to reflect the broadly distributed, fast-acting, and persistent dechlorination provided by the ZVI component of ABC+. ISCO is ranked lower in reduction of toxicity, mobility, and volume compared to ERD and ABC+ to reflect the more limited MNA potential for ISCO. Alternative 3 (ISCO) ranks lower than Alternatives 4 and 5 in short term effectiveness and implementabililty because of the inherent aggressiveness of ISCO treatment chemicals and because the current groundwater quality conditions include the effects of the Expanded ABC+ Pilot Study (reducing conditions and addition of organic substrate). Of the three active remedial alternatives, Alternative 5 (ABC+) has the lowest NPV and Alternative 3 (ISCO) has the highest NPV. The NPV for Alternative 4 (ERD) is about 30 percent higher than ABC+, which is a function of the lower persistence of ERD without the ZVI component, requiring more injection events to address back-diffusion and PCE rebound.

Table 8-3
Summary of Comparative Analysis Results

	ALTERNATIVES				
	No Action	MNA	ISCO	ERD	ABC+
Overall Protection of Human Health and the Environment	1	1	3	5	5
Compliance with ARARs	1	1	5	5	5
Long-Term Effectiveness and Permanence	1	1	4	4	5

Table 8-3
Summary of Comparative Analysis Results

	ALTERNATIVES				
	No Action	**MNA**	**ISCO**	**ERD**	**ABC+**
Reduction of Toxicity, Mobility, and Volume	1	1	4	4	5
Short term Effectiveness	1	1	4	4	5
Implementability	3	3	4	5	5
Net Present Worth Cost	5	3	1	3	4
Total Points	**13**	**11**	**25**	**30**	**34**

Section 9
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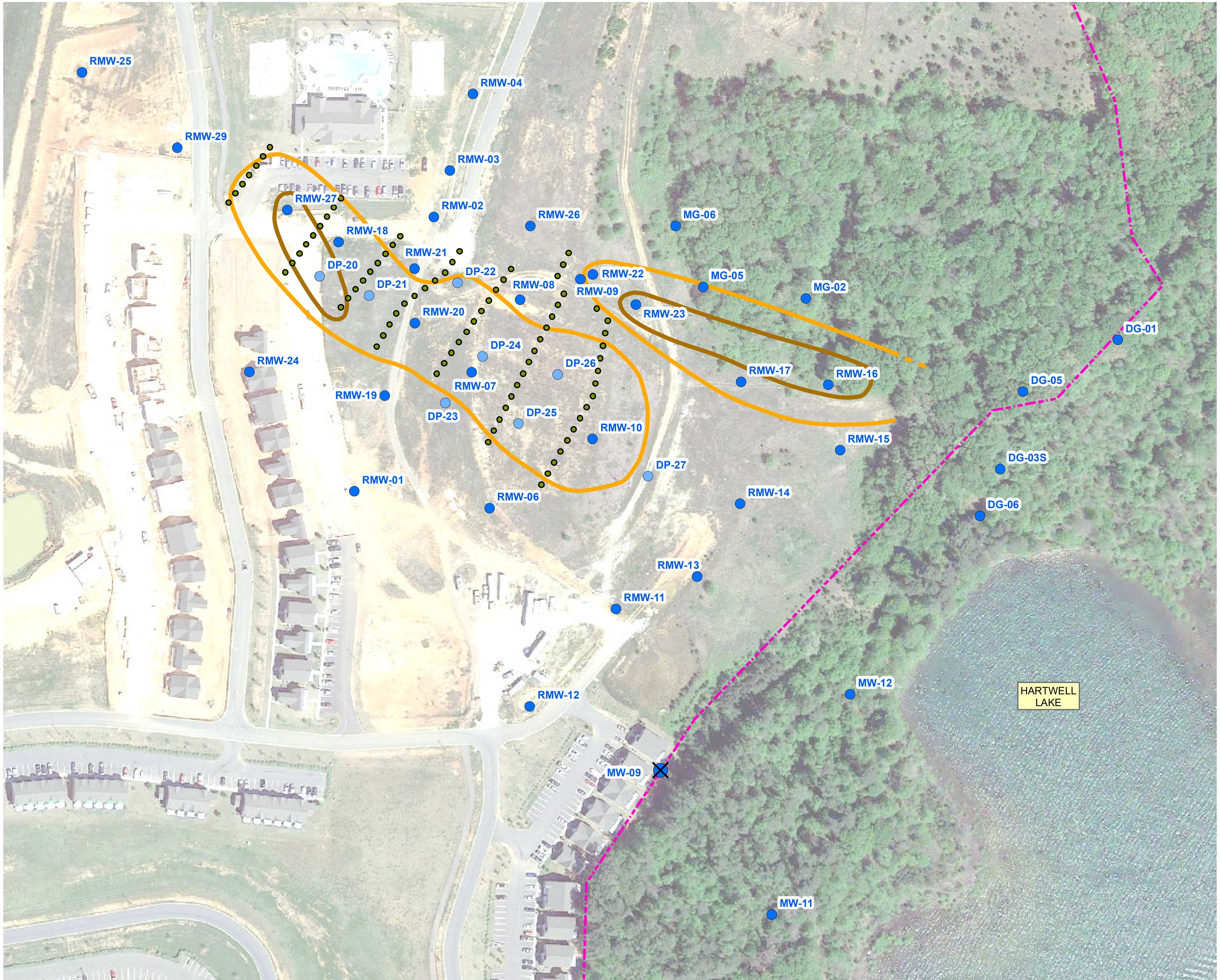
Appendix A
Expanded Pilot Study Report Figures



LEGEND

- Direct-Push Groundwater Sample
- Water Table Monitoring Well
- ABC+ Injection Points
- Destroyed Water Table Monitoring Well
- Property Boundary (Approximate)

NOTES

Aerial Photograph Source: Google Earth (2018).

Outlined areas are based on an aggregation of ERD field and laboratory indicator parameters.

Dashed areas indicate an inferrence.

Burnt orange outlined areas are from 2019.

Orange outlined areas are from 2021.

0 130 260 Feet

1 " = 150 '

1:1,800

PROJECT:

FORMER WESTPOINT HOME, INC.
CLEMSON, SOUTH CAROLINA

TITLE:

AREA OF ROBUST ERD CONDITIONS IN SHALLOW GROUNDWATER

DRAWN BY:	S. RAY	PROJ. NO.:	300688.0.0
CHECKED BY:		**FIGURE 4-13**	
APPROVED BY:			
DATE:	JUNE 2021		

TRC

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Patewood Plaza Three
Greenville, SC 29615
Phone: 864.281.0030
www.TRCcompanies.com

FILE NO.: Fig 4-13 - Area of Robust ERD Conditions Shallow GW.mxd

TRC - GIS

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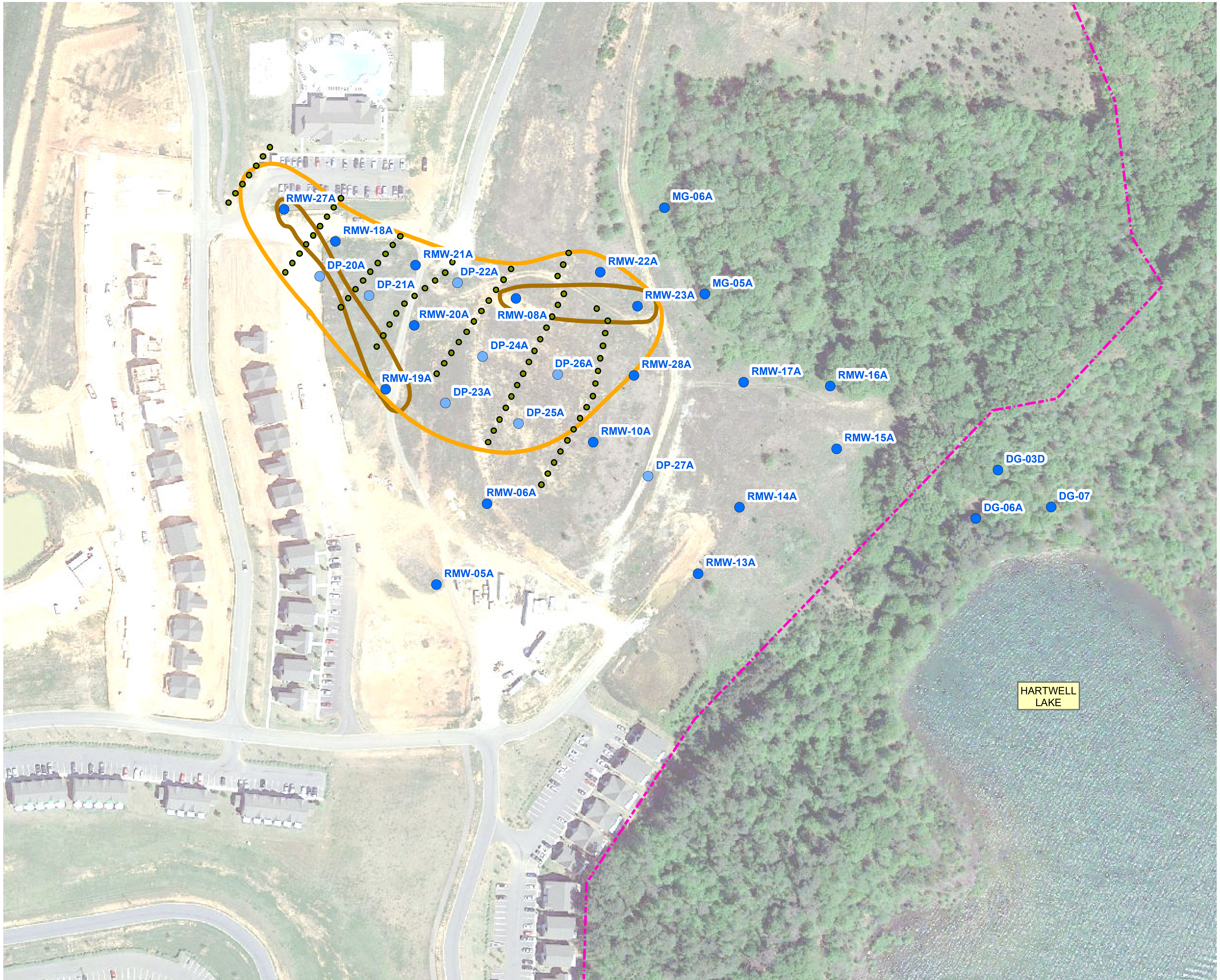

LEGEND

- Direct-Push Groundwater Sample
- Intermediate Aquifer Monitoring Well
- ABC+ Injection Points
- Property Boundary (Approximate)

NOTES

Aerial Photograph Source: Google Earth (2018).

Outlined areas are based on an aggregation of ERD field and laboratory indicator parameters.

Dashed areas indicate an inferrence.

Burnt orange outlined areas are from 2019.

Orange outlined areas are from 2021.

N

0 130 260 Feet

1 " = 150 '

1:1,800

PROJECT:

FORMER WESTPOINT HOME, INC.
CLEMSON, SOUTH CAROLINA

TITLE:

AREA OF ROBUST ERD CONDITIONS IN INTERMEDIATE AQUIFER WELLS

DRAWN BY:	S. RAY	PROJ. NO.:	300688
CHECKED BY:		**FIGURE 4-14**	
APPROVED BY:			
DATE:	JUNE 2021		

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FILE NO.: Fig 4-14 - Area of Robust ERD Conditions Intermediate AW.mxd

TRC - GIS

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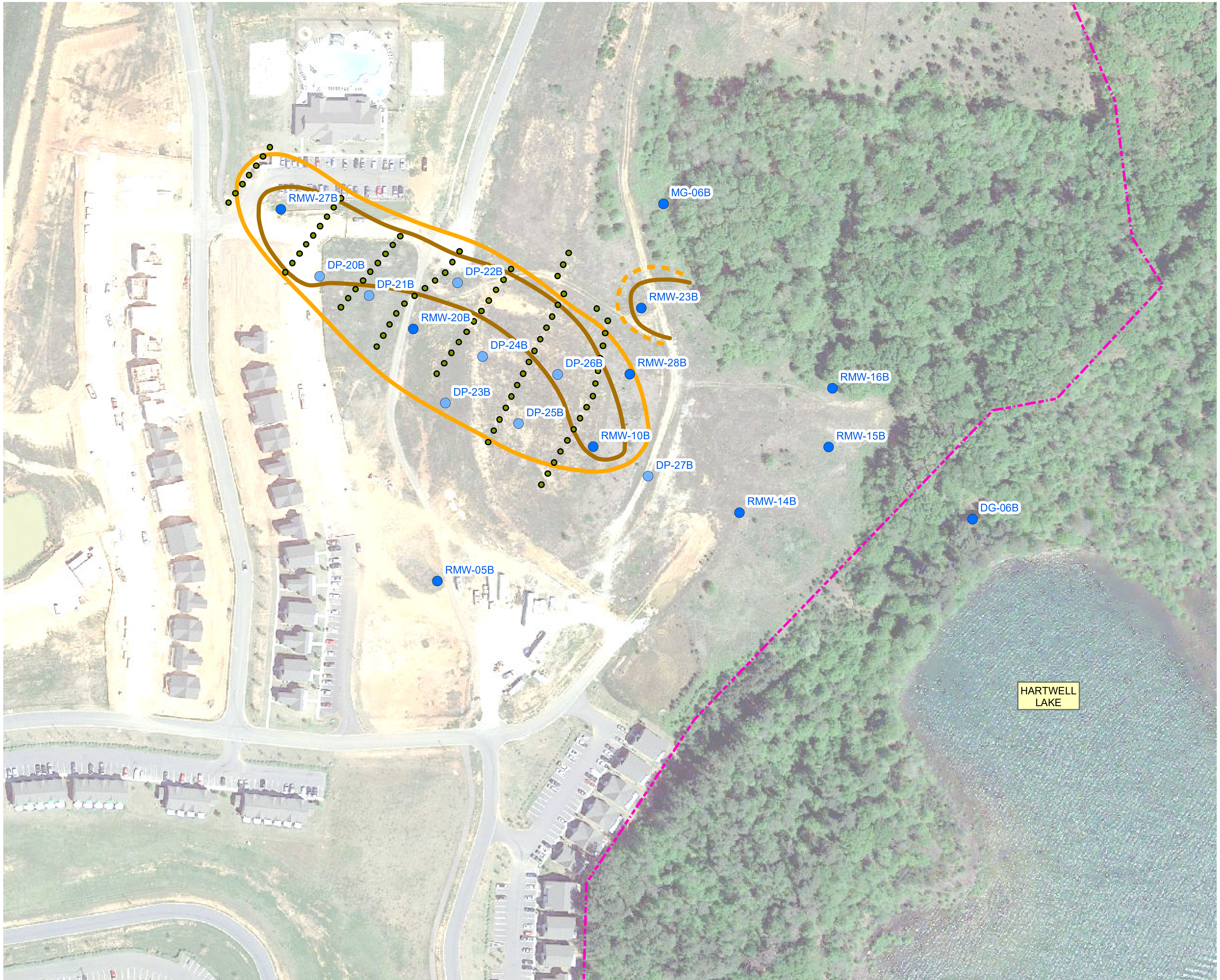

LEGEND

- Direct-Push Groundwater Sample
- Transition Zone Monitoring Well
- ABC+ Injection Points
- Property Boundary (Approximate)

NOTES

Aerial Photograph Source: Google Earth (2018).

Outlined areas are based on an aggregation of ERD field and laboratory indicator parameters.

Dashed areas indicate an inferrence.

Burnt orange outlined areas are from 2019.

Orange outlined areas are from 2021.

PROJECT: FORMER WESTPOINT HOME, INC. CLEMSON, SOUTH CAROLINA	
TITLE: AREA OF ROBUST ER CONDITIONS IN TRANSITION ZONE WELLS	
DRAWN BY: S. RAY	PROJ. NO.: 300688
CHECKED BY:	FIGURE 4-15
APPROVED BY:	
DATE: JUNE 2021	
TRC	50 International Drive, Suite 150 Patewood Plaza Three Greenville, SC 29615 Phone: 864.281.0030 www.TRCcompanies.com
FILE NO.:	Fig 4-15 - Area of Robust ERD Conditions Transition Zone Wells.mxd

TRC - GIS

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

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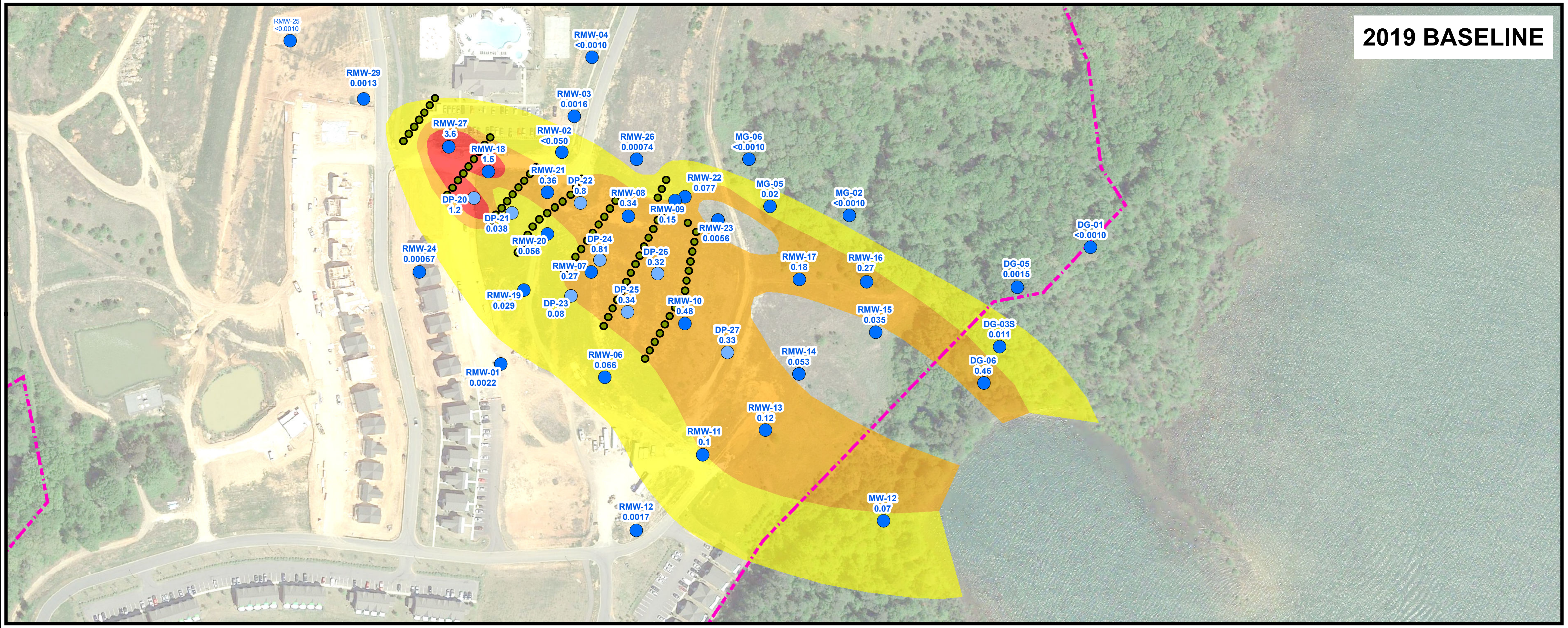
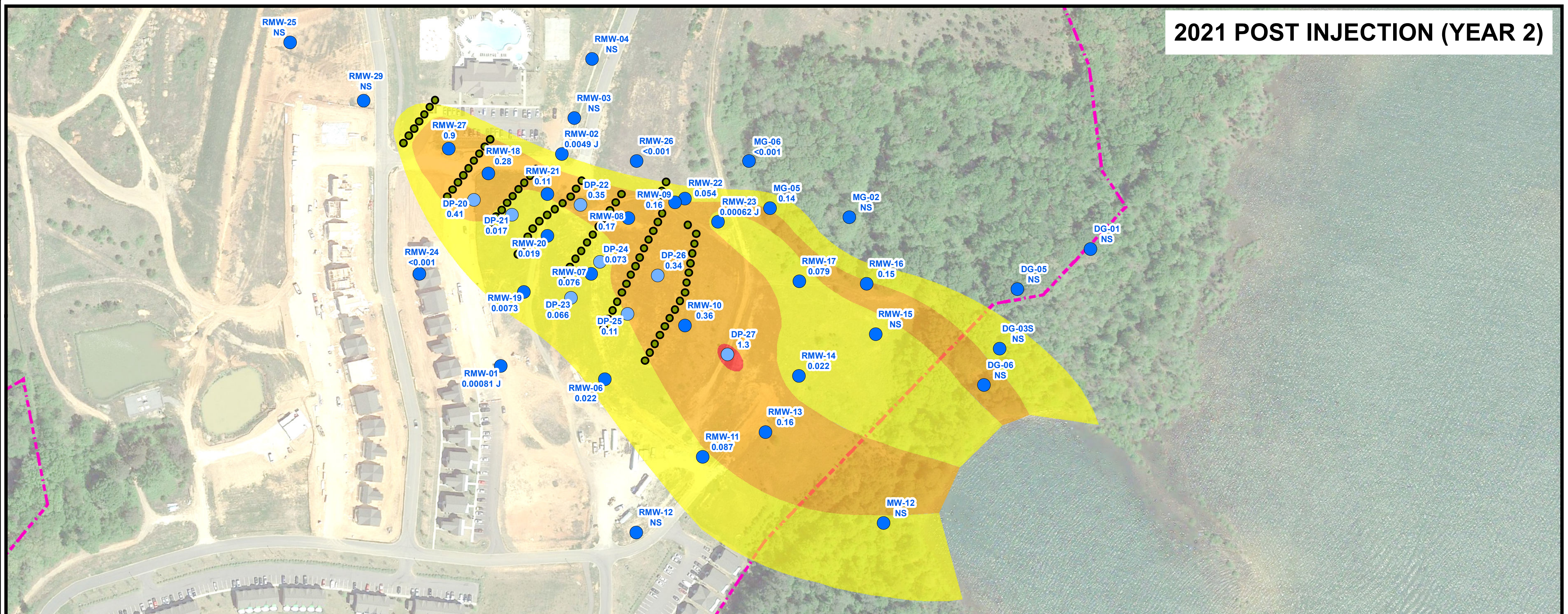
TRC - GIS





LEGEND

- Water Table Monitoring Well
- Direct-Push Groundwater Sample
- Property Boundary (Approximate)
- ABC+ Injection Locations

PCE Concentration Key

- > 0.005 to 0.1 mg/L
- > 0.1 to 1.0 mg/L
- > 1.0 mg/L

NOTES

Aerial Photograph Source: Google Earth (2018).

PCE concentrations are posted in mg/L.

PCE - Tetrachloroethene

NS - Not Sampled

J - Estimated Concentration

J+ - Estimated, high bias indicated

For wells not sampled in March 2021 the PCE configuration is presumed to remain unchanged from the 2019 sampling event.

ABC+ Injections Conducted May 14 - July 10, 2019.

N

0 250 500 Feet

1 " = 250 '

1:3,000

PROJECT:

FORMER WESTPOINT HOME, INC.
CLEMSON, SOUTH CAROLINA

TITLE:

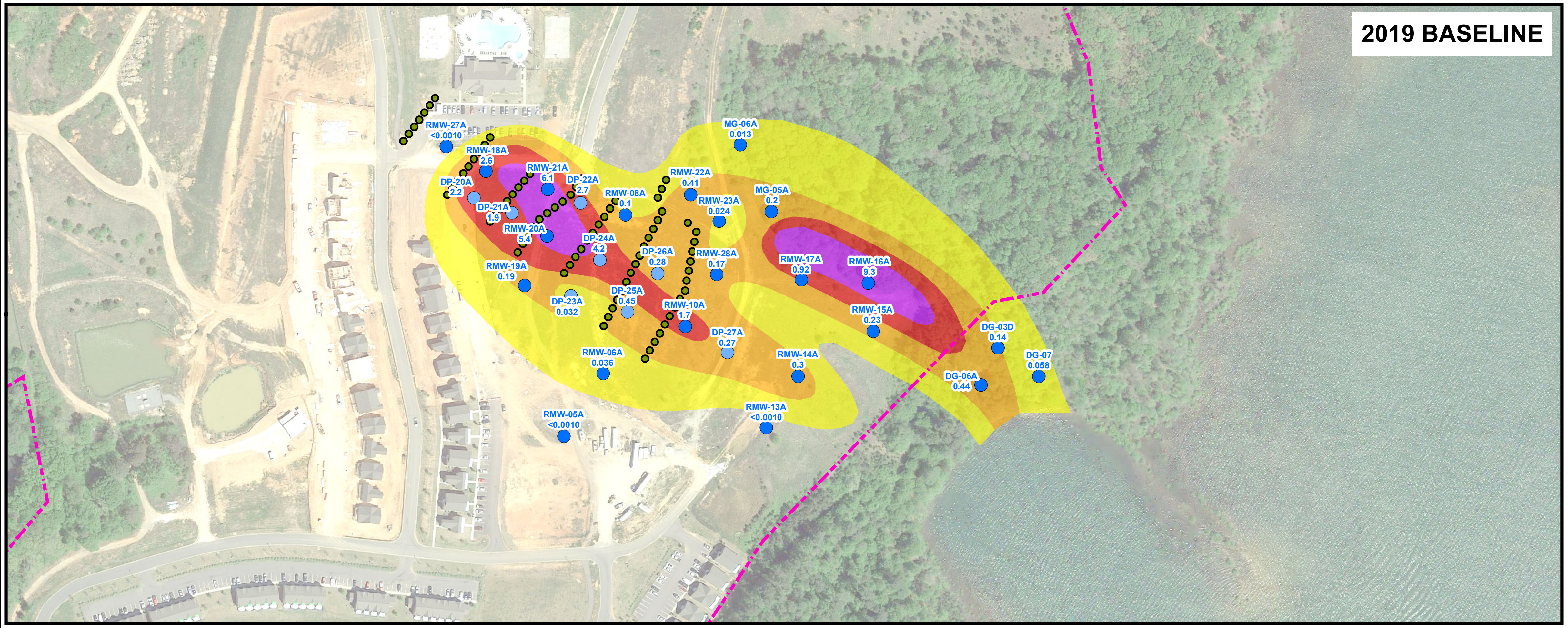
TETRACHLOROETHENE DISTRIBUTION IN SHALLOW GROUNDWATER

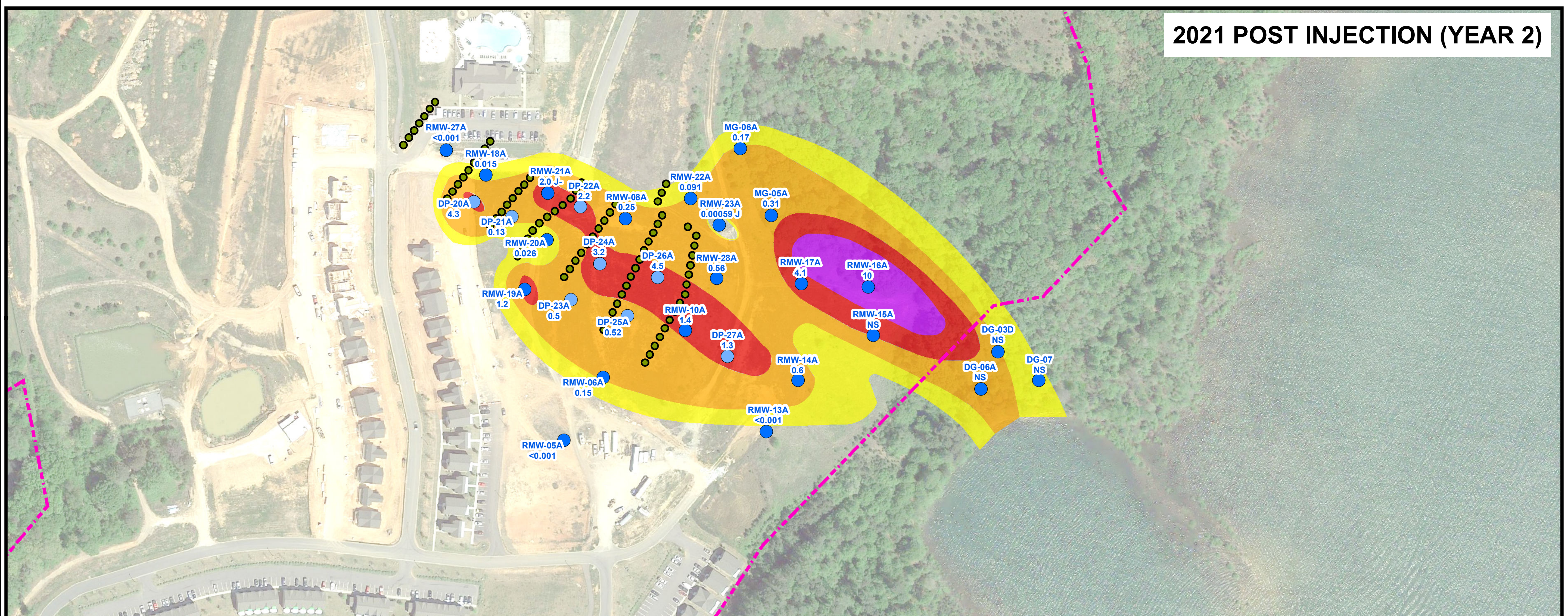
DRAWN BY:	SZYNAL D	PROJ. NO.:	300688.0.0.4
CHECKED BY:	CLARK L		
APPROVED BY:	WEBB S		**FIGURE 4-1**
DATE:	MAY 2021		

TRC
50 International Drive, Suite 150
Patewood Plaza Three
Greenville, SC 29615
Phone: 864.281.0030
www.TRCcompanies.com

FILE NO.: Fig 6 - PCE_2019-2021_Shallow_Plume.mxd

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0
Plot Date: 5/28/2021, 11:41:54 AM by DSZYNAL -- LAYOUT: ANSI B(11"x17")
Path: U:\West Point Home\Clemson SC\ArcGIS\10\300688\PCE Maps\Post Injection\2021\Fig 6 - PCE_2019-2021_Shallow_Plume.mxd





LEGEND

- Intermediate Monitoring Well
- Direct-Push Groundwater Sample
- Property Boundary (Approximate)
- ABC+ Injection Locations

PCE Concentration Key

- > 0.005 to 0.1 mg/L
- > 0.1 to 1.0 mg/L
- > 1.0 to 5.0 mg/L
- > 5.0 mg/L

NOTES

Aerial Photograph Source: Google Earth (2018).

PCE concentrations are posted in mg/L.

PCE - Tetrachloroethene

NS - Not Sampled

J - Estimated Concentration

J- - Estimated, low bias indicated

For wells not sampled in March 2021 the PCE configuration is presumed to remain unchanged from the 2019 sampling event.

ABC+ Injections Conducted May 14 - July 10, 2019.

N

0 250 500 Feet

1 " = 250 '

1:3,000

PROJECT:

FORMER WESTPOINT HOME, INC.
CLEMSON, SOUTH CAROLINA

TITLE:

TETRACHLOROETHENE DISTRIBUTION IN INTERMEDIATE AQUIFER WELLS

DRAWN BY:	SZYNAL D	PROJ. NO.:	300688.0.0.4
CHECKED BY:	CLARK L		
APPROVED BY:	WEBB S		**FIGURE 4-2**
DATE:	MAY 2021		

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Greenville, SC 29615
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FILE NO.: Fig 7 - PCE_2019-2021_Intermediate_Plume.mxd

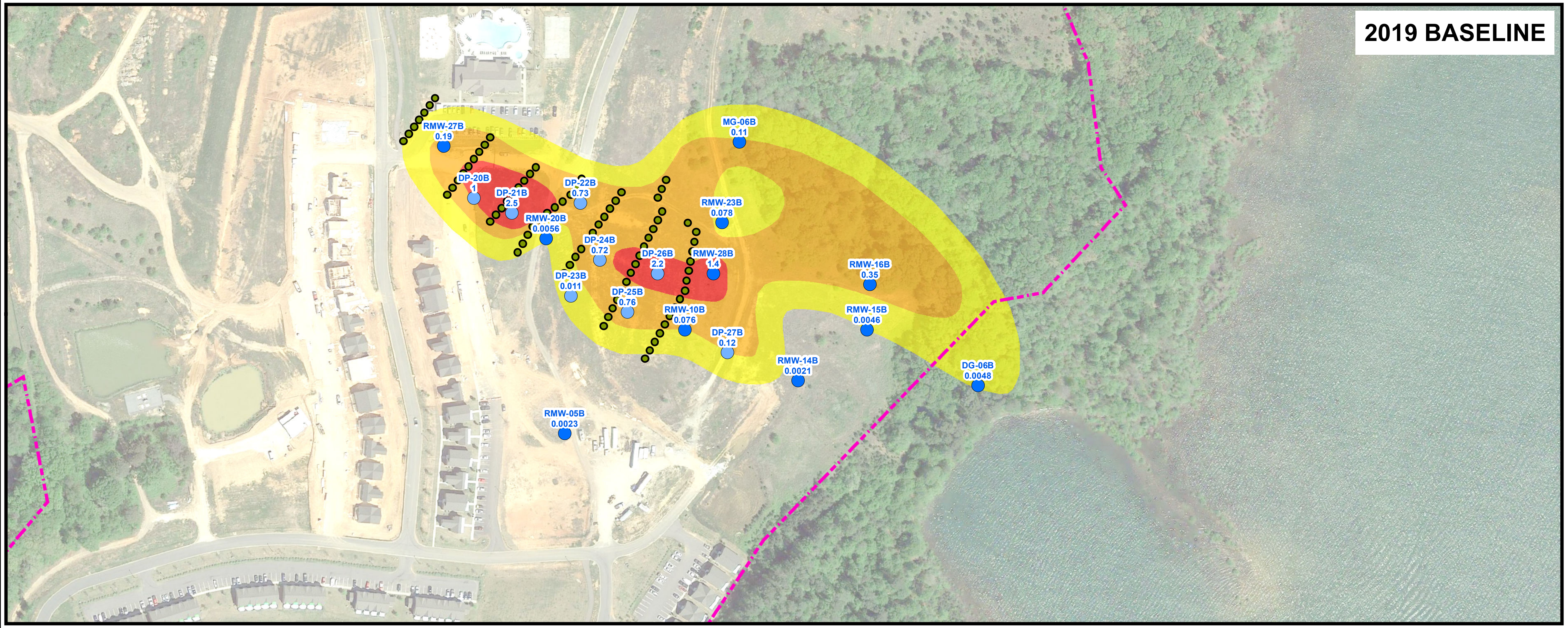
TRC - GIS

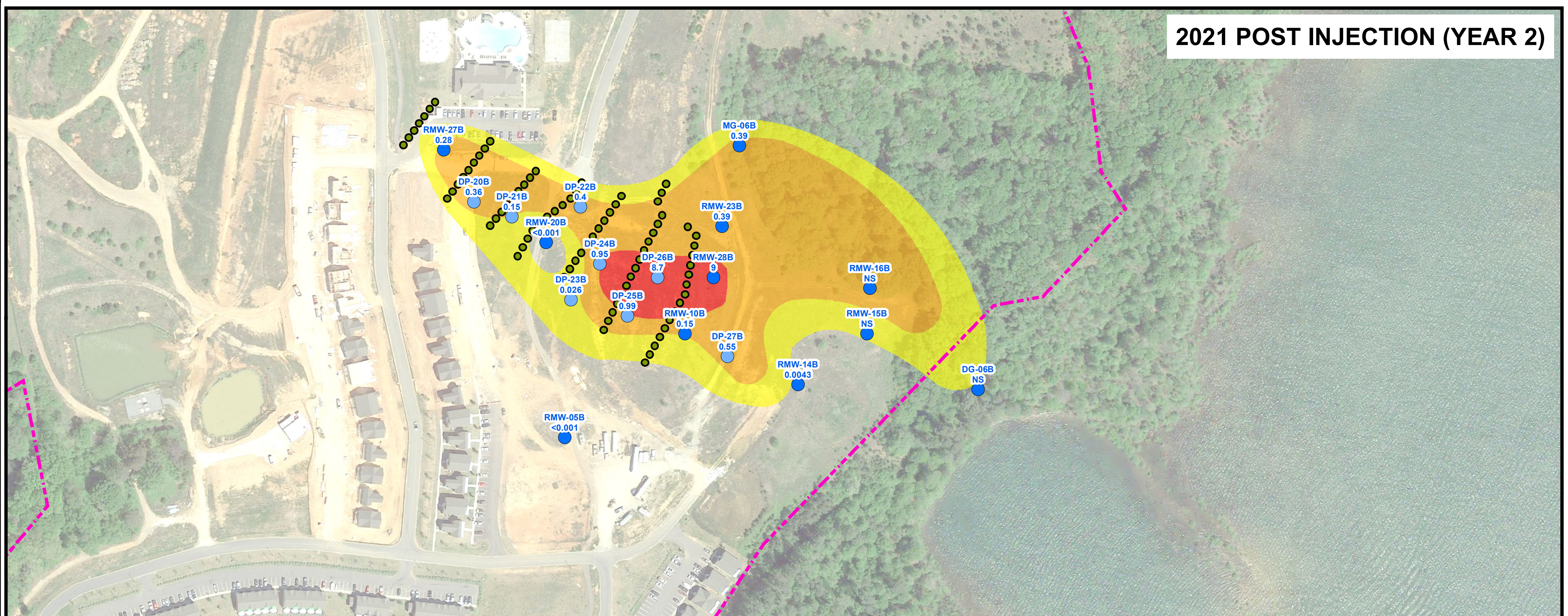
Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)

Map Rotation: 0

Plot Date: 5/28/2021, 11:38:15 AM by DSZYNAL -- LAYOUT: ANSI B(11"x17")

Path: U:\West Point Home\Clemson SC\ArcGIS\10\300688\PCE Maps\Post Injection\2021\Fig 7 - PCE_2019-2021_Intermediate_Plume.mxd





LEGEND

- Transition Zone Monitoring Well
- Direct-Push Groundwater Sample
- Property Boundary (Approximate)
- ABC+ Injection Locations

PCE Concentration Key

- > 0.005 to 0.1 mg/L
- > 0.1 to 1.0 mg/L
- > 1.0 mg/L

NOTES

Aerial Photograph Source: Google Earth (2018).

PCE concentrations are posted in mg/L.

PCE - Tetrachloroethene

NS - Not Sampled

J - Estimated Concentration

For wells not sampled in March 2021 the PCE configuration is presumed to remain unchanged from the 2020 sampling event.

ABC+ Injections Conducted May 14 - July 10, 2019.

N

0 250 500 Feet

1 " = 250 '
1:3,000

PROJECT:
FORMER WESTPOINT HOME, INC.
CLEMSON, SOUTH CAROLINA

TITLE:
TETRACHLOROETHENE DISTRIBUTION IN TRANSITION ZONE WELLS

DRAWN BY:	SZYNAL D	PROJ. NO.:	300688.0.0.4
CHECKED BY:	CLARK L		
APPROVED BY:	WEBB S	**FIGURE 4-3**	
DATE:	MAY 2021		

TRC

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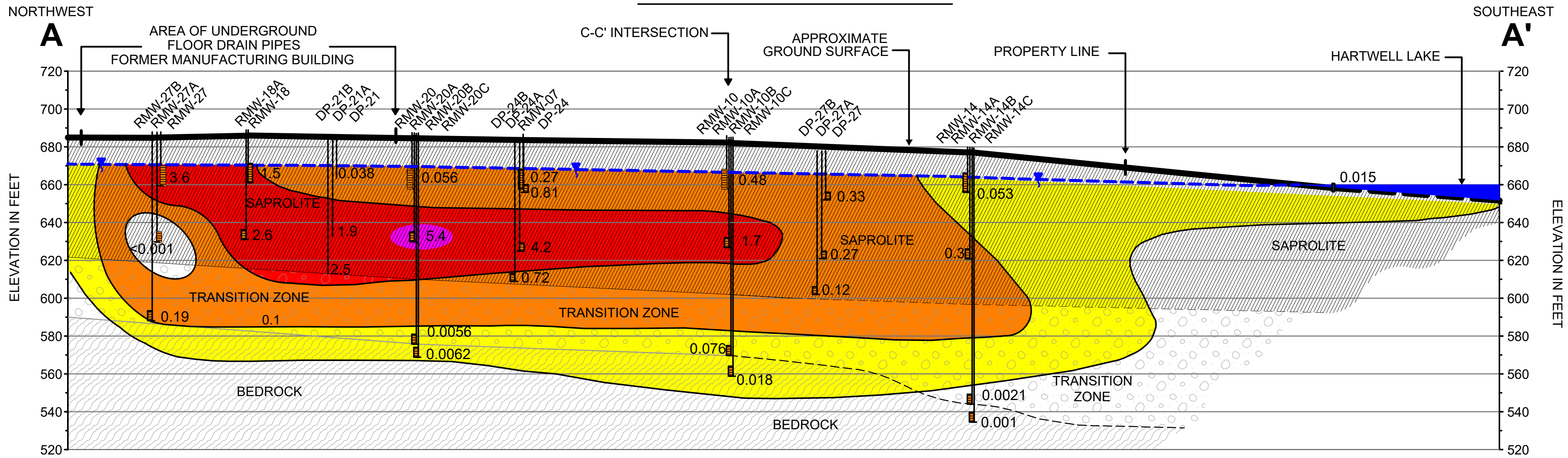
FILE NO.: Fig 8 - PCE_2019-2021_TransitionZone_Plume.mxd

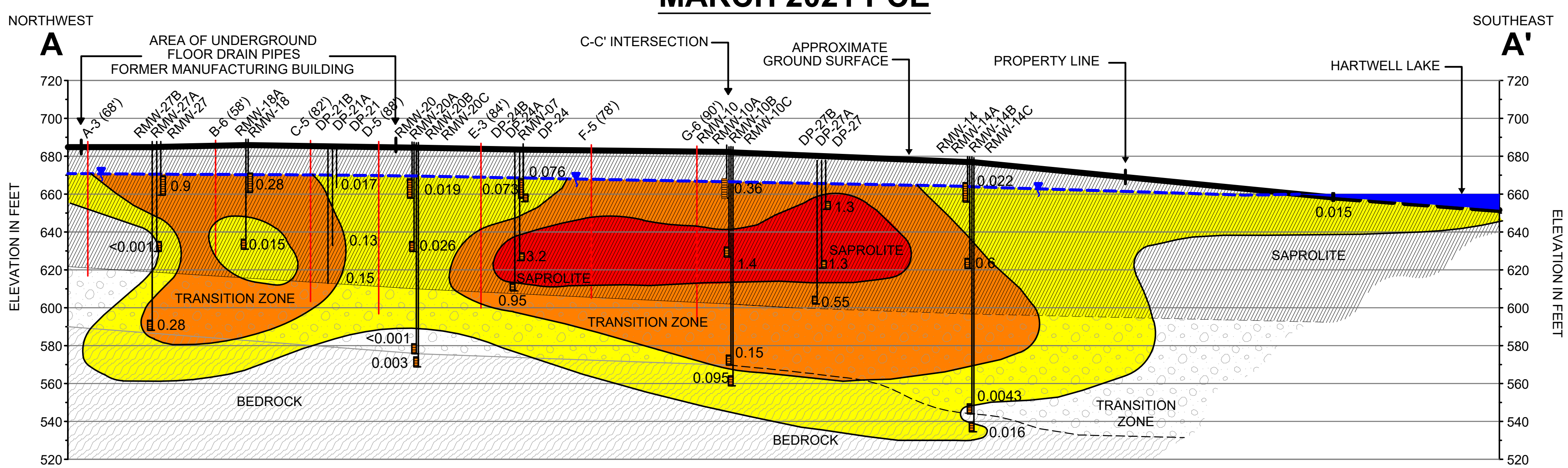
TRC - GIS

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0
Plot Date: 5/28/2021, 11:36:20 AM by DSZYNAL -- LAYOUT: ANSI B(11"x17")
Path: U:\West Point Home\Clemson SC\ArcGIS\10\300688\PCE Maps\Post Injection\2021\Fig 8 - PCE_2019-2021_TransitionZone_Plume.mxd

2019 PCE BASELINE



MARCH 2021 PCE



LEGEND

SAPROLITE

TRANSITION ZONE

BEDROCK

WELL

WELL SCREEN

WATER TABLE (MARCH 8, 2021)

TEMPORARY DIRECT PUSH DP WELL

WELL SCREEN

ABC+ INJECTION LOCATION

PCE CONCENTRATION KEY

> 5.0 mg/L

> 1.0 mg/L - 5.0 mg/L

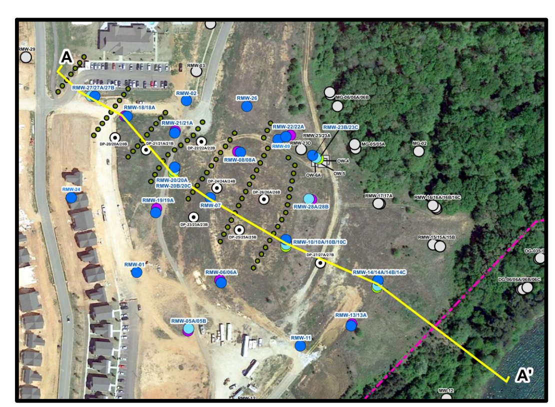
> 0.1 mg/L - 1.0 mg/L

> 0.005 mg/L - 0.1 mg/L

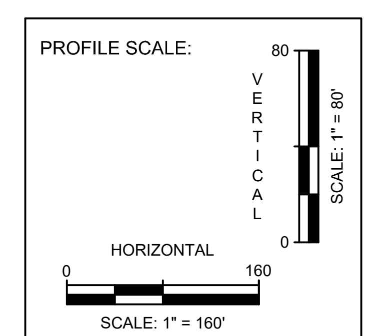
NOTES

A-3 (68') - MAXIMUM DEPTH OF ABC+ INJECTION AT LOCATION A-3 PROVIDED IN FEET BELOW GRADE.

TETRACHLOROETHENE (PCE) CONCENTRATIONS ARE IN MG/L.



CROSS SECTION LOCATOR MAP



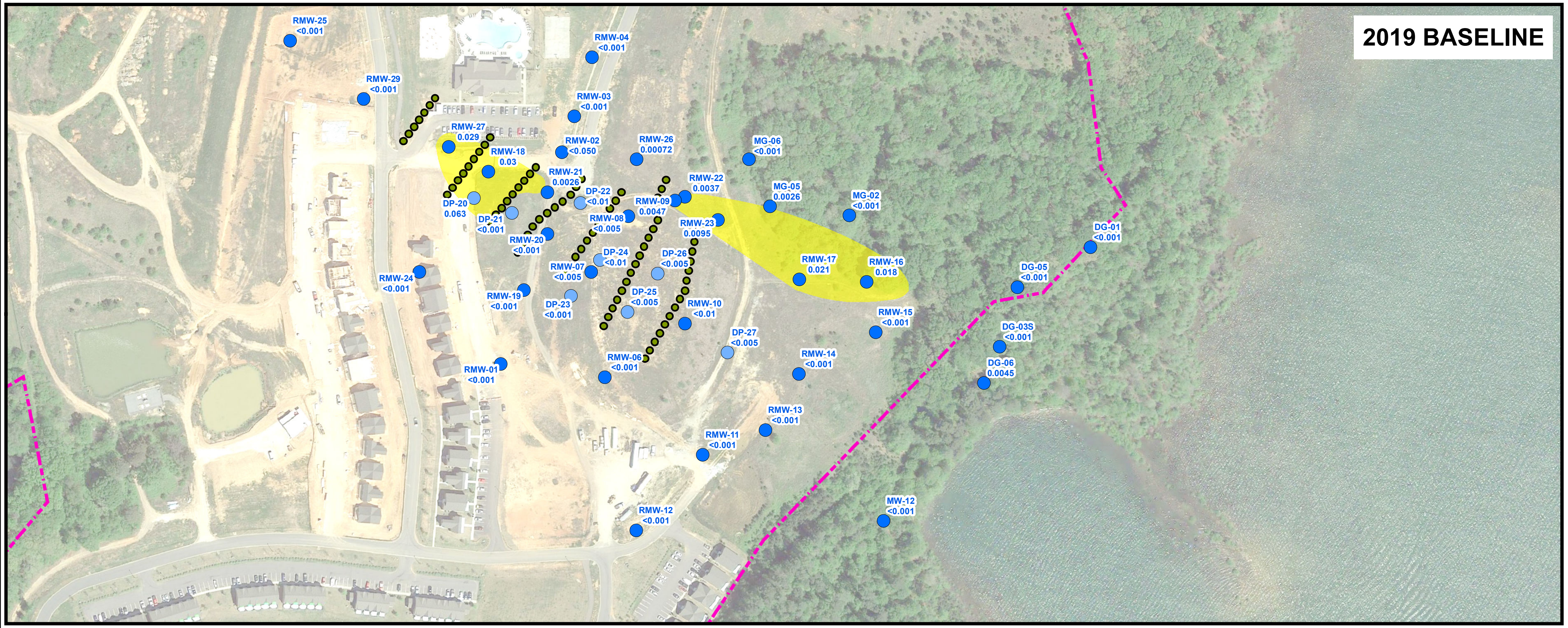
VERTICAL EXAGGERATION = 2X

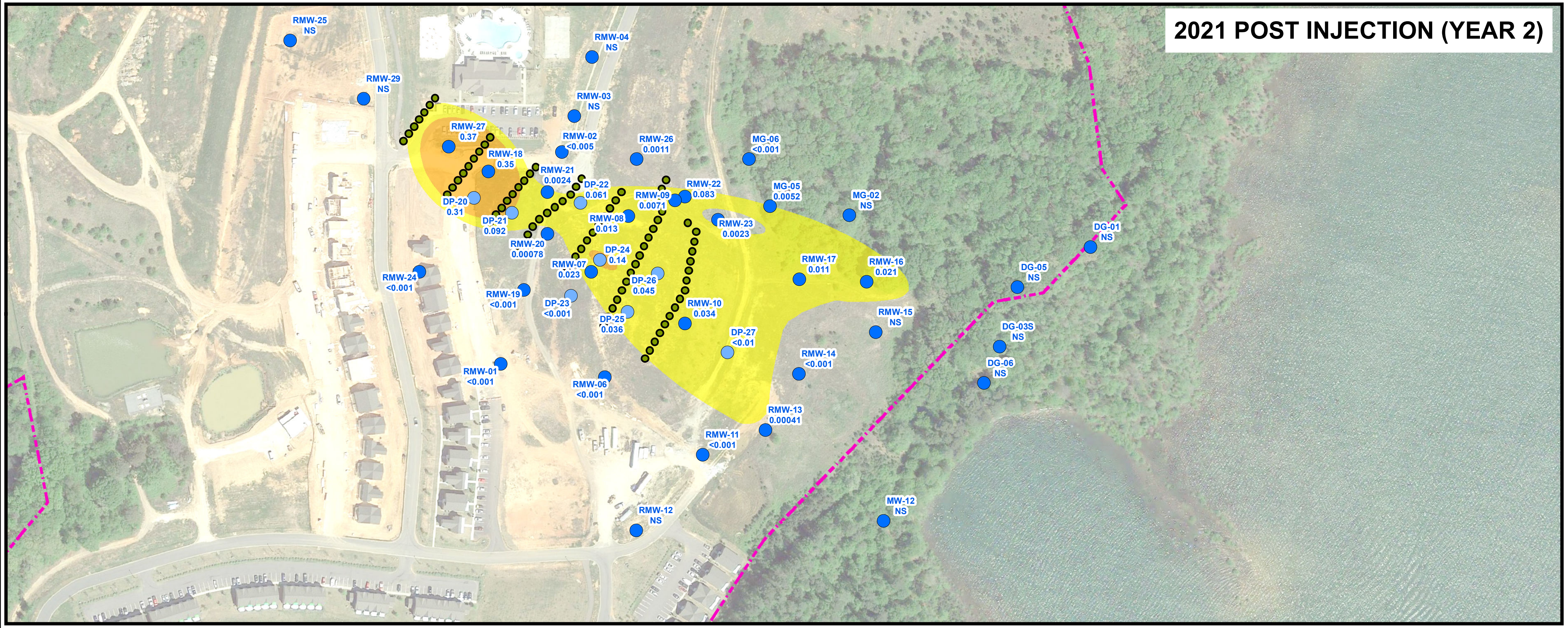
PROJECT:	WESTPOINT HOME, INC CLEMSON, SOUTH CAROLINA
TITLE:	TETRACHLOROETHENE (PCE) DISTRIBUTION CROSS SECTION A - A'
DRAWN BY:	S. HAMWAY
CHECKED BY:	L. CLARK
APPROVED BY:	S. WEBB
DATE:	AUGUST 2021
PROJ NO.:	450113.0000.0000
	FIGURE 4-4
FILE NO.:	450113 - FIG 4-4_XSECTA_PCE_11x17.dwg

TRC

650 Suffolk Street
Suite 200
Lowell, MA 01854
Phone: 978.970.5600

11x17 --- USER: CVining --- ATTACHED XREFS: --- ATTACHED IMAGES: TRC Logo (CMYK)
DRAWING NAME: J:\CADWPH Clemson\450113\0000\450113 - FIG 4-4_XSECTA_PCE_11x17.dwg --- PLOT DATE: August 23, 2021 - 1:17PM --- LAYOUT: FIGURE 4-4
Version: 2017-10-21





LEGEND

- Water Table Monitoring Well
- Direct-Push Groundwater Sample
- Property Boundary (Approximate)
- ABC+ Injection Locations

Cis-1,2-DCE Concentration Key

- > 0.005 to 0.1 mg/L
- > 0.1 to 1.0 mg/L
- > 1.0 mg/L

NOTES

Aerial Photograph Source: Google Earth (2018).

Cis-1,2-DCE concentrations are posted in mg/L.

Cis-1,2-DCE - Cis-1,2-Dichloroethene

NS - Not Sampled

For wells not sampled in March 2021 the Cis-1,2-DCE configuration is presumed to remain unchanged from the 2019 sampling event.

ABC+ Injections Conducted May 14 - July 10, 2019.

N

0 250 500 Feet

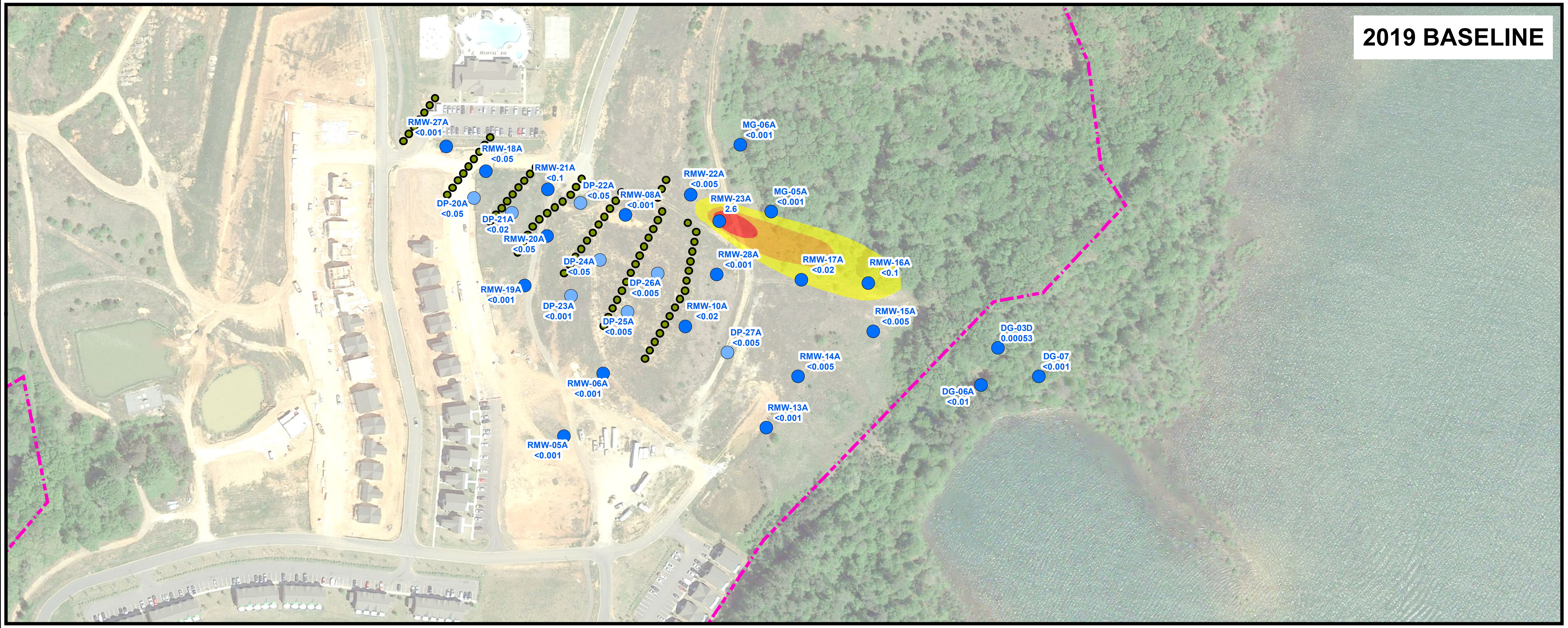
1 " = 250 '

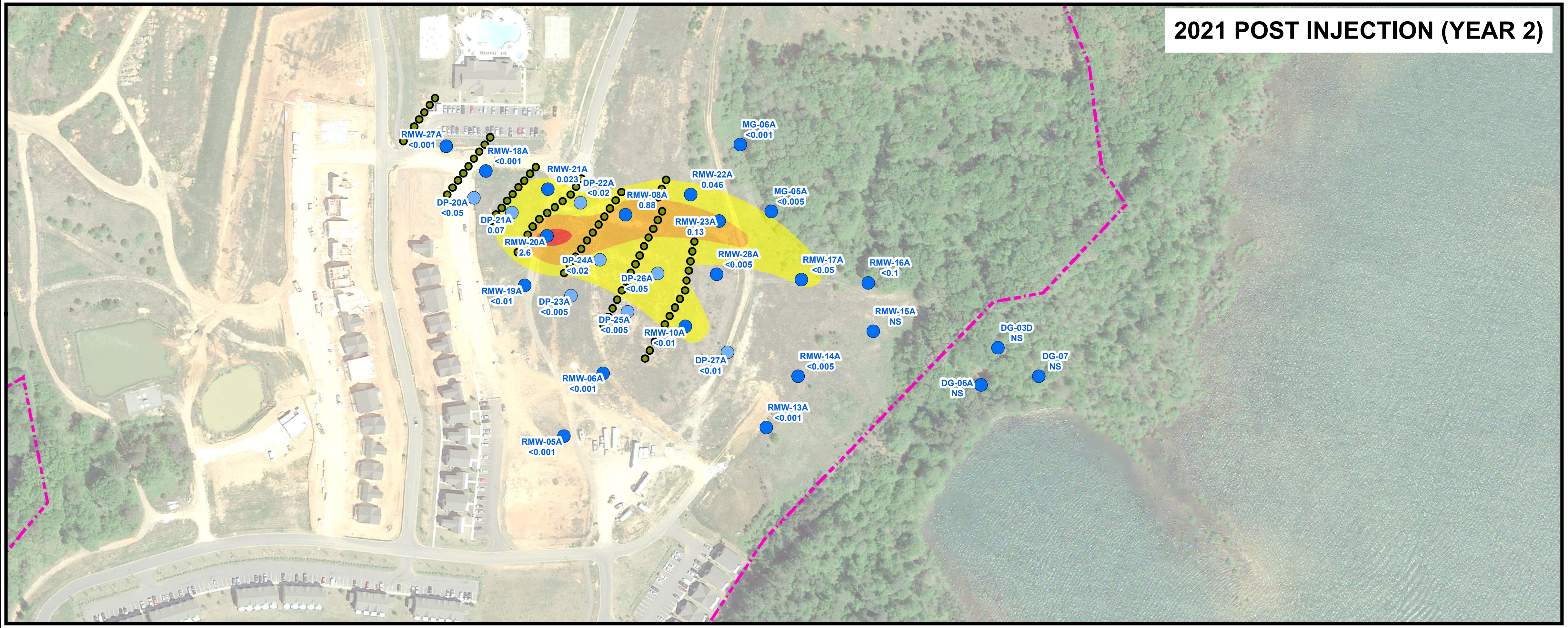
1:3,000

PROJECT: FORMER WESTPOINT HOME, INC. CLEMSON, SOUTH CAROLINA	
TITLE: CIS-1,2-DCE DISTRIBUTION IN SHALLOW GROUNDWATER	
DRAWN BY: SZYNAL D	PROJ. NO.: 300688.0.0.4
CHECKED BY: CLARK L	FIGURE 4-6
APPROVED BY: WEBB S	
DATE: MAY 2021	
TRC	50 International Drive, Suite 150 Patewood Plaza Three Greenville, SC 29615 Phone: 864.281.0030 www.TRCcompanies.com
FILE NO.: Fig 6 - CIS_2019-2021_Shallow_Plume.mxd	

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

Plot Date: 5/28/2021, 11:04:06 AM by DSZYNAL -- LAYOUT: ANSI B(11"x17")
Path: U:\West Point Home\Clemson SC\ArcGIS\10\300688\GIS Maps\2021\Fig 6 - CIS_2019-2021_Shallow_Plume.mxd





LEGEND

- Intermediate Monitoring Well
- Direct-Push Groundwater Sample
- Property Boundary (Approximate)
- ABC+ Injection Locations

Cis-1,2-DCE Concentration Key

- > 0.005 to 0.1 mg/L
- > 0.1 to 1.0 mg/L
- > 1.0 mg/L

NOTES

Aerial Photograph Source: Google Earth (2018).

Cis-1,2-DCE concentrations are posted in mg/L.

Cis-1,2-DCE - Cis-1,2-Dichloroethene

NS - Not Sampled

For wells not sampled in March 2021 the Cis-1,2-DCE configuration is presumed to remain unchanged from the 2019 sampling event.

ABC+ Injections Conducted May 14 - July 10, 2019.

N

0 250 500 Feet

1 " = 250 '

1:3,000

PROJECT:

FORMER WESTPOINT HOME, INC.
CLEMSON, SOUTH CAROLINA

TITLE:

CIS-1,2-DCE DISTRIBUTION IN INTERMEDIATE AQUIFER WELLS

DRAWN BY:	SZYNAL D	PROJ. NO.:	300688.0.0.4
CHECKED BY:	CLARK L		
APPROVED BY:	WEBB S		**FIGURE 4-7**
DATE:	MAY 2021		

TRC
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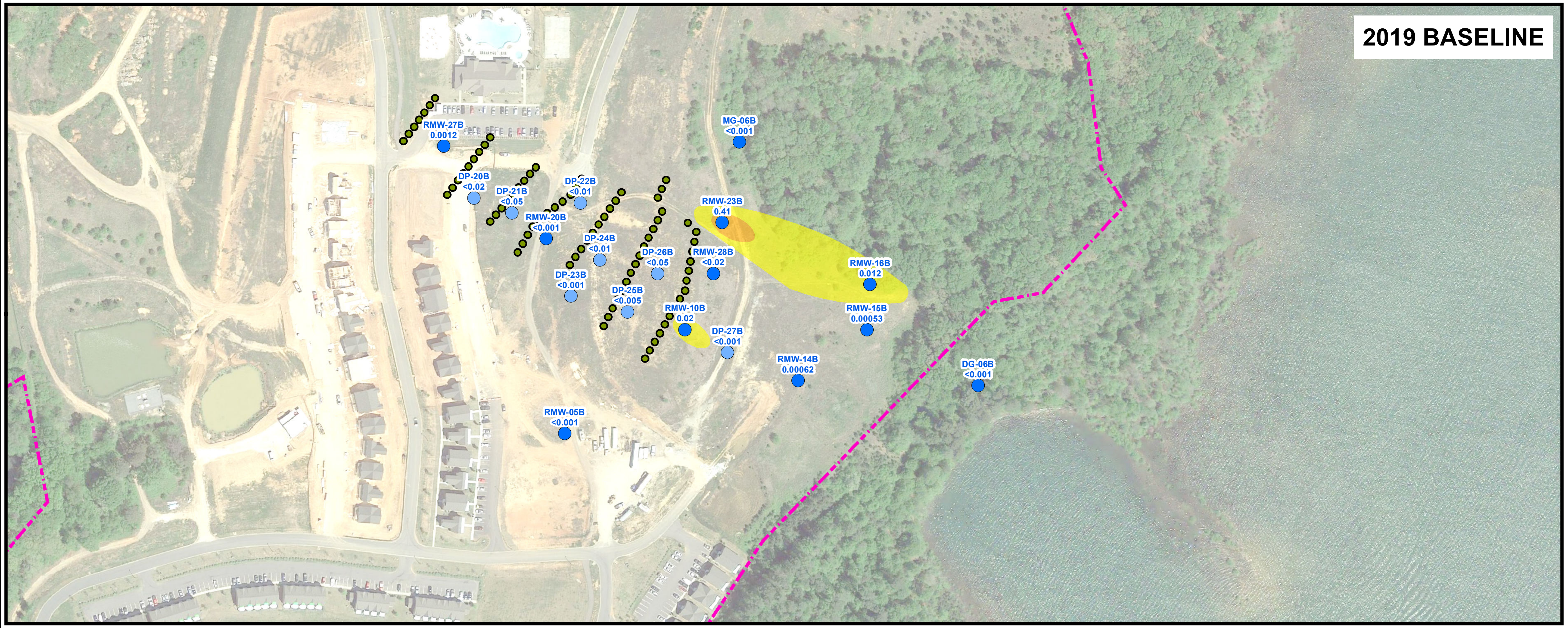
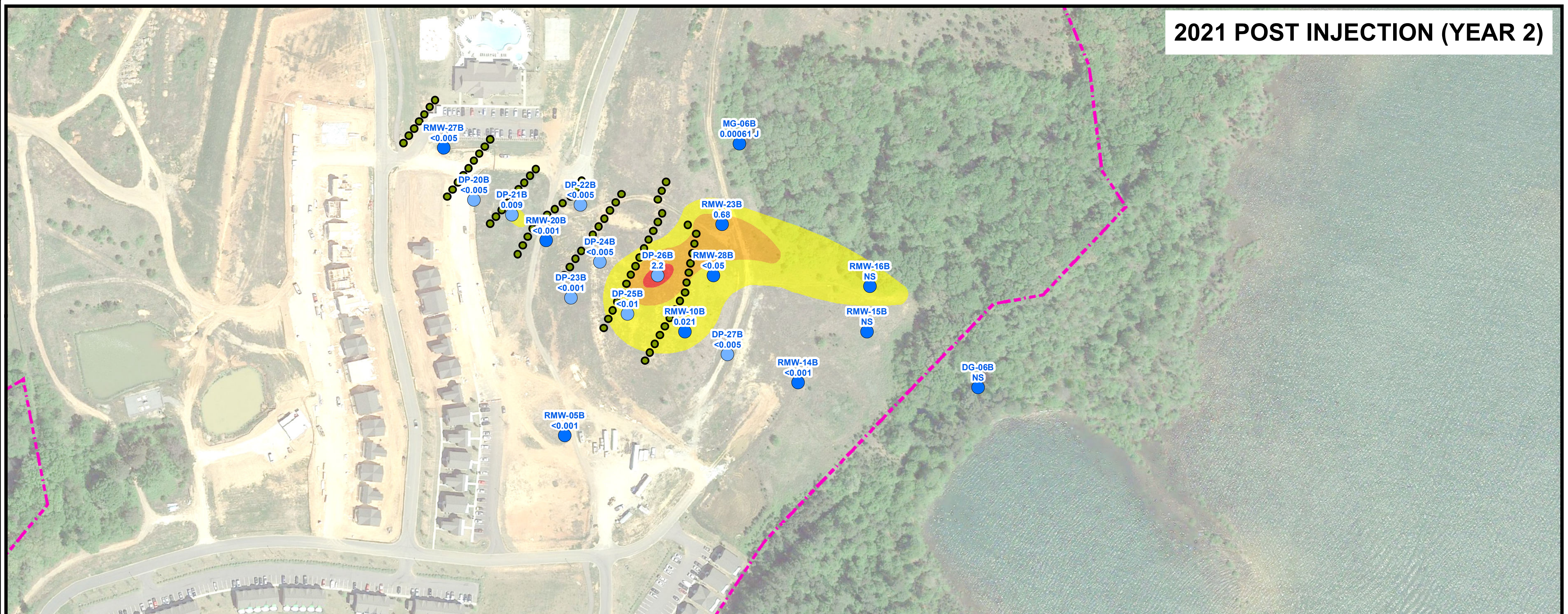
FILE NO.: Fig 7 - CIS_2019-2021_Intermediate_Plume.mxd

TRC - GIS

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

Plot Date: 5/28/2021, 11:06:21 AM by DSZYNAL -- LAYOUT: ANSI B(11"x17")
Path: U:\West Point Home\Clemson SC\ArcGIS\10\300688\GIS Maps\2021\Fig 7 - CIS_2019-2021_Intermediate_Plume.mxd





LEGEND

- Transition Monitoring Well
- Direct-Push Groundwater Sample
- Property Boundary (Approximate)
- ABC+ Injection Locations

Cis-1,2-DCE Concentration Key

- > 0.005 to 0.1 mg/L
- > 0.1 to 1.0 mg/L
- > 1.0 mg/L

NOTES

Aerial Photograph Source: Google Earth (2018).

Cis-1,2-DCE concentrations are posted in mg/L.

Cis-1,2-DCE - Cis-1,2-Dichloroethene

NS - Not Sampled

For wells not sampled in March 2021 the Cis-1,2-DCE configuration is presumed to remain unchanged from the 2019 sampling event.

ABC+ Injections Conducted May 14 - July 10, 2019.

N

0 250 500 Feet

1 " = 250 '

1:3,000

PROJECT:

FORMER WESTPOINT HOME, INC.
CLEMSON, SOUTH CAROLINA

TITLE:

CIS-1,2-DCE DISTRIBUTION
TRANSITION ZONE WELLS

DRAWN BY:	SZYNAL D	PROJ. NO.:	300688.0.0.4
CHECKED BY:	CLARK L		
APPROVED BY:	WEBB S		**FIGURE 4-8**
DATE:	MAY 2021		

TRC

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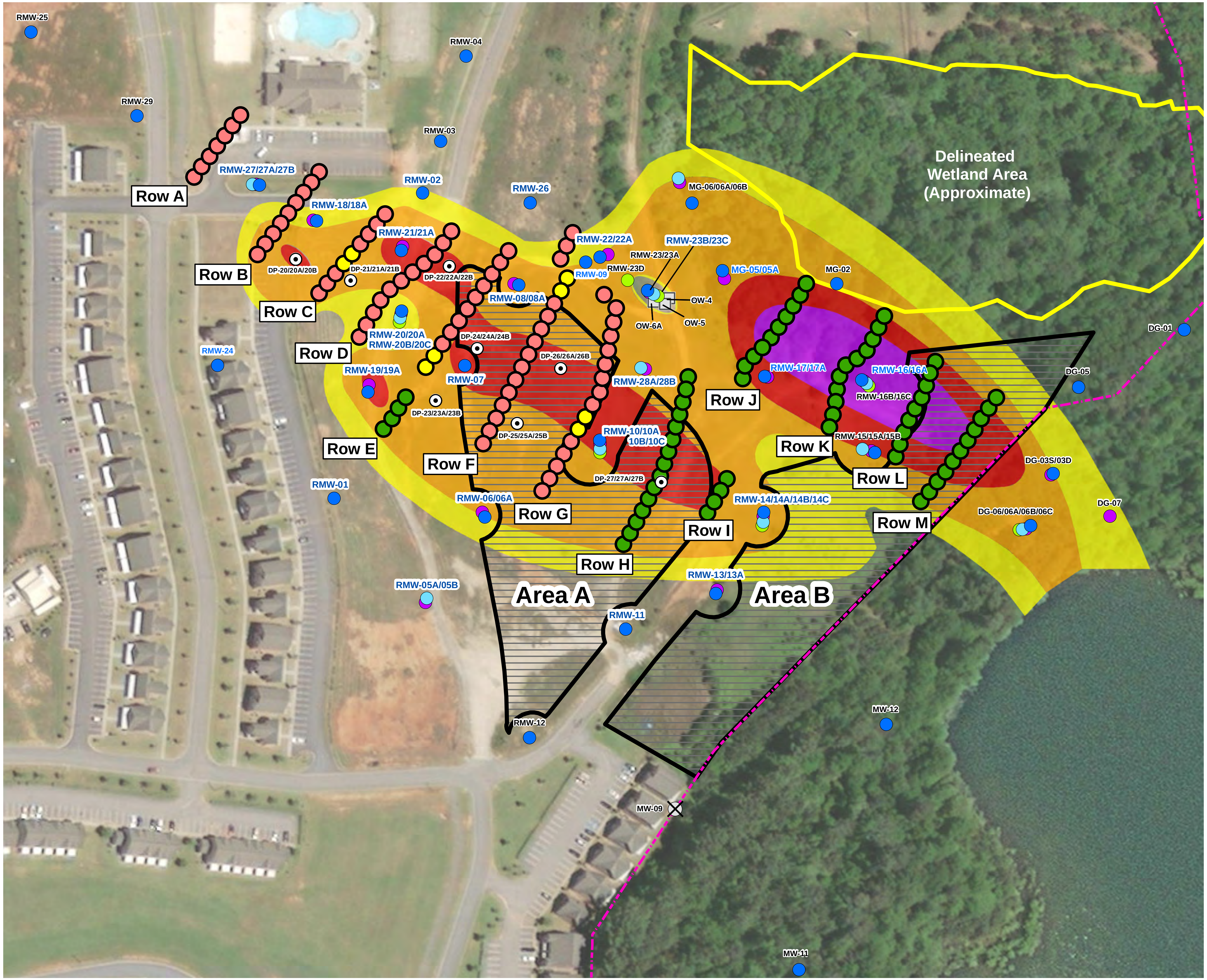
FILE NO.: Fig 8 - CIS_2019-2021_Transition_Plume.mxd

TRC - GIS

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

Plot Date: 5/28/2021, 10:58:49 AM by DSZYNAL -- LAYOUT: ANSI B(11"x17")
Path: U:\West Point Home\Clemson SC\ArcGIS\10\300688\GIS Maps\2021\Fig 8 - CIS_2019-2021_Transition_Plume.mxd

Appendix B
Cost Estimate Basis



LEGEND

- Water Table Aquifer Monitoring Well
- Intermediate Aquifer Monitoring Well
- Transition Zone Aquifer Monitoring Well
- Bedrock Aquifer Monitoring Well
- Direct-Push Groundwater Sample Location
- Destroyed Water Table Monitoring Well
- Pilot Study Injection Point
- Pilot Study Injection Point with Bromide Tracer
- Proposed Injection Point
- Property Boundary (Approximate)
- Proposed Development 2021

PCE Concentration in Groundwater (March 2021)

- > 0.005 to 0.1 mg/L
- > 0.1 to 1.0 mg/L
- > 1.0 mg/L
- > 5.0 mg/L

NOTES

Aerial Photograph Source: ESRI World Imagery. (Aquisition Date: 5/11/2020).

The groundwater treatment target area is based on the extent of PCE concentrations in groundwater greater than 0.1 mg/L.

0 120 240 Feet

1 " = 133 '

1:1,600

N

PROJECT:

FORMER WESTPOINT HOME
CLEMSON, SOUTH CAROLINA

TITLE:

PROPOSED ABC+ INJECTION PLAN

DRAWN BY:	WIXON S	PROJ. NO.:	450957.9990.0000
CHECKED BY:	CLARK L		
APPROVED BY:	WEBB S		**FIGURE 1**
DATE:	JULY 2021		

TRC

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Patewood Plaza Three
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FILE NO.: Fig 1_Injection Plan_2021-07.mxd

TRC - GIS

Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

Plot Date: 7/15/2021, 10:45:14 AM by RWIXON -- LAYOUT: ANSI B(11"x17")
Path: S:\1-PROJECTS\West Point Home\Clemson SC\GIS\300688\2021\Fig 1_Injection Plan_2021-07.mxd

Alternative 2 - MNA
One-time and Recurring Costs

Project Name:	WPH Clemson - Feasibility Study Estimates		
Description:	Alternative 2 (MNA) - Cost Details		
Project Number:	450113		
Project Manager:	SWW		
Prepared By:	JEP	**Date**	8/16/21
Checked By:	LMC	**Date**	

Description: Monitored Natural Attenuation

ALTERNATIVE 2 ONE-TIME & PERIODIC COSTS

Description	Quantity	Unit	Unit Price	Subtotal	Total
Work Plan	1	L.S.	30,000	$ 30,000	
Subtotal					**$ 30,000**
Contingency	10%			$ 3,000	
TOTAL					**$ 33,000**

ALTERNATIVE 2 ANNUAL & RECURRING COSTS

Description	Quantity	Unit	Price	Subtotal	Total
MNA Field Sampling and Analysis					
Labor	1	L.S.	30,000.00	$ 30,000	
Expenses	1	L.S.	5,000.00	$ 5,000	
Laboratory	1	L.S.	9,000.00	$ 9,000	
Annual Progress Reports	1	L.S.	26,000.00	$ 26,000	
Annualized Monitoring Well Maintenance	1	L.S.	3,000.00	$ 3,000	
Subtotal					**$ 73,000**
Contingency	10%			$ 7,300	
TOTAL					**$ 80,000**

Alternative 2 - MNA
Cost Summary

Project Name:	WPH Clemson - Feasibility Study Estimates
Description:	Alternative 2 (MNA) - Cost Details
Project Number:	450113
Project Manager:	SWW
Prepared By:	JEP
Checked By:	SWW

Description: Monitored Natural Attenuation

ALTERNATIVE 2 COST SUMMARY		
DESCRIPTION	**COST**	
Periodic Costs		
Work Planning	$	33,000
Subtotal Periodic Costs	**$**	**33,000**
Annual Costs		
Monitoring and Maintenance	$	80,000
Subtotal Annual Costs	**$**	**80,000**

Alternative 3 - ISCO
One Time and Recurring Costs

Project Name:	WPH Clemson - Feasibility Study Estimates		
Description:	Alternative 3 (ISCO) - Cost Details		
Project Number:	450113		
Project Manager:	SWW		
Prepared By:	JEP	**Date**	8/16/21
Checked By:	LMC	**Date**	

Description: *In Situ* Chemical Oxidation

ALTERNATIVE 3 ONE-TIME & PERIODIC COSTS

Description	Quantity	Unit	Unit Price		Subtotal		Total
Work Plans and Permits	1	L.S.	100,000	$	100,000	**$**	**100,000**
First ISCO Injection							
Mobilize/demobilize	8	EA	1,800	$	14,400		
Injections (equipment & labor)	39	per day	3,300	$	128,700		
Chemical Oxidant	600,000	lb	2.0	$	1,209,600		
Injection Oversight	10	percent		$	135,270		
Subtotal (Injection)						**$**	**1,487,970**
Contingency	10%			$	148,797		
TOTAL (Injection)						**$**	**1,637,000**

The cost estimate assumes a second full ISCO injection at year 3 ($1,489,000)
The cost estimate assumes a two half-scale ISCO injection events at years 6 and 8 ($745,000 each)

ALTERNATIVE 3 ANNUAL & RECURRING COSTS

Description	Quantity	Unit	Unit Price		Subtotal		Total
Field Sampling and Analysis							
Labor	1	L.S.	30,000.00	$	30,000		
Expenses	1	L.S.	5,000.00	$	5,000		
Laboratory	1	L.S.	9,000.00	$	9,000		
Annual Progress Reports	1	L.S.	26,000.00	$	26,000		
Annualized Monitoring Well Maintenance	1	L.S.	3,000.00	$	3,000		
Subtotal						**$**	**73,000**
Contingency	10%			$	7,300		
TOTAL						**$**	**80,000**

Alternative 3 - ISCO
Cost Summary

Project Name:	WPH Clemson - Feasibility Study Estimates
Description:	Alternative 3 - ISCO Cost Summary
Project Number:	450113
Project Manager:	SWW
Prepared By:	JEP
Checked By:	SWW

Description: *In Situ* Chemical Oxidation

ALTERNATIVE 3 COST SUMMARY		
DESCRIPTION	**COST**	
Periodic Costs		
Planning	$	100,000
First Injection Event	$	1,637,000
Second Injection Event	$	1,637,000
Third Injection Event	$	818,500
Fourth Injection Event	$	818,500
Subtotal Periodic Costs	**$**	**5,011,000**
Annual Costs		
Monitoring and Maintenance	$	80,000
Subtotal Annual Costs	**$**	**80,000**
Alternative 3 Total Costs	**$**	**5,971,000**

Alternative 4 - ERD
One-time and Recurring Costs

Project Name:	WPH Clemson - Feasibility Study Estimates		
Description:	Alternative 4 (ERD) - Cost Details		
Project Number:	450113		
Project Manager:	SWW		
Prepared By:	JEP	**Date**	8/16/21
Checked By:	LMC	**Date**	

Description: *In Situ* Enhanced Reductive Dechlorination

ALTERNATIVE 4 ONE-TIME & PERIODIC COSTS

Description	Quantity	Unit	Unit Price	Subtotal	Total
Work Plans and Permits	1	L.S.	30,000	$ 30,000	**$ 30,000**
First ERD Injection					
Mobilize/demobilize	8	EA	1,800	$ 14,400	
Injections (equipment & labor)	28	per day	3,300	$ 92,400	
Chemical (ABC and amendments)	250,000	lb	1.8	$ 455,000	
Injection Oversight	10%			$ 56,180	
Subtotal (Injection)					**$ 617,980**
Contingency	10%			$ 62,416	
TOTAL (Injection)					**$ 680,400**

The cost estimate assumes a second and third full ERD injection at years 4 and 7 ($575,400)
The cost estimate assumes a two half-scale ERD injection events at years 10 and 13 ($287,700 each)

ALTERNATIVE 4 ANNUAL & RECURRING COSTS

Description	Quantity	Unit	Unit Price	Subtotal	Total
Field Sampling and Analysis					
Labor	1	L.S.	30,000.00	$ 30,000	
Expenses	1	L.S.	5,000.00	$ 5,000	
Laboratory	1	L.S.	9,000.00	$ 9,000	
Annual Progress Reports	1	L.S.	26,000.00	$ 26,000	
Annualized Monitoring Well Maintenance	1	L.S.	3,000.00	$ 3,000	
Subtotal					**$ 73,000**
Contingency	10%			$ 7,300	
TOTAL					**$ 80,000**

Alternative 4 - ERD
Cost Summary

Project Name:	WPH Clemson - Feasibility Study Estimates
Description:	Alternative 4 - ERD Cost Summary
Project Number:	450113
Project Manager:	SWW
Prepared By:	JEP
Checked By:	SWW

Description: *In Situ* Enhanced Reductive Dechlorination

ALTERNATIVE 4 COST SUMMARY		
DESCRIPTION	**COST**	
Periodic Costs		
Planning	$	30,000
First Injection Event	$	680,400
Second Injection Event	$	680,400
Third Injection Event	$	680,400
Fourth Injection Event	$	340,200
Fifth Injection Event	$	340,200
Subtotal Periodic Costs	**$**	**2,751,600**
Annual Costs		
Monitoring and Maintenance	$	80,000
Subtotal Annual Costs	**$**	**80,000**
Alternative 4 Total Costs	**$**	**3,952,000**

Alternative 5 - ABC+
One-time and Recurring Costs

Project Name:	WPH Clemson - Feasibility Study Estimates		
Description:	Alternative 5 - ABC+ Cost Details		
Project Number:	450113		
Project Manager:	SWW		
Prepared By:	JEP	**Date**	8/16/21
Checked By:	LMC	**Date**	

Description: Combined ERD and ZVI Treatment (ABC+)

ALTERNATIVE 5 ONE-TIME & PERIODIC COSTS

Description	Quantity	Unit	Unit Price		Subtotal		Total
Work Plans and Permits	1	L.S.	30,000	$	30,000	$	**30,000**
First ERD Injection							
Mobilize/demobilize	8	EA	1,800	$	14,400		
Injections (equipment & labor)	48	per day	3,300	$	158,400		
Chemical (ABC+ and amendments)	250,000	lb	2.3	$	582,850		
Injection Oversight	10%			$	75,565		
Subtotal (Injection)						$	**831,215**
Contingency	10%			$	83,122		
TOTAL (Injection)						$	**914,300**

Redox Tech recommended a second injection event estimated cost set at one-half first injection event cost ($280,000).
Redox Tech recommended a third injection event estimated cost set at one-half second injection event cost ($140,000).

ALTERNATIVE 5 ANNUAL & RECURRING COSTS

Description	Quantity	Unit	Price		Subtotal		Total
Field Sampling and Analysis							
Labor	1	L.S.	30,000	$	30,000		
Expenses	1	L.S.	5,000	$	5,000		
Laboratory	1	L.S.	9,000	$	9,000		
Annual Progress Reports	1	L.S.	26,000	$	26,000		
Annualized Monitoring Well Maintenance	1	L.S.	3,000	$	3,000		
Subtotal						$	**73,000**
Contingency	10%			$	7,300		
TOTAL						$	**80,000**

Alternative 5 - ABC+
Cost Summary

Project Name:	WPH Clemson - Feasibility Study Estimates
Description:	Alternative 5 - Cost Summary
Project Number:	450113
Project Manager:	SWW
Prepared By:	JEP
Checked By:	SWW

Description: Combined ERD and ZVI Treatment (ABC+)

ALTERNATIVE 5 COST SUMMARY

DESCRIPTION	COST	
Periodic Costs		
Planning	$	30,000
First Injection Event	$	914,300
Second Injection Event	$	457,150
Third Injection Event	$	228,575
Subtotal Periodic Costs	**$**	**1,630,025**
Annual Costs		
Monitoring and Maintenance	$	80,000
Subtotal Annual Costs	**$**	**80,000**
Alternative 5 Total Costs	**$**	**2,590,000**

Appendix C
Net Present Value Cash Flow and Calculations

Net Present Value (NPV) is a financial calculation that takes into account the time value of money. Expenditures that are projected to take place in the future are discounted in a manner that allows the direct cost comparison of alternatives that have different expenditures in different time frames. NPV was calculated for the 5 remedial alternatives based on a discount rate of 7 percent.

The following tables show the cash flows for each of the 5 alternatives. Each table also states the calculated NPV, rounded to $1,000. The assumptions for each alternative are presented in Section 7 of this FFS. The estimates for capital and annual costs for each alternative are presented in Appendix B.

Alternative 2 (MNA) - Net Present Value Calculations

Year	Activity	Cost
0	Work Plan	$33,000
1	Maintenance, Monitoring, and Reporting	$80,000
2	Maintenance, Monitoring, and Reporting	$80,000
3	Maintenance, Monitoring, and Reporting	$80,000
4	Maintenance, Monitoring, and Reporting	$80,000
5	Maintenance, Monitoring, and Reporting	$80,000
6	Maintenance, Monitoring, and Reporting	$80,000
7	Maintenance, Monitoring, and Reporting	$80,000
8	Maintenance, Monitoring, and Reporting	$80,000
9	Maintenance, Monitoring, and Reporting	$80,000
10	Maintenance, Monitoring, and Reporting	$80,000
11	Maintenance, Monitoring, and Reporting	$80,000
12	Maintenance, Monitoring, and Reporting	$80,000
13	Maintenance, Monitoring, and Reporting	$80,000
14	Maintenance, Monitoring, and Reporting	$80,000
15	Maintenance, Monitoring, and Reporting	$80,000
16	Maintenance, Monitoring, and Reporting	$80,000
17	Maintenance, Monitoring, and Reporting	$80,000
18	Maintenance, Monitoring, and Reporting	$80,000
19	Maintenance, Monitoring, and Reporting	$80,000
20	Maintenance, Monitoring, and Reporting	$80,000
21	Maintenance, Monitoring, and Reporting	$80,000
22	Maintenance, Monitoring, and Reporting	$80,000
23	Maintenance, Monitoring, and Reporting	$80,000
24	Maintenance, Monitoring, and Reporting	$80,000
25	Maintenance, Monitoring, and Reporting	$80,000
26	Maintenance, Monitoring, and Reporting	$80,000
27	Maintenance, Monitoring, and Reporting	$80,000
28	Maintenance, Monitoring, and Reporting	$80,000
29	Maintenance, Monitoring, and Reporting	$80,000
30	Maintenance, Monitoring, and Reporting	$80,000
	NET PRESENT VALUE (at 7% discount rate)	**$959,000**

Alternative 3 (ISCO) - Net Present Value Calculations

Year	Activity	Cost
0	Work Plans and Permits	$100,000
1	Injection Event 1, Maintenance, Monitoring, Reporting	$1,717,000
2	Maintenance, Monitoring, and Reporting	$80,000
3	Injection Event 2, Maintenance, Monitoring, Reporting	$1,717,000
4	Maintenance, Monitoring, and Reporting	$80,000
5	Maintenance, Monitoring, and Reporting	$80,000
6	Injection Event 3, Maintenance, Monitoring, Reporting	$898,500
7	Maintenance, Monitoring, and Reporting	$80,000
8	Injection Event 4, Maintenance, Monitoring, Reporting	$898,500
9	Maintenance, Monitoring, and Reporting	$80,000
10	Maintenance, Monitoring, and Reporting	$80,000
11	Maintenance, Monitoring, and Reporting	$80,000
12	Maintenance, Monitoring, and Reporting	$80,000
	NET PRESENT VALUE (at 7% discount rate)	**$4,321,000**

Alternative 4 (ERD) - Net Present Value Calculations

Year	Activity	Cost
0	Work Plans and Permits	$30,000
1	Injection Event 1	$680,400
2	Maintenance, Monitoring, and Reporting	$80,000
3	Maintenance, Monitoring, and Reporting	$80,000
4	Injection Event 2	$680,400
5	Maintenance, Monitoring, and Reporting	$80,000
6	Maintenance, Monitoring, and Reporting	$80,000
7	Injection Event 3	$680,400
8	Maintenance, Monitoring, and Reporting	$80,000
9	Maintenance, Monitoring, and Reporting	$80,000
10	Injection Event 4	$340,200
11	Maintenance, Monitoring, and Reporting	$80,000
12	Maintenance, Monitoring, and Reporting	$80,000
13	Injection Event 5	$340,200
14	Maintenance, Monitoring, and Reporting	$80,000
15	Maintenance, Monitoring, and Reporting	$80,000
16	Maintenance, Monitoring, and Reporting	$80,000
17	Maintenance, Monitoring, and Reporting	$80,000
18	Maintenance, Monitoring, and Reporting	$80,000
19	Maintenance, Monitoring, and Reporting	$80,000
20	Maintenance, Monitoring, and Reporting	$80,000
	NET PRESENT VALUE (at 7% discount rate)	**$2,347,000**

Alternative 5 (ABC+) - Net Present Value Calculations

Year	Activity	Cost
0	Work Plans and Permits	$30,000
1	Injection Event 1	$914,300
2	Maintenance, Monitoring, and Reporting	$80,000
3	Maintenance, Monitoring, and Reporting	$80,000
4	Injection Event 1	$457,150
5	Maintenance, Monitoring, and Reporting	$80,000
6	Maintenance, Monitoring, and Reporting	$80,000
7	Injection Event 1	$228,575
8	Maintenance, Monitoring, and Reporting	$80,000
9	Maintenance, Monitoring, and Reporting	$80,000
10	Injection Event 1	$80,000
11	Maintenance, Monitoring, and Reporting	$80,000
12	Maintenance, Monitoring, and Reporting	$80,000
13	Maintenance, Monitoring, and Reporting	$80,000
14	Maintenance, Monitoring, and Reporting	$80,000
15	Maintenance, Monitoring, and Reporting	$80,000
	NET PRESENT VALUE (at 7% discount rate)	**$1,793,000**

PRESENT VALUE SUMMARY

Net Present Value Cost Estimates
Former WPH Clemson Site

Alternative 1: No Action

Alternative 2: Monitored Natural Attenuation

Alternative 3: *In Situ* Chemical Oxidation

Alternative 4: *In Situ* Enhanced Reductive Dechlorination

Alternative 5: *In Situ* ERD and ZVI (ABC+)

DESCRIPTION	ASSUMED O&M DURATION IN YEARS
Alternative 1	0
Alternative 2	30
Alternative 3	12
Alternative 4	20
Alternative 5	15

DESCRIPTION	PRESENT VALUE USING 6% INTEREST
Alternative 1	$ -
Alternative 2	$ 959,000
Alternative 3	$ 4,321,000
Alternative 4	$ 2,347,000
Alternative 5	$ 1,793,000