20395

TRC

50 International Drive, Suite 150
Patewood Plaza Three
Greenville, SC 29615

864.281.0030 PHONE
864.281.0288 FAX

www.trcsolutions.com

CD Scanned
PM Copy

October 10, 2018

Mr. Lucas Berresford
Program Manager
State Voluntary Cleanup Section
Bureau of Land and Waste Management
South Carolina Department of Health and Environmental Control
2600 Bull Street
Columbia, South Carolina 29201

Subject: Transmittal of Revised Workplan for Expanded ABC+ Pilot Study; Former WestPoint Home – Clemson Site, Oconee County; File #20395.

Dear Lucas,

In response to your letter of August 31, 2018, TRC Environmental Corporation (TRC) is pleased to transmit a revised workplan for the expanded ABC+ pilot study. The revisions to the workplan were prepared in accordance with the various comments and concerns offered in your letter. A hard copy of the revised pilot study workplan is attached to this transmittal letter. An electronic file copy will be sent to your attention via email.

To facilitate your review of the revised workplan, TRC has prepared the accompanying discussion that corresponds with the line items addressed within the Department's August 31st correspondence.

1. TRC has identified a need for 24 additional direct-push testing (DPT) locations that will be installed within 8 site areas and at varying depth intervals (*i.e.*, shallow, intermediate, and top of transition zone). These DPT borings will be utilized to augment permanent well sampling activities that will occur during the beginning, mid-point, and end of the pilot study. You will find revised graphics within the workplan that provide clarification to the number and location of these various sampling locations and depth intervals.

2. As we discussed during the call, we agree that performance criteria are necessary and appropriate for evaluation of the pilot study performance and aquifer response. We have summarized the technical criteria that we feel are relevant to the pilot study and inserted these details into Section 3.6. Table 4

provides a detailed summary of these various performance criteria and their technical relevance and applicability to the pilot study.

3. TRC has initiated well rehabilitation activities at each of the monitoring wells that previously experienced "daylighting" of the ABC+ injectate during the earlier pilot study. Preliminary results of indicator parameters at these wells are encouraging. TRC will soon provide SC DHEC with relevant data and details that provide an evaluation of the well rehabilitation and its future implications. This information will be submitted under separate cover, as soon as it is available.

4. As requested by the Department, TRC conducted an evaluation of the groundwater monitoring network that will be employed during the pilot study. During this review effort, we discerned some apparent confusion between the stated intent of our proposed monitoring program and SC DHEC's interpretation of the scope, leading to some data gap concerns. In order to better clarify and describe the scope and intent of our proposed groundwater monitoring program, Figures 2 and 6 have been revised to highlight the locations of the various DPT and permanent well locations. In addition to the 24 DPT sampling locations that were described earlier, the pilot study will also involve collection of groundwater samples from 18 permanent wells that are screened in the shallow aquifer, 13 wells that monitor intermediate depth intervals (*i.e.*, 50-55 feet bgs, where most of the VOC mass is located), 7 top-of-rock wells, and 4 bedrock wells. Each of these sampling locations will be monitored during the beginning, mid-point and ending of the pilot study. It is our belief that these permanent wells and DPT sampling locations will provide suitable and comprehensive groundwater quality data during the expanded ABC+ pilot study.

5. As requested by the Department, the workplan now includes provisions for additional qPCR testing that will be conducted during the beginning, mid-point and ending of the pilot study.

6. The workplan also provides details and clarification regarding periodic reporting and/or meetings that will be conducted following key sampling events anticipated during the pilot study. It is our desire and intent to work closely with the Department in this regard.

Please let us know if you should have any additional questions, comments, or concerns. We look forward to moving ahead with this pilot study and advancing our knowledge and understanding of treatment alternatives suitable for site conditions.

Very truly yours,

TRC Environmental Corporation
Steve W. Webb, Ph.D., PE

cc: Mr. Eddie Lanier – WPH
Lisa Clark - TRC

Attachment 1

Attachment 1

20395

TRC

CD Scanned
PM Copy.

Workplan for Expanded ABC+® Pilot Study

WestPoint Home, Inc.
Clemson, South Carolina

Issued May 2018

Revised October 2018

71

Workplan for Expanded ABC+® Pilot Study

WestPoint Home, Inc.

Former Clemson, South Carolina Facility

Issued May 2018

Revised October 2018

Lisa M. Clark, P.G.
Senior Hydrogeologist

Steve W. Webb, Ph.D., P.E.
Senior Project Manager

50 International Drive, Suite 150, Greenville, SC 29615, • 864.281.0030 Phone • 864.281.0288 Fax • www.TRCsolutions.com

Table of Contents

List of Tables

List of Figures

List of Appendices

Section 1
Introduction

WestPoint Home, Inc. (WPH) was the original owner/operator of a textile manufacturing complex located on West Cherry Road near Clemson, South Carolina (Figure 1). The facility was closed in April 2006 and the property was later sold to a group of real estate investors. The closed WPH textile facility was subsequently demolished and the site regraded for future redevelopment during the period of 2008 through 2009.

Subsequent environmental investigations conducted at the site revealed evidence of groundwater contamination emanating from beneath the former textile facility. This groundwater contamination was subsequently determined to comprise two distinct groundwater plumes, each containing volatile organic compounds (VOCs) that were primarily composed of tetrachloroethene (PCE). These two groundwater plumes are now more commonly referred to as the "upgradient" and "downgradient" VOC plume areas.

During these earlier site investigations, various lines of evidence revealed that both of these VOC plumes appear to have been sourced from underground process piping that once serviced the former textile manufacturing complex. Despite extensive field work, there has been no definitive field data or historic information to indicate or suggest that either of these two VOC plumes were ever related to any surficial spill and/or release. Furthermore, extensive soils data has failed to reveal any link between the underlying groundwater that contains elevated VOC levels and the surface soils that show no indication of VOC impact.

From their subsurface points of origin, each of the two VOC plumes migrate in a southeastwardly direction toward Hartwell Lake. Along the shores of Hartwell Lake, pore water sampling has revealed the presence of low levels of VOCs that are discharging into the surface water of the lake.

The former WPH property is currently owned and managed by Tom Winkopp, Realtor/Developer, LLC. To date, a large portion of the site has been the focus of considerable redevelopment effort, primarily consisting of construction of residential housing units and apartment buildings, and mixed-use commercial lots. For the most part, the housing units being constructed across the site are being occupied by students and family attending nearby Clemson University.

In recent months, there has been additional push of site development activities resulting in the construction of numerous residential housing units that are now in close proximity to the area

where the two VOC plumes are situated. The Winkopp site development team has indicated that further residential development within the immediate vicinity of the upgradient and downgradient VOC plumes is not being contemplated within the areas exhibiting underlying VOC-affected groundwater. However, there is nothing contractual to prevent future site development from occurring in this area and evidence of active site development is evident across most of the remaining acreage of the former WPH property.

In April 2015, TRC prepared and submitted a work plan for the conduct of a pilot study that was designed to investigate the possibility of applying an *in-situ* treatment remedy at the site. This work plan was submitted to the South Carolina Department of Health and Environmental Control (SC DHEC) and described the methods, means and materials necessary to assess and evaluate the possible application of a treatment technology that integrated a lactate-based treatment approach for a microbial-based technique for promoting enhanced reductive dichlorination with an abiotic technique that utilized zero valent iron (ZVI). This treatment technology is commercially referred to as ABC+®, and offered a promising approach to conducting an *in situ* treatment of VOCs present within the underlying groundwater and in close proximity to an expanding community of students and their dependents.

The ABC+® treatment technology involved integration of an Enhanced Reductive Dechlorination (ERD) treatment component with a ZVI-based treatment component and did not require use of treatment chemistries requiring otherwise hazardous chemicals or dangerous construction equipment. The possibility of applying two synergistic treatment processes and do so in a safe and robust manner was felt to represent a meaningful treatment strategy, appropriate to site conditions and the current pattern of land-use. Following subsequent discussion with SC DHEC and incorporation of Department review comments, the ABC+® pilot study work plan was formally approved for site implementation in June 2016.

The SC DHEC-approved pilot study was predicated upon a treatment technology developed and offered by Redox Tech, LLC, (Redox Tech). As indicated earlier, the treatment product is commercially offered by Redox Tech under the trade name of ABC+®. ABC+® is an acronym that stands for "Anaerobic BioChem Plus" and represents a formulation of Redox Tech's standard ERD treatment formulation (ABC®), with a supplemental treatment enhancement of finely-milled ZVI. Thus, ABC+® represents a hybridized treatment technology that can be deployed within the subsurface environment to promote and stimulate anaerobic ERD treatment processes in the subsurface groundwater, as well as enhance the physio-chemical degradation of VOCs using ZVI treatment enhancements.

Redox Tech literature reports that ABC+® treatment has been successfully applied at over 1000+ sites across the nation. Despite this history of successful treatment applications, there remained

many underlying concerns (of a site-specific nature) that can best be addressed via a pilot study evaluation. One major concern was whether or not the ABC+® treatment materials could be reasonably/reliably introduced into the subsurface via direct-push technology (DPT) injections. If DPT injection of the ABC+® treatment materials was not possible into the subsurface of the site, this would represent a fatal flaw for further consideration of this in-situ treatment technique.

The ABC+® pilot study was initiated in the field on June 20, 2016. The pilot study was conducted in two locations – one treatment area situated near the upper end of the upgradient VOC plume area and the second treatment area located near the head of the downgradient VOC plume area. As specified in the work plan, three DPT injection locations were designated for each pilot study work zone. In order to manage the required timing and cost of the pilot study, the overall scope and scale of the initial ABC+® pilot study was intentionally limited. Thus, the focus and objective of the initial ABC+® pilot study was to provide "proof of concept" information and details that could be incorporated into the contents of a pending Focused Feasibility Study (FFS).

After nearly a year of *in-situ* treatment and performance monitoring, the initial ABC+® Pilot Study Report was prepared and submitted to SC DHEC in May 2017. This report provided a summary and description of the various treatment and monitoring elements of the ABC+® pilot study effort, as well as a synopsis of the results and lessons learned during the field effort. In a letter dated October 12, 2017, SC DHEC offered their comments on the pilot study report and suggested that the pilot study was inconclusive and that more substantial evidence of active treatment response and PCE degradation was necessary. The State indicated that "before and after" PCE plume maps and more conclusive data would be necessary before the Department would be willing to consider ABC+® to represent a suitable remedial treatment alternative for the site.

Both Redox Tech and TRC maintain that the pilot study report did provide multiple lines of evidence that support and defend the efficacy of ABC+® treatment as a suitable and reliable treatment strategy for the upgradient and downgradient plume areas. The limited size and scale of the pilot study and the time constraints associated with following the transport/migration of the ABC+® treatment materials from the point of injection to detection within nearby observations wells, limited our ability to generate the "before and after" PCE isocontour maps sought by the SC DHEC reviewer.

Bearing these thoughts in mind, TRC revisited the scope of the initial ABC+® pilot study work plan, with the objective of expanding the work scope. In concert with Redox Tech and WPH staff, TRC has subsequently amended the pilot study work scope to encompass a substantially

larger treatment zone area and focused the treatment efforts within the most concentrated PCE contaminant mass present within the upgradient VOC plume area. By expanding the scope of the initial ABC+® pilot study, TRC developed a more robust experimental design capable of addressing SC DHEC concerns, extensive enough to impart meaningful treatment effort within a concentrated area of VOC mass and large enough in scale and scope to conclusively demonstrate the efficacy of ABC+® treatment as a suitable remediation tool for the former WPH-Clemson site. TRC also feels that this expanded version of the initial ABC+® pilot study should allow for generation of VOC plume maps that can reveal the progress/performance of the groundwater treatment over various time intervals (*i.e.*, before injection, during treatment and following completion of the expanded ABC+® pilot study treatments). Where the initial ABC+® pilot study utilized only 3 DPT injection points in the upgradient VOC plume, the expanded ABC+® pilot study will make use of 80 DPT injection points.

The Workplan for an Expanded ABC+® Pilot Study was originally submitted to SC DHEC in May 2018. In a letter dated June 8, 2018, SC DHEC provided its comments to the workplan, requesting various additional details and technical considerations (*i.e.*, permanent monitoring well locations, additional performance monitoring parameters, and introduction of numerical performance criteria, etc.). TRC subsequently prepared a technical response to address these comments that was submitted to the Department on June 22, 2018.

At the request of SC DHEC, a conference call was coordinated and conducted on August 30, 2018. During this call, the project stakeholders were able to discuss and exchange thoughts and ideas regarding the various technical considerations and concerns. As a result of these discussions, a mutually agreeable path forward was developed, which was subsequently summarized in a SC DHEC correspondence, dated August 31, 2018. This revised Workplan for Expanded ABC+® Pilot Study has been prepared to reflect and address the various technical discussions and agreements that were set forth in SC DHEC's August 31, 2018 correspondence.

TRC
50 International Drive, Suite 150
Patewood Plaza Three
Greenville, SC 29615
Phone: 864.281.0030
Fax 864.281.0288

WESTPOINT HOME, INC.
CLEMSON, SOUTH CAROLINA

FIGURE 1
LOCATION OF FORMER
WESTPOINT HOME SITE

DRAWN BY:	DJS
APPROVED BY:	LMC
PROJECT NO:	3000688.0.0
FILE NO.	
DATE:	SEPTEMBER 2018

U:\West Point Home\Clemson SC\ArcGIS10\300688\Pilot Study Work Plan\2018-09\Fig 1 - Site location.mxd
Date Saved: 9/6/2018 12:54:42 PM

Section 2
Pre-Injection Groundwater Quality

Prior to implementation of the expanded ABC+® pilot study, TRC will conduct a site-wide groundwater sampling event that is intended to update and refine our understanding of current site groundwater quality conditions and update the existing concentration and distribution of VOCs within the underlying aquifer. To accomplish this objective, TRC will employ the following logic and rationale:

There are 77 permanent monitoring wells that comprise the groundwater monitoring well network that currently exists at the former WPH Clemson facility (see Figure 2). Forty-five (45) of these monitoring wells are used to characterize and evaluate the upgradient VOC plume area. The remaining 32 monitoring wells are used to characterize the downgradient VOC plume area. These monitoring wells were installed to provide groundwater quality information that characterizes the underlying aquifer from the water table zone, across intermediate aquifer depths, and down into the top of rock and bedrock hydrogeologic units. In addition to these 77 permanent monitoring well locations, there are still three observation wells, previously installed within the lower VOC plume area, that were used during the initial ABC+® pilot study. In order to update our site-wide basis and understanding of groundwater quality conditions (*i.e.*, pre-injection or base-line conditions), TRC will conduct a comprehensive, base-line groundwater sampling event and submit the samples for laboratory analysis.

During this base-line/ pre-injection sampling event, TRC will re-sample each of the 77 existing monitoring wells and have them analyzed for the site-specific constituents of concern and applicable field parameters. In addition, TRC will sample 8 multi-depth DPT borings to evaluate the groundwater quality at sampling locations within the existing well network of the upgradient VOC plume area and augment our understanding of groundwater quality within the shallow, intermediate, and deep aquifer zones between the existing permanent monitoring well locations. The field and analytical data collected during this base-line sampling event will be used to develop a better knowledge and understanding of existing site conditions and provide an opportunity to further refine the ABC+® pilot study injection strategy described in Section 3.4 of this workplan. These data will also be utilized to aide in the development of pre-injection, VOC isoconcentration contour maps of the site, at a time prior to initiation of the expanded ABC+® pilot study.

2.1 Monitoring Well Redevelopment

During the initial ABC+® pilot study injections (conducted in June 2016), four of the nearby monitoring and/or observation wells (*i.e.*, RMW-23, RMW-23A, OW-6A, and RMW-27A) experienced "daylighting" of the injected ABC+® treatment materials into the well screens and casings. During the period of the initial pilot study, TRC field technicians conducted repeated attempts to promote fluid displacement and well redevelopment to rehabilitate these wells. Over time, TRC has observed that these wells were gradually responding to the rehabilitative efforts. Much of the residual ZVI and lactate amendments were removed from the wells. When these wells were last sampled in February 2017, they continued to exhibit some evidence of elevated specific conductance, suggesting the possible presence of residual ABC+® treatment media in the wells.

Nearly 19 months later, it is reasonable to presume that much of these residual treatment materials have been dispersed and/or metabolized by the indigenous soil microbes. As we discussed during our August 30, 2018 conference call, TRC field staff will revisit each of these wells and conduct additional well inspection and rehabilitation, as required. These well rehabilitation efforts will apply to wells RMW-23, RMW-23A, OW-6A, and RMW-27A. The well rehabilitation efforts employed in 2018 will be identical to those used in 2016. Aggressive fluid displacement (using surge blocks) and well purging/redevelopment efforts will be applied to clear the monitoring wells of residual treatment materials. Following well redevelopment, these wells will be further assessed/evaluated using field indicator parameters (*i.e.*, pH, specific conductance, temperature, oxidation reduction potential [ORP] and dissolved oxygen [DO]) to determine if there are any residual influences from the June 2016 ABC+® injection event. As requested by SC DHEC, TRC will provide the results of these well redevelopment efforts and subsequent field indicator parameter measurements to SC DHEC, for the Department's review and consideration. At this time, a decision will be made as to whether or not each of these wells is suitable for future performance monitoring activities. TRC expects that these well redevelopment activities and Department review considerations will be completed prior to implementation of the expanded ABC+® pilot study.

2.2 Pre-injection Groundwater Sampling and Analysis

As indicated earlier, pre-injection sampling and laboratory analysis will be conducted and the monitoring results evaluated as a point of future comparison with performance monitoring data collected during and after the expanded ABC+® injections have occurred. Monitoring data collected from the various permanent well locations and DPT borings will be used to prepare graphics depicting the horizontal and vertical configuration of VOC isoconcentration contours and geochemical conditions that exist within the upper VOC plume prior to the ABC+® injections. These graphics should provide a useful comparison with subsequent changes that

may be detected within the targeted treatment zone and offer a useful indication of the transport mechanisms of ABC+® treatment materials within the aquifer. Apparent changes within the subsurface geochemistry should also provide useful lines of evidence regarding the resulting biotic and abiotic treatment processes that may occur within the aquifer.

2.2.1 Permanent Well Sampling Activities

TRC field technicians will collect groundwater samples from each of the 77 existing site monitoring wells (see Figure 2). Well purging and sampling will be performed in accordance with the procedures described in Subsection 3.7 of the approved Site Sampling and Analysis Plan (SAP). Field parameters (*i.e.*, pH, ORP, DO, temperature and specific conductivity) will be measured during well purging activities. Samples will be submitted to a South Carolina certified analytical laboratory and analyzed for Target Compound List (TCL) VOCs using USEPA Method 8260B.

In addition to the site-wide VOC sampling effort, TRC anticipates submitting additional samples of the groundwater collected from each of the 45 monitoring wells located within the upgradient VOC plume area, plus five wells from the downgradient plume area, for additional testing and analyses. The five additional wells (RMW-09 and RMW-23/23A/23B/23C) were selected to provide additional monitoring points to the northeast of the upgradient VOC plume. These wells will be analyzed for the following additional parameters:

- Sulfate
- Chloride
- Nitrate
- Bromide
- Dissolved iron
- Dissolved lactate (semi-quantitative Ion Chromatographic peak)
- Dissolved gases including methane, ethane and ethene

In conjunction with the collection of the groundwater quality samples, water level measurements will also be collected and recorded from each of the 77 monitoring wells located on the site and within the adjacent United States Army Corps of Engineers (US ACOE) property along the shores of Hartwell Lake.

At SC DHECs request, qPCR testing of groundwater from select wells within the upgradient VOC plume area will be conducted to document/quantify the various types of halo-respiring bacteria that are present and capable of facilitating reductive

dechlorination, as well as identifying and quantifying the functional genes that may be actively involved in the desired anaerobic and aerobic (co)metabolic pathways for biodegradation of chlorinated ethenes, as well as competing microbiological processes. To accomplish this, TRC proposes collecting groundwater samples from each of three existing monitoring wells that are situated along the longitudinal axis of the upgradient VOC plume. These wells include:

- RMW-27 (shallow groundwater interval),
- RMW-18A (intermediate groundwater interval), and
- RMW-20B (top of rock groundwater interval).

The pre-injection sampling program for the permanent monitoring wells is summarized on Table 1.

2.2.2 Direct-Push Sampling

As further discussed and agreed, TRC will collect additional groundwater samples via DPT as a means of supplementing the groundwater quality data that is available from permanent groundwater monitoring locations. Eight (8) DPT sampling locations have been identified and illustrated on Figure 2. These DPT locations have been selected based on their location to nearby monitoring wells, as well as their location to proximal ABC+® injection lines (refer to discussion in Section 3.4). The precise locations of these DPT samples will be initially established in the field using a hand-held GPS unit and staked, to facilitate future sampling activities within the same general locations.

DPT groundwater samples will be collected at three aquifer depth intervals, generally characterized as the shallow water table zone (i.e., corresponding with the depth of the shallow well screens), the intermediate zone (i.e., corresponding to the screens of wells having the "A" in their well naming designation), and at DPT refusal (i.e., corresponding to the top of transition zone). DPT groundwater data will be utilized in conjunction with groundwater quality data collected from the permanent wells to prepare graphics illustrating the horizontal and vertical distribution of VOCs and changes identified in geochemical conditions existing within the upper VOC plume zone area.

This DPT sampling will occur prior to initiation of the expanded ABC+® pilot study, after approximately 6 months following injection completion (semi-annual monitoring event) and at completion (annual monitoring event) of the pilot study. Since these DPT activities will require prior SC DHEC review and approval, TRC will take steps to obtain the necessary well approval permits from the Department.

Once SC DHEC approval is received, DPT sample locations will be marked in the field and underground utilities will be cleared. A well driller licensed in the State of South Carolina will be contracted to collect the DPT groundwater samples. TRC anticipates that the DPT sampling activities will occur to coincide with the pre-injection sampling activities, the semi-annual (6 months following injection) sampling, and the annual (12 months following injection). As with the permanent well locations, all DPT groundwater samples will be analyzed by a South Carolina certified analytical laboratory for the identical parameters described in Section 2.2.1 (excluding qPCR) and summarized in Table 2. Field and indicator parameters will also be obtained during the DPT sample collection activities.

2.3 Investigation-Derived Waste Management Practices

Groundwater and other sampling waste produced during well redevelopment and sampling activities will be handled as follows:

- **Liquids:** Development, purge, and decontamination liquids will be contained, characterized, and properly disposed of offsite.
- **Used personal protective equipment (PPE):** All used latex or nitrile gloves, waste paper, and other general debris generated during sampling activities will be bagged and removed from the site for proper disposal.

Table 1

Baseline and Performance Monitoring Program - Permanent Monitoring Wells

Location and Monitoring Zone		Pre-Injection	Post-Injection			
		Month 0	Month 3	Month 6	Month 9	Month 12
Upgradient Plume Monitoring Wells						
MW-09	Water Table	W F I V	W	W	W	W
MW-11	Water Table	W F I V	W	W	W	W
MW-12	Water Table	W F I V	W	W	W	W
RMW-01	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-02	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-03	Water Table	W F I V	W	W	W	W
RMW-04	Water Table	W F I V	W	W	W	W
RMW-05A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-05B	Top of Rock	W F I V	W F I	W F I V	W F I	W F I V
RMW-06	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-06A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-07	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-08	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-08A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-10	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-10A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-10B	Top of Rock	W F I V	W F I	W F I V	W F I	W F I V
RMW-10C	Bedrock	W F I V	W F I	W F I V	W F I	W F I V
RMW-11	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-12	Water Table	W F I V	W	W	W	W
RMW-13	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-13A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-14	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-14A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-14B	Top of Rock	W F I V	W F I	W F I V	W F I	W F I V
RMW-14C	Bedrock	W F I V	W F I	W F I V	W F I	W F I V
RMW-18	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-18A	Intermediate	W F I V qPCR	W F I	W F I V qPCR	W F I	W F I V qPCR
RMW-19	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-19A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-20	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-20A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-20B	Top of Rock	W F I V qPCR	W F I	W F I V qPCR	W F I	W F I V qPCR
RMW-20C	Bedrock	W F I V	W F I	W F I V	W F I	W F I V
RMW-21	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-21A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-24	Water Table	W F I V	W F I	W F I V	W F I	W F I V

Legend:

W = Water Level Measurement

F - Field Parameters

I = Indicator Parameters

V = VOCs and dissolved gases

qPCR = Bacterial and functional gene testing

Field Parameters:

pH	Temperature	Specific conductivity
DO	ORP	Turbidity

Indicator Parameters:

Nitrate	Sulfate	Dissolved Ferrous Iron
Bromide	Chloride	Lactate Peak (IC)

Dissolved Gases:

Ethane	Methane
Ethene	

VOCs:

Target Compound List (TCL)

Table 1

Baseline and Performance Monitoring Program - Permanent Monitoring Wells

Location and Monitoring Zone		Pre-Injection	Post-Injection			
		Month 0	Month 3	Month 6 [(1)]	Month 9	Month 12
RMW-25	Water Table	W F I V	W	W	W	W
RMW-26	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-27	Water Table	W F I V qPCR	W F I	W F I V qPCR	W F I	W F I V qPCR
RMW-27A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-27B	Top of Rock	W F I V	W F I	W F I V	W F I	W F I V
RMW-28A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-28B	Top of Rock	W F I V	W F I	W F I V	W F I	W F I V
RMW-29	Water Table	W F I V	W	W	W	W
Downgradient Plume Monitoring Wells						
DG-01	Water Table	W F V	W	W	W	W
DG-03D	Intermediate	W F V	W	W	W	W
DG-03S	Water Table	W F V	W	W	W	W
DG-05	Water Table	W F V	W	W	W	W
DG-06	Water Table	W F V	W	W	W	W
DG-06A	Intermediate	W F V	W	W	W	W
DG-06B	Top of Rock	W F V	W	W	W	W
DG-06C	Bedrock	W F V	W	W	W	W
DG-07	Intermediate	W F V	W	W	W	W
MG-02	Water Table	W F V	W	W	W	W
MG-05	Water Table	W F V	W	W	W	W
MG-05A	Intermediate	W F V	W	W	W	W
MG-06	Water Table	W F V	W	W	W	W
MG-06A	Intermediate	W F V	W	W	W	W
MG-06B	Top of Rock	W F V	W	W	W	W
RMW-09	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-15	Water Table	W F V	W	W	W	W
RMW-15A	Intermediate	W F V	W	W	W	W
RMW-15B	Top of Rock	W F V	W	W	W	W
RMW-16	Water Table	W F V	W	W	W	W
RMW-16A	Intermediate	W F V	W	W	W	W
RMW-16B	Top of Rock	W F V	W	W	W	W
RMW-16C	Bedrock	W F V	W	W	W	W
RMW-17	Water Table	W F V	W	W	W	W
RMW-17A	Intermediate	W F V	W	W	W	W
RMW-22	Water Table	W F V	W	W	W	W
RMW-22A	Intermediate	W F V	W	W	W	W
RMW-23	Water Table	W F I V	W F I	W F I V	W F I	W F I V
RMW-23A	Intermediate	W F I V	W F I	W F I V	W F I	W F I V
RMW-23B	Top of Rock	W F I V	W F I	W F I V	W F I	W F I V
RMW-23C	Bedrock	W F I V	W F I	W F I V	W F I	W F I V
RMW-23D	Bedrock	W F V	W	W	W	W

Legend:

W = Water Level Measurement

F - Field Parameters

I = Indicator Parameters

V = VOCs and dissolved gases

qPCR = Bacterial and functional gene testing

Field Parameters:

pH	Temperature	Specific conductivity
DO	ORP	Turbidity

Indicator Parameters:

Nitrate	Sulfate	Dissolved Ferrous Iron
Bromide	Chloride	Lactate Peak (IC)

Dissolved Gases:

Ethane	Methane
Ethene	

VOCs:

Target Compound List (TCL)

Table 2
Baseline and Performance Monitoring Program - Direct Push Sample Points

Location and Monitoring Zone		Pre-Injection	Post-Injection			
		Month 0	Month 3	Month 6	Month 9	Month 12
Upgradient Plume Direct Push Sample Points						
DP-20	Water Table	F I V	--	F I V	--	F I V
DP-20A	Intermediate	F I V	--	F I V	--	F I V
DP-20B	Top of Transition Zone	F I V	--	F I V	--	F I V
DP-21	Water Table	F I V	--	F I V	--	F I V
DP-21A	Intermediate	F I V	--	F I V	--	F I V
DP-21B	Top of Transition Zone	F I V	--	F I V	--	F I V
DP-22	Water Table	F I V	--	F I V	--	F I V
DP-22A	Intermediate	F I V	--	F I V	--	F I V
DP-22B	Top of Transition Zone	F I V	--	F I V	--	F I V
DP-23	Water Table	F I V	--	F I V	--	F I V
DP-23A	Intermediate	F I V	--	F I V	--	F I V
DP-23B	Top of Transition Zone	F I V	--	F I V	--	F I V
DP-24	Water Table	F I V	--	F I V	--	F I V
DP-24A	Intermediate	F I V	--	F I V	--	F I V
DP-24B	Top of Transition Zone	F I V	--	F I V	--	F I V
DP-25	Water Table	F I V	--	F I V	--	F I V
DP-25A	Intermediate	F I V	--	F I V	--	F I V
DP-25B	Top of Transition Zone	F I V	--	F I V	--	F I V
DP-26	Water Table	F I V	--	F I V	--	F I V
DP-26A	Intermediate	F I V	--	F I V	--	F I V
DP-26B	Top of Transition Zone	F I V	--	F I V	--	F I V
DP-27	Water Table	F I V	--	F I V	--	F I V
DP-27A	Intermediate	F I V	--	F I V	--	F I V
DP-27B	Top of Transition Zone	F I V	--	F I V	--	F I V

Legend:

W = Water Level Measurement
F - Field Parameters
I = Indicator Parameters
V = VOCs and dissolved gases

Field Parameters:

pH	Temperature	Specific conductivity
DO	ORP	Turbidity

Indicator Parameters:

Nitrate	Sulfate	Dissolved Ferrous Iron
Bromide	Chloride	Lactate Peak (IC)

Dissolved Gases:

Ethane Methane
Ethene

VOCs:

Target Compound List (TCL)

Plot Date: 9/24/2018, 17:16:14 PM by RWIXON -- LAYOUT: ANSI B (11"x17")
Path: U:\West Point Home\Clemson SC\ArcGIS\10\300688\Pilot Study Work Plan\2018-09\Fig 2 - GW Monitoring Network.mxd
Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

Upgradient Plume

Downgradient Plume

RMW-25
RMW-04
RMW-29
RMW-03
RMW-27/27A/27B
RMW-02
RMW-26
MG-06/06A/06B
RMW-18/18A
RMW-21/21A
RMW-22/22A
MG-05/05A
MG-02
DP-20/20A/20B
DP-22/22A/22B
RMW-08/08A
RMW-23D
RMW-09
DP-21/21A/21B
RMW-20/20A/20B/20C
RMW-23/23A/23B/23C
OW-4
OW-5
OW-6A
DG-01
DP-24/24A/24B
RMW-24
RMW-28A/28B
DP-26/26A/26B
RMW-17/17A
RMW-19/19A
RMW-07
DG-05
DP-23/23A/23B
RMW-16/16A/16B/16C
DP-25/25A/25B
RMW-10/10A/10B/10C
RMW-15/15A/15B
DG-03S/03D
DP-27/27A/27B
RMW-01
RMW-14/14A/14B/14C
DG-07
RMW-06/06A
DG-06/06A/06B/06C
RMW-13/13A
RMW-05A/05B
RMW-11
MW-12
RMW-12
HARTWELL LAKE
MW-09
MW-11

0.005
0.05
0.5
5

LEGEND

- Water Table Aquifer Monitoring Well
- Intermediate Aquifer Monitoring Well
- Top of Rock Aquifer Monitoring Well
- Bedrock Aquifer Monitoring Well
- Multi-depth Direct-Push Technology (DPT) Sample Location
- Water Table Aquifer Pilot Study Observation Well
- Intermediate Aquifer Pilot Study Observation Well
- PCE Isoconcentration Contour (mg/L) Intermediate Aquifer - July 2014 and June 2015 (Dashed Where Inferred)
- Property Boundary (Approximate)

NOTES

Aerial Photograph Source: ESRI World Imagery (2018)

Upgradient plume monitoring well names highlighted in **GREEN**.

Downgradient plume monitoring well names highlighted in **ORANGE**.

Locations of buildings and other structures provided by developer.

N

0 100 200 Feet

1 " = 133 '

1:1,600

PROJECT:
FORMER WESTPOINT HOME SITE
CLEMSON, SOUTH CAROLINA

TITLE:
GROUNDWATER MONITORING NETWORK

DRAWN BY:	WIXON S	PROJ NO.:	300688.0.0 PHASE 5
CHECKED BY:	CLARK L		
APPROVED BY:	WEBB S		**FIGURE 2**
DATE:	SEPTEMBER 2018		

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

FILE NO.: Fig 2 - GW Monitoring Network.mxd

Section 3
Expanded ABC+® Pilot Study

As described earlier, the scope and scale of the original ABC+® pilot study were considerably reduced from what is currently envisioned for the expanded ABC+® pilot study. Where the earlier pilot study made use of three DPT injection points to introduce the prerequisite ABC+® treatment materials into the subsurface, the expanded pilot study will employ 80 injection locations across a much larger surface area. By expanding the scope and extent of the pilot study, TRC is expecting that the field results will provide a more compelling "proof of concept" evaluation and facilitate a more comprehensive review of the ABC+® treatment technology. In the event that the results of the expanded pilot study are favorable, then the logical outcome of this pilot study is to append the pilot study results for inclusion in the pending FFS.

During the initial pilot study, TRC was able to confirm the technical practicability of utilizing DPT as an effective means of introducing ABC+® treatment materials down to depths greater than 70 feet below ground surface. This was a significant finding from the initial pilot study and one that allowed us to develop more confidence that the required and appropriate depths for treatment of the VOC-affected groundwater of the site could be achieved using this *in-situ* treatment strategy.

During the initial pilot study, TRC also observed performance monitoring results that indicated where the ABC+® treatment media was introduced in sufficient quantity and areal extent, the applied treatment materials could promote and enhance the desired and necessary biochemical and physiochemical treatment responses. In an environment where previously anaerobic treatment activity was non-existent, TRC observed evidence that the PCE parent compound was being converted into its related VOC daughter products and dissolved gases were being generated.

In order to provide a more compelling technical response to the reviewer comments that were previously offered by SC DHEC on the *ABC+® Pilot Study Report* (TRC, 2017a), the goal of this expanded ABC+® pilot study effort is to introduce and promote a larger and more robust zone of anaerobic treatment influence and accomplish this within a prescribed area within the upgradient VOC plume, where observed VOC concentrations have been documented at their highest concentrations.

More specifically, TRC has identified PCE isocontour concentrations exceeding 0.10 mg/L for this pilot study. If ABC+® treatment influence can be successfully demonstrated and documented within this zone of elevated VOCs, then SC DHEC should be in a much better

position to conclude that this treatment technology can promote an appropriate treatment response and ABC+® represents an appropriate treatment strategy for site conditions and current property redevelopment activities.

Similar to the earlier 2016 pilot study, the expanded ABC+® pilot study will focus on injection of ABC+® into the underlying groundwater, this time the primary emphasis will be on the most contaminated zone of the up-gradient VOC plume, where PCE levels have been detected above a concentration of 0.10 mg/L. Because ABC+® is a lactate-based carbon substrate containing many essential nutrient amendments suitable for ERD and it also incorporates finely-milled ZVI powder, ABC+® affords a unique *in situ* treatment formulation that can impart both a biotic (*i.e.,* ERD) treatment component along with an abiotic (*i.e.,* ZVI) treatment component. Appendix A provides additional product descriptions for ABC+®. As before, TRC also anticipates introducing a suitable inoculum of anaerobic micro-organisms with the ABC+® to serve as a bio-augmentation source during the expanded pilot study. Appendix B provides a description of the intended bioaugmentation aide (Shaw's Dechlorinating culture – SDC-9™) that TRC anticipates using during the expanded pilot study.

3.1 Expanded Pilot Study Objectives

The objective of the expanded ABC+® pilot study is to conduct a more robust application of the ABC+® treatment technology, in order to facilitate collection of additional field data that can be used to provide a more compelling demonstration to SC DHEC that the treatment technology represents a suitable and appropriate treatment strategy for the Clemson site. In this manner, we expect to raise SC DHEC confidence and support that this treatment alternative is suitable for the current site conditions, as well as the ongoing site residential development activities. The expanded pilot study should also provide additional technical support and insight for further consideration of ABC+® treatment within the context of the pending FFS review of various remedial technology applications.

The Focused Feasibility Study (TRC, 2017b) for the WPH-Clemson site was previously submitted to the Department in August 2017 for review and consideration. By conducting the expanded ABC+® pilot study across a larger area and in a more robust manner and scope, TRC hopes to achieve and demonstrate more meaningful VOC reductions within the upper VOC plume area and document how the observed distribution of PCE and VOC daughter products has responded to the applied treatment efforts.

3.2 Lessons Learned from Initial ABC+® Pilot Study

During implementation of the initial ABC+® Pilot Study, several important lessons were learned, many of which have been incorporated into the design of this expanded ABC+® Pilot Study Workplan. These "lessons learned" include the following considerations:

- Direct push technology (DPT) represents a reasonable means of introducing ABC+® treatment materials to depths greater than 70 feet below ground surface. This depth generally corresponds with the observed top of the transition zone of the aquifer.
- Application of an injection pressure of up to 200 psi can produce a radius of treatment influence of approximately 15 to 25 feet.
- Because there exists potential for "daylighting" of the injectate, no ABC+® injections will be conducted within 30 feet of an existing monitoring well location, particularly if injection pressures are anticipated in the range of 200 psi or greater.
- At the observed rates of groundwater flow (approximately 25-100 ft/yr in shallow and intermediate zones) that are observed across the site, quarterly groundwater sampling events are felt to be suitable for meaningful performance monitoring.
- Performance monitoring activities at permanent well locations can be augmented with DPT-based groundwater sampling, when conducted at pre-selected, surveyed sampling locations. DPT-based sampling of the groundwater can provide considerable flexibility and useful information and details to supplement the permanent well data and in-fill data gaps that may exist between the permanent monitoring wells.

3.3 UIC Permit Application

Since ABC+® treatment will involve direct injection of a treatment media into the subsurface soils and groundwater, an Underground Injection Control (UIC) permit application is anticipated. This UIC permit application will be prepared and submitted to SC DHEC's UIC group and the Bureau of Land and Waste Management. The UIC permit application will be prepared, as a stand-alone document, for the UIC group's review, comment and approval. No UIC-related injection activities will be initiated until the appropriate SC DHEC permit approvals have been granted.

3.4 Expanded ABC+® Field Application

As depicted in Figure 3, TRC proposes to conduct the expanded ABC+® pilot study within the upper VOC plume area. For this expanded pilot study treatment effort, the 0.10 mg/L PCE isopleth (100 ppb) has been selected as the targeted treatment area for active ABC+® treatment and remediation. By targeting the 100 ppb PCE isopleth, TRC will focus on a specific portion of the VOC-affected aquifer that exhibits PCE concentrations at levels that are clearly in need of active treatment. The 100 ppb isopleth also represents a reasonably accessible and promising

target treatment area for the PCE groundwater plume. At the anticipated scope and extent of the expanded ABC+® pilot study, this targeted treatment area should adequately support development of suitable lines of evidence to evaluate/demonstrate the suitability/performance of the ABC+® treatment.

The expanded ABC+® pilot study effort will consist of direct-push injections of a bioaugmented, ABC+® treatment media at up to 80 locations and along seven lines of transect. Each line of transect has been selected/located to traverse the width of the estimated 100 ppb PCE isopleth and facilitate introduction of the treatment media at locations that are perpendicular to groundwater flow. The approximate locations of these 80 injection points are illustrated on Figure 4. Please bear in mind that proposed injection locations may require relocation/modification due to unexpected field conditions or infrastructure interference. In order to minimize the potential for "daylighting" of the ABC+® treatment materials into any of the existing monitoring wells, there will be no injection activities conducted within 30 feet of an existing monitoring well. Again, it is possible that field conditions may be encountered that might cause this prescribed distance to be extended further than 30 feet.

The vertical extent of treatment will extend from the water table to the depth of probe refusal, which will likely vary to some extent between injection locations. Depth of refusal will be presumed to represent the top of the transition zone. Injections will be conducted in 10-foot segments, beginning approximately 10 feet below the depth of the observed water table. The treatment suspension, consisting of the ABC+® treatment materials, Shaw's Dechlorinating culture – SDC-9™ (a commercially available DHC culture), and deoxygenated tap water (*i.e.*, a carrier/dilution fluid) will be injected under low-to-moderate pressure (ranging up to 200 psi) into the subsurface at two-foot depth intervals (*i.e.*, at 30, 28, 26, 24, and 22 feet, assuming a water table depth of 20 feet). Upon completion of these initial injections, the first probehole will be abandoned with bentonite and a second probe will be pushed to the bottom of the next 10-foot segment, with injections again occurring at two-foot increments (*i.e.*, 40, 38, 36, 34, and 32 feet). This DPT injection technique will be applied as a precaution to prevent short-circuiting between depth intervals. Assuming an overall treatment zone of 50 vertical feet, a total of five discrete DPT borings would be required to fully treat the prescribed 50-foot treatment interval. This technique would be repeated at each of the 80 selected treatment locations. Figure 5 illustrates the proposed injection strategy.

For each depth interval, TRC anticipates injection of approximately 100 lbs of ABC+® and 0.2 liters of the selected bioaugmentation culture of DHC and accomplish all this using 50-gallon batches of the treatment suspension. Assuming a 50-foot water column, a typical injection could involve approximately 5.0 liters of DHC bacteria and 2,500 lbs of ABC+®. This treatment suspension would be introduced into the subsurface using approximately 1,250 gallons of the

deoxygenated carrier fluid into each injection location. For a treatment matrix involving 80 injection locations, TRC estimates that the overall pilot study will involve injection of approximately 400 liters of DHC bacterial culture, 200,000 lbs of ABC+® and a total volume of 100,000 gallons of the treatment suspension.

Following completion of each injection, the DPT bore holes will be backfilled with bentonite. This step will be conducted to ensure that the borehole is sealed in accordance with SC DHEC regulations and to prevent "daylighting" of the treatment materials.

3.5 ABC+® Pilot Study Performance Monitoring

Over the projected 12-month span of the expanded ABC+® pilot study, TRC anticipates conducting a series of recurring field sampling events to collect and compile performance monitoring data for subsequent review and evaluation. Based on our prior pilot study experience, we have observed that groundwater flows across the site at a rate of between 25-100 ft/yr in the shallow and intermediate aquifer zones. The groundwater flow rate varies as a function of depth, with groundwater at shallower depths moving more rapidly than the groundwater at deeper depths. At these groundwater flow rates, TRC believes that it is appropriate for the performance monitoring events to be conducted on a quarterly (3-month) basis. By conducting a pre-injection, baseline monitoring event and subsequent 3-month (quarterly) sampling activities, suitable field data can be collected to monitor and evaluate the progress and performance of the ABC+® injection effort.

Approximately 3 months following completion of the ABC+® injection activities, TRC field technicians will mobilize to the site to begin collecting the initial round of the field indicator parameters and key laboratory performance indicator parameters. Table 1 and Table 2 provide a listing of the performance monitoring locations and the specific performance monitoring parameters, for permanent wells and direct-push sample locations, respectively, that will be evaluated during this sampling event.

3.5.1 Quarterly Performance Monitoring Activities

At 3-month intervals following the ABC+® injection event, TRC expects to conduct routine sampling and evaluation of the field parameters and key performance indicators listed on Table 1. The objective of these performance monitoring activities is to discern how the distribution of the ABC+® treatment materials is progressing within the

subsurface. These key field and performance-based indicator parameters are listed, below:

- pH
- specific conductance
- temperature
- turbidity
- sulfate
- bromide
- DO
- ORP
- dissolved ferrous iron
- nitrate
- chloride
- Semi-qualitative lactate peak

These key field and performance indicator parameters will be evaluated during the 3-month, 6-month, 9-month and 12-month sampling intervals (following completion of the ABC+® injections) and conducted at 37 of the 45 permanent monitoring wells situated within the upper VOC plume area plus the five additional wells located northeast of the upgradient plume (see Table 1). Monitoring wells located upgradient of the treatment area and wells located at a sufficient distance from the treatment area as to not experience treatment are not included as performance monitoring wells. The performance monitoring network is illustrated on Figure 6. This network includes monitoring wells screened in the shallow, intermediate, top of rock and bedrock zones. As discussed in Section 3.5.2, supplemental DPT sampling and more comprehensive VOC analytical activities will also be conducted during the 6-month and 12-month sampling events. More details and information regarding these sampling events follows.

During each of the 3-month performance monitoring events, wells will be purged until the pH and specific conductance values have stabilized. For the field and indicator parameters, removal of three well volumes of groundwater will not be required, as reliable and meaningful data can be collected once the pH and specific conductance have stabilized. DO and ORP measurements will be collected during well purging activities, using a flow-through cell. Turbidity and temperature values will be collected and recorded, but these data will not be used as a basis for groundwater quality stabilization. Purge water will be managed and disposed as described under Section 2.3.

Once stabilization of the groundwater can be demonstrated, groundwater samples will be collected. A filtered sample of the groundwater will be collected for field analysis of the dissolved ferrous iron concentration. Unfiltered groundwater samples will be collected and submitted to the analytical laboratory for sulfate, nitrate, chloride, and bromide analysis via EPA Method 300. The chromatographs generated using EPA Method 300 will also be evaluated to discern the presence/absence of a lactate peak.

TRC's prior experience has revealed that ion chromatography can document the presence of a lactate peak that can serve as a useful line of evidence that the ABC+® treatment materials have migrated into a particular area.

3.5.2 Semi-Annual and Annual Performance Monitoring Activities

At the mid-point of the ABC+® pilot study (*e.g.*, approximately 6 months following the ABC+® injections), TRC expects to conduct a broader groundwater sampling event that would encompass all of the quarterly field indicator parameters and performance indicators, as well as VOC analyses and dissolved gases that will be conducted at both the permanent monitoring well locations and the supplemental DPT boring locations.

Semi-annual monitoring will be conducted following a 6-month treatment interval and performed on the 42 permanent performance monitoring wells and the 8 multi-depth DPT sampling locations (see Figure 6). After a 12-month treatment interval has transpired, TRC anticipates that a similar level of effort will be conducted to comprise the annual sampling event and the final performance monitoring activity prior to preparation of the final pilot study report.

The analytical parameters that will be monitored during both the semi-annual and annual performance monitoring events are summarized in Table 1 and Table 2, and further discussed, below:

- pH
- specific conductance
- temperature
- turbidity
- sulfate
- bromide
- VOCs (EPA Method 8260)
- DO
- ORP
- dissolved ferrous iron
- nitrate
- chloride
- Semi-qualitative lactate peak
- Dissolved gases (*i.e.*, methane, ethane, ethene via EPA Method RSK 175)

During the semi-annual and annual monitoring events, permanent wells will be purged and sampled in accordance with the approved SAP. Purge water will be managed and disposed as described under Section 2.3.

Well construction details for each of the 42 permanent monitoring wells included in the performance monitoring program are provided in Table 3. Table 3 provides key details

regarding these monitoring wells, including the vertical interval within the aquifer that is monitored by each well. For the semi-annual and annual monitoring events, the 8 multi-depth DPT sample locations will be sampled to supplement the well coverage afforded by the permanent wells. As discussed earlier, the locations and depths of the various multi-depth DPT borings will be documented, so that sampling activities conducted during the semi-annual (6-month) event can be generally replicated during the annual sampling event. The integrated network of permanent monitoring wells and multi-depth DPT borings is illustrated on Figure 6. This network includes 7 top of rock and 4 bedrock monitoring wells, located beneath the zone of treatment, which will be used to assess potential changes in water quality in the deeper portions of the aquifer resulting from the injection and treatment processes.

Upon substantial completion of the pilot study, TRC intends to conduct an annual sampling event that is identical in scope to the semi-annual performance monitoring event. With the completion of the annual sampling event, TRC will have comprehensive sampling data collected during pre-injection and post-injection time-frames at 42 permanent monitoring wells and 8 multi-depth DPT borings – all located within the up-gradient VOC plume area. Of the permanent monitoring wells, 18 can be characterized as shallow wells, 13 were constructed to investigate intermediate depths, 7 wells were installed to the top-of-rock, and 4 were installed into bedrock. Each of the 8 multi-depth DPT sampling locations will be advanced to investigate the shallow zone, intermediate zone and top of the transition zone areas. TRC intends to integrate these multi-depth DPT borings with the permanent monitoring well network to provide an added level of flexibility and responsiveness to unexpected field conditions that may be encountered. The performance monitoring network anticipated for the pilot study will provide us with a detailed and comprehensive assessment of groundwater quality changes that may occur as a consequence of the ABC+® treatment activities conducted within the up-gradient VOC plume area.

During our August 30, 2018 discussions, the Department requested that qPCR testing of the groundwater be conducted to evaluate changes in the microbial community that might occur during the duration of the pilot study. Previously, TRC has described qPCR testing and evaluations that would be conducted within groundwater collected along the longitudinal axis of the up-gradient VOC plume area at the following monitoring wells:

- RMW-27 (shallow groundwater interval),
- RMW-18A (intermediate groundwater interval), and
- RMW-20B (top of rock groundwater interval).

In addition to the qPCR samples that will be collected during the pre-injection sampling activities, TRC also anticipates collection of additional qPCR samples from these same monitoring wells during both the semi-annual (6-month interval) and annual (12-month interval) performance monitoring events. These additional qPCR test results should provide us with additional lines of evidence regarding observed changes relating to viable microbial populations and ERD-related enzymatic activity/response.

3.6 Evaluation of Performance Criteria

Table 4 summarizes and describes the various performance criteria that TRC anticipates applying during the expanded pilot study. These performance criteria will be used to evaluate and assess the progress and performance of the Expanded ABC+® Pilot Study. These performance criteria have been developed to respond to SC DHEC's request for inclusion of site-specific performance criteria against which the field data collected during the pilot study may be evaluated to gauge and assess how the observed distribution of treatment materials have progressed across and within the aquifer and the relative effectiveness of the treatment in promoting and sustaining reductions both the mass and concentration of VOCs.

The performance monitoring criteria set forth in Table 4 have been developed as a function of TRC's prior knowledge and experience with ABC+® as a treatment technology at sites exhibiting chlorinated ethene impacts. This pilot study has been developed to critically assess and evaluate the performance of ABC+® treatment within the site-specific details and considerations of the former WPH-Clemson facility. As with all pilot studies, we expect to encounter various unexpected circumstances and uncertainties as we investigate the response of the underlying aquifer to these treatments. It is our collective desire and intent to evaluate and discuss all of the site data, laboratory results and interpretations with SC DHEC in a collaborative and unbiased manner. Thus, the following discussion is offered for your review and consideration:

DO levels and ORP represent standard performance criteria that are routinely applied for anaerobic-based microbial treatment techniques. Having previously documented that groundwater quality conditions at the WPH-Clemson site were primarily aerobic, TRC anticipates that application of the ABC+® treatment materials should considerably decrease DO levels and drive ORP conditions to negative values. If this should not be the case, then there would exist a likelihood that the ABC+® may not migrating along a desired pathway and further discussion/adjustment to the pilot study treatment strategy may be required.

During the pre-injection monitoring event, TRC anticipates documenting that dissolved ferrous iron levels are low to non-detect, at a time prior to treatment. After application of the ABC+®, we would expect Fe2+ levels to gradually increase with time. This would be expected to occur

as a function of ongoing microbial-based iron reduction. The presence of dissolved ferrous iron is a useful line of evidence that ERD is occurring, as well as an indicator of abiotic ZVI treatment activity.

As the Department has noted, the ultimate performance criteria for this pilot study is linked to the extent and magnitude that the observed VOC mass is reduced, over time. By tracking VOC concentrations over the course of the pilot study, we anticipate being able to observe and document changes in the distribution and concentration of VOCs within the upgradient plume. Introducing the concept of molarity into the pilot study evaluations allows us to anticipate/discern the influence that degradation of the VOC parent compound TCE/PCE and the subsequent generation of VOC daughter products plays in the observed changes to contaminant concentration. Once more, if such changes are not occurring, it is most likely a consequence of the VOC-affected groundwater not contacting the ABC+®. Based on our prior experience, we would offer that VOC mass reduction observed in excess of 80% should be viewed as unequivocal evidence of success. Similarly, VOC mass reduction below a target level of 40% would suggest a need for additional discussion and/or adjustment to the pilot study. VOC mass reductions between these levels will be evaluated in conjunction with other lines of evidence to assess the level of success.

By closely monitoring cis-DCE and vinyl chloride (VC) levels during the pilot study, we allow ourselves the opportunity to observe how the ABC+® treatment materials facilitate transformation/reduction of the TCE/PCE parent compounds into the respective daughter products. Over the course of the pilot study, we would expect the cis-DCE and VC levels to increase above their previously observed baseline concentrations. Gradually, we would then expect them both begin to decline and provide us with another line of evidence that ongoing biotic/abiotic treatment is occurring. Similarly, we expect the presence of dissolved gases (like methane, ethane and ethene) to serve as another useful indicator of ongoing anaerobic biological activity.

Like DO and ORP, pH is an important indicator parameter because the anaerobic microbes (DHC) tend to experience optimal growth and treatment efficacy within a relatively narrow range of pH values. In the event we should observe pH conditions that are outside of these bounds, there would be a need to discuss possible adjustments to the pilot study. For the Department's information and consideration, the ABC+® treatment formulation already contains an alkalinity buffer to account for unexpected influences.

TRC has included a number of field and laboratory indicator parameters (*i.e.*, specific conductance, nitrate, chloride, sulfate, bromide and the semi-quantitative lactate peak) to represent additional lines of evidence that the ABC+® treatment materials have migrated into a

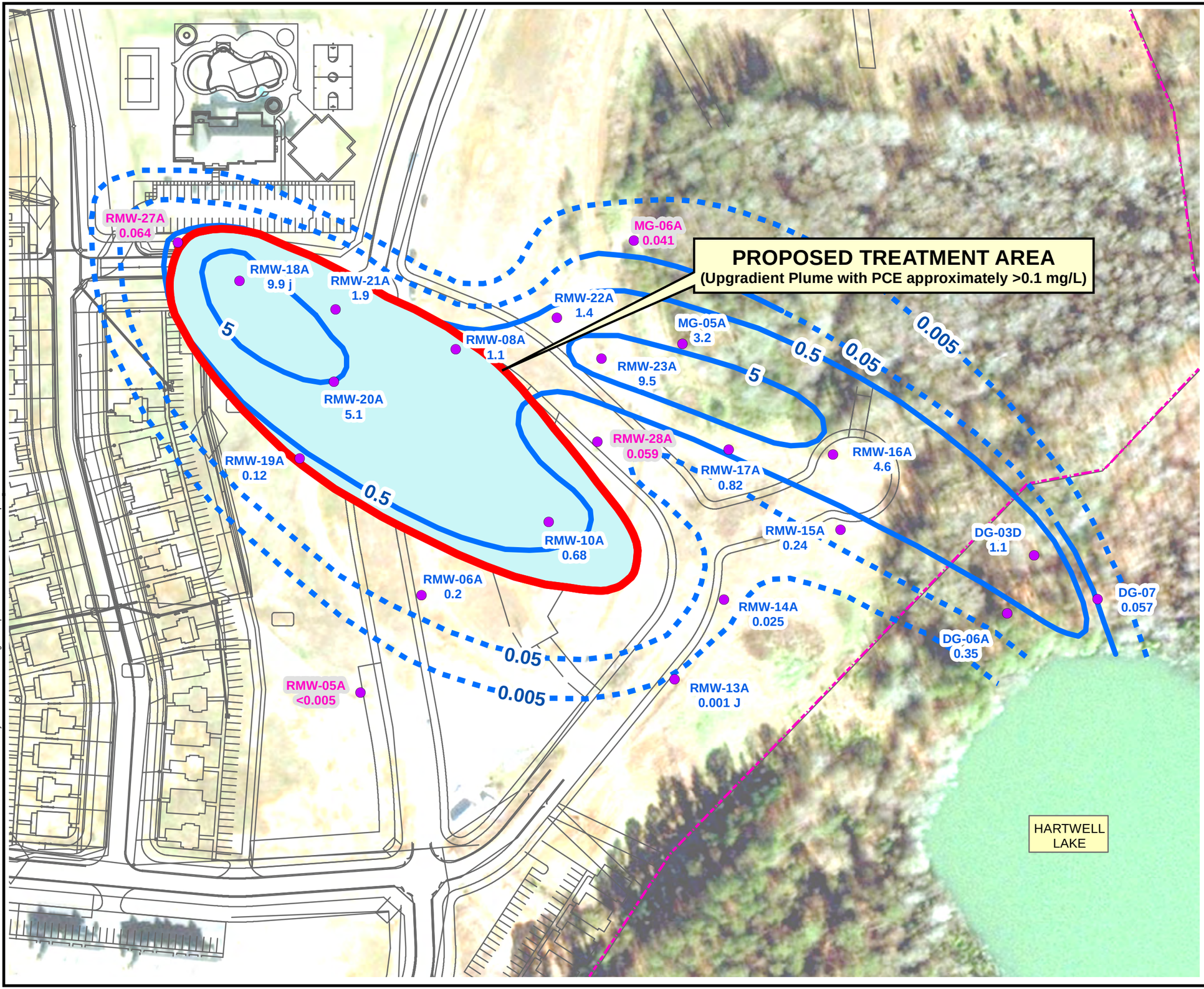
particular area and are at work. TRC has found bromide to be a particularly useful trace that we routinely add to ERD treatment supplements. Bromide is not typically present in Upstate soils and groundwater and it's also very cost-effective and can be detected at low concentrations. In the event that bromide (or other key indicator parameters) is not being detected in a down-gradient well/boring location, then there may be some underlying geologic control or unexpected site condition that may require additional discussion.

Table 3
Performance Monitoring Well Network

Well ID	Monitored Interval	Well Diameter (inches)	Northing	Easting	Ground Surface Elevation (ft MSL)	Top of Well Casing Elevation (ft MSL)	Total Well Depth (ft BGS)	Well Screen Interval (ft BGS)	Well Completion
RMW-01	Water Table	2	1028610.55	1440162.88	683.07	686.01	24	14-24	Above grade
RMW-02	Water Table	2	1029038.558	1440286.92	687.05	686.99	29	19-29	Flush
RMW-05A	Intermediate	2	1028464.99	1440290.78	683.11	685.89	55	50-55	Above grade
RMW-05B	Top of Rock	2	1028470.51	1440292.39	682.98	685.96	136	131-136	Above grade
RMW-06	Water Table	2	1028584.436	1440373.681	681.77	684.56	24	14-24	Above grade
RMW-06A	Intermediate	2	1028591.295	1440370.09	681.74	684.62	55	50-55	Above grade
RMW-07	Water Table	2	1028796.459	1440345.889	683.55	686.61	25	15-25	Above grade
RMW-08	Water Table	2	1028909.298	1440421.223	680.59	683.68	21	11-21	Above grade
RMW-08A	Intermediate	2	1028911.33	1440414.925	680.57	683.49	75.5	65.5-75.5	Above grade
RMW-09	Water Table	2	1028941.255	1440515.4	676.68	679.95	19	9-19	Above grade
RMW-10	Water Table	2	1028692.186	1440534.661	682.29	685.15	25	15-25	Above grade
RMW-10A	Intermediate	2	1028687.04	1440535.423	682.25	684.96	55.50	50.5-55.5	Above grade
RMW-10B	Top of Rock	2	1028680.061	1440535.324	682.2	685.04	112	107-112	Above grade
RMW-10C	Bedrock	2	1028674.501	1440535.071	682.02	684.97	123	118-123	Above grade
RMW-11	Water Table	2	1028427.396	1440571.125	676.31	679.47	21	11-21	Above grade
RMW-13	Water Table	2	1028477.539	1440697.535	676.15	679.18	18.50	8.5-18.5	Above grade
RMW-13A	Intermediate	2	1028482.191	1440699.214	675.96	678.96	55.5	50.5-55.5	Above grade
RMW-14	Water Table	2	1028591.034	1440764.739	678.1	681.12	21	11-21	Above grade
RMW-14A	Intermediate	2	1028585.679	1440763.67	677.77	680.74	55	50-55	Above grade
RMW-14B	Top of Rock	2	1028577.332	1440763.544	677.7	680.63	132	127-132	Above grade
RMW-14C	Bedrock	2	1028572.418	1440762.328	677.76	681.16	143	138-143	Above grade
RMW-18	Water Table	2	1028999.353	1440138.4	685.95	688.96	25	15-25	Above grade
RMW-18A	Intermediate	2	1029000.245	1440133.515	685.86	688.96	55	50-55	Above grade
RMW-19	Water Table	2	1028759.696	1440210.184	685.35	688.23	26	16-26	Above grade
RMW-19A	Intermediate	2	1028769.533	1440211.815	685.19	688.09	55	50-55	Above grade
RMW-20	Water Table	2	1028872.996	1440257.536	684.53	687.45	23	13-23	Above grade
RMW-20A	Intermediate	2	1028869.054	1440256.479	684.8	687.35	55	50-55	Above grade
RMW-20B	Top of Rock	2	1028863.852	1440255.1	684.5	687.1	108	103-108	Above grade
RMW-20C	Bedrock	2	1028857.563	1440254.491	687.26	687.26	119	114-119	Above grade
RMW-21	Water Table	2	1028957.931	1440257.111	688.52	688.52	24	14-24	Above grade
RMW-21A	Intermediate	2	1028963.108	1440258.52	688.56	688.56	55	50-55	Above grade
RMW-23	Water Table	2	1028901.862	1440601.755	675.47	678.49	16	6-16	Above grade
RMW-23A	Intermediate	2	1028899.181	1440604.209	675.06	677.94	55	50-55	Above grade
RMW-23B	Top of Rock	2	1028896.445	1440610.401	674.5	677.88	92	87-92	Above grade
RMW-23C	Bedrock	2	1028893.709	1440616.455	674.45	677.44	98	93-98	Above grade
RMW-24	Water Table	2	1028796.827	1439999.369	683.04	686.14	25	15-25	Flush
RMW-26	Water Table	2	1029024.434	1440437.373	682.52	685.19	24	14-24	Above grade
RMW-27	Water Table	2	1029049.48	1440058.33	684.96	687.91	25	15-25	Above grade
RMW-27A	Intermediate	2	1029050.23	1440053.17	684.91	687.79	55	50-55	Above grade
RMW-27B	Top of Rock	2	1029050.45	1440048.49	684.85	687.83	96.5	91.5-96.5	Above grade
RMW-28A	Intermediate	2	1028791.41	1440598.85	678.42	681.5	55	50-55	Above grade
RMW-28B	Top of Rock	2	1028793.26	1440592.44	678.4	681.19	98	93-98	Above grade

Table 4
Performance Monitoring Criteria

Indicator Parameter	Performance Criteria	Relevance
Dissolved Oxygen (DO) and Oxidation-Reduction Potential (ORP)	Decrease below baseline levels	Good overall indicators that suitable anaerobic treatment conditions are present
Dissolved Ferrous Iron (Fe+2)	Increase over baseline levels	Indication of microbial iron reduction
PCE/TCE concentration and molarity	Decrease below baseline levels	VOC mass reduction >= 80 % is indicative of treatment success. Mass reduction of less than 40% indicates possible need for treatment adjustment
cis-DCE/VC	Initial increase over baseline levels followed by decrease in both concentration and molarity	Indicative of ongoing PCE degradation
Dissolved gases (methane, ethane, and ethene)	Increase over baseline levels	Presence indicates ongoing degradation of chlorinated VOCs is occurring
pH	>5 and <9	Optimal range for desired microbial activity
Specific conductance	Increase over baseline levels	Can indicate the migration of lactate-based materials
Nitrate	Decrease over baseline levels	Useful indication of anaerobic biodegradation
Chloride	Increase over baseline levels	Indirect indicator of reductive dechlorination
Sulfate	Decrease over baseline levels	Indicates sulfate reducing conditions are present
Bromide tracer	Increase over baseline levels	Good groundwater tracer that indicates migration of ABC+® injectate
Lactate peaks	Lactate peak can reveal itself during ion chromatography analysis for bromide	Good indication there is ongoing migration of lactate-based materials
qPCR testing	Increase over baseline	Can provide evidence that suitable microbial communities are present as well as enzymatic activity related to ERD activity



LEGEND

- Intermediate Aquifer Monitoring Well
- PCE Isoconcentration Contour (mg/L) Intermediate Aquifer - July 2014 and June 2015 (Dashed Where Inferred)
- Proposed Treatment Area Outline
- Property Boundary (Approximate)

NOTES

Aerial Photograph Source: ESRI World Imagery (2018)

Groundwater samples collected July 2014 (Blue) and June 2015 (Pink).

Locations of buildings and other structures provided by developer.

N

0 100 200 Feet

1 " = 123 '

1:1,474

PROJECT:

FORMER WESTPOINT HOME, INC. SITE
CLEMSON, SOUTH CAROLINA

TITLE:

PROPOSED TREATMENT AREA

DRAWN BY:	WIXON S	PROJ NO.:	300688.0000.000 PHASE 5
CHECKED BY:	CLARK L		**FIGURE 3**
APPROVED BY:	WEBB S		
DATE:	SEPTEMBER 2018		

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

FILE NO.: Fig 3 - Proposed Treatment Area.mxd

Plot Date: 9/6/2018, 11:03:59 AM by RWIXON -- LAYOUT: ANSI B(11"x17")
Path: U:\West Point Home\Clemson SC\ArcGIS\10300688\Pilot Study Work Plan\2018-09\Fig 3 - Proposed Treatment Area.mxd
Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0

TRC - GIS

Line 1 = 7 Locations

Line 2 = 9 Locations

Line 3 = 12 Locations

Line 4 = 14 Locations

Line 5 = 14 Locations

Line 6 = 14 Locations

Line 7 = 10 Locations

PROPOSED TREATMENT AREA
(Upgradient Plume with PCE approximately >0.1 mg/L)

RMW-27A 0.064
RMW-18A 9.9 j
RMW-21A 1.9
RMW-22A 1.4
MG-06A 0.041
MG-05A 3.2
RMW-08A 1.1
RMW-23A 9.5
RMW-20A 5.1
RMW-19A 0.12
RMW-28A 0.059
RMW-17A 0.82
RMW-16A 4.6
RMW-15A 0.24
DG-03D 1.1
RMW-10A 0.68
RMW-06A 0.2
RMW-14A 0.025
DG-06A 0.35
DG-07 0.057
RMW-05A <0.005
RMW-13A 0.001 J

5
0.5
0.05
0.005

HARTWELL LAKE

LEGEND

- Intermediate Aquifer Monitoring Well
- PCE Isoconcentration Contour (mg/L) Intermediate Aquifer - July 2014 and June 2015 (Dashed Where Inferred)
- Proposed Treatment Area Outline
- Property Boundary (Approximate)

NOTES

Aerial Photograph Source: ESRI World Imagery (2018)

Groundwater samples collected July 2014 (Blue) and June 2015 (Pink).

Locations of buildings and other structures provided by developer.

Injection locations may be altered based on results of pre-injection groundwater sampling.

0 100 200 Feet

1 " = 123 '

1:1,473

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

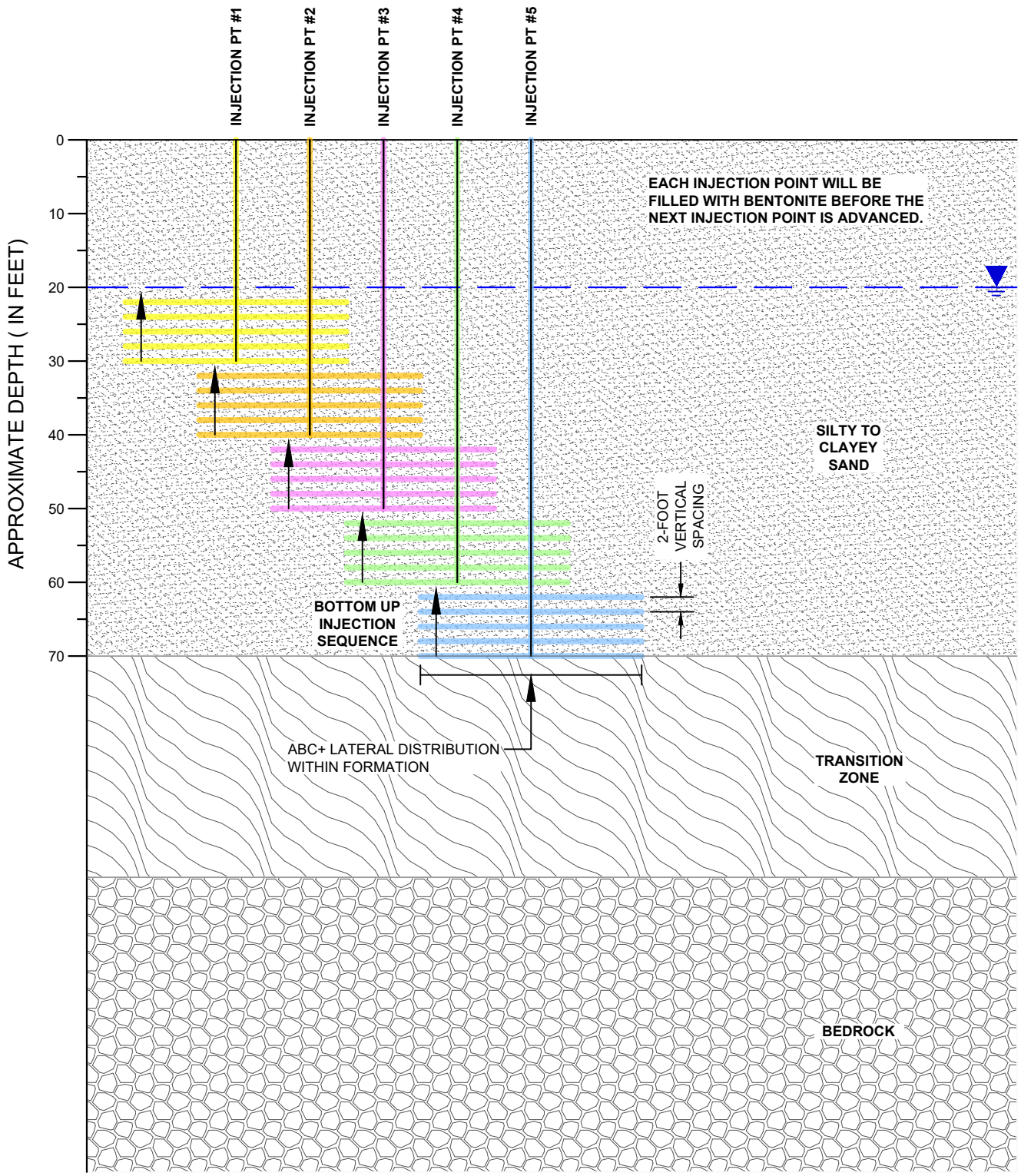
TITLE:
PROPOSED INJECTION LAYOUT

DRAWN BY:	WIXON S	PROJ NO.:	300688.0000.000 PHASE 5
CHECKED BY:	CLARK L		FIGURE 4
APPROVED BY:	WEBB S		
DATE:	SEPTEMBER 2018		

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

FILE NO.: Fig 4 - Proposed Injection Layout.mxd

TRC - GIS
Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0
Plot Date: 9/6/2018, 11:43:50 AM by RWIXON -- LAYOUT: ANSI B(11"x17")
Path: U:\West Point Home\Clemson SC\ArcGIS\10300688\Pilot Study Work Plan\2018-09\Fig 4 - Proposed Injection Layout.mxd



NOT TO SCALE

50 International Drive
Patewood Plaza Three, Suite 150
Greenville, SC 29615
Phone: 864.281.0030

PROJECT:

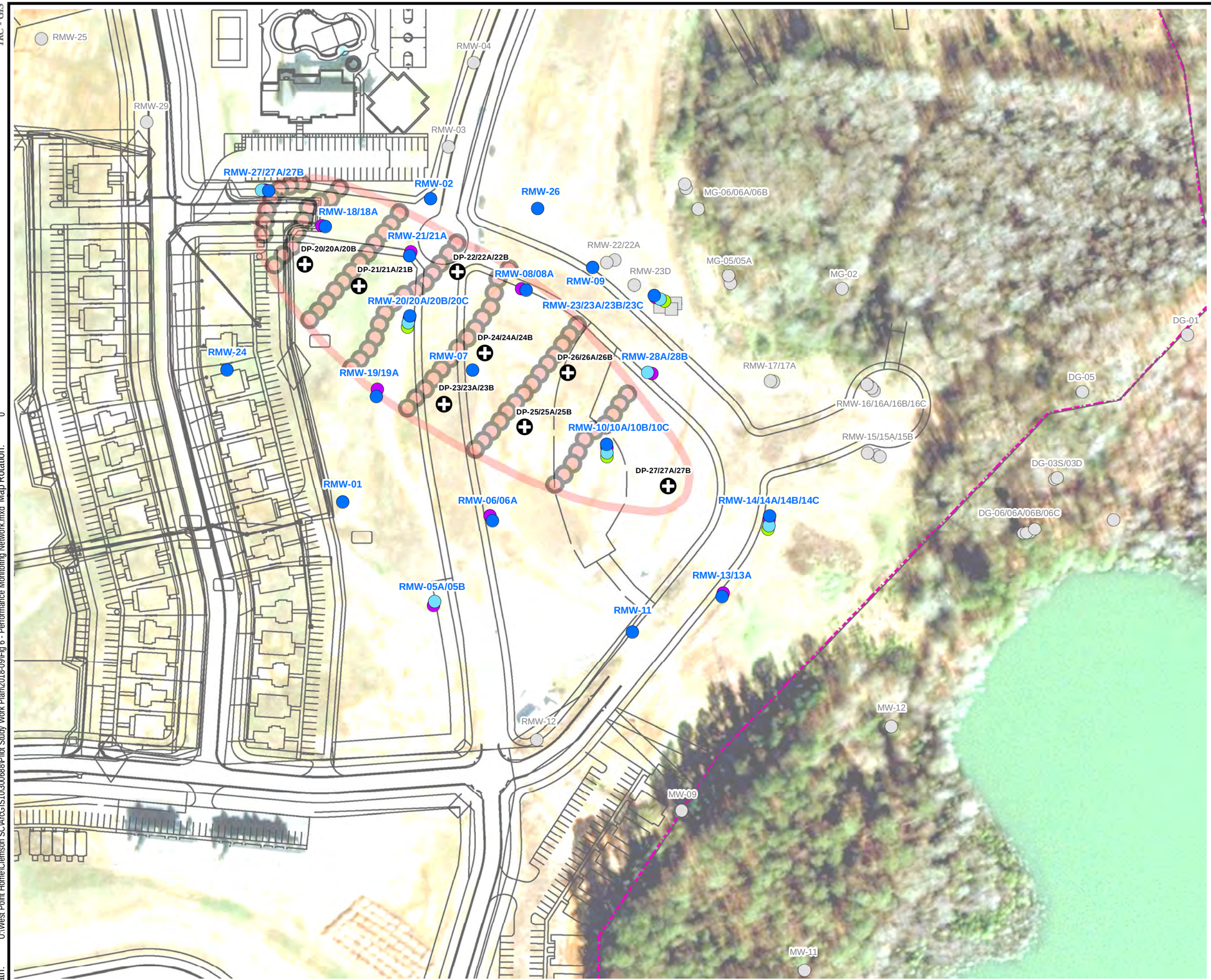
FORMER WESTPOINT HOME, INC. SITE
CLEMSON, SOUTH CAROLINA

TITLE:

ABC+ INJECTION STRATEGY

DRAWN BY:	S.ALBERTS
CHECKED BY:	L.CLARK
APPROVED BY:	L.CLARK
DATE:	OCTOBER 2018
PROJ. NO.:	300688.0000.0000.05
FILE:	300688.0000.0000.05-01.dwg

FIGURE 5



LEGEND

- Water Table Aquifer Monitoring Well
- Intermediate Aquifer Monitoring Well
- Top of Rock Aquifer Monitoring Well
- Bedrock Aquifer Monitoring Well
- Multi-depth Direct-Push Technology (DPT) Sample Location
- Observation Well
- Property Boundary (Approximate)

NOTES

Aerial Photograph Source: ESRI World Imagery (2018)

Locations of buildings and other structures provided by developer.

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

0 100 200 Feet

1 " = 133 '

1:1,600

PROJECT:

FORMER WESTPOINT HOME SITE
CLEMSON, SOUTH CAROLINA

TITLE:

PERFORMANCE MONITORING NETWORK

DRAWN BY:	WIXON S	PROJ NO.:	300688.0.0 PHASE 5
CHECKED BY:	CLARK L		**FIGURE 6**
APPROVED BY:	WEBB S		
DATE:	SEPTEMBER 2018		

TRC

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

FILE NO.: Fig 6 - Performance Monitoring Network.mxd

TRC - GIS
Coordinate System: NAD 1983 StatePlane South Carolina FIPS 3900 Feet (Foot US)
Map Rotation: 0
Plot Date: 9/25/2018, 08:54:16 AM by RWIXON -- LAYOUT: ANSI B(11"x17")
Path: U:\West Point Home\Clemson SC\ArcGIS\10\300688\Pilot Study Work Plan\2018-09\Fig 6 - Performance Monitoring Network.mxd

Section 4
Regulatory Reporting

As the quarterly performance monitoring efforts progress, TRC expects to generate periodic update reports that will be prepared and submitted to SC DHEC. Following the first and third quarters, we anticipate the reporting to be more concise and consist of a cover letter discussion, data point location map and applicable data summary tables. The content of the second quarterly report will be more detailed and include a summary of relevant observations, data tables revealing analytical results and VOC concentrations, VOC concentration and molarity graphs, contaminant distribution plume maps, and cross sections, as appropriate. It is also possible that conference calls, site visits and/or meetings might be coordinated with the Department to discuss the data, findings, observations, and align on a suitable path forward for implementation during the ensuing performance monitoring period.

Upon completion of the fourth quarterly performance monitoring event and likely completion of the pilot study, TRC envisions preparation of the more detailed and comprehensive Expanded ABC+® Pilot Study Report. At this time, TRC expects this technical report to be prepared in a manner and format consistent with the 2017 ABC+® Pilot Study Report. As previously requested by the Department, the Expanded ABC+® Pilot Study Report will include pre- and post-injection VOC isoconcentration maps and other relevant documentation that will support review and consideration of the ABC+® treatment technology.

Following SC DHEC review and consideration of the final report, it is possible that additional conference calls, site visits and/or meetings may be required to discuss the pilot study data, review its findings, observations, and conclusions, and develop alignment regarding a suitable path forward with regards to refining the existing FFS and defining the next steps towards implementing a site-wide treatment remedy.

Section 5
Schedule

Upon our receipt of formal SC DHEC approval of this workplan, WPH anticipates initiating the work activities described within this workplan within 30 days. Table 5 provides a preliminary schedule of the activities that can be reasonably projected at this time. TRC anticipates that this schedule will be periodically updated and shared with SC DHEC, as the work progress and/or unexpected Site conditions are encountered or technical adjustments are necessary to key milestone events or deliverables.

Table 5
Preliminary Pilot Study Schedule

ITEM	DATE
Receive SC DHEC Approval to Proceed	Week 0
PRE-INJECTION GROUNDWATER QUALITY	
Well Redevelopment and Rehabilitation Activities	Week 2
Collect Water level measurements and groundwater sampling (77 existing wells and 15 multi-level DPT points)	Week 4 – Week 5
Conduct laboratory analyses	Week 5 – Week 7
Conduct data validation, evaluation, and tabulation	Week 8 – Week 9
Submit interim report on Groundwater Quality Conditions	Week 12
ABC+® PILOT STUDY	
Prepare/submit UIC Permit Application	Week 1 – Week 2
Prepare/submit DPT Permit Application	Week 1 – Week 2
Receive UIC Permit Approval	Week 12
Conduct driller/remediation subcontracting, scheduling, and coordination	Week 13 – Week 14
Conduct ABC+® Injections at 80 locations across upper VOC plume area	Week 18 – Week 22
Conduct Quarterly and Semi-Annual Performance Monitoring	At 3 Month Intervals following Injection
Quarterly and Semi-Annual Progress Reporting	4 Weeks following receipt of Quarterly Performance Monitoring results
Conduct data evaluation of final pilot study results and prepare final pilot study report for submittal to SC DHEC	14-15 Months following completion of injection Activities
Discuss Expanded Pilot Test Report with SC DHEC	16 Months following completion of Injection Activities

Section 6
References

TRC Environmental Corporation (TRC). 2015. *Workplan for Well Installation, ABC+® Pilot Study, and Focused Feasibility Study*. WestPoint Home, Inc. Clemson, South Carolina. April.

TRC. 2017a. *ABC+® Pilot Study Report*. Former WestPoint Home Site – Clemson, South Carolina. May 1.

TRC. 2017b. *Focused Feasibility Study Report*. For Remediation of VOC-Affected Groundwater. WestPoint Home, Inc. Former Clemson, South Carolina, Facility. August.

Appendix A
ABC+® Product Description

REDOX TECH, LLC

"Providing Innovative In Situ Soil and Groundwater Treatment"

ABC+® PRODUCT DESCRIPTION

Redox Tech, Inc is pleased to offer an enhanced version of our industry proven Anaerobic Biochem (ABC®) formula, promoting both anaerobic biodegradation and reductive dechlorination of halogenated solvents in groundwater. This product, Anaerobic Biochem Plus (ABC+®), is a mixture of our ABC® formula and Zero Valent Iron (ZVI). Formulated and mixed on a site-by-site basis, generally up to seventy-five percent (75%) by weight of ZVI can be added. ZVI has been proven and widely accepted as an effective in situ remediation technology for treating chlorinated solvents such as TCA, PCE, TCE, and daughter products. The degradation process using ZVI alone is comprised of several abiotic reductive dechlorination processes occurring on the surface of the granular iron, with the iron acting primarily as an electron donor.

The addition of ZVI to the ABC® mixture provides a number of advantages for enhanced reductive dechlorination (ERD). The ZVI will provide an immediate reduction. The ABC® will provide short-term and long-term nutrients to support anaerobic bacteria growth, which also assists in creating a reducing environment. ABC® contains soluble lactic acid and a phosphate buffer that maintains the pH in a range that is best suited for microbial growth and provides an important micronutrient for bioremediation. In addition, the corrosion of iron metal yields ferrous iron and hydrogen, both of which are possible reducing agents. The hydrogen gas produced is also an excellent energy source for a wide variety of anaerobic bacteria.

The ABC® and ZVI are mixed with potable water and emplaced in the subsurface simultaneously. The dilution factor (i.e. water content) can be adjusted to achieve optimal dispersion and distribution based on site-specific parameters such as well spacing, permeability of the formation, and contaminant concentrations. The solution can be emplaced by a variety of techniques, including injection through wells or drill rods (for permeable geologic environments such as sands and fractured rock), hydraulic fracturing (for lower permeable environments such as silt and clay), and through soil blending (for all unconsolidated shallow depth applications less than 20 ft bgs). All of these techniques are part of Redox Tech's service offerings.

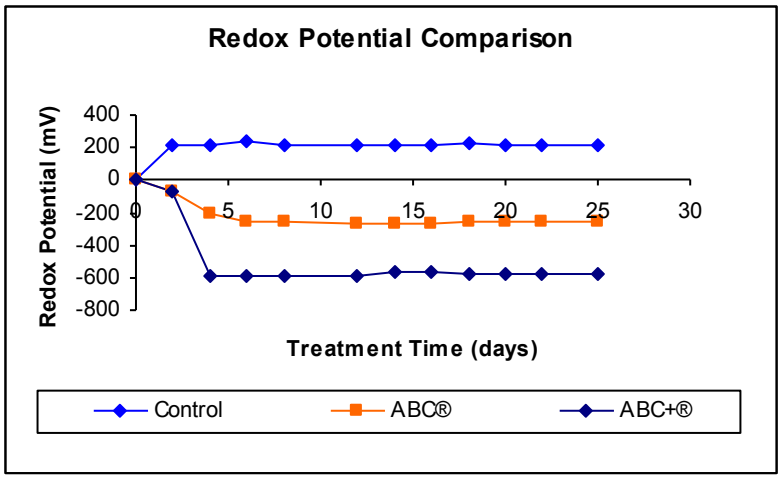
ABC+ also provides an effective treatment of soluble chromium by rapidly reducing the hexavalent state to the insoluble trivalent state. The dispersed ZVI also provides a multitude of immobilizing sorption sites for other heavy metal contaminants.

Benefits of ABC+ include:

- The presence of ZVI allows for the rapid and complete dechlorination of target compounds. Degradation rates using ZVI are several orders of magnitude greater than under natural conditions. As a consequence, the process does not result in the formation of daughter products other than ethene, ethane, and methane.
- ABC can potentially last more than 2 years in the subsurface environment due to slow releasing compounds, allowing for long-term anaerobic biodegradation

200 QUADE DRIVE, CARY, NC 27513 TEL 919.678.0140 FAX 919.678.0150
WWW.REDOX-TECH.COM E-MAIL: JHASELOW@REDOX-TECH.COM

- ZVI has been shown to last greater than 10 years in environmental applications
- By creating a reducing environment and a multitude of sorption sites, ABC+ has the ability to provide long term immobilization of heavy metals (e.g. Cr, Ni, Zn, Hg, As)
- Does not require direct contact to act on target constituents.
- Does not divert groundwater flow. ABC® is typically mixed at a 15% by weight solution with water. The viscosity of the solution is similar to sugar water and therefore does not measurably influence groundwater flow paths. Due to the relatively low volume of ZVI used, it does not measurably lower the bulk permeability of the formation.
- Ease of handling. The ABC+® product is comprised of food grade compounds and therefore does not require high-levels of personal protective equipment (PPE) or special training to handle. The ZVI is a stable compound that also requires low-level PPE protection.
- Patent protection: Redox Tech is licensed under Enviromental Technologies, Inc. (an Adventus Company) who is the current holder of patents pertaining to remediation using ZVI. Therefore, Redox Tech is able to market, sell, and emplace our ABC+ product. There is no patent infringement risk to the client in selecting the ABC+ approach.
- Price advantage. The cost of the ABC+ formula is an extremely competitive approach in relation to other ERD products on the market.
- ABC+ produces a significantly lower redox potential of approximately –600 mV



Let Redox Tech help formulate a remedial program for your site today. For more information visit our web page at www.redox-tech.com or contact:

John Haselow
Redox Tech, LLC
200 Quade Drive
Cary, NC 27513
919-678-0140
jhaselow@redox-tech.com

Appendix B
Proposed Bioaugmentation Product Information

Shaw's 4000-L Fermentor and Cell Concentrator

Simply Available

Shaw maintains the largest and most advanced fermentation facility in the environmental industry and is staffed with the industry's most experienced fermentation scientists. SDC-9™ cultures can be produced in volumes up to 4000 L per batch for treatment of even the largest contaminated sites. Typical lead times for large cultures (>200 L) are only 2 weeks, and smaller cultures are often available on even shorter notice.

About Shaw Environmental, Inc.

From restoring contaminated sites like the Fernald Closure Project in Ohio, a former uranium processing facility, to devising innovative solutions to complex environmental issues, such as the removal of MTBE and perchlorate, to designing modern, safe solid waste landfills, Shaw is a worldwide leader in environmental protection and remediation.

Using our engineering, design, and construction expertise, we work with our clients to:

- Remediate contamination and restore land to a usable state
- Safely dispose of hazardous and toxic waste, including high-level waste
- Develop modern solid waste landfills and transfer stations
- Keep the air and water contaminant-free
- Respond quickly and efficiently to emergency situations

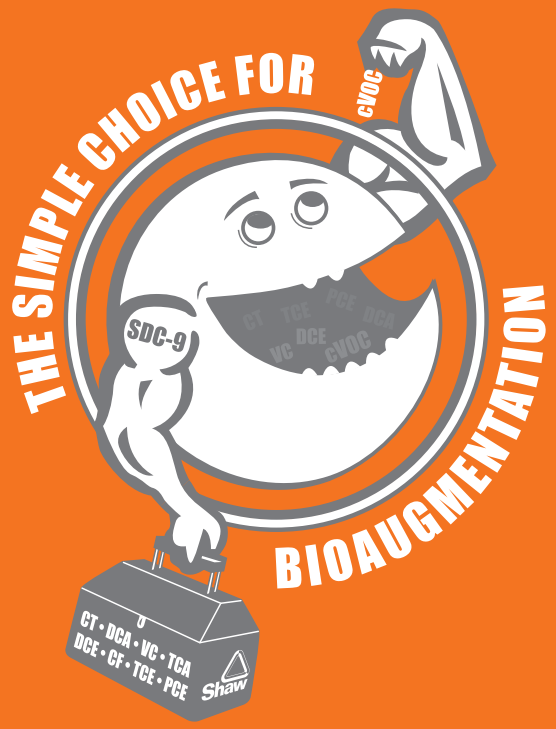
Shaw's broad experience and multidisciplinary approach provide the expertise and flexibility to meet your environmental project needs.

Contact

Robert J. Steffan, PhD
Director, Biotechnology Applications
17 Princess Road
Lawrenceville, NJ 08648
Phone: 609.895.5350
rob.steffan@shawgrp.com

www.shawgrp.com/bioaugmentation

33M032006D_3
04.17.08



The Simple Choice for Bioaugmentation™

Shaw's Dechlorinating Culture, SDC-9™

Shaw® a world of Solutions™

Shaw's Dechlorinating Culture—SDC-9™

The Simple Choice for Bioaugmentation™

Simply Better

- Degrades mixed chlorinated solvents (PCE, TCE, cDCE, VC, TCA, CT, CF)
- Not inhibited by Chloroform like other commercially available cultures
- Rapid and complete degradation of cDCE and Vinyl Chloride
- Degrades high concentrations of contaminants

Simply More for Your Money

- Lowest per-liter prices
- Highest DHC concentrations
- 10-fold cell concentration available to reduce shipping costs
- SDC-9 delivery kegs allow inexpensive and flexible culture injection
- No requirement for a Shaw technician to be on-site for injection

Simply Available

- 4000 L fermentation capacity
- Typical lead times only 2 weeks
- Affordable overnight UPS shipping

Simply Guaranteed

- Guaranteed lowest price!
- Guaranteed DHC concentrations
- Guaranteed highest activity
- Guaranteed lowest overnight shipping cost
- Cell concentration guarantees lowest culture impurities

Simply Better

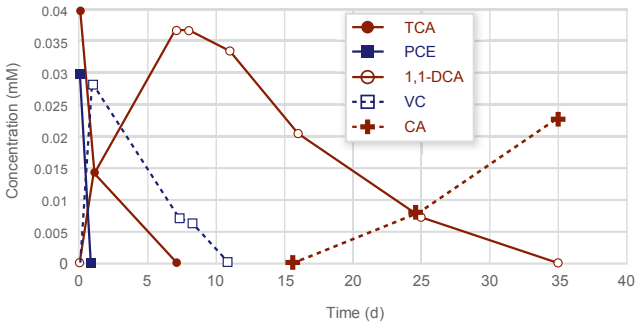
Shaw Environmental, Inc., a Shaw Group Company (Shaw) developed SDC-9™ specifically to treat chlorinated solvent contaminated aquifers. The culture contains Dehalococcoides sp. (DHC) bacteria that degrade a wide range of chlorinated contaminants via dehalorespiration. In addition to degrading highly chlorinated ethenes like PCE and TCE, the culture rapidly dechlorinates cDCE and vinyl chloride to non-toxic ethene, making it well suited for treating sites where remediation of PCE and TCE has stalled at these intermediates. In addition, SDC-9™ contains microbes capable of dehalogenating halomethanes (e.g., carbon tetrachloride and chloroform) and haloethanes (e.g. 1,1,1-TCA and 1,1-DCA), as well as mixtures of these halogenated contaminants. SDC-9™ is not inhibited by chloroform like other commercially available cultures. The culture has been successfully applied at sites throughout the United States, including some of the largest in situ bioaugmentation projects performed to date. The culture works effectively with any electron donor known to support reductive dehalogenation (e.g., vegetable oil, lactate, molasses, whey, etc.).

Simply More for Your Money

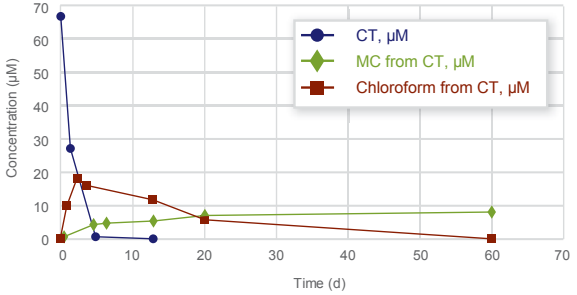
Kegs are shipped on ice in coolers and supplied with 2 quick connects (one for gas and one for liquid) that are fitted with hose barbs for attaching 1/4" ID tubing.

Shaw is the only company that concentrates its bacterial cultures before shipment to your site. The cell concentration process removes >90% of the fermentation by-products that accumulate during the fermentation process. This ensures that injection of SDC-9™ does not create unnecessary water quality issues. It also reduces shipping volume to ensure rapid and cost-effective delivery of SDC-9™ cultures. 180 L of SDC-9™ can be shipped overnight to your site in a single cooler. Overnight shipping allows your cultures to have their greatest activity when they arrive at your site.

Degradation of Mixed Chlorinated Solvents (PCE and 1,1,1-TCA) by SDC-9



Biodegradation of Carbon Tetrachloride by SDC-9



Shaw® a world of Solutions™