51778

AECOM

AECOM
10 Patewood Drive
Building 6, Suite 500
Greenville, SC 29615

T (864) 234-3000
F (864) 234-3069

July 12, 2017

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SITE ASSESSMENT, REMEDIATION & REVITALIZATION

Ms. Addie Walker
Bureau of Land and Waste Management
SC Department of Health & Environmental Control
2600 Bull Street
Columbia, SC 29201

RE: Focused Feasibility Study Report
Delavan Spray Technologies Site
Bamberg, South Carolina
SCDHEC VCC Number: 13-4762-RP
SCDHEC File Number: 51778
AECOM Project Number: 60314964

Dear Ms. Walker:

AECOM Technical Services, Inc. (AECOM), on behalf of United Technologies Corporation (UTC), is submitting to SCDHEC a copy of the Focused Feasibility Study Report for the Delavan Spray Technologies Site in Bamberg, South Carolina. A .pdf copy of the report is also included on the attached Compact Disk.

Please feel free to contact me if you have any questions or need additional information.

Sincerely,
AECOM Technical Services, Inc.

Walter C. Gerald

Walter C. Gerald, PG
Project Manager
walter.gerald@aecom.com
864-234-8925

cc: William Penn – United Technologies Corporation (1 copy via e-mail)
Kanistha Coombs – UTC Aerospace Systems (1 copy via e-mail)
Leslee Alexander – AECOM (1 copy via e-mail)
Matthew Zenker – AECOM (1 copy via e-mail)

Enclosure

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Focused Feasibility Study

United Technologies Corporation Delavan Spray Technologies Site 4334 Main Highway US Highway 301 South Bamberg, South Carolina

VCC 13-4762-RP

Prepared by:

AECOM Technical Services, Inc.
10 Patewood Drive
Building 6, Suite 500
Greenville, South Carolina

July 12, 2017

FOCUSED FEASIBILITY STUDY

UNITED TECHNOLOGIES CORPORATION (UTC)
DELAVAN SPRAY TECHNOLOGIES SITE
BAMBERG, SOUTH CAROLINA

RESPONSIBILITY PARTY VOLUNTARY CLEANUP CONTRACT NUMBER 13-4762

The undersigned certify that they have reviewed the attached document and that the document is in material compliance with the guidelines and requirements of the State of South Carolina and the South Carolina Department of Health and Environmental Control (SCDHEC) and specifically, requirements under the SCDHEC Voluntary Cleanup Contract (VCC). The data presentations contained herein are consistent with generally accepted practices in the environmental profession.

Prepared by:

LESLEE J. ALEXANDER REGISTERED No. 2433 SOUTH CAROLINA PROFESSIONAL GEOLOGIST

Leslee J. Alexander, PG
South Carolina PG No. 2433
AECOM Project Hydrogeologist

July 12, 2017
Date

Matthew Zenker
AECOM Project Engineer

July12, 2017
Date

Reviewed by:

WALTER C. GERALD REGISTERED No. 146 SOUTH CAROLINA PROFESSIONAL GEOLOGIST

Walter C. Gerald, PG
South Carolina PG No. 146
AECOM Project Manager

July 12, 2017
Date

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1.0 INTRODUCTION

AECOM has prepared this Focused Feasibility Study (FFS) for evaluation of remedial alternatives for residual chlorinated volatile organic compounds (cVOCs) source areas that have been identified beneath the Delavan Spray Technologies Site (Delavan Site). The site is located at 4334 Main Highway in Bamberg, South Carolina (Figure 1).

Assessments of soil and groundwater have been performed at the Site since December 2002. A Voluntary Cleanup Contract (VCC) (VCC 13-4762-RP) was signed between the South Carolina Department of Health and Environmental Control (SCDHEC) and Delavan Spray, LLC in July 2013. The response actions outlined in the VCC include, in part, the performance of a Remedial Investigation (RI), to evaluate environmental conditions beneath the property and in the Site vicinity (AECOM, 2014). VCC 13-4762-RP also states that if determined necessary by the Department (SCDHEC), conduct a Feasibility Study to evaluate remedial alternatives for addressing Contamination at the Site.

A Baseline Risk Assessment (BRA), was performed as part of the RI to evaluate risks to human health and the environment under current and likely future exposure scenarios (AECOM, 2014). The Human Health Risk Assessment portion of the BRA determined that the current site conditions do not pose a significant risk to on-Site workers that would necessitate remedial action, assuming the current commercial/industrial use of the property is maintained in the future. However, human health constituents of concern (COCs) were identified for a hypothetical future on-Site resident. Elevated concentrations of cVOCs, including tetrachloroethene (PCE), have been detected in shallow groundwater beneath the vicinity of the former degreasers and the former PCE underground storage tank (UST). Concentrations of PCE in excess of the United States Environmental Protection Agency (USEPA) maximum contaminant levels (MCLs) for drinking water have also been detected in off-Site areas. Therefore, it is deemed prudent at this time to address the elevated concentrations of cVOCs beneath the facility so that they do not continue to act as on-going contaminant sources to groundwater.

Consequently, this FFS has been prepared to screen and evaluate remedial technologies that could be applicable for treatment of source area cVOCs. Following SCDHEC concurrence/approval of the FFS options, a remedial alternative can then be selected for pilot testing and further implementation, if successful.

2.0 SITE DESCRIPTION

The Site is comprised of a main manufacturing building and smaller associated support buildings, which are located on approximately 20 acres (Figure 2). The facility manufactures several types of metal spray nozzles for fuel oils. A chain-link fence surrounds the operational portion of the Site. An old family cemetery is located within a small, discrete portion of the 20 acre Site.

An unnamed creek flows through the area immediately north and northwest of the Site and enters Halfmoon Branch approximately 300 feet west of the Site. The Bamberg wastewater treatment plant (WWTP) is located to the northwest beyond the creek and approximately 500 feet from the Site perimeter, with its surrounding spray infiltration fields extending to within approximately 200 feet of the Site. Properties to the northeast across Log Branch Road consist of residential properties and the County of Bamberg Rhodes Senior Center. Properties to east and southeast across Main Highway (US Highway 301 South) include a propane distribution facility, Jeff's Auto Care, and a sparsely populated residential area. Remaining properties to the south across Main Highway are undeveloped and used for silviculture. Properties to the southwest consist of a sparsely populated residential area, a junk yard, and a machinery shop (Figure 2).

Surrounding properties are under either Bamberg County or City of Bamberg zoning. The Site and the commercial businesses to the east of the Site (propane distribution facility and Jeff's Auto Body) are zoned Industrial by Bamberg County. Properties to the northeast, east, southeast, south, and southwest are zoned by Bamberg County as Rural District. The Bamberg WWTP facilities and spray fields to the west and northwest of the Site are zoned by the City of Bamberg as Industrial. Properties to the north of the Site are zoned R-15 (residential) by the City of Bamberg (Hart & Hickman, August 2013).

3.0 SITE HISTORY

The following summary of the Site history was taken from the RI Work Plan (Hart & Hickman, August 2013). The Site was developed by Delavan, Inc. (a.k.a., Delavan Corporation) from previously undeveloped land for the manufacture of fuel metering equipment and spray nozzles in the late 1960s to early 1970s. The Site has been used for manufacturing of fuel metering equipment and spray nozzles from the early 1970s to present by various entities including Delavan Corporation (early 1970s to 1984), Delavan, Inc. (1984 to 2002), and Delavan Spray, LLC (2002 to present). During its ownership and operations, Delavan Spray, LLC has operated the business as Delavan Spray Technologies and continues to operate the facility for the manufacture of spray nozzles.

The property (Figure 2) contains an approximate 50,000 square foot (ft) manufacturing building, a storage warehouse, a virgin material and hazardous waste storage building (oil shed), aboveground storage tank (AST) containment areas, a maintenance building, and a combustion lab. The manufacturing building was constructed between approximately 1969 and 1973. A wastewater pre-treatment plant was constructed in the mid-1980s to treat plant mop water and wastewater generated in an acid dip operation (used to de-bur spray nozzles). The pre-treatment plant has since been decommissioned and all associated equipment removed from the Site.

Chlorinated solvents were reportedly utilized at the Site from the early 1970s until 2002. Delavan Spray Technology personnel indicated that tetrachloroethene (PCE) was historically stored in a 750-gallon UST that was located along the southern side of the manufacturing building (Figure 2). The PCE UST was reportedly closed by removal from the ground sometime in the 1970s. PCE was also historically stored in above-ground storage tanks (ASTs) (a 1,000-gallon virgin PCE AST and a 2,000-gallon used PCE AST) in a concrete containment area located along the southeast corner of the manufacturing building. According to facility personnel, the ASTs were removed from the containment area in approximately 2002.

Multiple phases of environmental assessments have been performed at the Site to characterize the subsurface geology and groundwater quality. Some of these assessments include, but are not limited to the following:

- *Ground Water Assessment Report,* Hart & Hickman, August 29, 2003,
- *Report of HRC Injection and Pre- and Post-Injection Ground Water Monitoring,* Hart & Hickman, January 31, 2006,
- *Supplemental Site Assessment Report,* Hart & Hickman, December 5, 2012,
- *Remedial Investigation Report*, AECOM, July 3, 2014
- *Post Remedial Investigation Report*, AECOM, May 17, 2016, and
- *Groundwater Delineation Report,* AECOM, June 23, 2017.

In 2005, Hart & Hickman, PC (H&H) injected Hydrogen Release Compound® (HRC) into shallow groundwater at three locations to stimulate natural biodegradation of chlorinated compounds in groundwater (Figure 3 and H&H, January 31, 2006). Post-injection monitoring was conducted by H&H between 2005 and 2007. Concentrations of PCE have decreased in monitoring wells located near the HRC injections, but it is doubtful that these decreases are attributed to injection activities. Geochemical conditions were not affected by the HRC injection and the rate of decrease of PCE is relatively slow. It is, therefore, likely that decreases in PCE at these locations are due to natural attenuation processes such as dilution and dispersion. Groundwater VOCs at these locations remain at concentrations exceeding the USEPA MCLs for drinking water.

A groundwater quality monitoring program is currently being performed on a semiannual basis in accordance with SCDHEC directives. The analytical results are evaluated and submitted to SCDHEC as spring and fall semi-annual groundwater monitoring reports, respectively. The most recent report is the Spring 2017 Semi-Annual Groundwater Monitoring Report (AECOM, June 14, 2017).

No specific release incidents are reported to have occurred at the Site.

4.0 GEOLOGICAL SETTING

4.1 Regional Setting

The Site lies within the western portion of the South Carolina Coastal Plain Province, which is characterized as a seaward thickening wedge of sediments from the fall line to the coast. These sediments consist of sands, silts, clays and limestones; representing a variety of non-marine and marine depositional environments. Changes in depositional environment are due, in part, to changes in sea level. During transgression (rising sea level), sedimentary units tend to fine upward. During regression (falling sea level) sedimentary units tend to coarsen upward. During periods of regression, sediments can be left exposed and subject to erosion. The resulting geologic complexity can make it challenging to correlate geologic units over long distances (Logan and Euler, 1989).

The surficial geologic units that have been identified in the Bamberg County area of South Carolina include the Huber/Lisbon/Barnwell Formations of Eocene age, the Duplin Formation of Pliocene age, and the Penholoway Formation of Pleistocene age (http://mrdata.usgs.gov/geology/state/fips-unit.php?code=f45009). The undifferentiated sands and clays in that occur in the vicinity of the Delavan Spray Site are likely Pliocene in age and are assigned to the Duplin Formation (Willoughby and others, 2005).

The Santee Limestone (of middle Eocene age) likely underlies the Site at depths of approximately 12 to 20 feet. The Santee Limestone is used extensively in the southeastern part of the Coastal Plain as a groundwater resource for private, municipal and industrial use. Often, the limestone is not confined and is hydraulically connected to underlying and overlying units. In these cases, the units are often referred to as the Floridan or Tertiary Limestone Aquifer system (Logan and Euler, 1989).

Bamberg County and thus, the Site, lie within the Ashepoo, Combahee and Edisto (ACE) River Basin of South Carolina. The ACE Basin is drained by the Ashley-Cooper, Combahee-Coosawhatchie, and Edisto rivers. The Town of Bamberg is located at the junction between the Salkehatchie River and Edisto River watersheds, with the South Fork Edisto River being the closest major river to the Site, located approximately four miles to the northeast.

Groundwater occurrence in the Coastal Plain is typically within the intergranular pore spaces of the sands, silts and limestones (primary porosity) and within solution cavities or fractures of indurated sediments (secondary porosity). Primary production of groundwater occurs from within the more permeable units, while lower permeability clay layers typically retard groundwater movement. Recharge for significant aquifers in the Coastal Plain occurs both as transport from up-dip areas toward the Fall Line, where the sediments are generally exposed at the land surface, and as leakage from adjacent aquifer units through the aquitards.

Groundwater flow in deeper confined aquifer units is typically to the south and southeast toward the coast. Locally, the water-table surface can subtly mimic land surface topography, with recharge of shallow unconfined aquifers occurring from direct infiltration of precipitation in upland areas and discharge occurring within nearby creeks and streams.

4.2 Site Hydrogeology

Based on the prior assessment activities conducted to date, the stratigraphy of the uppermost sediments beneath the Site and vicinity is characterized as follows:

- Ground surface to approximately 10 to 15 ft bgs: Clayey fine- to medium-grained sands;
- 15 ft to approximately 25 ft bgs: Fine- to coarse-grained sandy clays and fine-grained sands;
- 25 ft to approximately 40 ft bgs: Fossiliferous limestone with loosely to moderately cemented coarse-grained shell fragments;
- 40 ft to approximately 60 ft bgs: Fossiliferous limestone with loose to well-cemented shell fragments; and
- 60 ft to the limits of exploration (approximately 85 ft bgs): Fine- to medium-grained sandstone, loosely to moderately cemented, calcareous, clayey.

Groundwater monitoring wells have been completed in the upper sandy water table aquifer zone, the lower limestone aquifer zone and in the underlying cemented sandstone. The vertical limits of Site-related cVOC impact are limited to the upper sandy unit and the underlying limestone. No cVOCs have been reported in groundwater from the two wells completed in the cemented sandstone unit.

Ground water elevations measured in April 2017 from monitoring wells completed in the shallow aquifer zone were used to create a water-table surface map during the spring 2017 semi-annual monitoring period (Figure 4). From the equal potential lines, groundwater flow directions can be inferred. Beneath the northern portion of the Facility groundwater flow varies between northward and southward flow directions, with local groundwater highs at MW-4, MW-5/MW-6, MW-10, and MW-17. Groundwater levels appear depressed at MW-3, MW-8 and MW-18. The primary horizontal groundwater flow direction is inferred to be toward the west, toward Halfmoon Branch, which is consistent with findings from prior investigations conducted at the Site. The three monitoring wells recently installed on private property to the west of the Site indicate the presence of an isolated groundwater high at MW-27 (AECOM, June 14 and June 23, 2017).

Groundwater level elevations measured in April 2017 from monitoring wells completed within the deeper limestone aquifer zone were used to create a potentiometric surface map during the spring 2017 semi-annual monitoring period (Figure 5). From the equal potential lines, the inferred horizontal groundwater flow direction is to the south-southwest and is consistent with regional topography, drainage and findings from prior investigations conducted at the Site (AECOM, June 14 and June 23, 2017).

The vertical hydraulic gradients were evaluated at well clusters MW-3/MW-3D, MW-9/MW-9D, MW-10/MW-10D, MW-14/MW-14D, MW-15/MW-15D, and MW-16/MW-16D using the water level dataset obtained during the Spring 2017 semiannual monitoring event (AECOM, June 14, 2017). Based on this data, with one exception, the vertical gradient between the shallow water table zone and the deeper limestone aquifer zone wells was downward, varying between 0.02 to 0.11 feet per foot (ft/ft). The vertical gradient between MW-15 and MW-15D was calculated to be upward at 0.01 ft/ft. This well cluster is located adjacent to Halfmoon Branch. A slight upward gradient at this location would be expected if the Branch is acting as a local groundwater discharge point. The vertical hydraulic gradient was determined to be neutral (0.00 ft/ft) between the deeper limestone aquifer zone and the deeper sandstone aquifer zone (MW-3D/MW-3D1 and MW-15D/MW-15D1).

Slug tests have been used to estimate the horizontal hydraulic conductivity of the uppermost aquifer units beneath the site. During the recent groundwater delineation study, additional slug tests were performed in the newly installed shallow monitoring wells MW-27, MW-28, and MW-29 and newly installed deeper monitoring wells MW-30D, MW-31D, and MW-32DR in order further to evaluate hydrologic properties of the aquifer units (AECOM, June 14, 2017).

The estimated horizontal hydraulic conductivity values calculated for the newly installed shallow monitoring wells ranged from 0.215 feet per day (ft/day) in MW-28 to 0.701 ft/day in MW-29, with a geometric mean of 0.355 ft/day. The estimated horizontal hydraulic conductivity values for the newly installed deeper limestone aquifer monitoring wells ranged from 10.7 ft/day in MW-31D to 161 ft/day in MW-30D, with a geometric mean of 63.5 ft/day. These values are similar to those previously estimated for shallow and deeper aquifer wells in the Site vicinity.

5.0 SUMMARY OF CONCEPTUAL SITE MODEL

A conceptual site model (CSM) has been developed from historic site documents and the RI. The CSM provides the technical basis for the identification, evaluation, and selection of remedial alternatives for the Site and consists of the following components:

Environmental Media Requiring Remedial Action

The media that will be addressed through remedial actions include saturated and unsaturated zone subsurface soils and groundwater of the shallow unconfined and limestone aquifers containing cVOCs. Significant soil and groundwater cVOC impacts are present beneath the locations of the former degreasers and to a lesser extent at the former PCE UST. Significantly lesser soil VOC impacts are present at the former northern secondary containment area and the northeastern wooded area. The remedial focus of this FFS will be on the locations of the former PCE UST and the former degreasers. These locations were chosen due to the magnitude of cVOC impact relative to the other areas at the Site and the persistence of elevated cVOC groundwater concentrations at these locations, which continue to provide mass to the groundwater regime beneath the Site.

Constituents of Concern, Potential Receptors and Exposure Pathways

A Human Health Risk Assessment (HHRA) was previously conducted for the Delavan Spray Technologies Site to evaluate chemicals detected in Site-related media, including groundwater, soil gas, surface and subsurface soils, and surface water. Potential risks to human health under current and future land use scenarios were quantitatively evaluated (see the RI Report, AECOM, 2014 for more details).

Constituents of Concern (COCs) were identified in the Risk Characterization based on the risk and hazard calculations. Human health COCs were identified for a hypothetical future on-Site resident, a scenario that is unexpected and unlikely, and for an off-Site resident assumed to regularly consume and use groundwater, which is not likely to occur based on current land use and due to the availability of municipal water in the Site vicinity (AECOM, 2014).

The residents located immediately downgradient of the shallow aquifer flow direction (west of the Site) are no longer using their water well for domestic use and have been connected to the local municipal water supply.

The metals COCs do not appear to be mobile and are not of concern for off-Site groundwater use scenarios. With respect to the cVOCs, five compounds exceed their respective MCLs (chloroform, cis-1,2-DCE, methylene chloride, tetrachloroethene, and trichloroethene). PCE can be used as a surrogate compound for the purposes of assessment and treatment given its relatively high concentrations in groundwater relative to the other COCs and its MCL of 5 μg/L.

Contaminant Source Areas

The contaminant source areas to be addressed in this FFS are the two locations of the former parts degreasers (Wickman room and the Stamp & Pack room), which are beneath the concrete floor of the manufacturing building, and the former PCE UST, located along the front of the manufacturing building (Figure 2). Both of the former degreasers used PCE to clean parts and the former 750-gallon UST was historically used to store PCE until its removal sometime in the 1970s. PCE concentrations detected in RI soil samples indicate that there are soil impacts in these areas, and the groundwater cVOC concentrations in these areas continue to remain elevated and define the PCE "hot spots" in shallow groundwater (see Figure 6).

Migration Pathways

Hydrogeologic information developed to date suggests that the primary pathway for cVOCs migration from beneath the locations of the former degreasers and lessor source areas is downward, into the more permeable limestone aquifer. From there, the transport is primarily horizontal within the more permeable limestone aquifer unit. cVOCs are also migrating to a lesser extent in dissolved phase within the surficial aquifer zone. Remedial actions will be evaluated that could be effective in addressing potential migration pathways for COCs:

- Leaching/dissolution of COCs from saturated and unsaturated zone soils into groundwater and vapor phases, and
- Migration of dissolved COCs in groundwater to off-Site locations.

Figure 7 illustrates the known occurrence of PCE in off-Site areas of the deeper aquifer.

6.0 IDENTIFICATION OF RAOs AND RGs

This section describes the specific Remedial Action Objectives (RAO) and remedial goals (RGs) for the cVOC source areas beneath and adjacent to the facility given the target treatment media and the contaminants of concern.

6.1 Target Media and Contaminants of Concern

The treatment area at the site includes the following target media:

- Soil
- Groundwater
- Soil Vapor

The primary contaminants of concern (COCs) at the Site are cVOCs in groundwater, including PCE, trichloroethene (TCE), cis-1,2-dichloroethene (DCE), chloroform, and methylene chloride. Soil and soil vapor are also being addressed to remediate any residual source mass in these media that have a potential to contribute to groundwater impacts beneath the Site.

6.2 Remedial Action Objectives

Remedial Action Objectives are defined as follows:

- Protection of human health and the environment
- Reduce subsurface COC mass associated with soils, groundwater and soil vapor

6.3 Remedial Goals

For the purposes of this FFS, RGs are defined as numerical criteria for environmental media that, when exceeded, result in a violation of statutory regulations. For the State of South Carolina, the RGs are based on Federal MCLs. Table 6-1 presents the RGs for the cVOCs in groundwater at the Site.

7.0 SCREENING OF REMEDIAL TECHNOLOGIES

To begin the remedial technology evaluation process, a list of applicable remedial technologies was developed as a preliminary screening step. This step is focused as only one class of COCs is present at the Site.

Candidate technologies are screened using three criteria:

- Applicability and appropriateness to the Site
- Technical feasibility and implementability
- Relative cost

Applicability and appropriateness of a potential technology must consider the specific constituents present; the media; the nature, extent, and status of sources of contamination; the physical condition of the Site and surroundings; and the ability of the technology to achieve the stated RAOs.

Technical feasibility and implementability of a potential technology must consider steps and procedures required to implement the remedy; site-specific conditions (size, topography, current and future land use, drainage routes, surface conditions, and other permanent conditions); practicality; and probability of success. In assessing practicality and probability of success, the remedial approach performance history and implementation impacts to public welfare and the environment have to be considered.

Relative cost of a technology examines the expected level of expense required to implement the technology at the Site relative to the other remedial technologies. This is not a detailed cost estimate but, rather, a general judgment based on experience implementing the technology at similar sites.

The remedial technologies that were evaluated as part of the preliminary screening process are listed below with their applicable media:

Remedial Technology	Media to be Treated
No Action and Institutional Controls	None
Source Area Excavation	Soil
Monitored Natural Attenuation (MNA)	Groundwater
Vapor Abatement	Soil and Soil Vapor
Groundwater Capture	Groundwater

Remedial Technology	Media to be Treated
Dual Phase Extraction (DPE)	Soil, Soil Vapor and Groundwater
In Situ Chemical Oxidation (ISCO)	Saturated Soil and Groundwater
Enhanced Reductive Dechlorination (ERD)	Groundwater

Technologies that meet all of the three screening criteria will be retained for incorporation into remedial alternatives.

7.1 No Action and Institutional Controls

No Action is included as a benchmark for the comparison of costs and benefits associated with other technologies. Currently, impacts to soils and groundwater at the Site do not pose a risk to potential Site receptors; therefore, No Action is an appropriate option for consideration with respect to potential on-Site receptors.

Institutional Controls (ICs), in the form of the land use restrictions imposed by a Declaration of Covenants and Restrictions, have not been implemented at the Site. Land use restrictions should be a component of each of the remedial alternatives that are evaluated in this document, including the No Action alternative.

ICs are typically implemented as tools designed to protect human health, the environment, and to maintain the current and future integrity of the remedy at contaminated sites. ICs are generally non-engineered mechanisms such as administrative and/or legal controls that minimize or eliminate the potential for human exposure to contamination and/or protect the integrity of a remedy. These are typically designed to work by limiting land and resource use at a Site, or by providing guidance to help modify human behavior at a Site. IC's that are implemented through the use of deed restrictions offer greater risk control than local or regional zoning. Typical IC's for the Site would include the following:

1. Site property will not be used for residential purposes (including single family homes, multiple family dwellings, schools, day care facilities, child care centers, apartment buildings, dormitories, other residential style facilities, hospitals, in-patient health care facilities, or other uses permitted by local regulations for residential zoning).

2. Use of groundwater at the Site will be limited to current uses only, including environmental testing, and for other purposes to support selected corrective measures. New groundwater supply wells will not be installed at the Site.

There is minimal cost associated with the implementation of this technology. Currently, however, there are environmental groundwater impacts known to exist off-Site. Although there are no known groundwater users, future receptors would remain a possibility. While this is a technically feasible remedial alternative, community and regulatory acceptance could prevent implementation. No monitoring of the COC plume would be done during the implementation of No Action. Therefore, any impacts to the community would be unknown. This technology will be retained for incorporation into remedial alternatives as a baseline comparison.

7.2 Source Area Excavation

Excavation involves the physical removal of impacted source area soils for treatment and/or off-Site disposal. Excavation is an appropriate technology for the remediation of impacted soils. However, the implementation of this technology would be difficult and be high in cost because it would involve access to the inside of the building with heavy equipment, opening the floor slab, shoring, vertical excavation and restoration. Currently, the building is an active manufacturing facility and access is limited due to many large/ precision milling machines and other equipment. This equipment is in constant use and cannot be shut down or moved without disrupting product manufacturing. Costs to implement source area excavation are expected to be high and would involve a temporary shutdown of manufacturing operations, manufacturing equipment relocation, heavy equipment operations indoors, air monitoring, and manual labor. Due to the high concentrations of cVOCs in the soils beneath the former locations of the two degreasers, the wastes would likely be characteristically or listed as a hazardous waste, which would result in increased transportation and disposal costs as compared to non-hazardous classification. Due to the access limitations described above, the ease of implementability of this option is very low. This technology, however, will be retained for incorporation into remedial alternatives.

7.3 Monitored Natural Attenuation

MNA is widely utilized either as a stand-alone technology at sites that pose a relatively low risk to human or ecological receptors, or as a long-term component of more aggressive alternatives. MNA involves tracking the natural degradation of contaminants without the introduction of foreign microorganisms, nutrients, oxygen, or mechanical enhancement. MNA is implemented by performing preliminary studies that determine the natural mechanisms resulting in degradation of target constituents. Periodic sampling is then performed to monitor actual degradation rates of target constituents. Natural attenuation is typically most effective for maintaining low and decreasing levels of COCs in groundwater.

Although there are no known groundwater users, future receptors would remain a possibility since COCs have been detected on off-Site properties. However, the COC plume would be monitored over time. While this is a technically feasible remedial alternative, community and regulatory acceptance could prevent implementation as a stand-alone remedy. The cost for MNA is low as it incorporates the existing monitoring well network and sampling and analysis costs are relatively low. MNA would also be easily implemented at the Site. This technology will be retained for incorporation into remedial alternatives.

7.4 Vapor Abatement

Vapor abatement is the process of utilizing sub-slab depressurization to remove volatile COCs in the subsurface. This process can provide benefit not only for the removal of cVOCs from source area soils but also to reduce the risk of vapors migrating into the manufacturing facility. To accomplish vapor abatement, penetrations are generally made through the concrete floor slab and piping installed and sealed to the floor. The piping can be connected to vertical vapor wells or to a gravel filled sump installed beneath the concrete flooring. The piping is then connected to fans or blowers to create a negative pressure and remove the vapors. Modeling of anticipated cVOC loading in the air discharge would be performed to determine if the recovered vapors would need to be directed through a treatment processes (e.g., granular activated carbon) or if permitting would be required to vent the vapors directly to the atmosphere.

Effective implementation would involve coring through the manufacturing facility's concrete floor in multiple locations, installing PVC piping in short runs of saw-cut trenches and directing that piping up along walls or columns to a common header. The header piping would be connected to fan(s) or blower(s) to create a partial vacuum and the exhaust is then directed outside of the building for treatment/discharge.

The cost for Vapor Abatement is relatively low to moderate. The technology is easily implemented and will address cVOC mass in the vadose zone soil beneath the concrete building slab, which makes it a feasible technology. This technology will be retained for incorporation into remedial alternatives.

7.5 Groundwater Capture

The groundwater capture technology would include the installation of pumping wells in the shallow and limestone aquifer units downgradient of the source zones to capture and remove COC impacted groundwater. This action would prevent groundwater from migrating off-Site into other properties beyond the limits of the Delavan facility. The recovered groundwater would be pumped to an equalization tank and then treated with an air stripper and/or granular activated carbon (GAC). The treated groundwater would then be discharged either to the municipal sanitary sewer or to a nearby surface water body (stream). Treated groundwater could also potentially be re-injected into the aquifer up-gradient of the cVOC impacted source areas.

Groundwater extraction is a proven technology that could be easily implemented at the Delavan Site. However, because it is an active remedy, ongoing operations and maintenance would be required by a licensed waste water treatment operator. Groundwater capture is not sufficient as a stand-alone remedy, and is typically used only in conjunction with a source area treatment technology as a last line of defense to prevent impacted groundwater migration. Assuming source area treatment is sufficiently effective, groundwater capture systems may not be required to result in acceptable reduction of groundwater migration. Groundwater capture systems can operate from a few years to several decades, depending on site conditions and the mass removal and effect on the off-site plume would likely be minimal compared to the effects of the source area treatment. Numerical flow and transport modeling would be performed to determine the number of wells, well depths, well spacing and anticipated flow rates. Permitting would be required for the discharge of treated water. Modeling of air discharges would also be performed to determine if an air discharge permit would be required for release of cVOCs into the atmosphere. The cost for Groundwater Capture is moderate to high and does not directly address residual source material beneath the facility. However, it intercepts the groundwater plume before it migrates off-Site and it is a readily implementable remedy, which makes it a feasible technology. This technology will be retained for incorporation into remedial alternatives.

7.6 Dual Phase Extraction (DPE)

This technology involves the combination of a vacuum system with a downhole pump that is used to remove contaminated groundwater and vapors from the subsurface. DPE both lowers the water table near the well and creates airflow through the unsaturated zone. Groundwater extraction exposes previously saturated areas of the formation to greater airflow. As the COCs present at the Site are highly volatile, they are more readily recovered via vapor extraction than with groundwater extraction. Above ground, the extracted vapors and liquids are treated separately and discharged.

This technology could be implemented to address the source areas on-Site with moderate to high cost and high effort. This implementation would be limited by the ability to drill extraction wells inside the building. It is difficult to get the needed drilling equipment to desired locations because of the active manufacturing operations and the location of manufacturing machinery. Effective implementation could involve a temporary shutdown of manufacturing operations and manufacturing equipment relocation. Alternatively, horizontal wells could be drilled from locations outside the foot print of the manufacturing facility to target the COC source areas beneath the building. This technology will be retained for incorporation into remedial alternatives.

7.7 In Situ Chemical Oxidation (ISCO)

This technology involves the chemical destruction of organic contaminants in groundwater and saturated soil by subsurface injection of strong oxidant solutions. Effective treatment requires the selection of oxidants that will react with the specific types of contaminants present at the Site. For sites where chlorinated solvents are the predominant COCs, Fenton’s Reagent (hydrogen peroxide with an iron catalyst), sodium persulfate and sodium permanganate are effective oxidants for addressing chlorinated ethenes. ISCO is an aggressive technology used to address relatively high contaminant concentrations in saturated soils and groundwater.

The implementation of this technology would be difficult and it would be high in cost. This process would be difficult to implement due to the active factory floor and the proximity of machinery inside the building. This would complicate the injection process due to the limited ability to position a drilling rig at the desired locations inside the building. Effective implementation could involve a temporary shutdown of manufacturing operations and manufacturing equipment relocation. Alternatively, horizontal wells could be drilled from locations outside the foot print of the manufacturing facility to target the COC source areas beneath the building.

Permits, including an underground injection control (UIC) permit would be required. In preparing for an ISCO remedy, a bench scale study would be performed to determine the optimum oxidant and dosing concentrations for soils and contaminants at this site. This technology would be difficult to implement because it is a passive distribution technique relying on dispersive mechanisms, thus requiring a relatively high density of injection points. The injected oxidant can follow preferential pathways (also where most contamination is found) but may miss materials that have diffused into less transmissive geologic strata. This condition is often observed by short-term reduction of dissolved COC concentrations, followed by a rebound in constituent concentrations. Secondary water quality issues such as purple color due to permanganate, or daylighting of oxidant solutions during injection could also be an issue. In situ chemical oxidation, however, typically has low O&M requirements. This technology will be retained for incorporation into remedial alternatives.

7.8 Enhanced Reductive Dechlorination (ERD)

ERD involves the delivery of an organic substrate into the subsurface in order to stimulate microbial growth and activity by creating an anaerobic groundwater treatment zone and generating hydrogen through fermentation reactions. The creation of anaerobic, hydrogen producing conditions is a favorable environment for the microbiological process of reductive dechlorination. This technology is proven to sequentially dechlorinate chlorinated ethenes to the non-toxic end products ethene and ethane.

This technology can be implemented with moderate to high cost. Concerns regarding secondary water quality issues (e.g., ferrous iron, methane, volatile fatty acids) and accumulation of daughter products from incomplete dechlorination (e.g., vinyl chloride) may preclude its implementation along property boundaries. Permits, including a UIC permit would be required.

This process option would be difficult to implement because it is a passive distribution technique relying on dispersive mechanisms, thus requiring a relatively high density of injection points. Access to inside the building on site would also be a limiting factor due to the proximity of machinery inside the building. This would complicate the injection process due to the limited ability to position a drilling rig at the desired locations inside the building. Effective implementation could involve a temporary shutdown of manufacturing operations and manufacturing equipment relocation. Alternatively, horizontal wells could be drilled from locations outside the foot print of the manufacturing facility to target the COC source areas beneath the building.

A previous field-scale ERD injection was performed at the Site, as stated in Section 3.0 (H&H, 2006). This investigation did not support a conclusion that ERD is effective in stimulating biotic degradation of cVOCs. Further, data collected during ongoing groundwater monitoring demonstrates minimal evidence for presence of biotic degradation mechanisms for chlorinated ethenes. Biotic degradation of chlorinated ethenes is an anaerobic process. The dissolved oxygen and oxidation-reduction potential (ORP) values in groundwater are relatively high in the area of treatment, which are indicative of aerobic conditions. Further, the pH of the shallow groundwater is relatively low (less than 6 standard units), which is sub-optimal for biotic dechlorination. This technology will, therefore, not be retained for incorporation into remedial alternatives.

8.0 EVALUATION OF REMEDIAL ALTERNATIVES

The remedial technologies that were identified in Section 7 above have been grouped into the Remedial Alternatives listed below. Remedial alternatives will be capable of addressing soil, groundwater and soil vapor.

- **Alternative 1 -** No Action and ICs**.**
- **Alternative 2 -** Excavation, Vapor Abatement, MNA, Groundwater Capture, and ICs.
- **Alternative 3 -** Vapor Abatement, DPE, MNA, and ICs.
- **Alternative 4 -** Vapor Abatement, ISCO, MNA, and ICs.

8.1 Evaluation Criteria

Detailed evaluation of the remedial alternatives is performed by comparison to eight criteria:

- **Protection of human health and the environment, including attainment of remediation goals.** The assessment against this criterion describes how the alternative, as a whole, achieves and maintains protection of human health and the environment.
- **Compliance with applicable federal, state, and local regulations.** The assessment against this criterion describes how the alternative complies with ARARs or if a waiver is required and how it is justified. The assessment also addresses other information from advisories, criteria, and guidance that the lead and support agencies have agreed is "to be considered." The ARARs can be chemical specific, location specific and action specific. Chemical specific ARARs are generally numerical values, thus the chemical ARARs for the Site will be MCLs. Location specific ARARs place restrictions on the conduct of the cleanup activities because they are in a particular location. Action specific ARARs are related to implementation of the technology.
- **Long-term effectiveness and permanence.** The assessment of alternatives against this criterion evaluates the long-term effectiveness of alternatives in maintaining protection of human health and the environment after conclusion of active remediation activities.
- **Reduction of toxicity, mobility, and volume through treatment.** The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies to permanently and significantly reduce the toxicity, mobility and/or volume of COCs.
- **Short-term effectiveness.** The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy.
- **Implementability.** This assessment evaluates the technical and administrative feasibility of alternatives and the availability of required goods and services.

- **Cost.** This assessment evaluates the capital and operation and maintenance (O&M) costs of each alternative.
- **Community and state acceptance.** This assessment reflects the community and state's (or support agency's) apparent preferences or concerns about alternatives. These criteria are assessed formally after public comment, and will not be further discussed herein.

Table 8-1 provides a comparison of each of the remedial alternatives with respect to the evaluation criteria listed above. Table 8-2 summarizes the costs for each alternative (detailed cost estimates and associated assumptions are provided in Appendix A).

8.2 Detailed Analysis

8.2.1 Alternative 1

Alternative 1 is the approach in which no active action is taken. No action means no remediation activities will be performed at the Site, including monitoring and sampling. MNA is not a part of this technology because, even though natural attenuation would be occurring, there would be no monitoring activities conducted to measure it. It is noted, however, that ICs, in the form of land use restrictions, will be prepared as part of this alternative.

No Action is a benchmark that is useful for comparison to the other remedial alternatives. The benefit of any proposed remedial alternative must be greater than No Action to justify consideration.

8.2.1.1 Protection of Human Health and the Environment; Attainment of Remediation Goals

Although COCs have been detected in the deeper aquifer at off-Site locations, there are no known receptors in the Site vicinity. The No Action option is likely to benefit from naturally occurring attenuation of COCs via such pathways as microbial degradation, volatilization, and dilution. However, without a monitoring plan, the rate of natural attenuation will be unknown, as will the progress of the Site toward meeting the remedial action objectives. Additionally, it can be presumed that the cVOC plume will continue to migrate off-Site. Without a monitoring plan, the extent of plume displacement, and the occurrence of potential new receptors, will be unknown.

8.2.1.2 Compliance with Applicable Federal, State, and Local Regulations

This option will not comply with chemical specific ARARs (RGs) until groundwater MCLs are met. Since no remedial activities would be conducted under this alternative, action specific ARARs are not applicable. Location specific ARARs also do not apply to this alternative.

8.2.1.3 Long-term Effectiveness and Permanence

Over the long term, No Action may meet the criterion of effectiveness and permanence as many natural degradation processes can be permanent, although these mechanisms have not been explored. However, for areas with especially high concentrations of COCs, the time required to meet the RGs may be decades. The recordation of land use restrictions would minimize risk to hypothetical future residents from groundwater use or soil disturbance.

8.2.1.4 Reduction of Toxicity, Mobility, and Volume

Over time, the No Action option may reduce contaminant mass, mobility, and toxicity through natural attenuation processes; however, the time required to achieve RGs throughout the Site is difficult to estimate at this time.

8.2.1.5 Short-term Effectiveness

The Site does not currently pose a threat to the community or environment. However, the plume will likely continue to migrate off-Site. Therefore, the No Action alternative provides adequate short-term effectiveness, but inadequate monitoring of the cVOC plume long term.

8.2.1.6 Implementability

This option does not require work plans, design, equipment, or construction. It is easily implemented.

8.2.1.7 Cost

This option does not require work plans, design, equipment, or construction. There are no costs associated with implementation and no monitoring will be performed. There are only minimal costs associated with implementing ICs ($25,000). Probable costs and key assumptions are included in Table 8-2 and Appendix A.

8.2.2 Alternative 2

Alternative 2 includes a combination of excavation, vapor abatement, MNA, groundwater capture to treat COCs and implementation of ICs. The goal of this approach would be to remove COC mass beneath the manufacturing building through excavation of soil in the vicinity of the former degreasers (MW-19 and MW-20 areas, total of approximately 280 cubic yards). The vapor abatement would include sub slab depressurization in combination with the installation of extraction fans, suction pits and applicable conveyance piping. It would be installed only within the two identified source areas in the vicinity of the former degreasers (approximately 850 square feet in area each) within the primary manufacturing building; outer buildings would not be included. The vapor abatement system would operate for up to 10 years. The groundwater capture would include approximately four extraction wells located downgradient of the source areas to protect from off-Site migration of COCs, and would operate for 30 years. Extracted groundwater would be treated using air stripping and/or activated carbon adsorption prior to discharge to either a municipal sewer or surface water. During this process, MNA would be carried out and ICs would be put in place.

8.2.2.1 Protection of Human Health and the Environment; Attainment of Remediation Goals

Excavation within the source areas will remove a large portion of the source mass, while vapor abatement will remove COCs prior to reaching indoor air. Groundwater capture would limit further migration of the plume to off-Site areas. Therefore, Alternative 2 will be protective of human health and the environment. Although excavation will remove a significant amount of COC mass, the vapor abatement and groundwater capture will be inefficient at obtaining RGs. Therefore, MNA will be relied upon for the bulk of the groundwater plume to reach RGs. Data collected during groundwater monitoring demonstrates minimal evidence for presence of anaerobic conditions, which would support biotic degradation mechanisms for chlorinated ethenes. Specifically, the dissolved oxygen and ORP values are high, which are indicative of aerobic conditions. Further, the pH of the shallow aquifer groundwater is relatively low (less than 6 standard units), which is sub-optimal for biotic dechlorination. Therefore, it is likely that MNA will require many years to reduce dissolved phase COC's in groundwater to below the RGs throughout the Site.

8.2.2.2 Compliance with Applicable Federal, State, and Local Regulations

This alternative is expected to meet chemical specific ARARs (RGs) but it would require a long time period. A discharge permit for treated groundwater would be required to fulfill action specific ARARs. There are no location specific ARARs for this alternative.

8.2.2.3 Long-term Effectiveness and Permanence

Excavation, groundwater extraction and vapor abatement processes will permanently remove subsurface COCs. Natural attenuation processes can be highly effective in permanently destroying chlorinated ethenes when biotic processes are occurring. However, the extent of biotic processes under intrinsic conditions is likely limited. Adsorptive natural attenuation processes are likely occurring, but this process does not result in the destruction of COCs. Other abiotic natural attenuation processes may be occurring, but their presence/activity is unexplored.

8.2.2.4 Reduction of Toxicity, Mobility, and Volume

Excavation, vapor abatement, and groundwater capture will result in the reduction of toxicity, mobility, and volume of COCs on site. Current likely natural attenuation processes (i.e., adsorption) will reduce the mobility and volume of COCs.

8.2.2.5 Short-term Effectiveness

The Site does not currently pose a threat to the community or environment. Implementation of this alternative would involve heavy equipment operations, air monitoring and manual labor to construct groundwater and vapor conveyance systems. Routine O&M of the groundwater extraction and vapor abatement systems would be required, along with periodic MNA sampling. Proper use of personal protective equipment (PPE) and adhering to a site specific health and safety plan (HASP) would minimize or eliminate impacts during construction, operation and maintenance and groundwater sampling activities. Implementation of this alternative would not result in adverse environmental impacts and short-term risks are minimal.

8.2.2.6 Implementability

Excavation would be relatively more difficult to implement, due to the high level of industrial manufacturing activity and limited space available in the main building. Effective implementation of source area excavations would involve a temporary shutdown of manufacturing operations and manufacturing equipment relocation. Vapor abatement would be of moderate difficulty to implement within the manufacturing facility by installing vertical wells in the source areas. Effective implementation of vapor abatement may involve a limited temporary shutdown of manufacturing operations and manufacturing equipment relocation. Groundwater extraction would be easily implementable, as extraction wells and treatment equipment would be located outside the building footprint. MNA and ICs are easily implemented with site activities consisting of periodic groundwater monitoring using the existing wells at the Site.

8.2.2.7 Cost

The 30 year present worth of an opinion of probable costs for this alternative is approximately $2,773,000. The present worth cost was calculated using a discount rate of 5 percent. Details of the probable cost and key assumptions are included in Table 8-2 and Appendix A. It should be noted that these costs are for comparison of alternatives and actual costs of implementation may vary (typically around -30 to +50 percent).

8.2.3 Alternative 3

Similar to Alternative 2, Alternative 3 will also utilize vapor abatement, MNA, and institutional controls as treatment technologies. In addition, Alternative 3 will utilize dual phase extraction (DPE) as a source zone remedial alternative. The DPE will be implemented by the installation of four extraction wells located within the 10,000 ppb total cVOCs groundwater contour near MW-19 and two additional wells near MW-20 and MW-21, respectively. Therefore, the DPE process will effect treatment of a larger subsurface volume than excavation alone. Extracted groundwater would be treated using air stripping and/or activated carbon adsorption prior to discharge to either a municipal sewer or surface water. Extracted vapor will be treated to remove moisture and discharged to the atmosphere. During this process, MNA would be carried out and ICs would be put in place. Vapor abatement would be implemented as described in Alternative 2, above.

8.2.3.1 Protection of Human Health and the Environment; Attainment of Remediation Goals

Implementation of DPE within the source areas will remove a large portion of the source mass, while vapor abatement will remove COCs prior to reaching indoor air. It is expected that DPE operations would sufficiently reduce source zone impacts to allow reduction of off-site migration of groundwater COCs. Therefore, Alternative 3 will be protective of human health and the environment. Similar to Alternative 2, MNA will be relied upon for the bulk of the groundwater plume to reach RGs, as the effective zone of DPE will be relatively limited compared to the overall footprint of the cVOC plume. Data collected during groundwater monitoring demonstrates minimal evidence for presence of anaerobic conditions, which would support natural biotic degradation mechanisms for chlorinated ethenes. Specifically, the dissolved oxygen and ORP values are high, which are indicative of aerobic conditions. Further, the pH of the shallow groundwater is relatively low (less than 6 standard units), which is sub-optimal for biotic dechlorination. Therefore, it is likely that MNA will require many years to reduce dissolved phase COC's in ground water to below the RGs throughout the Site.

8.2.3.2 Compliance with Applicable Federal, State, and Local Regulations

This alternative is expected to meet with chemical specific ARARs (RGs) but it would require a long time period. A discharge permit for treated groundwater would be required to fulfill action specific ARARs. There are no location specific ARARs for this alternative.

8.2.3.3 Long-term Effectiveness and Permanence

DPE and vapor abatement processes will permanently remove subsurface COCs. Natural attenuation processes can be highly effective in permanently destroying chlorinated ethenes when biotic processes are occurring. However, the extent of biotic processes under intrinsic conditions is likely limited. Adsorptive natural attenuation processes are likely occurring, but this process does not result in the destruction of COCs. Other abiotic natural attenuation processes may be occurring, but their presence/activity is unexplored.

8.2.3.4 Reduction of Toxicity, Mobility, and Volume

DPE and vapor abatement will result in the reduction of toxicity, mobility, and volume of COCs on site. Current likely natural attenuation processes (i.e., adsorption) will reduce the mobility and volume of COCs.

8.2.3.5 Short-term Effectiveness

The Site does not currently pose a threat to the community or environment. Implementation of this alternative would involve heavy equipment operations, air monitoring and manual labor to construct groundwater and vapor conveyance systems. Routine O&M of the DPE and vapor abatement systems would be required, along with periodic MNA sampling. Proper use of PPE and adhering to a site specific HASP would minimize or eliminate impacts during construction, operation and maintenance and groundwater sampling activities. Implementation of this alternative would not result in adverse environmental impacts and short-term risks are minimal.

8.2.3.6 Implementability

DPE and vapor abatement would be relatively difficult to implement, due to the high activity and limited space available in the main building. Effective implementation of DPE and vapor abatement may involve a temporary shutdown of manufacturing operations and manufacturing equipment relocation. Alternatively, horizontal wells could be drilled from locations outside the foot print of the manufacturing facility to target the COC source areas beneath the building. MNA and ICs are easily implemented with site activities consisting of periodic groundwater monitoring using the existing wells at the Site.

8.2.3.7 Cost

The 30 year present worth of an opinion of probable costs for this alternative is approximately $1,560,000 for vertical DPE wells and $2,008,000 for horizontal DPE wells. The present worth cost was calculated using a discount rate of 5 percent. Details of the probable cost and key assumptions are included in Table 8-2 and Appendix A. It should be noted that these costs are for comparison of alternatives and actual costs of implementation may vary (typically around -30 to +50 percent).

8.2.4 Alternative 4

Alternative 4 includes the use of ISCO, vapor abatement, MNA, and ICs. ISCO will be implemented as a source zone remedial alternative. The ISCO injections would focus on the 10,000 ppb total cVOC groundwater contour near MW-19 and near wells MW-20 and MW-21. This comprises an area of approximately 8,100 square feet and a depth from 5 to 20 ft below ground surface. Oxidant solution will be applied at up to 36 permanent injection points with 4 injection events over a 12 month period. During this process, MNA would be carried out and ICs would be put in place. Vapor abatement would be implemented as described in Alternative 2 above.

8.2.4.1 Protection of Human Health and the Environment; Attainment of Remediation Goals

The use of ISCO in the saturated zone soils will result in the rapid destruction of organic COCs, removing the source of dissolved-phase COCs. As a result, successful implementation of ISCO will provide a high degree of protection of human health and the environment. Due to inherent variability in subsurface geologic/hydrogeologic conditions, some areas may be more completely treated than others; and, therefore, dissolved COC concentrations in the areas of the Site that are not effectively treated may exhibit a gradual rebound as residual COCs bound to soils partition back into the groundwater.

The effective zone of ISCO will be relatively limited compared to the overall footprint of the cVOC plume. Therefore, MNA will be relied upon for the bulk of the groundwater plume to reach RGs, which will likely require many years to achieve. Data collected during groundwater monitoring demonstrates minimal evidence for presence of anaerobic conditions, which would support biotic degradation mechanisms for chlorinated ethenes. Specifically, the dissolved oxygen and ORP values are high, which are indicative of aerobic conditions. Further, the pH of the shallow groundwater is relatively low (less than 6 standard units), which is sub-optimal for biotic dechlorination. Therefore, it is likely that MNA will require many years to reduce dissolved phase COC’s in ground water to below the RGs throughout the Site.

During the post RI assessment, background soil samples were analyzed for total oxidant demand (TOD) in order to evaluate the background oxidant demand in vadose zone soils for different oxidants (AECOM, May 2016). These results are summarized in Table 8-3. Results varied across the different oxidants and concentrations of oxidant. The lowest TOD was measured using persulfate, where TOD results ranged from 8.0 grams per kilogram (g/kg) to 11 g/kg. Results from using permanganate were in the mid-range, with measured TOD values ranging from 25 g/kg to 58 g/kg. Hydrogen peroxide with ferrous sulfate provided the highest TOD values, with measured TOD ranging from 131 g/kg to 144 g/kg.

8.2.4.2 Compliance with Applicable Federal, State, and Local Regulations

This alternative is expected to meet with chemical specific ARARs (RGs) but it would require a long time period. An underground injection permit would be required to fulfill action specific ARARs. There are no location specific ARARs for this alternative.

8.2.4.3 Long-term Effectiveness and Permanence

Chemical oxidation and vapor abatement processes will permanently remove subsurface COCs. Natural attenuation processes can be highly effective in permanently destroying chlorinated ethenes when biotic processes are occurring. However, the extent of biotic processes under intrinsic conditions is likely limited. Adsorptive natural attenuation processes are likely occurring, but this process does not result in the destruction of COCs. Other abiotic natural attenuation processes may be occurring, but their presence/activity is unexplored.

8.2.4.4 Reduction of toxicity, mobility, and volume

Chemical oxidation and vapor abatement will result in the reduction of toxicity, mobility, and volume of COCs on Site. Current likely natural attenuation processes (i.e., adsorption) will reduce the mobility and volume of COCs.

8.2.4.5 Short-term Effectiveness

The Site does not currently pose a threat to the community or environment. Implementation of this alternative would involve heavy equipment operations, air monitoring and manual labor to construct vapor conveyance systems and implement oxidant injection. Periodic MNA sampling would be required following implementation of vapor abatement and ISCO activities. Proper use of PPE and adhering to a site specific HASP would minimize or eliminate impacts during construction, operation and maintenance and groundwater sampling activities. The use of ISCO may result in temporary issues regarding secondary water quality (e.g., colored groundwater, increases in metals, etc.), however these factors will decrease once the oxidant is depleted. Therefore, Implementation of this alternative would not result in significant adverse environmental impacts and short-term risks are minimal.

8.2.4.6 Implementability

The radius of influence of the ISCO injection wells is anticipated to be on the order of about 10 feet, requiring a relatively dense network of injection wells. Injections of oxidants inside the building using direct push technology (DPT) or similar drilling means will be difficult due to it being an active manufacturing facility and the proximity of manufacturing machinery. Effective implementation of ISCO and vapor abatement may involve a temporary shutdown of manufacturing operations and manufacturing equipment relocation. Alternatively, horizontal wells could be drilled from locations outside the foot print of the manufacturing facility to target the COC source areas beneath the building. MNA and ICs are easily implemented with site activities consisting of periodic groundwater monitoring using the existing wells at the Site.

8.2.4.7 Cost

The 30-year present worth of an opinion of probable costs for this alternative is approximately $1,794,000 for vertical injection wells and $2,108,000 for horizontal injection wells. The present worth cost was calculated using a discount rate of 5 percent. Details of the probable cost and key assumptions are included in Table 8-2 and Appendix A. It should be noted that these costs are for comparison of alternatives and actual costs of implementation may vary (typically around -30 to +50 percent).

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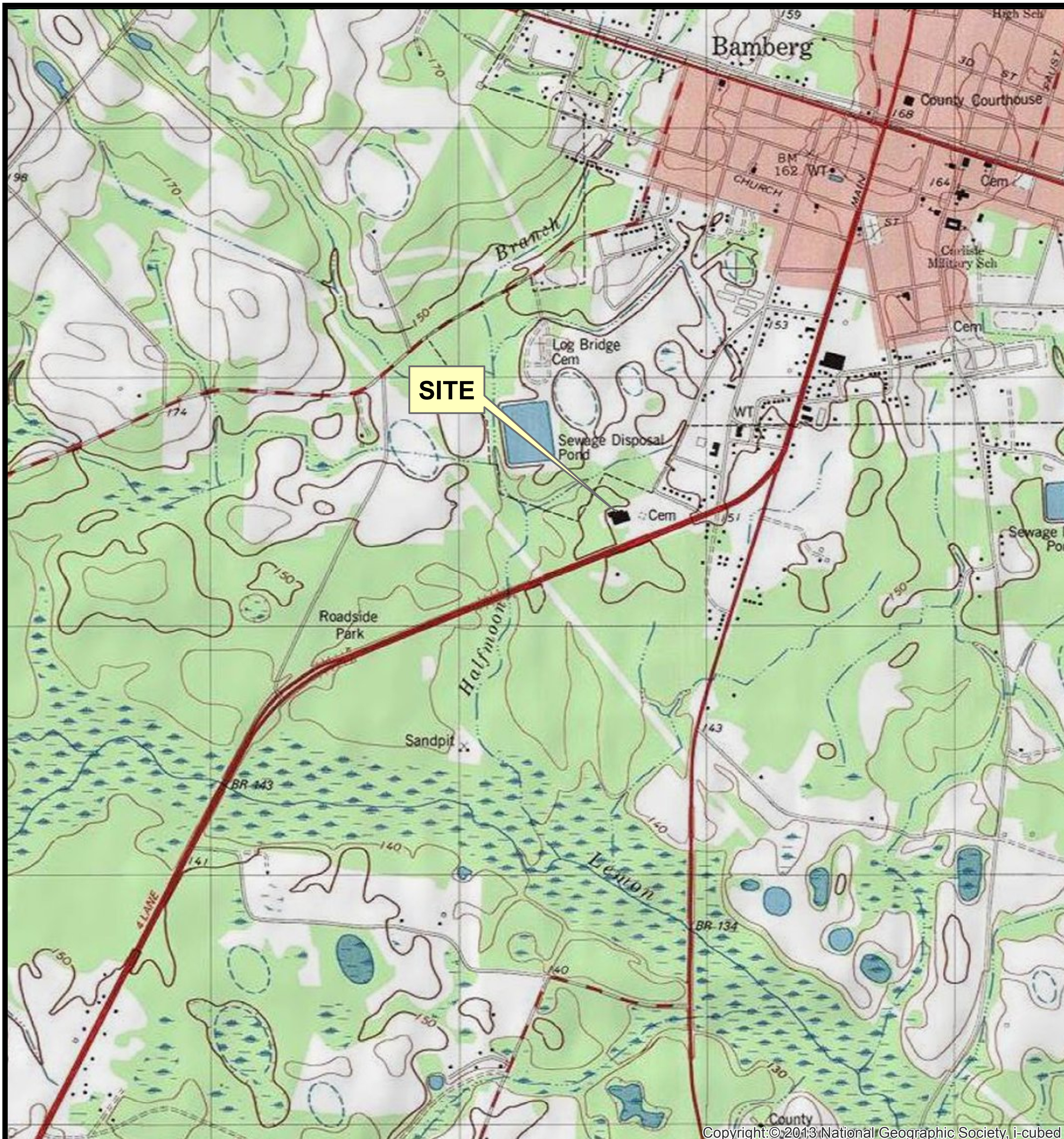
www.weatherbase.com for Bamberg, South Carolina.

FIGURES



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U.S.G.S. QUADRANGLE MAP

BAMBERG, SC 1979 (PHOTO REVISED 1987)

QUADRANGLE
7.5 MINUTE SERIES (TOPOGRAPHIC)

AECOM

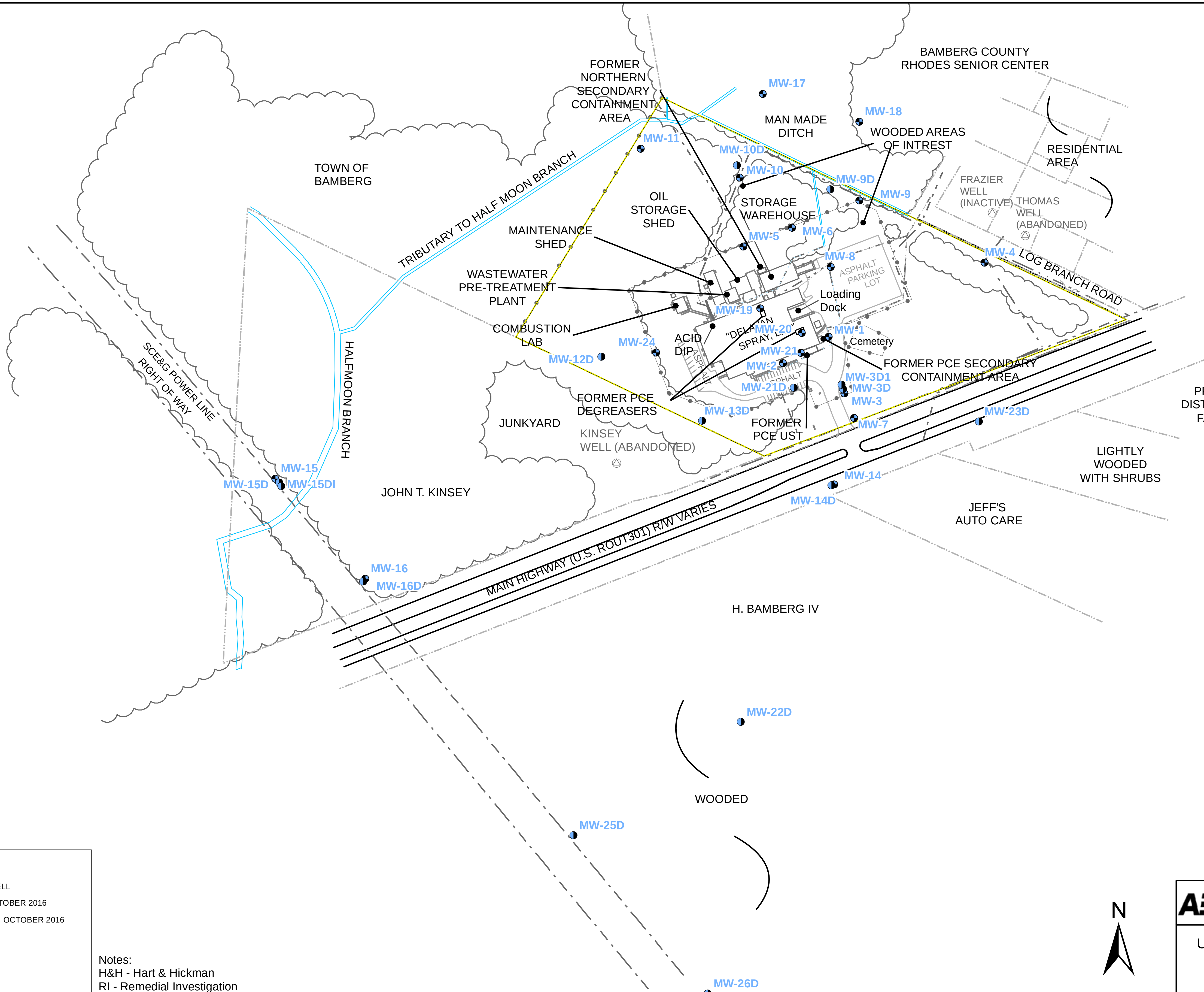
10 Patewood Drive, Building 6, Suite 500
Greenville, SC 29615
T: (864) 234-3000 F: (864)234-3069

UTC Delavan Spray Technologies Site
Bamberg, South Carolina

Site Location Map

Project No.	Prepared by	Date	
60314964	K. Clark	July 2017	Figure 1

Path: L:\Projects\60314964\900-CAD-GIS\920 GIS-Graphics\Maps\June 2017\Figure 1 Site Location Map.mxd



Legend

- ABANDONED OR INACTIVE WELL
- DEEP WELL - SAMPLED IN OCTOBER 2016
- SHALLOW WELL - SAMPLED IN OCTOBER 2016
- DRAINAGE
- FENCE LINE
- PROPERTY BOUNDRY
- OVERHEAD POWER LINE
- ROAD
- SANITARY SEWER LINE
- STORM DRAIN
- SUBJECT PROPERTY BOUNDRY

Notes:
H&H - Hart & Hickman
RI - Remedial Investigation
1. Base map obtained from surveys prepared by Edisto Engineers & Surveyors, Inc. (dated 6/3/2011 and 4/14/2014) and from Work Plan maps provided by H&H (August 2013).
2. 2012 sample locations were surveyed on 8/28/2012 and RI sample locations were surveyed on 3/20/2014. Post RI assessment locations were surveyed on 1/26/2016.

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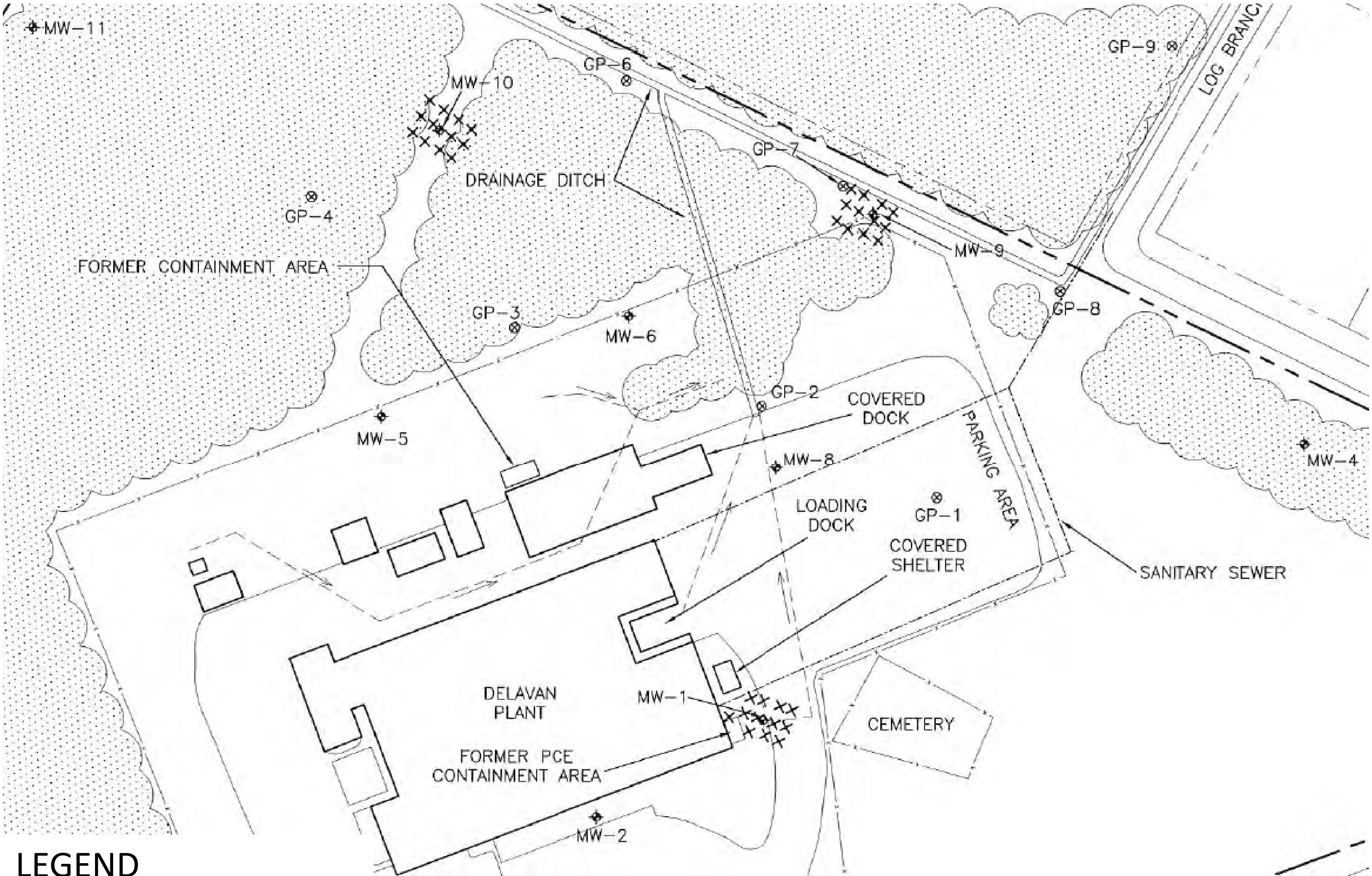
10 Patewood Drive, Building 6, Suite 500
Greenville, SC 29615
T: (864) 234-3000 F: (864)234-3069

UTC Delavan Spray Technologies Site
Bamberg, South Carolina

Site Layout Map

Project No.	Prepared by	Date	
60314964	K. Clark	July 2017	Figure 2

Path: L:\Projects\60314964\900-CAD-GIS\920 GIS-Graphics\Maps\Maps for January 2017\Figure 2 Site Layout.mxd



LEGEND

✕ Approximate Location of Historic HRC Injection Points

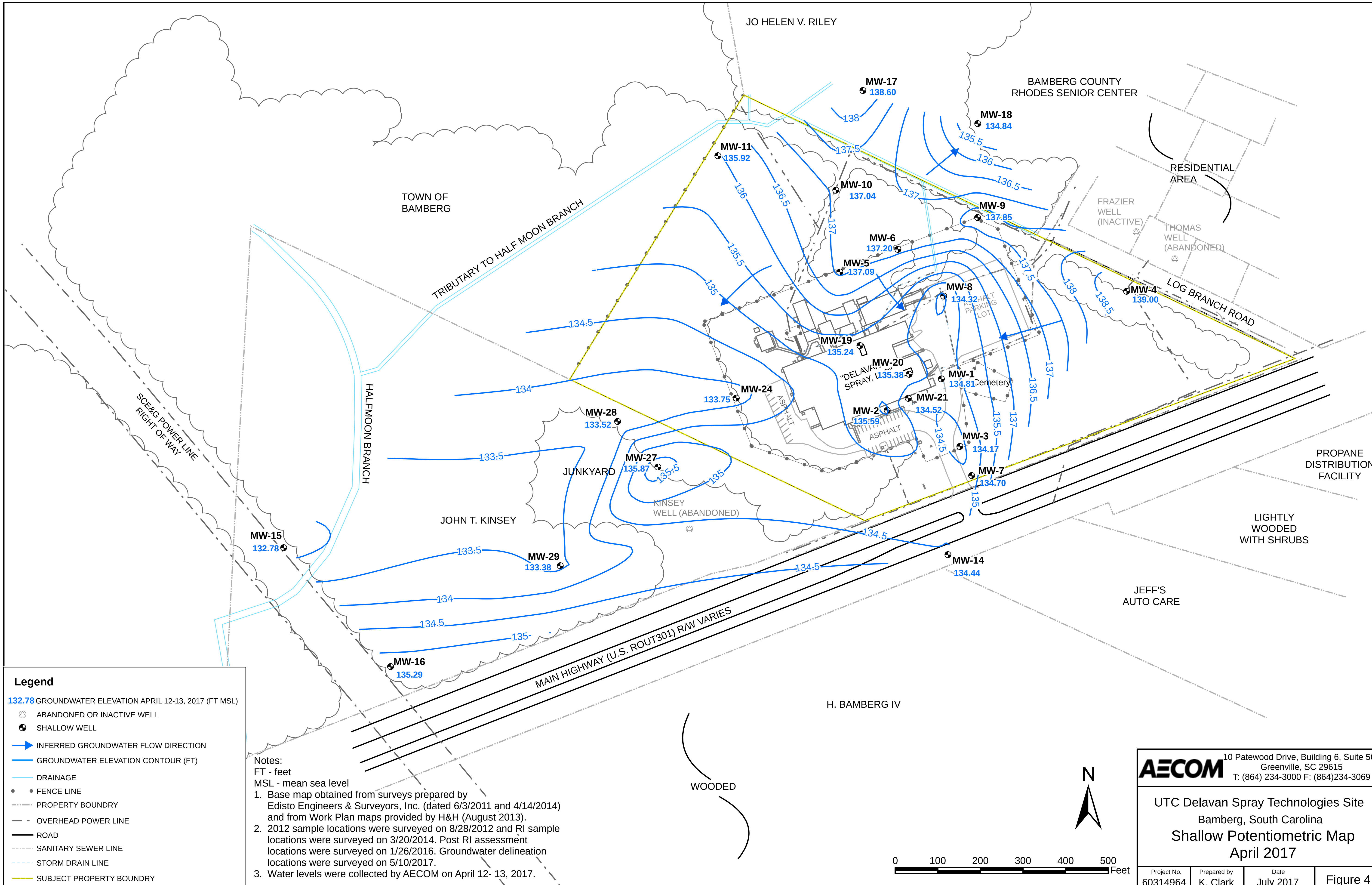
From Figure 3 – Report of HRC Injection and Pre- and Post-Injection Groundwater Monitoring, Hart & Hickman, January 31, 2006.

AECOM

FIGURE 3
Historic HRC Injection Areas

UTC Delavan Spray Technologies Site
Bamberg, South Carolina

60314964 **JULY 2017**



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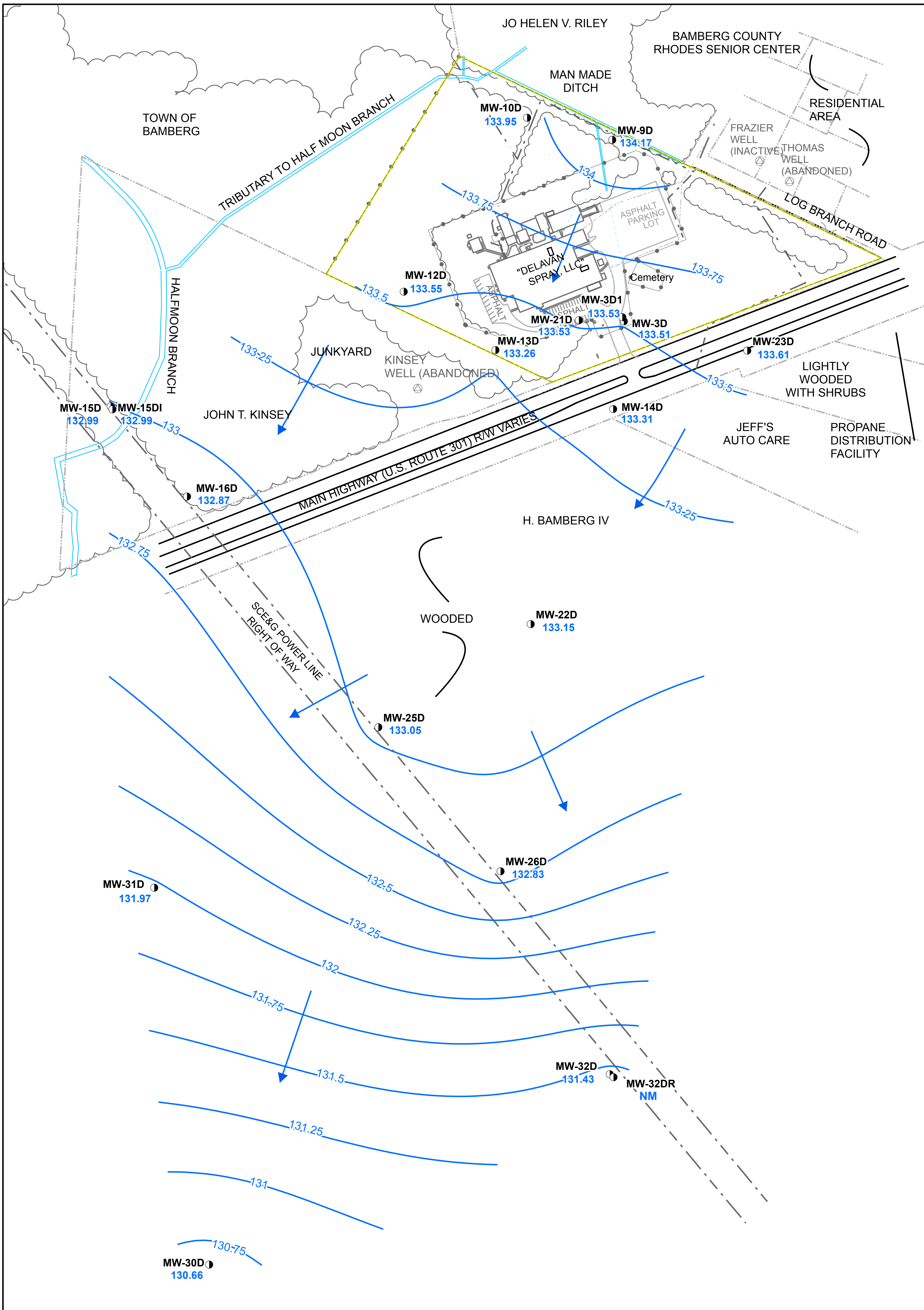

Legend

- 130.66 GROUNDWATER ELEVATION APRIL 12-13, 2017 (FT MSL)
- ABANDONED OR INACTIVE WELL
- DEEP WELL
- INFERRED GROUNDWATER FLOW DIRECTION
- GROUNDWATER ELEVATION CONTOUR (FT) (DASHED WHERE INFERRED)
- DRAINAGE
- FENCE LINE
- PROPERTY BOUNDRY
- OVERHEAD POWER LINE
- ROAD
- SANITARY SEWER LINE
- STORM DRAIN LINE
- SUBJECT PROPERTY BOUNDRY

Notes:
H&H - Hart & Hickman
RI - Remedial Investigation
NM - Not Measured

1. Base map obtained from surveys prepared by Edisto Engineers & Surveyors, Inc. (dated 6/3/2011 and 4/14/2014) and from Work Plan maps provided by H&H (August 2013).
2. 2012 sample locations were surveyed on 8/28/2012 and RI sample locations were surveyed on 3/20/2014. Post RI assessment locations were surveyed on 1/26/2016. Groundwater delineation locations were surveyed on 5/10/2017.
3. Water levels were collected by AECOM on April 12-13, 2017
4. MW-32DR was not measured because it was not installed at the time of the event.

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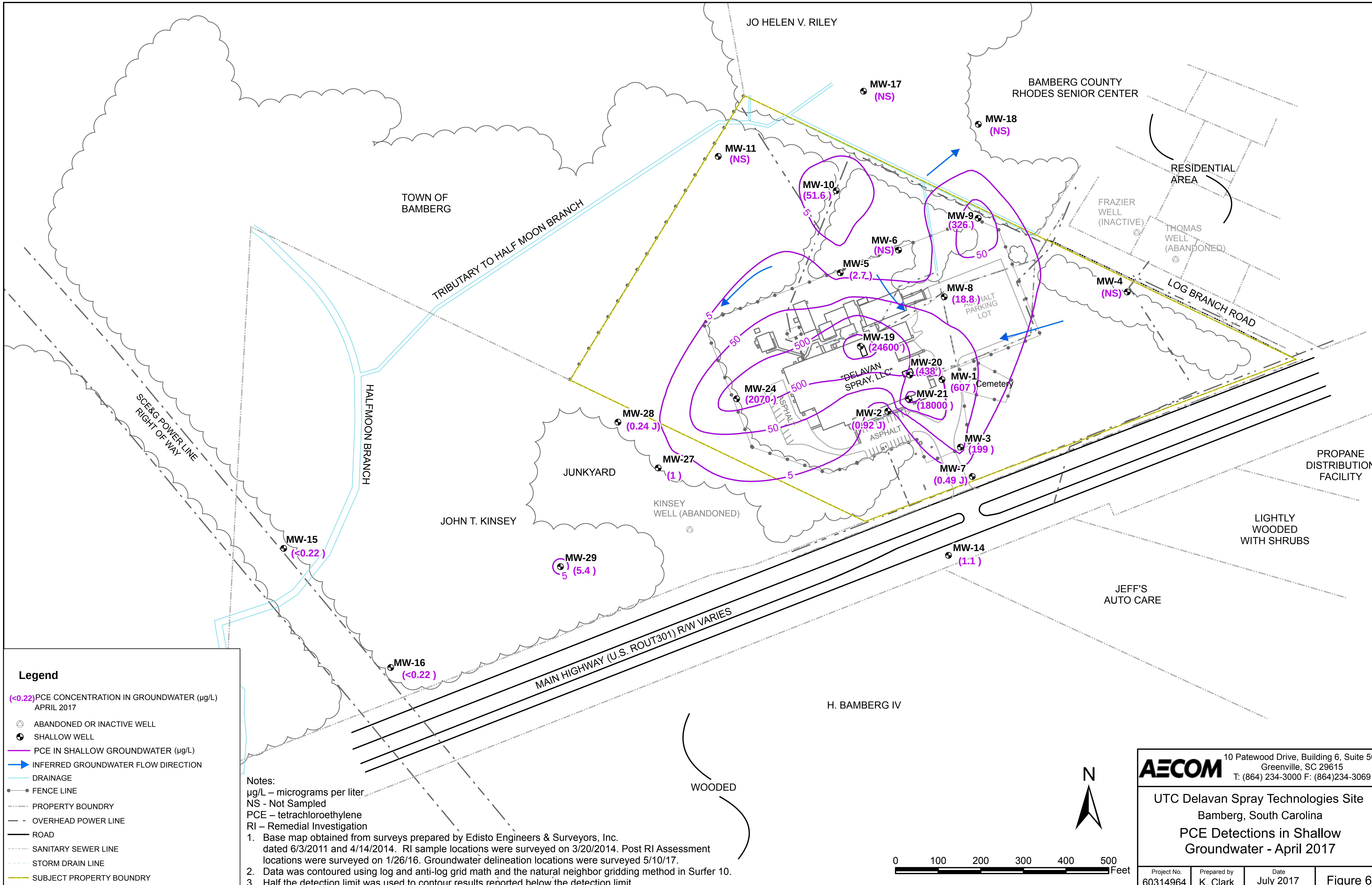
Greenville, SC 29615
T: (864) 234-3000 F: (864)234-3069

UTC Delavan Spray Technologies Site
Bamberg, South Carolina

Deep Potentiometric Map
April 2017

Project No.	Prepared by	Date	
60314964	K. Clark	July 2017	Figure 5

Path: L:\Projects\60314964\900-CAD-GIS\920 GIS-Graphics\Maps\June 2017\Figure 4 Deep Pot.mxd



Legend

(<0.22) PCE CONCENTRATION IN GROUNDWATER (µg/L) APRIL 2017

ABANDONED OR INACTIVE WELL

SHALLOW WELL

PCE IN SHALLOW GROUNDWATER (µg/L)

INFERRED GROUNDWATER FLOW DIRECTION

DRAINAGE

FENCE LINE

PROPERTY BOUNDRY

OVERHEAD POWER LINE

ROAD

SANITARY SEWER LINE

STORM DRAIN LINE

SUBJECT PROPERTY BOUNDRY

Notes:

µg/L – micrograms per liter
NS - Not Sampled
PCE – tetrachloroethylene
RI – Remedial Investigation

1. Base map obtained from surveys prepared by Edisto Engineers & Surveyors, Inc. dated 6/3/2011 and 4/14/2014. RI sample locations were surveyed on 3/20/2014. Post RI Assessment locations were surveyed on 1/26/16. Groundwater delineation locations were surveyed 5/10/17.
2. Data was contoured using log and anti-log grid math and the natural neighbor gridding method in Surfer 10.
3. Half the detection limit was used to contour results reported below the detection limit.

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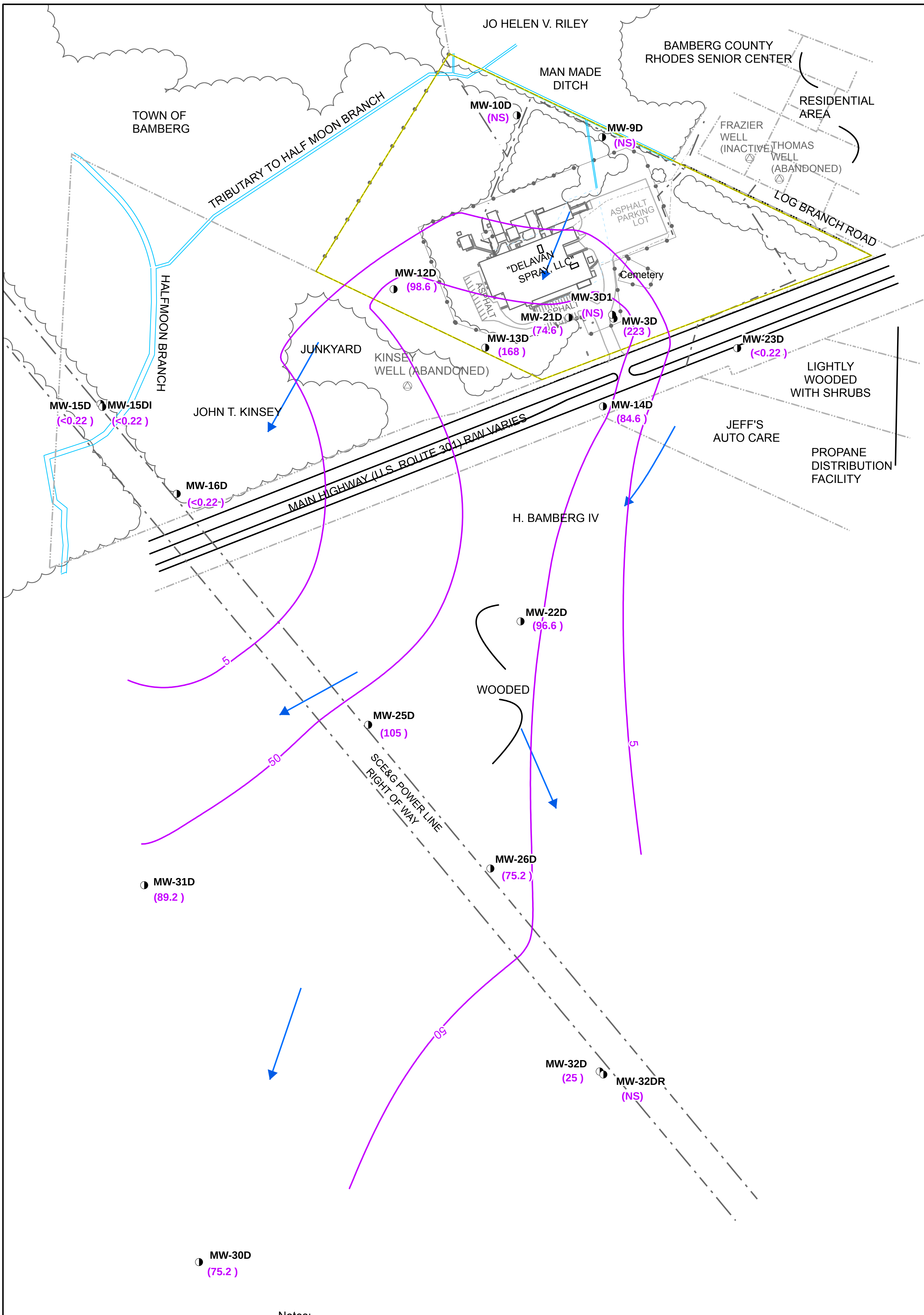
Greenville, SC 29615
T: (864) 234-3000 F: (864)234-3069

UTC Delavan Spray Technologies Site
Bamberg, South Carolina

PCE Detections in Shallow Groundwater - April 2017

Project No.	Prepared by	Date	
60314964	K. Clark	July 2017	Figure 6

Path: L:\Projects\60314964\900-CAD-GIS\920 GIS-Graphics\Maps\June 2017\Figure 5 ShallowPCE.mxd



Legend

- (<0.22) PCE CONCENTRATION IN GROUNDWATER (µg/L) APRIL 2017
- ABANDONED OR INACTIVE WELL
- DEEP WELL
- PCE IN SHALLOW GROUNDWATER (µg/L)
- INFERRED GROUNDWATER FLOW DIRECTION
- DRAINAGE
- FENCE LINE
- PROPERTY BOUNDRY
- OVERHEAD POWER LINE
- ROAD
- SANITARY SEWER LINE
- STORM DRAIN LINE
- SUBJECT PROPERTY BOUNDRY

Notes:
FT – feet
MSL – mean sea level
NS - Not Sampled
PCE – tetrachloroethylene

1. Base map obtained from surveys prepared by Edisto Engineers & Surveyors, Inc. dated 6/3/2011 and 4/14/2014. RI sample locations were surveyed on 3/20/2014. Post RI assessment locations were surveyed on 1/26/2016. Groundwater delineation locations were surveyed 5/10/17.
2. Data was contoured using log and anti-log grid math and the natural neighbor gridding method in Surfer 10.
3. Half the detection limit was used to contour results reported below the detection limit.

0 250 500 750 Feet

N

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Greenville, SC 29615
T: (864) 234-3000 F: (864)234-3069

UTC Delavan Spray Technologies Site
Bamberg, South Carolina

PCE Detections in Deeper Groundwater - April 2017

Project No.	Prepared by	Date	
60314964	K. Clark	July 2017	Figure 7

Path: L:\Projects\60314964\900-CAD-GIS\920 GIS-Graphics\Maps\June 2017\Figure 9 DeepPCE.mxd

TABLES

Table 6-1
Remedial Goals for Site-Specific Chlorinated VOCs
UTC Delavan Spray Technologies Site
Bamberg, South Carolina

	USEPA MCL	Maximum Detected Concentration [2]
Volatile Organic Compounds by USEPA Method 8260 (µg/L)		
Chloroform	80 [1]	131
cis-1,2-Dichloroethylene	70	466
Methylene chloride	5	765
Tetrachloroethylene	5	16300
Trichloroethylene	5	209

USEPA MCL - United States Environmental Protection Agency Maximum Contaminant Level (April, 2012).

South Carolina Department of Health and Environmental Control (SCDHEC) R.61-68 Water Classifications and Standards (June 22, 2012) were also identified for the list of detected chemicals in groundwater. In each case, however, they were the same values as the USEPA MCLs.

[1] 1998 Final Rule for Disinfectants and Disinfection By-products. The total for trihalomethanes (THM) is 0.08 mg/L.

[2] Groundwater data from the Remedial Investigation (AECOM, July 2014).

Table 8-1
Comparison of Remedial Alternatives to Evaluation Criteria
UTC Delavan Spray Technologies Site
Bamberg, South Carolina

	Remedial Alternatives			
	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Criterion	No Action and Institutional Controls	Excavation, Vapor Abatement, MNA, Groundwater Capture and ICs	Vapor Abatement, DPE, MNA and ICs	Vapor Abatement, ISCO, MNA and ICs
Overall Protection of human health and the environment	1	3	4	4
Compliance with applicable federal, state and local regulations	0	3	4	4
Long-term effectiveness and permanence	2	4	4	4
Reduction of toxicity, mobility and volumes	1	4	4	4
Short-term effectiveness	1	3	4	4
Implementability	5	1	3	3
Cost	5	2	3	3
State and community acceptance	--	--	--	--

Notes:
Numeric ranking assigned according to following scale:
0 = unacceptable
1 = poor
2, 3 = fair
4, 5 = good
DPE - Dual Phase Extraction
ICs - Institutional Controls
ISCO - In Situ Chemical Oxidation
MNA - Monitored Natural Attenuation
-- Not Ranked

Table 8-2
Comparison of Costs for Remedial Alternatives
UTC Delavan Spray Technologies Site
Bamberg, South Carolina

Remedial Alternative	Description	Design and IC	Construction	O&M (1)	O&M Duration (est. years)	Total Cost	Total Cost (rounded)	Total Cost -30%	Total Cost +50%
1	No Action and Institutional Controls	$ 25,000	$ -	$ -	--	$ 25,000	$ 25,000	$ 17,500	$ 37,500
2	Excavation, Vapor Abatement, MNA, Groundwater Capture and ICs	$ 271,600	$ 944,600	$ 1,557,131	30	$ 2,773,331	$ 2,773,000	$ 1,941,100	$ 4,159,500
3	Vapor Abatement, DPE, MNA, and ICs	$ 271,600	$ 635,500	$ 652,682	30	$ 1,559,782	$ 1,560,000	$ 1,092,000	$ 2,340,000
3a	Alternative 3 using Horizontal Wells	$ 271,600	$ 1,083,400	$ 652,682	30	$ 2,007,682	$ 2,008,000	$ 1,405,600	$ 3,012,000
4	Vapor Abatement, ISCO, MNA, and ICs	$ 271,600	$ 940,900	$ 581,903	30	$ 1,794,403	$ 1,794,000	$ 1,255,800	$ 2,691,000
4a	Alternative 4 using Horizontal Wells	$ 271,600	$ 1,254,540	$ 581,903	30	$ 2,108,043	$ 2,108,000	$ 1,475,600	$ 3,162,000

Notes:
(1) - Operation and maintenance calculated using net present value assuming an estimated duration and a discount rate of 5%.
Costs for Remedial Alternatives do not include costs due to potential business disruption during construction.
DPE - Dual Phase Extraction
ICs - Institutional Controls
ISCO - In Situ Chemical Oxidation
MNA - Monitored Natural Attenuation
O&M - Operation and Maintenance

Table 8-3
Analytical Results for Soil Samples - TOD
UTC Delavan Spray Technologies Site
Bamberg, South Carolina

Sample Used	BG-6-6	BG-6-10	BG-7-6	BG-7-10	none
Lab Package ID	SC15664-05	SC15664-06	SC15664-07	SC15664-08	SC15664-09
Sample Sample ID	4-01 A.3	4-02 A.3	4-03 A.3	4-04 A.3	Control A.3
Additive	28.9 g/L of 30% peroxide and 2 g/kg of ferrous sulfate				
Hydrogen Peroxide (g/L)	2.65	2.20	0.424	1.82	0.055
TOD Peroxide (g/kg)	131	134	142	135	144

Sample Used	BG-6-6	BG-6-6	BG-6-10	BG-6-10	BG-7-6	BG-7-6	BG-7-10	BG-7-10	none
Lab Package ID	SC15664-10	SC15664-11	SC15664-12	SC15664-13	SC15664-14	SC15664-15	SC15664-16	SC15664-17	SC15664-18
Sample Sample ID	4-01 A.1	4-01 A.2	4-02 A.1	4-02 A.2	4-03 A.1	4-03 A.2	4-04 A.1	4-04 A.2	Control A.2
Persulfate Added	10 g/L	20 g/L	10 g/L	20 g/L	10 g/L	20 g/L	10 g/L	20 g/L	20 g/L
Persulfate (g/L)	7.90	17.3	7.77	17.9	7.77	18.2	7.90	18.3	18.4
TOD Persulfate (g/kg)	11	14	11	11	11	9.0	11	8.5	8.0

Sample Used	BG-6-6	BG-6-6	BG-6-10	BG-6-10	BG-7-6	BG-7-6	BG-7-10	BG-7-10	none
Lab Package ID	SC15664-19	SC15664-20	SC15664-21	SC15664-22	SC15664-23	SC15664-24	SC15664-25	SC15664-26	SC15664-27
Sample Sample ID	4-01 B.1	4-01 B.2	4-02 B.1	4-02 B.2	4-03 B.1	4-03 B.2	4-04 B.1	4-04 B.2	Control B.2
Permanganate Added	20 g/L	30 g/L	20 g/L	30 g/L	20 g/L	30 g/L	20 g/L	30 g/L	30 g/L
Permanganate (g/L)	12.5	18.4	13.6	19.1	14.3	20.6	15.1	21.4	30.8
TOD Permanganate (g/kg)	38	58	32	55	29	47	25	43	0

Notes:
g/L - grams per Liter
g/kg - grams per kilogram
TOD - total oxidant demand

APPENDIX A

Remedial Alternative Cost Estimates and Assumptions

Table A.1
Alternative 1 Cost Estimate

			DESCRIPTION	NOTES	UNITS	QUANTITY	UNIT COST ($)	TOTAL COST ($)
I.	**Institutional Control**							
	1.	Institutional Controls						
		a.	NFA Letter and Deed Restriction for Soils and Groundwater		ls	1	$25,000	$25,000
			Subtotal Institutional Controls					*$25,000*
			Total Institutional Control Costs					**$25,000**
			Cost Summary					
		I.	Institutional Control					$25,000
			TOTAL PROBABLE COSTS					**$25,000**
			TOTAL PROBABLE COSTS RANGE (-30%; + 50%)			**$17,500**	**to**	**$37,500**

Notes/Key Assumptions:

NFA - no further action

Table A.2
Alternative 2 Cost Estimate

			DESCRIPTION	NOTES	UNITS	QUANTITY	UNIT COST ($)	TOTAL COST ($)
I.	**Pre-Construction Costs**							
	1.	Office Preparation						
		a.	Remedial Action Plan		ls	1	$35,000	$35,000
		b.	Work Plan		ls	1	$15,000	$15,000
		c.	HASP Update		ls	1	$13,000	$13,000
		d.	Erosion Plan		ls	1	$15,000	$15,000
			Subtotal Office Preparation					*$78,000*
	2.	Pre-Design Investigation						
		a.	Pre-Design Investigation		ls	1	$100,000	$100,000
			Subtotal Pre-Design Investigation					*$100,000*
			Subtotal prior to services					*$100,000*
	3.	Services						
		a.	Contingency (20% Pre-Design Investigation)		ls	1	$35,600	$35,600
		b.	Project Management/Coordination	a	ls	1	$8,000	$8,000
		c.	Engineering Design	b	ls	1	$15,000	$15,000
		d.	Construction Management	c	ls	1	$10,000	$10,000
			Subtotal Services					*$68,600*
			Total Pre-Construction Costs					**$246,600**

Table A.2
Alternative 2 Cost Estimate

II.	**Construction Costs**							
	1.	Site Preparation						
		a.	Utility Locate and Survey		ls	1	$3,800	$3,800
		b.	Equipment Decontamination Pad		ls	1	$10,249	$10,300
			Subtotal Site Preparation					*$14,100*
	2.	Excavation						
		a.	Mobilization		ls	1	$10,000	$10,000
		b.	Break Concrete		bcyd	53	$250	$13,300
		c.	Excavation		bcyd	287	$10	$2,900
		d.	Backfill and Recompaction		bcyd	241	$60	$14,500
		e.	Gravel Backfill		bcyd	46	$41	$1,900
		f.	Infiltration piping		lf	35	$45	$1,600
		g.	Off-site disposal (hazardous soil)		tons	361	$400	$144,500
		h.	Off-site disposal (no-hazardous concrete)		tons	56	$37	$2,100
		i.	Excavation Confirmation Survey		ls	1	$1,400	$1,400
		j.	Monitoring		day	3	$1,400	$4,100
		k.	Confirmation Sampling		ea	5	$456	$2,300
			Subtotal Excavation					*$198,600*
	3.	Sub Slab Depressurization						
		a.	SSD Testing		ea	1	$13,000	$13,000
		b.	Pipe Installation		lf	6000	$6	$36,000
		c.	Point installation		ea	40	$700	$28,000
		d.	SSD Equipment		ls	1	$65,000	$65,000
		e.	SSD Equipment Installation		ls	1	$20,000	$20,000
		f.	Confirmation Sampling		ls	1	$5,000	$5,000
			Subtotal SSD					*$167,000*
	4.	Repair to Prior Conditions						
		a.	Repair Concrete		cy	53	$415	$22,000
		b.	Re-install Monitoring Wells		ea	2	$5,597	$11,200
		c.	Disposal Cost Drums (non-hazardous)		ea	4	$125	$500
			Subtotal Repair to Prior Conditions Costs					*$33,700*
	5.	Recovery Well Install						
		a.	Recovery Well Install		ea	4	$14,480	$58,500
		b.	Down Well Equipment		ea	4	$5,000	$20,500
		c.	Non-Hazardous Off-site Waste T&D		drum	24	$125	$3,000
		d.	Survey		ls	1	$1,400	$1,400
			Subtotal Recovery Well Install Costs					*$83,400*
	6.	Pump and Treat System Installation						
		a.	OWS Building and System		ls	1	$81,000	$81,000
		b.	Mechanical and Electrical Contractors		ls	1	$40,000	$40,000
		c.	Trenching & backfill (off-site)		ls	280	$25	$6,900
		d.	Home Run Piping		ls	1,120	$9	$10,200
		e.	Disposal Cost (non-hazardous)		tons	124	$37	$4,700
		f.	Detection Tape		ls	1	$200	$200
		g.	AECOM Oversight		day	5	$1,400	$7,000
			Subtotal Pump and Treat Installation Costs					*$150,000*
			Subtotal prior to services					*$646,800*
	7.	Services						
		a.	Contingency (20% Construction Costs)		ls	1	$129,360	$129,400
		b.	Project Management/Coordination	a	ls	1	$38,808	$38,900
		c.	Engineering Design	b	ls	1	$77,616	$77,700
		d.	Construction Management	c	ls	1	$51,744	$51,800
			Subtotal Services					*$297,800*
			Total Construction Costs					**$944,600**

Table A.2
Alternative 2 Cost Estimate

III.	**Institutional Control**							
	1.	Institutional Controls						
		a.	NFA Letter and Deed Restriction for Soils and Groundwater		ls	1	$25,000	$25,000
			Subtotal Institutional Controls					*$25,000*
			Total Institutional Control Costs					**$25,000**
IV.	**O&M Costs**							
	1.	MNA Year 1						
		a.	Quarterly Well Gauging		ea	4	$500	$2,000
		b.	Groundwater Reporting (annual)		yr	1	$10,000	$10,000
		c.	Quarterly VOC Sampling		ea	4	$7,500	$30,000
		d.	Quarterly Geochemical Sampling		ea	4	$2,500	$10,000
		e.	Quarterly Waste Stream Sampling		ea	4	$1,000	$4,000
			Subtotal Year 1 MNA					*$56,000*
	2.	MNA Years 2-30 (Annual Cost)						
		a.	Annual Well Gauging		ea	1	$500	$500
		b.	Groundwater Reporting (annual)		yr	1	$10,000	$10,000
		c.	Annual VOC Sampling		ea	1	$7,500	$7,500
		d.	Annual Geochemical Sampling		ea	1	$2,500	$2,500
		e.	Annual Waste Stream Sampling		ea	1	$1,000	$1,000
			Subtotal Year 2-30 MNA					*$325,533*
	3.	O&M SSD Years 1-10 (Annual Cost)						
		a.	Utilities		yr	1	$250	$300
		b.	Monthly O&M		mo	12	$725	$8,700
			Subtotal Year 1 -10 SSD					*$72,970*
	4.	O&M GW Recovery (Years 1-30) (Annual)						
		a.	Weekly System O&M		ea	52	$632	$32,900
		b.	Utilities		mo	12	$980	$11,800
		c.	Carbon O&M		ea	0.5	$1,650	$900
		d.	Water Disposal		1000 gal	10512	$0.26	$2,800
			Subtotal Year 1-30 GW Recovery					*$781,228*
			Subtotal prior to services					*$1,235,731*
	5.	Services						
		a.	Contingency (20% O&M Costs)		ls	1	$247,146	$247,200
		b.	Project Management/Coordination	a	ls	1	$74,144	$74,200
			Subtotal Services					*$321,400*
			Total O&M Costs					**$1,557,131**
			Cost Summary					
		I.	Pre-Construction Costs					$246,600
		II.	Construction Costs					$944,600
		III.	Institutional Control					$25,000
		IV.	O&M Costs					$1,557,131
			TOTAL PROBABLE COSTS					**$2,773,331**
			TOTAL PROBABLE COSTS RANGE (-30%; + 50%)			**$1,941,332**	**to**	**$4,159,997**

Notes/Key Assumptions:

a/ Project management/coordination costs based on Table 5-8 from "A guide to developing and documenting cost estimates during the feasibility study" ; Capital costs <100K (10%), 100K-500K (8%); 500K-2M (6%); 2M-10M (5%); >10M (5%)

b/ Engineering design costs based on Table 5-8 from "A guide to developing and documenting cost estimates during the feasibility study" ; Capital costs <100K (20%), 100K-500K (15%); 500K-2M (12%); 2M-10M (8%); >10M (6%)

c/ Construction management costs based on Table 5-8 from "A guide to developing and documenting cost estimates during the feasibility study" ; Capital costs <100K (15%), 100K-500K (10%); 500K-2M (8%); 2M-10M (6%); >10M (6%)

Operation and maintenance costs are discounted at a rate of 5 percent.

Table A.3
Alternative 3 Cost Estimate

			DESCRIPTION	NOTES	UNITS	QTY	UNIT COST ($)	TOTAL COST ($)
I.	**Pre-Construction Costs**							
	1.	Office Preparation						
		a.	Remedial Action Plan		ls	1	$35,000	$35,000
		b.	Work Plan		ls	1	$15,000	$15,000
		c.	HASP Update		ls	1	$13,000	$13,000
		d.	Erosion Plan		ls	1	$15,000	$15,000
			Subtotal Office Preparation					*$78,000*
	2.	Pre-Design Investigation						
		a.	Pre-Design Investigation		ls	1	$100,000	$100,000
			Subtotal Pre-Design Investigation					*$100,000*
			Subtotal prior to services					*$100,000*
	3.	Services						
		a.	Contingency (20% Pre-Design Investigation)		ls	1	$35,600	$35,600
		b.	Project Management/Coordination	a	ls	1	$8,000	$8,000
		c.	Engineering Design	b	ls	1	$15,000	$15,000
		d.	Construction Management	c	ls	1	$10,000	$10,000
			Subtotal Services					*$68,600*
			Total Pre-Construction Costs					**$246,600**

Table A.3
Alternative 3 Cost Estimate

II.	**Construction Costs**							
	1.	Site Preparation						
		a.	Utility Locate and Survey		ls	1	$3,800	$3,800
		b.	Equipment Decontamination Pad		ls	1	$10,249	$10,300
			Subtotal Site Preparation					*$14,100*
	2.	Sub Slab Depressurization						
		a.	SSD Testing		ea	1	$13,000	$13,000
		b.	Pipe Installation		lf	6000	$6	$36,000
		c.	Point installation		ea	40	$700	$28,000
		d.	SSD Equipment		ls	1	$65,000	$65,000
		e.	SSD Equipment Installation		ls	1	$20,000	$20,000
		f.	Confirmation Sampling		ls	1	$5,000	$5,000
			Subtotal SSD					*$167,000*
	3.	DPE Well Install						
		a.	Break Concrete		bcyd	4	$250	$1,000
		b.	Recovery Well Install		ea	6	$10,000	$60,500
		c.	Down Well Equipment		ea	6	$200	$1,700
		d.	Repair Concrete		cy	4	$415	$1,700
		e.	Off-site disposal (non-hazardous concrete)		tons	8	$37	$300
		f.	Hazardous Off-site Waste T&D (Wells in Source Zone)		drum	36	$450	$16,200
		g.	Non-Hazardous Off-site Waste T&D (Wells outside Source Zone)		drum	18	$125	$2,300
		h.	Survey		ls	1	$1,400	$1,400
			Subtotal DPE Well Install Costs					*$85,100*
	3A.	Horizontal DPE Well Install (Alternate)						
		a.	Horizontal Well		lf	2000	$200	$400,000
		b.	Hazardous Off-site Waste T&D (Wells in Source Zone)		bcyd	146	$400	$58,400
			Subtotal Horizontal DPE Well Install Costs					*$458,400*
	4.	DPE System Installation						
		a.	OWS and Stripper Building and System		ls	1	$80,000	$80,000
		b.	Mechanical and Electrical Contractors		ls	1	$40,000	$40,000
		c.	Trenching & backfill (off-site)		ls	280	$25	$6,900
		d.	Home Run Piping		ls	1,120	$9	$10,200
		e.	Disposal Cost (non-hazardous)		tons	124	$37	$4,700
		f.	Detection Tape		ls	1	$200	$200
		g.	AECOM Oversight		day	5	$1,400	$7,000
			Subtotal DPE System Installation Costs					*$149,000*
			Subtotal prior to services					*$415,200*
	5.	Services						
		a.	Contingency (20% Construction Costs)		ls	1	$83,040	$83,100
		b.	Project Management/Coordination	a	ls	1	$33,216	$33,300
		c.	Engineering Design	b	ls	1	$62,280	$62,300
		d.	Construction Management	c	ls	1	$41,520	$41,600
			Subtotal Services					*$220,300*
			Total Construction Costs					**$635,500**

Table A.3
Alternative 3 Cost Estimate

III.	**Institutional Control**								
	1.	Institutional Controls							
		a.	NFA Letter and Deed Restriction for Soils and Groundwater		ls	1	$25,000	$25,000
			Subtotal Institutional Controls					*$25,000*
			Total Institutional Control Costs					**$25,000**
IV.	**O&M Costs**							
	1.	MNA Year 1						
		a.	Quarterly Well Gauging		ea	4	$500	$2,000
		b.	Groundwater Reporting (annual)		yr	1	$10,000	$10,000
		c.	Quarterly VOC Sampling		ea	4	$7,500	$30,000
		d.	Quarterly Geochemical Sampling		ea	4	$2,500	$10,000
		e.	Quarterly Waste Stream Sampling		ea	4	$1,000	$4,000
			Subtotal Year 1 MNA					*$56,000*
	2.	MNA Years 2-30 (Annual Cost)						
		a.	Annual Well Gauging		ea	1	$500	$500
		b.	Groundwater Reporting (annual)		yr	1	$10,000	$10,000
		c.	Annual VOC Sampling		ea	1	$7,500	$7,500
		d.	Annual Geochemical Sampling		ea	1	$2,500	$2,500
		e.	Annual Waste Stream Sampling		ea	1	$1,000	$1,000
			Subtotal Year 2-30 MNA					*$325,533*
	3.	O&M SSD Years 1-10 (Annual Cost)						
		a.	Utilities		yr	1	$250	$300
		b.	Monthly O&M		mo	12	$725	$8,700
			Subtotal Year 1-10 SSD					*$72,970*
	4.	O&M DPE Recovery (Years 1-3) (Annual Cost)						
		a.	Weekly System O&M		ea	12	$632	$7,600
		b.	Utilities		mo	12	$980	$11,800
		c.	Water Disposal		1000 gal	10512	$0.26	$2,800
			Subtotal Year 1-3 DPE					*$63,479*
			Subtotal prior to services					*$517,982*
	5.	Services						
		a.	Contingency (20% O&M Costs)		ls	1	$103,596	$103,600
		b.	Project Management/Coordination	a	ls	1	$31,079	$31,100
			Subtotal Services					*$134,700*
			Total O&M Costs					**$652,682**
			Cost Summary					
		I.	Pre-Construction Costs					$246,600
		II.	Construction Costs					$635,500
		III.	Institutional Control					$25,000
		IV.	O&M Costs					$652,682
			TOTAL PROBABLE COSTS					**$1,559,782**
			TOTAL PROBABLE COSTS RANGE (-30%; + 50%)			**$1,091,848**	**to**	**$2,339,674**

Notes/Key Assumptions:

a/ Project management/coordination costs based on Table 5-8 from "A guide to developing and documenting cost estimates during the feasibility study" ; Capital costs <100K (10%), 100K-500K (8%); 500K-2M (6%); 2M-10M (5%); >10M (5%)

b/ Engineering design costs based on Table 5-8 from "A guide to developing and documenting cost estimates during the feasibility study" ; Capital costs <100K (20%), 100K-500K (15%); 500K-2M (12%); 2M-10M (8%); >10M (6%)

c/ Construction management costs based on Table 5-8 from "A guide to developing and documenting cost estimates during the feasibility study" ; Capital costs <100K (15%), 100K-500K (10%); 500K-2M (8%); 2M-10M (6%); >10M (6%)

Operation and maintenance costs are discounted at a rate of 5 percent.

Table A.4
Alternative 4 Cost Estimate

			DESCRIPTION	NOTES	UNITS	QTY	UNIT COST ($)	TOTAL COST ($)
I.	**Pre-Construction Costs**							
	1.	Office Preparation						
		a.	Remedial Action Plan		ls	1	$35,000	$35,000
		b.	Work Plan		ls	1	$15,000	$15,000
		c.	HASP Update		ls	1	$13,000	$13,000
		d.	Erosion Plan		ls	1	$15,000	$15,000
			Subtotal Office Preparation					*$78,000*
	2.	Pre-Design Investigation						
		a.	Pre-Design Investigation		ls	1	$100,000	$100,000
			Subtotal Pre-Design Investigation					*$100,000*
			Subtotal prior to services					*$100,000*
	3.	Services						
		a.	Contingency (20% Pre-Design Investigation)		ls	1	$35,600	$35,600
		b.	Project Management/Coordination	a	ls	1	$8,000	$8,000
		c.	Engineering Design	b	ls	1	$15,000	$15,000
		d.	Construction Management	c	ls	1	$10,000	$10,000
			Subtotal Services					*$68,600*
			Total Pre-Construction Costs					**$246,600**

Table A.4
Alternative 4 Cost Estimate

II.	**Construction Costs**							
	1.	Site Preparation						
		a.	Utility Locate and Survey		ls	1	$3,800	$3,800
		b.	Equipment Decontamination Pad		ls	1	$10,249	$10,300
			Subtotal Site Preparation					*$14,100*
	2.	Sub Slab Depressurization						
		a.	SSD Testing		ea	1	$13,000	$13,000
		b.	Pipe Installation		lf	6000	$6	$36,000
		c.	Point installation		ea	40	$700	$28,000
		d.	SSD Equipment		ls	1	$65,000	$65,000
		e.	SSD Equipment Installation		ls	1	$20,000	$20,000
		f.	Confirmation Sampling		ls	1	$5,000	$5,000
			Subtotal SSD					*$167,000*
	3.	Injection Well Install						
		a.	Break Concrete		bcyd	16	$250	$4,000
		b.	Injection Well Install		ea	32	$4,000	$128,500
		c.	Repair Concrete		cy	16	$415	$6,700
		d.	Off-site disposal (non-hazardous concrete)		tons	32	$37	$1,200
		e.	Hazardous Off-site Waste T&D (Wells in Source Zone)		drum	96	$450	$43,200
		f.	Non-Hazardous Off-site Waste T&D (Wells outside Source Zone)		drum	96	$125	$12,000
		g.	Survey		ls	1	$1,400	$1,400
			Subtotal Injection Well Install Costs					*$197,000*
	3A.	Horizontal Injection Well Install (Alternate)						
		a.	Horizontal Well		lf	2000	$200	$400,000
		b.	Hazardous Off-site Waste T&D (Wells in Source Zone)		bcyd	146	$400	$58,400
			Subtotal Horizontal Injection Well Install Costs					*$458,400*
	4.	Injection Events						
		a.	Mobilization		ea	4	$1,000	$4,000
		b.	Injection Manifold		ls	1	$7,500	$7,500
		c.	Injectate		lbs	116,000	$2.23	$258,700
			Subtotal Injection Event Costs					*$266,200*
			Subtotal prior to services					*$644,300*
	5.	Services						
		a.	Contingency (20% Construction Costs)		ls	1	$128,860	$128,900
		b.	Project Management/Coordination	a	ls	1	$38,658	$38,700
		c.	Engineering Design	b	ls	1	$77,316	$77,400
		d.	Construction Management	c	ls	1	$51,544	$51,600
			Subtotal Services					*$296,600*
			Total Construction Costs					**$940,900**
III.	**Institutional Control**							
	1.	Institutional Controls						
		a.	NFA Letter and Deed Restriction for Soils and Groundwater		ls	1	$25,000	$25,000
			Subtotal Institutional Controls					*$25,000*
			Total Institutional Control Costs					**$25,000**

Table A.4
Alternative 4 Cost Estimate

IV.	**O&M Costs**							
	1.	MNA Year 1						
		a.	Quarterly Well Gauging		ea	4	$500	$2,000
		b.	Groundwater Reporting (annual)		yr	1	$10,000	$10,000
		c.	Quarterly VOC Sampling		ea	4	$7,500	$30,000
		d.	Quarterly Geochemical Sampling		ea	4	$2,500	$10,000
		e.	Quarterly Waste Stream Sampling		ea	4	$1,000	$4,000
			Subtotal Year 1 MNA					*$56,000*
	2.	MNA Years 2-30 (Annual Cost)						
		a.	Annual Well Gauging		ea	1	$500	$500
		b.	Groundwater Reporting (annual)		yr	1	$10,000	$10,000
		c.	Annual VOC Sampling		ea	1	$7,500	$7,500
		d.	Annual Geochemical Sampling		ea	1	$2,500	$2,500
		e.	Annual Waste Stream Sampling		ea	1	$1,000	$1,000
			Subtotal Year 2-30 MNA					*$325,533*
	3.	O&M SSD Years 1-10 (Annual Cost)						
		a.	Utilities		yr	1	$250	$300
		b.	Monthly O&M		mo	12	$725	$8,700
			Subtotal Year 1-10 SSD					*$72,970*
			Subtotal prior to services					*$454,503*
	4.	Services						
		a.	Contingency (20% O&M Costs)		ls	1	$90,901	$91,000
		b.	Project Management/Coordination	a	ls	1	$36,360	$36,400
			Subtotal Services					*$127,400*
			Total O&M Costs					**$581,903**
			Cost Summary					
		I.	Pre-Construction Costs					$246,600
		II.	Construction Costs					$940,900
		III.	Institutional Control					$25,000
		IV.	O&M Costs					$581,903
			TOTAL PROBABLE COSTS					**$1,794,403**
			TOTAL PROBABLE COSTS RANGE (-30%; + 50%)			**$1,256,082**	**to**	**$2,691,605**

Notes/Key Assumptions:

a/ Project management/coordination costs based on Table 5-8 from "A guide to developing and documenting cost estimates during the feasibility study" ; Capital costs <100K (10%), 100K-500K (8%); 500K-2M (6%); 2M-10M (5%); >10M (5%)

b/ Engineering design costs based on Table 5-8 from "A guide to developing and documenting cost estimates during the feasibility study" ; Capital costs <100K (20%), 100K-500K (15%); 500K-2M (12%); 2M-10M (8%); >10M (6%)

c/ Construction management costs based on Table 5-8 from "A guide to developing and documenting cost estimates during the feasibility study" ; Capital costs <100K (15%), 100K-500K (10%); 500K-2M (8%); 2M-10M (6%); >10M (6%)

Operation and maintenance costs are discounted at a rate of 5 percent.