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SITE ASSESSMENT, REMEDIATION & REVITALIZATION

SCANNED

November 20, 2018

Ms. Kim Kuhn
Bureau of Land and Waste Management
SC Department of Health and Environmental Control
2600 Bull Street
Columbia, SC 29201

Regarding: Remedial Investigation Report and Baseline Risk Assessment
Shakespeare Composite Structures Site
Newberry, South Carolina
SCDHEC VCC Number 14-6271-RP
AECOM Project Number 60534283

Dear Ms. Kuhn:

On behalf of Philips Lighting North America (now known as Signify) please find attached the Remedial Investigation (RI) Report and Baseline Risk Assessment for the Shakespeare Composite Structures Site ('the Site") located in Newberry, South Carolina. This RI report is being submitted to the South Carolina Department of Health and Environmental Control (SCDHEC) in accordance with Sections 3.A and 3.B of the voluntary clean-up contract (VCC) number 14-6271-RP, which was executed on September 8, 2014.

We have attached one hard copy of the report and one electronic copy on compact disc (CD). The hard copy of the report is being submitted in two volumes. Volume I contains the report text, tables, and figures. Volume II contains all of the appendices (A through I) referenced in the report. Appendices F and G include analytical data reports for the investigative efforts performed at the Site. Due to the number of pages required for the analytical reports, these appendices have been included on CD. Appendix H includes an electronic version of a 3-D conceptual site model (CSM) for the Site. Appendix H is also included on the same CD. The Baseline Risk Assessment (BRA) is included as Appendix I to the RI Report.

Should you have any questions or require further information, please feel free to contact me.

Sincerely,

AECOM Technical Services, Inc.

Scott E. Ross, PG
Project Manager
scott.ross@aecom.com

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SC Department of
Health & Environmental Control

cc: Mr. Dean Weeks – Signify

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AECOM Technical Services, Inc.

Submitted by:
AECOM
Columbia, S.C
November 2018

CD Scanned
PM Copy

Remedial Investigation Report Shakespeare Composite Structures Site

Voluntary Cleanup Contract 14-6271-RP

File # 51025

19845 US Highway 76

Newberry, SC

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SITE ASSESSMENT,
REMEDIATION &
REVITALIZATION

VOLUME I OF II – Report text, tables and figures

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AECOM Technical Services, Inc.

Remedial Investigation Report
Shakespeare Composite Structures Site

Voluntary Cleanup Contract 14-6271-RP

File # 51025

19845 US Highway 76

Newberry, SC

Prepared By: Scott E. Ross, P.G.
Project Manager

Reviewed by: Walter Gerald, P.G
Sr. Program Manager

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List of Acronyms

ASTM	America Society of Testing and Materials
BLS	below land surface
BRA	baseline risk assessment
BTEX	benzene, toluene, ethylbenzene, and xylenes
CD	compact disc
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cis-1,2-DCE	cis-1,2 – dichloroethene
COC	chemical of concern
COPC	contaminants of potential concern
COPEC	chemical of potential environmental concern
CSM	conceptual site model
CSS	construction support services
CT	carbon tetrachloride
CVOCs	chlorinated volatile organic compounds
DAF	dilution-attenuation factor1,1-DCA 1,1-dichloroethane
DI	deionized
DO	dissolved oxygen
DOT	Department of Transportation
DPT	direct push technology
Eco	ecological
EI	Expanded Investigation
ERA	ecological risk assessment
ERAGS	Ecological Risk Assessment Guidance for Superfund
ESA	environmental site assessment
FBQSTP	Field Branches Quality System and Technical Procedures
FS	feasibility study
FT	feet
GPR	ground penetrating radar
HASP	Health and Safety Plan

HH	human health
HHRA	human health risk assessment
HQ	hazard quotient
HSA	hollow stem auger
i	groundwater gradient
ID	inside diameter
IDW	investigation derived waste
K	hydraulic conductivity
MCL	maximum contaminant level
µg/L	micrograms per liter
MEK	methyl ethyl ketone
mg/L	milligrams per liter
MNA	monitored natural attenuation
MI	Microbial Insights, Inc.
MSL	mean sea level
MTBE	methyl tertiary butyl ether
n	porosity
ng	nanogram
NCP	National Contingency Plan
NGVD	National Geodetic Vertical Datum
NTu	nephlometric turbidity units
OD	outside diameter
ORP	oxidation-reduction potential
OSWER	Office of Solid Waste and Emergency Response
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PCOI	potential chemical of interest
PENAC	Philips Electronics North America Corporation
PID	photoionization detector

PLNA	Philips Lighting North America
PPE	personal protective equipment
PVC	polyvinyl chloride
QC	quality control
RA	risk assessment
RBSL	regional based screening level
RCRA	Resource Conservation and Recovery Act
RECs	recognized environmental conditions
RI	remedial investigation
RP-VCC	responsible party-voluntary cleanup contract
RLS	registered land surveyor
RSL	regional screening level
SC	specific conductance
SCDHEC	South Carolina Department of Health and Environmental Control
SESD	EPA Region IV Science and Ecosystems Support Division
Shealy ES	Shealy Environmental Service (certified SC analytical lab)
SI	site investigation
SIWP	Supplemental Investigation Work Plan
SLERA	screening-level ecological risk assessment
SMDPs	scientific/management decision points
SOPs	standard operating procedures
SPDWS	State Primary Drinking Water Standards
SSL	soil screening level
SU	standard unit
SV	soil vapor
SVS	soil vapor sample
TCE	trichloroethene
TCL	target compound list
TMW	temporary monitoring well
trans-1,2-DCE	trans-1,2-dichloroethene

1,1,2,2-TCA	1,1,2,2-trichloroethene
ug/kg	micrograms per kilogram
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
V	average groundwater flow velocity
VC	vinyl chloride
VCC	voluntary cleanup contract
VOCs	volatile organic compounds

Professional Geologist Certification

"I certify that I am a qualified groundwater scientist who has received a baccalaureate degree in geology and have sufficient training and experience in groundwater hydrology and related fields, as demonstrated by South Carolina registration and completion of accredited university courses that enable me to make sound professional judgments regarding groundwater monitoring and contaminant fate and transport. I further certify that I have technically reviewed this report."

SCOTT E. ROSS
REGISTERED
NO. 2201
SOUTH CAROLINA
PROFESSIONAL GEOLOGIST

By: ______________________

Scott E. Ross, PG
Project Manager
South Carolina P.G. No.: 2201

Date: 11/20/2018

Executive Summary

The Shakespeare Composite Site is located in Newberry County, South Carolina. The Site includes a design and fabrication facility that produces tubular fiberglass-reinforced poles, and related components, for exterior lighting applications and several surrounding properties (collectively referred to as the "Site"). The production facility has been in operation since the mid-1960s. In December 2013, Shakespeare Composite Structures, LLC (Shakespeare), a division of Philips Electronics North America Corporation (PENAC), initiated a series of environmental assessment and investigative efforts at the Site. As a result of the detection of organic compounds in environmental media, PENAC entered into a responsible party voluntary cleanup contract (RP-VCC) with the South Carolina Department of Health and Environmental Control (SCDHEC). In accordance with Section 3.A of the RP-VCC (VCC-14-6271-RP), a Remedial Investigation (RI) and Baseline Risk Assessment (BRA) were implemented at the facility and surrounding properties. The results of the Remedial Investigation at the Site are presented in this report.

The investigative efforts performed prior to execution of the VCC are briefly summarized below:

Phase II Environmental Site Assessment (ESA) – collection of initial soil and groundwater samples from the Shakespeare facility;

Site Investigation – Collection of additional soil and groundwater samples from the Shakespeare facility along with several groundwater samples from surrounding private parcels; and

Expanded Investigation - Collection of additional shallow groundwater samples and evaluation of shallow bedrock for impacted groundwater on surrounding properties.

The RI was implemented in two phases, beginning in 2014 after execution of the VCC. The RI was conducted to further evaluate the vertical and/or horizontal extent of previously identified chlorinated volatile organic compounds (CVOCs) in soil and groundwater; assess additional potential areas of interest for either secondary sources of VOCs that could be contributing to soil and/or groundwater impacts; evaluate potential vapor intrusion pathways; determine risk to potential human and ecological receptors; and provide additional data needed to develop a remedial strategy for the Site.

Phase I RI - Evaluation of intermediate water quality and delineation of CVOCs to east, south, and west; and.

Phase II RI - Additional evaluation of subsurface soil quality on the former Shakespeare property and delineation of CVOCs in the shallow groundwater zone to the north and the bedrock interval across the Site.

The Site geology has been subdivided into two general geologic zones. The upper zone (a severely weathered residuum) which consists of clayey sand, silty sands, and silty clays. This is underlain by a saprolitic interval consisting of severely weathered bedrock with relict rock fabric. The lower geologic zone consists of partially weathered/severely fractured to competent granitic bedrock.

The groundwater level detections within the shallow aquifer zone occur between approximately 549 feet mean sea level (ft msl) at the east end of the Shakespeare property to 526 ft msl to the north beneath the Dickert property and 520 ft msl to the southwest beneath the Shealy property. The primary horizontal groundwater flow direction in this interval is inferred to be toward the west-southwest beneath the Shealy property with a component to the north-northwest beneath the Dickert property. This flow pattern is consistent with regional topography and drainage.

The groundwater elevation in the intermediate (saprolite) interval occurs between 547 ft msl beneath the east end of the Shakespeare property to 529 ft msl to the southwest beneath the Shealy property to 527 ft msl to the northwest beneath the Dickert property. The inferred direction of horizontal groundwater flow in the intermediate interval ranges from the south-southwest towards the Shealy property and to the north-northwest beneath the Dickert property.

The groundwater elevation in the bedrock wells range between 548 ft msl near the east end of the Shakespeare property to 508 ft msl along the southwest side of the Shealy property. The flow direction in the bedrock zone can be interpreted to be to the southwest. It is evident that this flow pattern within the bedrock fracture system has been influenced by the pumping of several water supply wells located to the west-southwest of the Shakespeare property.

A slight downward vertical gradient exists between the shallow aquifer zone and the underlying intermediate interval. Vertical flow between these two zones may be impeded due to the tightness of the silt/clay component of the saprolite.

Surface and subsurface soil samples were collected from Shakespeare property initially focusing on areas identified during the Phase II ESA. However the soil assessment efforts expanded and then focused on the western portions of both the Main and Pole Winder buildings based on sample results. Soil sample results were screened against maximum contaminant level (MCL) based Soil Screening Levels (SSLs) and Residential Regional Screening Levels (RSLs) to further characterize the Site and provide a preliminary indication of potential risk.

MCL-based SSLs were exceeded in soils for the following constituents at one or more locations: trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE) and 1,1-dichloroethene (1,1-DCE), ethylbenzene, and toluene.

Sub-slab soil vapor was collected and analyzed for VOCs from three locations within the Pole Winder building and four locations within the Main building. Benzene, ethylbenzene, PCE, TCE, and xylenes were detected above their respective Industrial RSLs. TCE was detected above its Industrial (Indus) RSL in six of the seven soil vapor samples (SVS) samples. Benzene and PCE were detected above their respective RSLs in five SVS samples. Ethylbenzene and xylenes were detected above their respective RSLs in at least two samples.

Groundwater samples have been collected from numerous temporary and permanent monitoring wells and several private water supply wells in the vicinity of the Shakespeare facility. All groundwater samples were analyzed for United States Environmental Protection Agency (USEPA) TCL VOCs. A subset of samples was also analyzed for biogeochemical and natural attenuation parameters. Analytical results were screened against USEPA MCLs to identify compounds of interest in groundwater beneath the Site.

Concentrations of TCE, cis-1,2-DCE, and Vinyl Chloride (VC) exceeded their respective MCLs in several groundwater samples collected from the Site. Of these, TCE was detected most frequently in groundwater samples. The elevated concentrations are most widespread in the shallow zone (upper portion of the water table aquifer).

TCE and cis-1,2-DCE also exceeded their respective MCLs in one or more samples of the intermediate (saprolite) zone. Of these, TCE was again detected most frequently above its MCL in groundwater samples collected from several private water supply wells screened in the underlying granitic bedrock and in monitoring wells installed in the bedrock.

As part of the groundwater monitoring efforts performed at the Site, several wells were tested for the presence of Natural Attenuation (NA) parameters. The presence of several NA parameters (methane, nitrate, and sulfate) along with daughter products cis-1,2 DCE and VC indicate anaerobic degradation of CVOCs may be occurring beneath a limited portion of the Site. Overall, however, low pH and total organic carbon (TOC) levels and limited areas with favorable (low) dissolved oxygen (DO) concentrations prohibit large scale anaerobic degradation site-wide.

A Baseline Risk Assessment (BRA) was conducted for the Site to evaluate potential risks posed to human health and the environment. Potential risks to human health (HH) under current and future land use scenarios were quantitatively evaluated. Chemicals of concern (COCs) were identified in the Risk Characterization based on the risk and hazard calculations. The HH COCs identified for each receptor were the following:

- Future On-Facility Resident (Adult) –

  chloroform, cis-1,2-dichloroethene, trichloroethene, and vinyl chloride in shallow/intermediate groundwater

- Future On-Facility Resident (Child) –

  cis-1,2-dichloroethene and trichloroethene in shallow/intermediate groundwater

- Future Off-Facility Resident (Adult) –

  1,2-dichloroethane, chloroform, and trichloroethene in bedrock groundwater;

  trichloroethene in existing drinking water wells PW-2 and PW-8

- Future Off-Facility Resident (Child) –

  trichloroethene in bedrock groundwater;

  trichloroethene in existing drinking water wells PW-2, PW-5, and PW-8.

HH COCs were identified based on very conservative assumptions including use of currently inactive private water supply wells, a hypothetical future on-facility resident, an off-facility resident assumed to regularly consume and use groundwater. Each of these assumptions is unlikely to occur due to the current use and future availability of municipal water.

An Ecological Risk Assessment (ERA) was also performed to evaluate whether potentially Site-related chemicals of concern (COC) in the environment pose unacceptable risks to ecological receptors. None of the chemicals in Site media were found to warrant designation as Chemicals of Potential Environmental Concern (COPECs).Therefore, further evaluation of ecological risk posed by the chemicals detected at the Site to ecological receptors was not necessary.

1.0 SITE INTRODUCTION

The Shakespeare Composite Structures site (Site) is located on US Highway 76, northwest of Newberry, South Carolina (**Figure 1-1**). The Site includes a design and fabrication facility (Facility) that produces tubular fiberglass-reinforced poles, and related components, for exterior lighting applications. The Facility has been in operation since the mid-1960s.

In December 2013, Shakespeare Composite Structures, LLC (Shakespeare), a division of Philips Electronics North America Corporation (PENAC), retained AECOM Technical Services, Inc. (AECOM) to perform a Phase I Environmental Site Assessment (Phase I ESA) at the Facility.

The Phase I ESA was followed by a Phase II Environmental Site Assessment (Phase II ESA), which investigated several potential recognized environmental conditions (RECs) identified at the Facility during the Phase I ESA.

The Phase II ESA and subsequent phases of investigative efforts identified concentrations of chlorinated volatile organic compounds (CVOCs) in soil and groundwater beneath the facility. As a result of the Phase II ESA, PENAC entered into a responsible party voluntary cleanup contract (RP-VCC) with the South Carolina Department of Health and Environmental Control (SCDHEC). In accordance with Section 3.A of the RP-VCC, a Remedial Investigation (RI) was implemented at the facility and surrounding properties (referred to as the “Site”). This document serves as the Remedial Investigation (RI) Report for the Site.

This RI Report summarizes the investigative efforts performed at the Site, including those prior to entering into the RP-VCC, as well as the activities completed since the VCC was executed. Included with this report is the Baseline Risk Assessment (BRA) completed utilizing information obtained during the RI.

1.1 Project Overview and Objectives

The objectives of the RI performed at the Site are:

- Definition of the vertical and horizontal extent of impact to soil and groundwater onsite;
- Definition of the vertical and horizontal extent of elevated contaminant concentrations off-site;
- Collection of information to support a BRA; and
- Collection of data needed for development of a remedial strategy for the Site.

1.2 Site Description and Physical Setting

The Site includes the property occupied by the former Shakespeare facility (Facility) and several adjacent properties to the north, west and south of the facility (**Figure 1-2**). The Site is essentially centered on the Facility property. Descriptions of the Facility property and surrounding properties are included below.

1.2.1 Facility Description

The Facility is located on US Highway 76, approximately 1 mile northwest of the City of Newberry (**Figure 1-1**). According to information reviewed in previous documents and confirmed by Shakespeare personnel, the Facility property was undeveloped, wooded land until purchased from Ruth Amis by Shakespeare in 1965 for development as a manufacturing location. The Facility property occupies ~24 acres. The majority of the existing Facility, including all buildings, are surrounded by a chain link fence.

The Facility includes the Main production building (Main Building) and the Pole Winder building, totaling approximately 250,000 square-feet under roof. The Main Building of the facility was constructed in ~1966. Smaller outlying buildings have been added periodically through the Facility's history. The Pole Winder building was added to the facility in the late 1970s.

The Main Building of the facility is constructed of concrete block covered with brick on three sides; the floor a concrete slab-on-grade foundation; and several observed subgrade sumps or vaults. The Pole Winder building, the second largest Facility structure, is located to the north of the Main Building. The Pole Winder building is a concrete block building with sheet metal siding, with a concrete slab on grade floor. Both buildings are one story although there are some elevated second floor offices in the Main Building, and 2+ story structure designated the former "tower" area. Each building has several small additions, primarily consisting of the three areas for wastewater treatment (fiberglass separation). At one time, both buildings utilized a floor drain system with lines oriented primarily west to east. Each line had several floor drains. Over time, the floor drains have become filled with sealant and the drain lines are no longer in use.

The property also has several smaller structures located at the west end of the property including a hazardous waste storage building, a residual resin curing building, along with other smaller storage buildings.

An employee parking lot, with asphalt covering, is located to the south of the Main Building. The east end of the property contains another asphalt-paved area, which is the former employee overflow parking area where equipment and other materials currently are staged. There is a covered shed area at the northeast end of the property where finished products are packaged for shipment. The area between the two buildings in the center of the property is mostly grassed and is used for equipment or material storage, and some grassed areas are present at the west and northwest sides of the property. Loading docks are located on the northwest and southeast corners of each building and are accessed via concrete-paved or asphalt-paved driveways from U.S. Highway 76. The northwest, northeast, and southeast perimeters of the subject property are fenced, and locking gates are present at the two driveways beyond the employee parking lot (**Figure 1-2**).

1.2.2 **Facility Operational Background**

The facility was originally opened to produce fiberglass products and has continued to be used for this process. Operations at the facility include the design and manufacture of large fiberglass utility poles and cross arms, and a variety of other fiberglass outdoor products such as posts, signs, sheet piling, and sign posts. The manufacturing processes include the following categories: materials receiving, formulation of resin mixes, pultrusion of fiberglass products, extrusion of plastic products, winding of fiberglass poles, painting and heat curing of poles, testing of materials, warehouse/storage of finished goods, and packaging/shipping. Fiberglass rolls, twine, and/or sheets are wrapped around or through molds and then bound with a liquid resin mix using a variety of application processes depending on the items that are being produced. Product finishing efforts include sanding and grinding, painting, drying, and heat curing. Manufacturing is conducted inside two separate buildings – the Main Building and the Pole Winder building.

The facility has been owned by several entities including Shakespeare, Genlyte Thomas, and PENAC. The facility had maintained the Shakespeare Composite Structures name throughout several ownership changes. At the time the VCC was executed the facility was still known as Shakespeare Composite Structures; therefore the VCC refers to the facility and surrounding properties included in the RI as the Shakespeare Composite Structures Site. In 2014 the Shakespeare facility was sold to Valmont

Corporation. The facility is now known as Valmont Composite Structures. For the purposes of this report, hereafter, the Valmont facility may be referred to as the Shakespeare property or the Facility property.

1.2.3 Surrounding Properties

In addition to the Shakespeare property, the Site includes several surrounding properties (**Figure 1-2**). General land use surrounding the facility consists of agricultural, residential, undeveloped and commercial/light industrial properties. Uses of adjacent properties are as follows:

North: The Shakespeare property is bordered immediately to the north by a CSX rail line and undeveloped land planted with pine trees. The property bounding the facility to the north of the CSX rail line is owned by Mr. J.L. Dickert.

East: The Shakespeare property is bordered immediately to the east by a residential parcel (owned by Mr. Jesse Stephens), beyond which is vacant land (pine trees) and vacant buildings formerly occupied by the Dickert Lumber Company. The property immediately east of the private residence up to Lumber Road is also owned by J.L. Dickert.

South: The Shakespeare property is bordered to the south by U.S. Highway 76 and properties owned by the Newberry County Airport, Mr. Walter Shealy, and Ms. Yvonne Fisher. The property owned by Mr. Shealy is primarily farmland with a few small residences (rental homes) located sporadically across more than 60 acres.

West: There are three properties located immediately to the west of the Shakespeare property. The property that immediately bounds the facility to the west is owned by Ms. Harriet Boazman. The properties to the west of the Boazman property are owned by Ms. Edna Ringer and Ms. Kimberly Chapman, respectively.

Northwest: Property located to the north-northwest of the Ringer property and west of the Dickert property is owned by Ms. Merri Folk.

1.3 Site Topographic Setting

Topography of the Facility property is generally flat, with a gradual downward slope to the west-northwest. The property appears to have been graded during the construction of the facility with the western edge sitting an average seven feet higher in elevation than the neighboring Boazman property, located to the west. Surface elevations range from approximately 562 ft mean sea level (msl) on the east side of the Facility to 555 ft msl near the western edge of the property.

The Dickert and Folk properties, located to the north and northwest of the Facility, are heavily wooded with planted pine trees. A CSX rail line runs between the Facility and the Dickert and Folk properties. The Dickert and Folk properties slope from south to north, away from the Facility towards an intermittent stream and wetland area. Elevations range from approximately 550 ft msl at the CSX rail line to less than 520 ft msl at the intermittent stream. The properties slope upward on the north side of the creek to elevations approaching 550 ft msl.

The Boazman, Ringer, and Chapman properties lay to the west of the Facility, The Boazman property bounds the west side of the Facility. The Ringer property bounds the west side of the Boazman property. The Boazman and Ringer properties have rolling topography with elevations ranging from a low of 536 ft msl near the southern edge along US Highway 76 to over 550 ft msl back down to less than 535 ft msl on the northern edge of these properties. The Chapman property bounds the west edge of the Ringer property. This property generally decreases in elevation west of the Ringer property but also increases in surface elevation to the north, similar to the Boazman and Ringer properties.

The Shealy property lies to the south, across US Highway 76, from the Facility. The Shealy property also has a rolling surface topography that generally slopes to the west and to the south. The property slopes more drastically to the south to an unnamed intermittent stream. Elevations range from near 560 ft msl near US Highway 76 to less than 520 ft msl at the unnamed intermittent stream.

1.4 Climate

The climate of the Newberry area is characterized as humid subtropical; with relatively high summertime temperatures and evenly distributed precipitation throughout the year. The average annual low and high temperatures are 44.2 and 73 degrees Fahrenheit (^{o}F), respectively. Precipitation averages 47 inches per year (www.weatherbase.com).

1.5 Organization of the Report

This RI report is organized into eight sections.

Section 1 includes an introduction and general overview of the purpose of the RI and RA, provides a brief description of the site and physical setting and an overview of the facility’s operational background.

Section 2 briefly summarizes the environmental investigative efforts performed at the Site to date.

Section 3 summarizes the methods used during the various phases of investigation at the Site.

Section 4 presents a discussion of the regional and site-specific geology and hydrogeology.

Section 5 discusses contaminant fate and transport.

Section 6 provides a summary of the Baseline Risk Assessment (BRA).

Section 7 presents a summary and conclusions that may be drawn from this RI.

Section 8 identifies pertinent references cited throughout this RI Report.

2.0 SITE INVESTIGATION HISTORY

As mentioned above, PENAC [hereafter referred to as Philips Lighting North America (or simply, and collectively, Philips))] initially retained AECOM to assist with multiple ESAs to determine if the facility had any environmental issues or concerns. The ESAs were followed by multiple phases of more in depth subsurface investigation both at the Facility property and on properties adjacent to the facility. The activities completed during each phase of work are briefly summarized in this section.

2.1 Phase I ESA

In December 2013, AECOM performed a Phase I ESA at the Facility. In accordance with American Society of Testing and Materials (ASTM) standard (E-1527-13), the Phase I ESA included review of historical records for the Facility, inspection of the property, and the consideration of 11 areas that were believed to represent potential environmental impacts. Based on the identification of recognized environmental conditions (REC's) in the Phase ESA, Philips requested that a follow-up Phase II ESA be performed at the Facility.

2.2 Phase II ESA

In January 2014, AECOM initiated the Phase II ESA at the Facility in accordance with ASTM standard (E1903-11). The Phase II ESA included investigation of groundwater, soil, sediment, and surface water at various locations across the Facility and its property. In total 11 RECs were investigated. A brief list of the initial portion of the Phase II ESA activities is outlined below:

- Installation and sampling of eight shallow temporary monitoring wells (TMW-1 through TMW-8);
- Collection and analysis of four surface soil samples;
- Collection and analysis of 15 subsurface soil samples;
- Collection of a sediment sample from a storm water drain in the eastern portion of the property (REC-7a); and
- Collection of a sediment and surface water sample from the storm water outfall located on the northwestern side of the property (REC-7b).

Samples of these media were analyzed for a variety of parameters. Analytical results from this Phase II ESA indicated that the CVOC trichloroethene (TCE), and degradation compounds cis-1,2 dichloroethene (cis-1,2-DCE) and vinyl chloride (VC), were present above their respective drinking water standards (MCLs) in groundwater beneath the facility. As a result of the detection of these CVOCs, Philips requested that AECOM initiate a more thorough investigation of the Facility.

2.3 Site Investigation

In April 2014, AECOM developed the Site Investigation Work Plan (SIWP) (AECOM, 2014). The SIWP outlined the rationale for performing additional investigative efforts at the Site and referenced technical approaches and methodologies to be used to collect additional data from the Site based on the results of the Phase II ESA. The SIWP included plans for additional soil and groundwater sampling. The SIWP was originally intended for submittal to Philips only, however, it was prepared assuming it may be submitted to the SCDHEC for review at a later date. Therefore, the SIWP was developed assuming the Site would eventually be evaluated utilizing procedures consistent with the National Contingency Plan (NCP) which are part of the USEPA Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process. The SIWP included references to the USEPA Region 4 Standard Operating Procedures and guidance.

The original phase of the SIWP was implemented in April 2014. This sub-phase of work included the following efforts:

- Installation and sampling of 10 shallow temporary monitoring wells (TMW-9 through TMW-18) attempting to delineate the horizontal extent of groundwater impacts on the Facility property.
- Installation of nine permanent monitoring wells (MW-1 through MW-9). Each of these wells was installed as replacements for several the temporary wells. These wells are identified in tables and text referenced in Section 3.
- Collection of additional subsurface soil samples from Phase II ESA boring locations B-12, B-13, and B-16. The intent of this phase of soil sampling was to focus on possible source areas based on their historical use and results from the initial Phase II ESA sampling efforts in these areas. Field personnel utilized the AQR Color-Tec field screening tool to determine which subsurface samples from each boring would be submitted for chemical analysis.

Results of this phase of the site investigation (SI) indicated CVOC impacted groundwater may be migrating off-site and subsurface soils beneath portions of the Facility contain low concentrations of CVOCs. Results of the Phase II ESA and soil and groundwater investigation efforts performed as part of this early phase of the SI are included in the Site Investigation Summary (AECOM, 2014b).

Following review of the first phase of SI results, AECOM implemented a subsequent soil and groundwater sampling phase of work attempting to identify likely source areas for the CVOCs beneath the Site. This source investigation phase of work was initiated in May 2014 and included the following:

- Advancement of 25 soil borings (B-20 through B-44) at locations within and adjacent to the Main Building and the Pole Winder building at the Facility. The soil borings allowed collection of continuous subsurface soil cores from land surface to approximately 25 feet or drilling refusal. Soil samples were screened at one to two foot intervals using a photoionization detector (PID) and evaluated using the AQR Color-Tec field screening tool to determine which soil samples from each boring would be submitted for chemical analysis.
- Installation of 15 shallow temporary monitoring wells (TMW- 19 through TMW-33) to further delineate potential source areas and boundaries for CVOC impacts in groundwater.
- Conversion of ten of these TMWs to permanent wells (TMW-21 through TMW-25 and TMW29 through TMW-33).
- Collection of groundwater samples from four existing permanent monitoring wells (MW-1, MW-6, MW-7, and MW-8) for geochemical and biological analyses to determine attenuation conditions beneath the Site.
- Collection of samples from seven private water supply wells (Boazman well, PW-2 through PW-7) located on properties adjacent to the Facility.

This phase of investigative work included utilization of the AQR Color-Tec field screening technique along with confirmatory laboratory analysis to detect CVOCs in soils beneath the Main Building and Pole Winder building. These results coupled with anecdotal information from facility personnel regarding historic use of solvents indicated a primary source area for CVOCs underlies the western portion of the Main Building with other, smaller source areas under the east central portion of the Main Building and under the western portion of the Pole Winder building.

Groundwater results generated during this phase of the investigation confirmed that CVOC impacted groundwater has migrated to the north and west of the Site. In addition, two private water wells located to the west and southwest of the Site were sampled and found to contain elevated CVOC concentrations. As a result, Philips installed organic compound filter systems on these wells within days of the discovery of the presence of CVOCs. The results of this phase of work led to an even more elaborate groundwater investigation both on and off-site.

2.4 Expanded Investigation

In response to the June 2014 meeting with SCDHEC representatives to present results of the Phase II and SI efforts, Philips submitted a brief work plan to the regulatory department presenting a scope of work for additional groundwater investigative activities and requesting approval to perform these proposed efforts. This [Expanded Investigation (EI)] effort included multiple phases of work performed between mid-July 2014 and August 2014. These additional phases of work included a more elaborate investigation of groundwater quality in multiple depth zones at locations on- and off-site using the AQR Color-Tec field screening tool in an attempt to delineate the extent of CVOCs in groundwater. AQR Color-Tec field screening results were used to guide the groundwater sampling efforts both vertically and horizontally. More specifically this investigation included the following:

- Collection of shallow and intermediate depth groundwater samples from 15 locations (TMW-34 through TMW-41, TMW-101 through TMW-107) on private properties to the south and west of the Facility;
- Collection of shallow and intermediate depth groundwater samples from 57 locations (TMW-42 through TMW-99) on property that bounds the northern side of the Facility;
- Collection of groundwater samples from intermediate depth intervals at ten locations (TMW-44, TMW-45, TMW-46, TMW-47, TMW-48, TMW-49, TMW-50, TMW-51, TMW-100, and TMW-106) beneath the Facility;
- Installation and sampling of four deep bedrock wells on the Facility property (MW-2D, MW-3D, MW-6D, MW-7D);
- Installation and sampling of three deep bedrock wells on private properties to the south and west of the Facility (RDW-1, RDW-2, and SDW-1); and
- Collection of three surface water samples (SW-1, SW-2, and SW-3) from a small creek that bounds the northern end of the groundwater sampling grid on the property that bounds the northern side of the Facility (Dickert Property).

Results of the EI determined that CVOC impacted groundwater in the shallow zone has migrated several hundred yards to the north of the facility and to a lesser extent to the west and southwest of the Facility (AECOM, 2014c). The EI also determined that the competent surface of the underlying granite bedrock varies substantially beneath the Site and that CVOC impacted groundwater is migrating into the uppermost fracture zones in the granite bedrock underlying the Facility and to the southwest.

2.5 Remedial Investigation

As a result of the investigative efforts performed to date, Philips entered into a responsible party - voluntary cleanup contract (RP-VCC) with the SCDHEC in September 2014. The RP-VCC required completion of a Remedial Investigation (RI), Risk Assessment (RA), and Feasibility Study (FS). Following their review of the investigative efforts performed to date, SCDHEC requested Philips submit a work plan to complete the delineation of the vertical and horizontal extent of CVOC impacts to groundwater both on- and off-site and to evaluate the potential risks these compounds pose to human health and the environment. In response to this request, Philips submitted the Site Investigation Work

Plan Addendum (SIWP Addendum) to SCDHEC in December 2014. The SIWP Addendum was revised in April 2015 and approved by SCDHEC in August 2015.

2.5.1 **Phase I RI**

Subsequent to additional negotiation efforts for access to the Boazman, Chapman, Dickert, and Ringer properties, the Phase I Remedial Investigation efforts were implemented in August 2015. These included the following:

- Installation of nine shallow permanent wells (MW-10 through MW-18) on the Dickert Property;
- Installation of one shallow well each on the Boazman (MW-20) and Ringer (MW-21) properties;
- Installation of one shallow well (MW-22) on the Facility property;
- Installation of six intermediate zone wells on the facility (MW-2I, MW-3I, MW-5I, MW-6I, MW-7I, and MW-9I), one on the Dickert property (MW-10I), one on the Boazman property (MW-20I), and one on the Ringer property (MW-21I);
- Installation of one bedrock well on the Dickert property (MW-18D);
- Collection of groundwater samples from all existing and newly installed permanent monitoring wells on the Site;
- Collection of three additional surface water samples [SW1(2) through SW3(2)] from the tributary on the Dickert property; and
- Re-sampling of several private water wells located south and west of the facility [Boazman well and Chapman well (PW4)].

Following negotiation of access to the Shealy property in late-November 2015, investigative efforts were implemented for this portion of the Site. These efforts included the following:

- Installation, sampling and field screening at temporary well locations TMW-110, TMW-111, TMW-112, TMW-113, and TMW-114;
- Installation and sampling of three shallow wells (MW-23 through MW-25);
- Installation and sampling of one intermediate well (MW-24I); and
- Installation and sampling of additional bedrock well (SDW-2).

2.5.2 **Phase II RI**

Upon review of the data collected during the initial Phase I of the RI, SCDHEC requested performance of an additional round of investigation to complete the RI. In April 2017 Philips submitted the Phase II Remedial Investigation (Phase II RI) Work Plan to SCDHEC for review (AECOM, 2017d). SCDHEC approved the Phase II RI Work Plan in May 2017.

The majority of the Phase II RI efforts were performed between May and August 2017. These efforts included the following:

- Passive soil gas survey on the Facility property;
- Installation of one additional intermediate zone well each on the Dickert (MW-12I) and Chapman (MW-19I) properties;
- Installation of a two additional bedrock wells on the Dickert Property (MW-12D and MW-17D);
- Installation of a bedrock well on the Chapman property (MW-19D);
- Installation of a new bedrock well on the Shealy property (SDW-3);

- Sampling of the entire monitoring well network at the Site;
- Collection of surface water samples (SW-4 and SW-5) from an unnamed tributary on the Shealy property, and
- Performance of brief aquifer performance tests in 10 wells at the Site.

After review of the data collected from the initial portion of the Phase II RI, SCDHEC requested some additional investigative efforts be performed. The additional efforts included the following:

- Installation and sampling of four additional shallow monitoring wells on the Folk (MW-26 and MW-27) and Dickert properties (MW-28 and MW-29);
- Performance of a follow-up soil vapor sampling effort at seven of the original passive soil vapor sample locations (SV-20, SV-23, SV-31, SV-45, SV-46, SV-49, and SV-54); and
- Collection of subsurface soil samples for confirmatory analyses from borings installed around three confirmatory SV locations [SV-31 (B-47), SV-41 (B-48), and SV-45 (B-49)] within the Main Building and three locations [(SV-14 (B-50), SV-20 (B-45), and SV-23 (B-46)] from the Pole Winder building that had the highest VOC concentrations.

3.0 METHODS OF INVESTIGATION

As discussed in the previous section, the investigative efforts have been performed during multiple phases between November 2014 and April 2018. This section of the report summarizes the methods used during the various phases of investigation at the Site.

3.1 Field Program Preparation Activities

Preparation for the multiple phases of field work included the following activities: resolution of Site access issues with several property owners, selection and procurement of qualified subcontractors for drilling and well installation, waste management and disposal, sample analysis, and procurement of necessary field and sampling equipment.

3.1.1 Resolution of Access Issues and Permits

Philips and AECOM have negotiated long term access to several properties surrounding the Facility property (**Figure 1-2**).

In accordance with the South Carolina Well Standards [R.61-71(H)(1)(a)], AECOM has obtained approval from SCDHEC for each phase of well installation.

3.1.2 Selection of Qualified Subcontractors

Several contractors were procured to assist with completion of the investigative efforts including private utility locating, drilling, sample analyses, and management of investigative derived waste (IDW).

3.1.2.1 Utility Clearance

AECOM procured Reed Tech, Inc. to scan numerous areas for underground utilities before drilling efforts were initiated. Reed Tech, Inc. utilized a combination of metal detection and ground penetrating radar (GPR) to scan many of the proposed drilling locations for buried underground utilities. The scanning efforts were performed on private properties and on the Facility.

3.1.2.2 Drilling Subcontractor

The multiple phases of drilling and well installation required procurement of a SC licensed well drilling contractor. Multiple drilling contractors have been utilized for the various phases of drilling at the Site. The drilling contractors include A.E. Drilling Services, LLC (A.E. Drilling) of Greenville, South Carolina; Terrasonic, Inc., of Aiken, South Carolina; and Cascade Drilling, Inc. (formerly Terrasonic). AE Drilling was used to perform the drilling efforts for the Phase II ESA, the follow-up Site Investigation, and a portion of the Phase II RI. Terrasonic and Cascade were used to perform the well installation efforts completed during the Phase I RI. Elite Techniques, Inc. of Camden, South Carolina was utilized for the shallow well installation and soil boring efforts completed during the later portion of the RI Phase II.

3.1.2.3 Land Surveying Subcontractor

The monitoring wells, soil borings, and surface water sample locations were appropriately located and their elevations determined with respect to the most recent geodetic datum using South Carolina Professional Land Surveyors. Well and boring locations advanced through the EI were surveyed by Construction Support Services (CSS) of Columbia, S.C. Sample points and wells installed after the EI were surveyed by AECOM's internal survey department.

3.1.2.4 Laboratory Subcontractor

AECOM contracted with three SCDHEC-certified laboratories during the RI including Shealy Environmental Services, Inc. (Shealy ES), Pace Analytical Services (Pace), and Microbial Insights, Inc., (MI). Shealy ES based in West Columbia, SC, was utilized to perform the majority of the chemical analyses. Pace was utilized to analyze groundwater samples for specific dissolved gases and other specialty parameters. MI was utilized to analyze samples for specific anaerobic indicator bacteria.

3.1.2.5 Investigative Derived Waste Subcontractor

AECOM coordinated with multiple IDW management contractors for transportation and disposal of IDW generated during the various phases of efforts on the Site. A&D Environmental Services, Inc. and NuEarth, Inc. were used for transport and disposal of IDW. All IDW was characterized as non-hazardous waste disposed of at licensed /approved disposal facilities. Documentation of IDW management will be made available upon request.

3.2 Soil Investigation

The soil investigation efforts included the advancement of several soil and well borings using various drilling technologies, collection of soil and rock cores, visual examination and classification of cores, field screening and laboratory analysis of soil samples, and performance of both passive and active (confirmatory) soil vapor sampling efforts. The methods utilized during the soil investigative efforts and the rationale for sample locations are briefly discussed below.

3.2.1 Soil Boring Advancement

Soil/monitoring well borings were advanced using several methods of drilling. Soil borings advanced for soil sample collection and installation of temporary monitoring wells during the pre-RI and RI related efforts were done so using a Geoprobe 6620 DT, 7820 or 8040 track mounted direct push drill rig. The Geoprobe rigs enabled the collection of continuous soil core samples in acetate sleeves using a dual tube soil core sampling system. This entailed advancement of a 2.25 outside diameter (O.D.) stainless steel core barrel fitted with a disposable acetate liner to a desired depth. A slightly larger (3 inch OD) outer casing was then advanced over the core barrel, to the same depth. Once the casing was advanced over the core barrel it was retrieved from the borehole, allowing removal of the disposable acetate liner containing the soil core. The core liner could then be cut open by field personnel allowing visual examination of the contents.

Sonic drilling techniques were also utilized for advancement of soil and well borings. The sonic drilling technique allowed collection of continuous soil cores utilizing a 10 foot long, 4 inch inside diameter (ID) core barrel with a six inch ID temporary (over-ride) casing. This process entailed the advancement of a core barrel through a desired depth interval. The outer casing was then advanced over the core barrel to the same depth. The core barrel was then removed from the boring and the soil/rock core was then dispensed into a clear polyethylene bag. The soil core bag was assessed by field personnel for field screening, visual examination of the contents, and collection of soil samples, if necessary. **Table 3-1** lists the soil borings advanced at the Site during the investigative efforts.

Soil borings advanced for the purpose of collecting soil samples only, were abandoned in accordance with South Carolina Well Standards and Regulations (R.61-71(H)(2)(e). This included backfilling of a borehole from the bottom to land surface with a cement-bentonite grout or bentonite clay pellets via a tremie pipe.

3.2.2 Soil Sample Collection

As indicated in Section 2, soil samples were collected from numerous locations beginning with the Phase II ESA. Soil investigation activities at the Site evolved from determination of impact during the Phase II ESA to delineation of extent of CVOCs as part of the RI.

3.2.2.1 Pre-RI Soil Sampling

As discussed in Section 2.0 soil samples were collected during both the Phase II ESA and SI phases of investigation. Soil samples were collected from 29 soil borings advanced during the Phase II ESA. Eighteen (18) soil samples were initially collected at 11 RECs identified during the Phase I ESA. Eleven (11) additional soil samples were collected from borings centered on Phase II ESA borings B-12, B-13, and B-16 (**Figure 3-1**). **Table 3-1** lists the soil borings and soil samples collected from the Site during the pre-RI and RI related investigative efforts.

Soil samples were collected from soil cores obtained using the Geoprobe dual tube and sonic soil coring technologies described in Section 3.2.1 above. Soil cores were screened every foot for the presence of organic vapors using a photoionization detector (PID). Intervals determined, using the PID, to contain the highest organic vapor concentrations were selected for sample collection. The majority of these samples were analyzed for TCL VOCs. Therefore, soil samples were collected directly from the designated intervals using the Terra core soil sampling system.

The Terra core sampling system utilizes a pre-cleaned, disposable polyethylene syringe and four 40 milliliter (mL) vials, all of which are provided by Shealy ES. The syringe was used to collect one aliquot of soil that was dispensed into each vial. Two vials are pre-preserved with sodium thiosulfate and one with methanol. The fourth vial contains deionized water. Once soil is placed in each vial, the syringe was discarded. This process was used to collect each soil sample to be analyzed for VOCs during all investigative efforts completed at the Site.

Soil samples collected from three locations (B-13, B-17, and B-18) were also analyzed for polynuclear aromatic hydrocarbons (PAHs) and the eight resource conservation recovery act (RCRA) metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver), and nickel (**Table 3-1)**. Soil collected from these intervals were homogenized and containerized using a clean stainless steel bowl and spoon in accordance with procedures detailed in the USEPA Region 4 SESDPROC-300-R3 (USEPA, 2014a).

Soil samples were collected from 29 soil/well borings (B-20 through B-45, TMW-21, TMW-22, and TMW-29) advanced during the SI efforts. These borings were advanced at locations primarily in and around the Main and Pole Winder buildings. The locations of the borings were initially determined based on possible sources for materials entering the subsurface including floor drains, proximity to drain lines, doors and other points of egress to exterior areas. As necessary, boring locations were added in an attempt to delineate areas of possible impact using field screening efforts. Locations were also selected based on access the Geoprobe drill rig. Soil boring depths ranged between 13 feet (subsurface refusal) and 25 feet below land surface (BLS).

During the SI field efforts each soil core was initially field screened for elevated organic vapors using a PID. Soil samples were then collected from multiple intervals that contained elevated organic vapor concentrations following additional screening using the AQR Color-Tec field screening tool to determine if CVOCs were present. The AQR Color-Tec screening method uses a tetrachloroethene (PCE) colorimetric detector tube to screen the headspace sample for the presence of total chlorinated ethenes. The Color-Tec screening was performed in accordance with the procedures prescribed by AQR (AQR, 2013). **Table 3-2** summarizes the Color-Tec screening results for soil samples collected during pre-RI sampling efforts. Field screening results were used to select soil samples for confirmatory analysis by the contract laboratory, Shealy ES. Each confirmatory sample was collected via the Terra core soil sampling system.

3.2.2.2 Phase II RI Confirmation Soil Sampling

During Phase II of the RI, six additional soil borings were advanced around select passive soil vapor (SV) points to allow collection of additional soil samples for confirmatory analysis. The soil vapor sampling efforts are discussed in Section 3.2.4, below. The intent of this Phase II RI soil sampling was to confirm the presence of elevated organics, as reported in the passive soil vapor samples, which may identify possible release/source areas. This sampling included collection of samples from borings advanced at three SV locations at the Pole Winder building [SV-14 (B-46), SV-20 (B-45PW), SV-23 (B-50)] and three locations at the Main building [SV-31 (B-47), SV-41 (B-48), SV-45(B-49)] (**Figure 3-1**).

Soil borings advanced at these locations allowed collection of continuous soil cores via the soil core sampling system (referenced above) from land surface to approximately 15 feet BLS. Once a soil core was removed from the subsurface, field personnel cut the core liner allowing collection of soil samples at two foot intervals. Soil samples were collected using the Terra-Core soil sample kit, providing samples to be analyzed for TCL VOCs (**Table 3-1**). Eight soil samples were collected from each boring for confirmatory analysis. Soil samples were containerized and prepared for shipment to Shealy ES for chemical analysis. Soil sample analytical results are discussed in Section 5.2.

3.2.3 **Lithologic Inspection and Classification**

Each of the soil and well boring drilling techniques allowed collection of soil and/or rock cores for visual examination by an AECOM field scientist. Soil core collection procedures are described in the previous sections. Rock core collection procedures are described in Section 3.2.5 below. Lithologic data collected from well borings was documented on soil boring logs. The lithologic data obtained from the soil borings allowed for shallow stratigraphic control to be determined beneath the Site. Soils were visually classified in accordance with ASTM standards D 2487 and D2488 using the Unified Soils Classification System (USCS) and the visual-manual procedure, respectively. These systems were used to provide a written identification of the soil and rock types. The USCS allowed for standard description of soils based on grain size, texture, color, and other characteristics. Field classification information was recorded by a field geologist on soil boring logs generated for each well boring. Copies of boring logs generated for each well boring, are included in **Appendix A**. Lithologic information for the Site is described in detail in Section 4.3.2 of this report.

3.2.4 **Soil Vapor Sampling**

During Phase II of the RI, additional soil investigative efforts were performed on the Facility property in an attempt to define source areas beneath the Main and Pole Winder buildings and to determine if contaminant vapors were migrating off the Facility. These efforts included a multi-step process – passive soil vapor (SV) sample collection, active confirmatory sampling, and collection of confirmatory soil samples.

3.2.4.1 Passive Soil Vapor Sampling

The initial stage of the soil vapor evaluation entailed collection of soil vapor samples using a passive soil vapor collection method. This included collection of six samples (SV1 through SV-6) from the west property boundary and six from the north property boundary (SV-7 through SV-12), 15 from beneath the Pole Winder building, and 26 from beneath the Main building. **Table 3-3** lists the soil vapor samples collected from the Site during the RI. **Figure 3-2** illustrates the locations of the soil vapor sample locations.

The passive SV samples were collected from locations spaced on a 20-foot grid system beneath the buildings and at approximately 25 feet apart along the western and northern boundaries. The passive soil gas sampling effort included drilling of pilot borings to approximately 3 feet in depth and installation of small vials that contained two mesh membranes and a cap with a permeable membrane. The vials were temporarily sealed in each pilot boring and allowed to stand for approximately two weeks. After two weeks, the vials were removed from the boreholes, sealed with a solid cap, packaged and shipped to Beacon Environmental Services, Inc. (Beacon) and analyzed for TCL-VOCs using SW-846 Method 8260c.

Each SV boring was backfilled and sealed at land surface with a concrete mix.

3.2.4.2 Confirmatory Vapor Sampling

Results of the passive vapor sampling efforts indicated the presence of elevated organic vapor concentrations beneath both the Pole Winder and Main buildings. Based on a review of the passive SV data, SCDHEC requested collection of additional SV samples using an active collection method from locations SV-20 and SV-23 located in the Pole Winder building and from locations SV-31,45, 46,49, and 54 located in the Main building (**Figure 3-2**).

The active soil vapor sampling procedure included advancement of a small diameter boring through the building floor using a 3/4 inch rotary hammer drill. A small diameter (3/8 inch) section of Teflon lined tubing with a dedicated disposable aluminum tip was placed in the borehole and connected to a 1 liter summa canister at land surface. Once the summa canister was connected to the tubing, the borehole was closed at land surface with a hydrated bentonite seal.

Once all Summa canisters were installed, field personnel activated the calibrated regulators on each device allowing collection of soil vapors over a one hour period of time. Once the one hour period had ended, the regulator valves were closed and the canisters were disconnected from the tubing. The tubing was then removed from each core hole after which each was sealed with concrete. Summa canisters were shipped to Pace Analytical Services, Inc. under standard Chain of Custody protocols and analyzed for a limited set of VOCs; which were selected as a result of the previous passive soil vapor survey (using EPA Compendium Method TO-15). Results of the soil vapor sampling efforts are discussed in Section 5.3.

3.3 Groundwater Investigation

The investigation of groundwater quality beneath the Site has been performed during numerous phases starting with the Phase II ESA. The objective of the investigative phases evolved from detection during the Phase II ESA to delineation of impacted zones during the RI efforts. The groundwater investigation efforts included the installation and sampling of temporary and permanent monitoring wells, periodic sampling of the permanent well network, and sampling of private water wells surrounding the Facility. The groundwater investigation activities and sampling procedures are described in Section 3.3.4 below.

3.3.1 Well Installation Methods

This section of the report summarizes the well installation methods and discusses the rationale for well placement efforts. More than 100 temporary wells (TWM), 39 permanent shallow zone monitoring wells, 12 intermediate zone monitoring wells, and 15 bedrock wells have been installed at the Site during the pre-RI and RI efforts. The procedures used to perform the well installations are summarized below. The rationale for placement of the wells during the various phases of work is discussed later in this section.

Tables 3-4 and **3-5** list the temporary and permanent monitoring wells installed at the Site since the initiation of the Phase II ESA. Each of these tables list the depths at which the wells were advanced/completed, the phase of work during which they were installed, and the purpose/rationale for their installation.

3.3.1.1 Temporary Wells

TMW borings were advanced at the site during multiple phases using one of the models of the Geoprobe rigs mentioned in Section 3.2.1 above. Temporary wells were installed to allow collection of groundwater samples for field screening and/or confirmatory laboratory analysis. Temporary wells were constructed in one of three ways: a 3/4 inch ID, five foot stainless steel screen point sampler; a 2-inch stainless steel screen point fitted with an inflatable packer; or a 1- inch ID 10 foot long schedule 40 PVC screen. Soil sampling was not performed at any of the locations at which the screen point sampler was utilized.

The screen point sampler was simply driven to desired depths, as determined by the AECOM geologist. Once the sampler was advanced to the desired interval the sleeve covering the 5-foot screen interval was pulled back exposing the screen to the subsurface. The screen point sampler was allowed to remain in place long enough for AECOM field personnel to purge and collect a groundwater sample from the screened interval. The Sonic drilling technique was used to advance a 2-inch diameter stainless steel screen point instead of the smaller diameter sampler as referenced above. The sonic drilling screen point was used to collect groundwater samples as part of the vertical profiling process during the Phase I RI.

Temporary wells constructed of 1 inch ID schedule 40 PVC were installed through, small diameter (2-1/4 inch ID) drive rods. Prior to advancement, the drive rods were fitted with a disposable drive point. The drive rods were advanced to a desired depth as directed by the AECOM geologist or refusal. Upon reaching the target depth, the 1-inch ID material was lowered through the drive rod to the bottom of the boring. The drive rods were then removed, exposing the well screen to the subsurface. AECOM field personnel then purged and sampled the temporary well.

The majority of the TMW borings advanced at the site during this investigation were abandoned in accordance with the SCDHEC regulations referenced above. A limited number of temporary wells installed through the floors of the Main building and Pole Winder building during the SI were converted to permanent wells. Several TMWs advanced during the vertical profiling efforts as part of the Phase I RI were converted to two inch diameter intermediate zone permanent wells. The rationale for these wells and their construction details are discussed later in this section. **Table 3-4** lists the TMW borings advanced at the Site. The table indicates the depths at which the wells were advanced/completed and the phase of work during which they were installed.

3.3.1.2 Permanent Monitoring Wells

Permanent monitoring wells of varying depths have been installed during multiple phases of work at the Site. Permanent wells were installed in the shallow zone (typically upper portion of the water table), intermediate zone (typically in lower portion of water table in saprolite and/or to top of bedrock), and in the underlying bedrock. **Table 3-5** lists the permanent monitoring wells installed at the Site since the initiation of the Phase II ESA.

Shallow and Intermediate Wells

Shallow monitoring wells have been installed using DPT via Geoprobe rig, sonic and/or hollow stem auger (HSA) drilling techniques. Intermediate monitoring wells were installed using either HSA or sonic drilling techniques.

Shallow well DPT well borings were advanced using a 3-¼ inch inside diameter steel temporary drive casing with a disposable drive point. Once the casing was advanced to a desired depth, well materials were placed inside the temporary drive casing. Shallow wells installed using this process were constructed of 1- or 2- inch diameter schedule 40 polyvinyl chloride (PVC), 0.01 inch slotted screen attached to PVC riser pipe of appropriate length. Once the well screen and riser pipe were installed in the drive casing, a silica sand filter pack (#1 well gravel) was then added to the casing annulus as it was pulled from the subsurface. Filter pack material was installed to no less than two feet above the top of a well screen. A bentonite clay seal (chips or pellets) no less than two feet thick was then placed atop the filter pack material. The remaining annulus above the bentonite seal was filled with a cement-bentonite grout to within one foot of land surface. Most of the shallow wells were completed at land surface with a concrete pad and eight inch diameter, bolt down, flush mount, cast iron cover. Wells completed through the floor of the buildings were completed with a - inch diameter bolt-down cast iron cover.

A limited number of shallow and intermediate depth wells were installed using hollow stem auger (HSA) drilling techniques. This process required advancement of a well boring using a 4-¼ inch inside diameter HSA fitted with a disposable wooden or PVC end plug that prevented cuttings from filling the auger annulus. Once the auger flight was advanced to its target depth, the end plug was knocked out of the lead auger flight and the well materials were installed through the auger annulus. This entailed installation of a 2 inch diameter, schedule 40 PVC, 10 foot long, 0.01-inch slotted screen and schedule 40 PVC riser pipe through the auger annulus. Silica sand filter pack material was then placed in the annulus between the well pipe and auger string. Once the filter placement process was initiated, the auger flights were periodically pulled up allowing the well materials to settle into the newly created borehole. This process was continued until the bentonite clay seal is installed and allowed to hydrate for at least one hour. Once the bentonite seal had hydrated, cement-bentonite grout is placed in the annulus. Grout placement would continue until the auger string was removed from the borehole. Wells installed via the HSA drilling method were also completed at land surface with concrete pads and bolt down, flush mount covers.

Sonic drilling technology was used to install several shallow wells and most of the intermediate wells. The depths for the majority of the intermediate wells were determined using field screening techniques, which are discussed later in this chapter. As discussed in Section 3.2.1, well borings advanced using the Sonic drilling technology allowed collection of continuous soil cores utilizing a 10 foot long, 4 inch ID core barrel with a 6-inch ID temporary (over-ride) casing. Once the core barrel was advanced through a desired depth interval, the outer casing was advanced over the core barrel to the same depth. The core barrel was then removed from the casing creating a temporarily cased borehole. Once the casing was advanced to a desired depth well installation included placement of a 2-inch diameter, schedule 40 PVC, 10 foot long, 0.01-inch slotted screen and schedule 40 PVC riser pipe though the outer casing. A silica sand filter pack material was then placed in the annulus between the well pipe and outer casing. Once the filter placement process was initiated, the outer casing was periodically vibrated and pulled up allowing the well materials to settle into the newly created borehole. This process is continued until the bentonite clay seal is installed and allowed to hydrate for at least one hour. Once the bentonite seal had hydrated, cement grout was placed in the annulus. Grout placement would continue until the outer casing was removed from the borehole. Wells installed via the rotosonic drilling method were also completed at land surface with concrete pads and bolt down, flush mount covers.

Bedrock Wells

Bedrock monitoring wells were installed using either Sonic, mud rotary with wireline coring, or air hammer drilling techniques. Bedrock wells installed during the pre-RI efforts were advanced using mud rotary and wireline coring techniques. For bedrock wells installed using a mud rotary and wireline coring process, pilot borings were advanced through the overlying residuum and saprolite to the top of bedrock using HSA or mud rotary drilling techniques. A tricone drill bit was then used to cut a socket approximately two to four feet into the bedrock. Once the socket was completed, a 6 inch diameter, schedule 40 PVC surface casing fitted at the bottom with a grout plug was installed through the borehole and seated in the rock socket. The surface casings were secured in place with a cement-bentonite grout, which was pumped through a tremie pipe connected to the grout plug. This allowed the grout to be pumped through the bottom of the surface casing into the annulus around the outside of the surface casing up into the outer casing borehole annulus. Once the casing grout seal had cured (approximately 48 hours), mud rotary-wireline coring drilling techniques were used to advance borings into the bedrock.

A 2-inch diameter (NQ) wireline coring tool was used to advance pilot borings into the bedrock. Rock cores were evaluated by field personnel for evidence of fractures, structure and mineral assemblages. Coring efforts completed during the pre-RI phase of work were stopped at the first water bearing fracture in the competent rock. Each of the seven bedrock wells (MW-2D, MW-3D, MW-6D, MW-7D, RDW-1, RDW-2, and SDW-1) installed during pre-RI efforts were completed as open-hole wells in the borehole.

Three bedrock wells installed during Phase I of the RI (MW-18D, MW-9D, and SDW-2) were completed using Sonic drilling methods. Pilot boreholes were advanced through the residuum and saprolite as described above using the 4-inch core barrel and 6-inch over-ride casing. The boring for MW-18D was installed on the Dickert property to determine if CVOCs had impacted groundwater in bedrock north of the Facility property. This well was extended to just below the initial fracture zone encountered in this boring (approximately 58 feet BLS). At the time of this well bores advancement, a larger diameter casing was not available for drilling to set a surface casing, therefore this well was constructed using a 10 foot long, prepacked PVC screen system. The pre-packed screen system contains a 2-inch diameter, 0.01-inch slotted PVC screen surrounded by a 4-inch diameter, 0.01-inch slotted outer screen. The annulus between the inner and outer screens was filled with filter pack material and then lowered into the borehole using the 2-inch diameter riser pipe. The remainder of the well including bentonite seal and cement grout was constructed in accordance with the Sonic well installation procedures for shallow monitoring wells described above.

Well borings for MW-9D and SDW-2 were constructed as double cased monitoring wells during a later stage of Phase I of the RI. Once these boreholes were cored to the top of bedrock a 9-inch inside diameter over-ride casing was advanced over the 6-inch casing to the top of bedrock. The 6-inch steel casing was then removed allowing installation of a 6 inch PVC surface casing. The surface casing was grouted into place as the 9 inch over-ride casing was removed from the well bore. After the surface casing grout seal had set, the rock was cored using a 4 inch diameter core barrel to the desired depth. The Phase I RI bedrock wells were cored to fracture intervals at various depths. Well completions during Phase I of the RI were determined based on field screening results and/or visual examination by field oversight personnel. These bedrock wells installed using the rotosonic method were completed through the surface casings with 10 foot long, 2-inch diameter, 0.01 inch slotted screen, and riser pipe, filter pack material, and bentonite and grout seals, as before.

During Phase II of the RI, four bedrock wells were installed at the Site using a combination of HSA, mud rotary/wireline coring and air hammer drilling technologies. The first phase of the drilling at these bedrock wells entailed advancement of a pilot boring to the top of bedrock using 10 ¼ -inch ID HSAs fitted with a disposable wooden plug. Once the pilot borings reached the top of bedrock, the augers were left in place as a temporary casing. The drilling method was then switched to air hammer to allow a 7-inch diameter, two to three foot "socket" into the top of the bedrock. Once the socket was cored into the bedrock, the air hammer drill bit and rods were removed from the auger annulus and a 6 inch diameter, schedule 40 PVC casing was installed through the augers into the rock socket. The surface casings were secured in place with a cement-bentonite grout, which was added to the auger annulus as they were pulled from the boring.

Once the casing grout seal had cured (approximately 48 hours), mud rotary-wireline coring drilling techniques were used to advance well bores into the bedrock. NQ wireline coring was used to advance pilot borings through the bedrock. Rock cores were evaluated by field personnel for evidence of fractures, structure and mineral assemblages. Rock cores were examined and characterized by field personnel in accordance with procedures described in Section 3.2.3. The depths at which these bedrock wells were completed were based on field screening results and visual examination.

Once field personnel determined the fracture intervals to be screened, the Phase II bedrock well borings were reamed using a 6 ¼ -inch diameter air hammer drill bit. Once the well borings were reamed to the desired depth, the wells were constructed in a manner similar to those procedures utilized for the shallow and intermediate wells, as described above. Each of these wells were also completed at land surface using a eight inch diameter bolt down, flush mount covers. Construction diagrams for each permanent well are included in **Appendix B**.

3.3.2 **Well Placement Rationale**

This section of the report briefly discusses the rationale for placement of monitoring wells during the pre-RI and RI groundwater investigation efforts.

3.3.2.1 Phase II ESA

During the Phase II ESA, temporary monitoring wells were installed in the shallow zone (water table aquifer) using either direct push technology or HSA drilling techniques. Eight temporary monitoring wells (TMW-1 through TMW-8) were initially installed at strategic locations across the Facility property, focusing mainly on RECs identified during the Phase I ESA. **Table 3-4** lists all the temporary wells installed at the Site, summarizes their locations and their general purpose. **Figure 3-3** illustrates the locations of the TMWs installed at the Site since the beginning of the investigative efforts.

Following the initial portion of the Phase II ESA, ten additional TMWs (TMW-9 through TMW-18) were installed on the facility property. After review of the TMW data, nine permanent 2-inch diameter monitoring wells (MW-1 through MW-9) were installed to replace several of the Phase II ESA TMW locations (**Table 3-5).**

3.3.2.2 Site Investigation

As a result of the detection of TCE in several of the Phase II ESA temporary well samples, fifteen additional temporary wells (TMW-19 through TMW-33) were advanced at locations across the Facility property during the SI. Many of the TMWs were installed at other possible source areas, at locations suspected to be downgradient or side gradient to the original round of TMWs or at property boundaries. The temporary wells at locations TMW-19, TMW-20 and TMW-26 through TMW-28 were sampled and abandoned in accordance with procedures described in Section 3.3.1.1 above.

During this portion of the investigation process, several borings were advanced near floor drains or possible drain lines in the Main and Pole Winder buildings as these were possible points for releases of CVOCs source materials into the subsurface. Based on the detection of elevated CVOC concentrations in soil and groundwater samples collected from several of these soil and/or TMW borings , ten of these TMWs were converted to permanent 1-inch diameter wells. This included TMW-21 through TMW-23 and TMW-29 through TMW-31 in the Main building and TMW-24, TMW-25, TMW-32, and TMW-33 in the Pole Winder building.

3.3.2.3 Expanded Investigation

Upon review of the SI results, Philips determined that investigative efforts were necessary to further evaluate the extent of y VOC impacts to groundwater. The EI was the next phase of pre-RI related work. The EI entailed the installation of 69 shallow and eight intermediate depth TMWs on properties to the north, west, and south of the Facility property. The intent of this effort was to delineate the horizontal and vertical extent of impacts whenever possible using a combination of field screening and confirmatory laboratory analysis.

During the early stages of the EI, eight shallow TMWs (TMW-34 through TMW-41) were installed on the Boazman and Ringer properties located to the west of the facility property (**Figure 3-3**). This allowed collection of groundwater samples from the upper portion of the water table aquifer. In addition to the shallow sample points, groundwater samples were collected from the intermediate zone (within the saprolite) at locations TMW-35 and TMW-36, both of which were located on the Ringer property. In addition, two TMWs were also installed on the Dickert property that bounds the north side of the facility (TMW-42 and TMW-43). Samples collected during the initial phase of the EI were analyzed for TCL VOCs by the contract laboratory (Shealy ES). CVOCs were detected in at least two samples to the southwest of the facility (TMW-34 and TMW-38) and the two samples from the Dickert property.

Upon review of the results for the samples collected from these properties, Philips continued investigation of shallow and intermediate groundwater quality on the Facility property and to the north and west of the Facility property. This entailed the installation of nine additional intermediate depth TMWs on the Facility property (TMW44 through TMW-51 and TMW-100), 47 additional TMWs (TMW-52 through TMW-99) on the Dickert property, two additional intermediate depth TMWs on the Boazman property (TMW-101 and TMW-102), and three shallow TMWs on the Chapman property (TMW-103 through TMW-105).

Groundwater samples collected from shallow TMWs installed in multiple horizontal directions at the locations north of the facility during the second portion of the EI were screened on-site using the AQR Color-Tec field screening tool to determine if CVOCs were present. The AQR Color-Tec screening method used the tetrachloroethene (PCE) colorimetric detector tube to screen a headspace sample for the presence of total chlorinated ethenes, including the CVOCs for groundwater at the Site. The screening method was performed in accordance with the procedures described in the method procedures manual as prepared by AQR (AQR, 2013). If the field screening indicated CVOCs were present in a sample from a TMW, additional TMWs were installed in suspected side and downgradient directions. Laboratory analysis of samples collected from several of the TMWs was used to confirm the results of the field screening. **Table 3-6** summarizes the field screening and confirmatory sample results for groundwater samples collected from the site during pre-RI and RI related sampling efforts.

The field screening process was also utilized to screen groundwater samples from multiple depths at eight locations on the facility property (TMW-44 through TMW-51) in order to determine vertical extent of CVOCs.

In addition to the TMW installation and sampling efforts, several bedrock wells were also installed on the Facility property and on properties to the west. Bedrock wells were installed at four locations on the Facility property including upgradient (MW-2D), mid-facility property (MW-6D), and at the northwest and southwest property corners (MW-3D and MW-7D, respectively). On the Facility property, competent bedrock was encountered at depths ranging from 84 ft BLS (MW-2D, MW-3D, and MW-7D) to as deep as 94 feet in MW-6D. Two bedrock wells (RDW-1 and RDW-2) were also installed on the western edge of the Ringer property (downgradient). Bedrock was encountered at depths of 74 ft (RDW-1) and 84 ft (RDW-2). The intent of these wells was to determine if CVOCs were present in the shallow fractures in underlying bedrock. The methods used to install these wells were discussed in Section 3.3.1.2.

3.3.2.4 Phase I RI

During the initial portion of the RI, several additional temporary and permanent shallow monitoring wells along with intermediate and bedrock monitoring wells were installed at the Site. Direct push technology (DPT) via Geoprobe rig was used to install temporary wells in accordance with procedures described in Section 3.3.1.1 above. Sonic and/or HSA drilling techniques were used to install the shallow wells in accordance with the procedures described in Section 3.3.1.2. Information generated during field screening performed during the EI and during this Phase of the RI was used to determine locations for permanent wells. Sonic techniques were used to install each of the intermediate and bedrock wells during Phase I of the RI. The rationale and procedures used for the Phase I screening and drilling efforts are briefly discussed below.

Phase I - Temporary Shallow Monitoring Wells

Previous investigative efforts have determined that the extent of shallow groundwater impacts were not delineated to the southwest of the Facility property after the VCC was executed. As a result, in November 2015, five shallow temporary monitoring wells (TMW-110 through TMW-114) were installed on the Shealy property to allow collection of groundwater samples for field screening (**Table 3-4**).

Groundwater samples collected from each of these temporary wells were screened on-site using the AQR Color-Tec field screening tool to determine if CVOCs were present. The original scope of work for this sampling included the installation and sampling of only three TMWs (TMW-110 through TMW-112). However based on the results of Color-Tec screening for the sample from TMW-110, the proposed locations for TMW-111 and TMW-112 were adjusted to allow sampling to the east and south of TMW-110 and locations TMW-113 and TMW-114 were advanced to the southwest of TMW-110 (**Figure 3-3**). Field screening did not detect CVOCs in any of the remaining TMW samples collected during this event.

Duplicate groundwater samples were collected from TMW-110 and TMW-114 and submitted to Shealy ES for confirmation analysis. The results for these samples were used to determine locations for permanent shallow wells installed in this area, as described below (**Figure 3-3**).

Phase I - Permanent Shallow Wells

During Phase I of the RI, 16 shallow monitoring wells (MW-10 through MW-25) were installed across the Site. Nine of these wells (MW-10 through MW-18) were installed on the Dickert property, north of the Facility property, at locations selected based on the results from temporary wells installed during previous investigations. Three shallow wells were installed on the properties to the west of the facility including MW-19 (Chapman property), MW-20 (Boazman property), and MW-21 (Ringer property). One shallow well (MW-22) was also installed on the south side of the Main building on Facility property. Three shallow wells (MW-23 through MW-25) were also installed on the Shealy property (**Table 3-5**). Their locations were selected based on the results of the field screening from the temporary wells discussed above (**Figure 3-4**).

Permanent monitoring wells were installed, using either sonic or HSA drilling methods, and constructed in accordance with the SC Well Standards (R.61-71) and procedures described above. The sonic drill method was used to install all but two of the shallow monitoring wells during Phase I. MW-23 and MW-24, located on the Shealy property, were installed using HSA drilling techniques.

Well construction diagrams illustrating boring and well depths, filter pack thickness, bentonite and cement grout seal and well completion information were generated for each permanent well installed during the RI. Copies of the well construction diagrams are included in **Appendix B**.

Phase I - Intermediate Zone

During Phase I of the RI, Philips utilized vertical sampling/profiling to determine the impact to groundwater between the shallow zone (water table) and the underlying bedrock in several portions of the Site. **Figure 3-5** depicts the locations of the permanent intermediate depth wells. The depths at which the vertical profiling efforts were initiated in each well boring were dependent upon the depth of the nearest shallow well. **Table 3-6** also summarizes the intermediate well profiling and field screening information including sampling depths, screening results, and confirmation laboratory results if available.

Groundwater profiling via the rotosonic drilling method entailed the following:

- Advancement of 10 foot long inner core barrel to desired depth;
- Advancement of over-ride casing to same depth as inner barrel;
- Removal of inner core barrel followed by installation of 5-foot long, two inch diameter stainless steel, 5-foot long, 0.01-inch slotted screen to the bottom of the over-ride casing. A one foot section of riser pipe, attached to the top of the screen is fitted with an inflatable packer. The packer is connected to an air compressor at land surface via polyethylene air supply line;
- The over-ride casing is then pulled up approximately five feet, exposing the screen interval to the bottom of the borehole. The packer is then inflated, sealing off the casing above the bottom of the borehole and screen;

- A small submersible pump with disposable polyethylene tubing is then lowered into the screen interval and used to purge water from the screen. Purging and sampling procedures are described in Section 3.3.4.2, below;
- Once field measurements indicated stable groundwater conditions were achieved, a groundwater sample was collected from the boring for field testing using the Color-Tec screening method; and
- If the field screening determined CVOCs were present, a well boring was advanced to a greater depth to allow additional screening.

Vertical boring advancement at a well location and profiling was stopped once field screening did not detect CVOCs or bedrock was encountered. Intermediate wells were constructed within the deepest intervals in a boring that field screening determined was not impacted by CVOCs or contained the lowest field screening results above bedrock. The intermediate wells were constructed and completed using the procedures described in Section 3.3.1.2 above. Construction diagrams for intermediate wells are included in **Appendix B.**

The depths at which intermediate wells were constructed are also listed in **Table 3-5.**

Phase I - Bedrock Zone

As previously discussed, three bedrock wells (MW-18D, MW-9D, and SDW-2) were installed at the Site using sonic drilling technology (**Figure 3-6**) during Phase I of the RI. MW-18D was installed on the Dickert property to determine if CVOCs were present in the bedrock zone north of the facility. Bedrock was encountered at 42 feet in this borehole and its total depth is approximately 66 feet. Multiple fracture zones were encountered between 47 and 60 feet in this well bore, therefore the pre-packed well screen was placed between 47 and 57 feet in accordance with procedures described in Section 3.3.1.2.

SDW-2 was installed on the Shealy property, north of SDW-1, west of water wells PW-2, PW-5, and PW-8 and to the south of RDW-2 to determine if CVOCs are present in the bedrock zone to the southwest of the facility. Bedrock was encountered at 43 feet BLS in boring SDW-2. The bedrock coring was performed from 43 to 88 feet BLS in SDW-2. There was little evidence of fractures between the bottom of the surface casing and 78 feet in SDW-2. Although not prominent, some limited fracturing was noted between 78 and 88 feet, therefore a ten foot long well screen was installed in this depth interval in SDW-2 in accordance with procedures describe in Section 3.3.1.2 above.

MW-9D was installed on the west end of the Facility property. Bedrock was encountered at approximately 90 feet in MW-9D. Existing bedrock wells located on the facility (MW-3D, MW-7D, and MW-6D) were completed as open-hole wells accessing the shallowest fracture zone in the competent bedrock. The intent of MW-9D was to delineate the vertical extent of CVOCs beneath the facility. Multiple fracture zones were encountered throughout the bedrock in this borehole. A more competent interval of bedrock with a lower occurrence of fractures was encountered below 142 feet in the borehole for MW-9D borehole. MW-9D was completed to allow screening of a limited number of fractures between 147 and 155 feet BLS and serves as a monitoring point delineating the vertical extent of CVOCs in bedrock beneath the Facility. MW-9D was also constructed with a 10-foot long, 0.01 inch slotted schedule 40 PVC screen and riser pipe of appropriate length in accordance with procedures described in Section 3.3.2.1. Well construction logs for each of these bedrock wells are included in **Appendix B.**

3.3.2.5 Phase II RI

The investigative efforts completed in Phase II of the RI included collection of groundwater samples from additional temporary well points, installation of four shallow monitoring wells, installation of two intermediate wells, and installation of four bedrock wells. Boring advancements and well installations were accomplished via Geoprobe, HSA and/or mud rotary-wireline coring techniques. The rationale for the Phase II RI well installation efforts are discussed below.

Phase II – Temporary Well Sampling

Vertical sampling/profiling was planned to fully delineate the horizontal extent of CVOC impact in the intermediate zone at a limited number of locations. The originally proposed locations included MW-12I, MW-14I, MW-17I and MW-19I (**Figure 3-3**). This included using a DPT screen point sampler to collect samples from various depths at each proposed intermediate well location MW-14I (24 ft), MW-12I (32, 45, and 55 ft), MW-17D (44 ft), MW-19I (23 ft), TMW-117 (25 ft), and TMW-118 (34 ft).

The intermediate zone vertical screening process was intended to start at a depth below a closely located shallow well and drill downward screening groundwater at various intervals until bedrock was encountered. However, during this drilling phase, bedrock was encountered at shallow depths equivalent to or within no more than five feet below two shallow wells (MW-14 and MW-17). Therefore, permanent intermediate wells were not installed at these locations.

Each of the samples collected from these Phase II RI temporary points were submitted to Shealy ES and analyzed for TCL VOCs.

Phase II - Permanent Shallow Wells

Four shallow permanent monitoring wells (MW-26 through MW-29) were installed as downgradient sentinel wells on the north (Dickert Property) and northwest (Folk property) portions of the Site during Phase II. **Figure 3-4** illustrates the locations of all the permanent shallow wells installed at the Site. These wells were installed using a Geoprobe dual tube sampling system as described in Section 3.3.1.2. These shallow wells were constructed within the 3-inch diameter outer barrel using 1-inch diameter schedule 40 PVC, 10 foot long, 0.01 inch pre-packed slotted screen and riser pipe of appropriate length and completed in accordance with procedures also described in Section 3.3.1.2.

Well construction diagrams illustrating boring and well depths, filter pack thickness, bentonite and cement grout seal and well completion information are included in **Appendix B**.

Phase II - Intermediate Zone

Analysis of groundwater samples from the three depth intervals in MW-12I did not detect any site related VOCs above their respective screening levels. As a result, MW-12I was installed to encompass the middle interval sampled during the boring advancement. MW-19I was installed on the Chapman property, west of the facility property. This well boring was advanced to the top of bedrock (approximately 24 feet BLS). Both of these intermediate wells were installed via HSA drilling methods as described in Section 3.3.1.2 above.

Construction diagrams for intermediate wells are included in **Appendix B. Table 3-5** lists the depths at which intermediate wells were constructed. **Figure 3-5** illustrates the locations of the permanent intermediate wells installed at the Site.

Phase II - Bedrock Zone

During Phase II of the RI, four bedrock wells were installed at the Site using a combination of HSA, mud rotary/wireline coring and air hammer drilling technologies as described in Section 3.3.1.2., above. **Table 3-5** lists the permanent wells installed at the Site during the investigative efforts. **Figure 3-6** illustrates the locations of the bedrock wells installed at the Site during the investigative efforts. Competent bedrock was encountered in the four wells between 11 feet BLS (in MW-19D) to as deep as 62 feet (in MW-12D). Field personnel also utilized a vertical profiling process to sample groundwater from fracture intervals in bedrock well bores when possible. The process was similar to that utilized in the intermediate zone described above. Once a fracture zone to be sampled was identified by field personnel, the borehole above the zone was isolated/temporarily sealed off via installation of drill rods without the wireline coring device. This allowed installation of a small diameter submersible pump through the rods into the borehole within the fracture interval. The submersible pump was used to purge drilling fluids and water from the borehole and fracture zone interval. Monitoring of field parameters was performed during the core hole purging efforts similar to the procedures described for intermediate well vertical profiling above. Monitoring for a drop in pH, temperature, and ORP were indicators that groundwater was being pumped from the fracture interval as opposed to water added during the drilling effort. Samples collected from the bedrock boreholes were forwarded to Shealy ES for expedited analysis.

MW-12D was cored to 125 feet BLS. Multiple fracture zones were encountered in this well bore - including 76 to 81 feet and at deeper intervals, many of which were interconnected. Based on the interconnection of many of the fractures below 82 feet, only one groundwater sample was collected from the bedrock borehole at MW-12D. The sample collected from MW-12D (71-81) did have a slightly elevated TCE concentration. Based on these results, MW-12D was completed to 82 feet BLS to ensure, at the request of SCDHEC; the well screen intersects an interval at which COVCs were detected.

Bedrock was encountered at MW-17D at approximately 41 feet BLS. The well boring for MW-17D was cored to 50 feet BLS. Groundwater elevation data in existing drilled bedrock wells indicates a general westerly flow direction in bedrock underlying the Site. This coupled with the fact that there are no water supply wells to the north of the Site and there appears to be no extraction or pumping that would influence groundwater flow in the bedrock zone beneath the east portion of the Site, Philips and AECOM determined that coring at this well to deeper fracture zones was not necessary and that is would serve as an appropriate background well for the bedrock zone beneath the Site. MW-17D was completed to 50 feet BLS.

MW-19D was installed on the Chapman property, west of the Facility property. Bedrock was encountered at approximately 11 feet BLS at this location. The well bore for MW-19D was cored to 163.5 feet BLS. A limited number of productive fractures were encountered in this boring: the first between 40 and 45 feet and the second at 162 feet BLS. A groundwater sample was collected from the 40 to 45 feet BLS interval in this core hole using the vertical profiling process described above. Laboratory analysis of this sample (MW-19D- 45) did not detect any site related CVOCs. The fracture zone encountered at 162 feet was a far more productive interval; therefore MW-19D was screened across this deep fracture zone.

SDW-3 was installed on the Shealy property, south of the Facility property. Bedrock was encountered at 52 feet BLS in this boring. Multiple productive fracture zones were encountered in this well boring. SDW-3 was cored to 141 ft BLS. Groundwater samples were collected from 56, 86 and 133 ft BLS using the bedrock vertical profiling procedures described above. Distances between the sampled intervals varied due to the numerous fractures encountered between competent zones of rock. The intervals for vertical profile sampling were selected in this borehole by field personnel based on the thickness of competent zones of bedrock overlying the fracture intervals. Analysis of the groundwater samples indicated that site related CVOCs were not present. This well was screened between 90 and 100 feet BLS.

Well construction diagrams illustrating the bedrock boring and well depths, filter pack thickness, bentonite and cement grout seal and well completion information are included in **Appendix B**.

3.3.3 **Well Development**

Permanent monitoring wells installed at the Site during each phase of investigation were developed within seven days of installation. Development of two inch and larger diameter wells entailed surging and over-pumping with a submersible pump. One inch diameter wells were developed by over pumping with a peristaltic pump. Development of the permanent wells was performed in accordance with the USEPA SESDPROC-301-R3. Copies of the well development logs are included in **Appendix C** of this RI Report.

3.3.4 Groundwater Monitoring

The RI groundwater monitoring efforts included sampling of temporary wells, vertical profile sampling, sampling of permanent monitoring wells, and sampling of a select number of private water supply wells. This section summarizes the procedures used during the sampling efforts. Groundwater purging and sampling was performed in accordance with the methods and procedures described in the USEPA SESDPROC-301-R3 and Section 3.2.3 of the Phase II RI Work Plan (AECOM, 2017).

3.3.4.1 Temporary Well Sampling

As indicated above numerous TMWs were installed to allow collection of samples for field screening and/or laboratory analysis during the pre-RI and RI phases of work. Each TMW was purged and sampled using a peristaltic pump and dedicated, disposable silicon and Teflon lined tubing. Due to the possibility of limited volume collection during shallow TMW sampling and screening efforts in particular, field parameters were not always measured when utilizing this procedure. When possible general water quality parameters including temperature, pH, specific conductance, dissolved oxygen (DO), and oxidation Reduction Potential (ORP) were measured during purging using an YSI 556 series or equivalent meter. Turbidity was measured with an HF Scientific, LaMotte, or equivalent turbidity meter. Well purging information was documented on groundwater sampling logs. Copies of the logs for sampling logs temporary and permanent wells are included in **Appendix D**.

As indicated previously, **Table 3-6** lists the groundwater samples collected from the Site for field screening using the Color Tec method. Several samples collected from TMWs advanced during the investigative efforts were also submitted to Shealy ES for confirmatory analysis. **Table 3-7** lists the TMW samples collected for laboratory analysis from the Site during the entire groundwater investigation process.

3.3.4.2 Vertical Profile Groundwater Sampling

As indicated above, vertical profiling of groundwater quality for field screening and/or laboratory analysis was performed to assist with installation of ten intermediate and four bedrock zone wells during the RI.

The sonic drilling method was used to install nine intermediate wells during Phase I of the RI - MW-2I, MW-3I, MW-5I, MW-6I, MW-7I, MW-9I, MW-10I, MW-20I, and MW-21I. Vertical profiling using the sonic method entailed advancement of four inch core barrel and a six inch over-ride casing to a desired depth as described in Section 3.2, above. A small submersible pump with dedicated, disposable polyethylene tubing was then lowered into the screen interval and used to purge water from the screen. The rotosonic drilling method sometimes requires the addition of water during the drilling process. Therefore, as water is pumped from the screen interval, field parameters including pH, temperature and ORP were monitored when possible by field personnel. Water used during the drilling efforts was provided by a Town of Newberry fire hydrant. The pH of this water is close to neutral (7 standard units - SU). A drop in pH, temperature, and ORP were indicators that groundwater was being pumped from the screened interval as opposed to water added during the drilling effort. Once field measurements indicated representative groundwater was being evacuated from the screened interval, a groundwater sample would be collected for screening and/or laboratory analysis.

The Geoprobe drilling method was used to assist with installing MW-12I, during Phase II of the RI. This entailed advancement and sampling of a 1 inch diameter stainless steel screen point sampler similar to procedures described in Section 3.3.1.1. During this process, groundwater samples were collected directly into sample containers and eventually transported to a laboratory for analysis. Due to the possibility of limited volume collection using this procedure, field parameters were not measured when utilizing this procedure. This same process was repeated to allow sampling of deeper intervals at a boring location, when necessary.

Samples collected during the profiling process were either screened on-site using the AQR Color-Tec screening method or submitted for laboratory analysis during Phase II of the RI.

The vertical profiling process was also used to sample groundwater from fracture intervals in Phase II bedrock well bores when possible. The process was similar to that utilized in the intermediate zone described above. Once a fracture zone to be sampled was identified by field personnel, the borehole above the zone was isolated/temporarily sealed off via installation of drill rods without the wireline coring device. This allowed installation of a small diameter submersible pump through the rods into the borehole with the fracture interval. The submersible pump was used to purge drilling fluids and water from the borehole and fracture zone interval. Monitoring of field parameters was performed during the core hole purging efforts similar to the procedures described for intermediate well vertical profiling above. Monitoring for a drop in pH, temperature, and ORP were indicators that groundwater was being pumped from the fracture interval as opposed to water added during the drilling effort. Samples collected from the bedrock boreholes during Phase II of the RI were forwarded to Shealy ES for expedited analysis.

3.3.4.3 Permanent Well Sampling

Permanent monitoring wells have been sampled on several occasions as the investigative efforts have progressed. **Table 3-8** lists the groundwater samples collected from permanent monitoring wells since the investigative efforts were initiated. Low flow-low volume well purging and sampling procedures were used to sample the permanent monitoring wells. Well purging and sampling was completed in accordance with the USEPA SESDPROC-301-R3 and Section 3.2.3 of the Phase II RI Work Plan (AECOM, 2017). Either a peristaltic or submersible pump was used to purge the permanent wells. Water quality parameters including pH, temperature (temp), specific conductivity (SC), DO, ORP, and turbidity were measured periodically during purging and recorded on groundwater sampling logs. Copies of these logs are included in **Appendix D** of this RI Report.

3.3.5 Water Well Sampling

During the SI, the water well located closest to the downgradient side of the Facility property (Boazman Well) was sampled to determine if Site related compounds were present. TCE was detected in this sample at an elevated concentration. SCDHEC was notified of the concentration detected in the Boazman well sample and as a result requested that Philips sample water wells surrounding the Facility property. Beginning in June 2014, groundwater samples were collected from eight water wells located in the vicinity of the Facility property. **Figure 3-7** illustrates the locations of the water wells sampled during the investigation efforts at the Site.

The majority of the water wells were purged and sampled in accordance with the USEPA SESD SOP-305R3. The supply well sampling procedures were as follows:

- The spigot or discharge pipe closest to well head was located;
- The spigot was opened allowing evacuation/purging of well for 10 to 15 minutes;
- The flow/discharge rate was monitored;
- Water quality parameters (pH, temperature, specific conductivity, dissolved oxygen, oxidation reduction potential, and turbidity) were measured; and
- The groundwater sample was collected for analysis.

3.3.5.1 Additional Water Well Sampling

In accordance with the VCC, two private water wells – (Boazman/Ringer well and Chapman Well) have been sampled periodically during each phase of the RI. **Table 3-7** lists the water well samples collected from this Site during pre-RI and RI portions of the investigation. Copies of groundwater sampling forms completed for the water wells sampled during the RI are also included in **Appendix D**.

3.3.5.2 Water Supply Line Installation

Once TCE was detected above its USEPA maximum contaminant level (MCL) of 5 micrograms per liter (ug/L) in the Boazman well, several other wells surrounding the facility were also sampled for TCL VOCs. TCE was also detected in the well for a rental house located to the southwest of the facility property (PW-2). As a result, Philips installed granular activated carbon filter systems were installed within a week of TCE detection on the water supply systems for each of these properties.

In June 2015, Philips coordinated the installation of new potable water supply lines from Newberry County Water and Sewer Authority (NCWSA) to the Boazman and Ringer properties along with the house on the Shealy property that was utilizing water supply well PW-2. Once these water supply lines were installed, the water wells were disconnected from the supply system to each of these houses.

In June 2016, water lines were also installed to a second rental house on the Shealy property that was utilizing water well PW-3 and to a livestock water supply system that was using well PW-5. These two wells were then taken out of service.

3.3.5.3 Water Well Inspection and Fracture Zone Sampling

After water wells PW-2 was no longer used as a supply well, AECOM coordinated a downhole camera survey by AE Drilling, Inc. in this well and an unused well located nearby on the Shealy property (PW-8). Data gathered using the downhole camera verified the construction of each well as containing a PVC surface casing set into weathered bedrock. Both well bores were completed as open hole below the surface casing with no additional casing or well screen material. The visual scan identified multiple fracture zones in each well bore. In order to determine if each fracture interval had been impacted by CVOCs, AECOM coordinated the use of a packer system which isolated fracture zones and allowed purging and sampling of specific zones without interference from other bedrock fracture.

The inflatable packer sampling process entailed the installation of a dual packer system for fracture intervals encountered above the bottom 20 feet of a well bore. Fractures encountered within the lower 20 feet were isolated from overlying fractures with a single packer.

The single packer system has a 2-inch diameter, 5-foot long, 0.01-inch slotted stainless steel screen. The packer is situated on top of the screen. A two inch diameter riser pipe is attached to the top of the packer and extends to land surface. In order to purge and sample an isolated interval, a submersible pump was lowered through the riser pipe and into screen below the packer. The packer is connected to an air compressor at land surface. Once the packer is situated in a desired depth, it was inflated using the compressor. After the packer was inflated the interval was purged using the submersible pump.

The dual packer system allowed isolation of a fracture zone by sealing off intervals above and below the zone of interest. The dual packer system includes a 5-foot long, 2-inch diameter, 0.01-inch slotted screen that attaches between an upper and lower packer. Each packer is attached to an individual airline connected to a compressor at land surface. Once the packers were situated at a desired depth, both were inflated sealing off the desired sample interval. A submersible pump was inserted into the screen interval between the packers and used to purge and sample the isolated interval, as described above.

Due to varying production rates for the fracture zones selected for sampling, detailed groundwater sampling logs were not completed for each zone sampled using this process. Purging efforts removed all water collected in an isolated interval. Sampling personnel were then required to wait until a sufficient volume of water collected in the interval for sample collection. This process was used to sample three intervals in PW-2 (84 ft, 120 ft, and 130 ft) and four intervals in PW-8 (70 ft, 115 ft, 155 ft, and 182 ft). Groundwater samples collected from each interval were submitted to Shealy ES for TCL VOC analysis (**Table 3-9**).

3.3.6 Groundwater Sample Analysis

As indicated above several groundwater samples collected during the RI were tested for the presence of CVOCs using the AQR Color-Tec screening method. In several cases, samples collected from the same locations were also submitted to Shealy ES for confirmatory analysis. All groundwater samples collected from the Site for laboratory analysis during the various investigative phases of investigative were tested for the TCL VOCs using USEPA analytical procedure SW-846 Method 8260c. Groundwater samples collected from water supply wells during the RI were tested for VOCs using the USEPA drinking water Method 524. This procedure has a lower detection limit for VOCs that the SW-846 method.

Biogeochemical Monitoring

A subset of wells (MW-1, MW-6, MW-7, and MW-8) sampled during pre-RI and RI related sampling was also tested for several biogeochemical parameters in 2014. These parameters were used to determine if site conditions indicate degradation of the CVOCs is occurring. During Phase II of the RI wells ten wells (MW-1, MW-6, MW6D, MW7I, MW8, MW9I, MW10, MW10I, MW-20, and MW-20I) were also tested for these parameters.

The biogeochemical parameters are listed below:

- Alkalinity
- Sulfate (SO4),
- Sulfide
- Chloride
- Total iron
- Total manganese
- Dissolved manganese
- Ferrous iron
- Ferric iron (calculated)
- Dissolved gases - carbon dioxide, ethane, ethene, and methane.
- Biological indicators – *dehalococcoides*, tceA1 reductase, BAV1 vinyl chloride reductase, Vinyl chloride reductase, and *dehalobacter* (SPP)

3.3.7 Sample Point Location and Surveying

Soil boring locations, soil vapor, and permanent well locations have been surveyed by a South Carolina Registered Land Surveyor (RLS). At a minimum, horizontal coordinates were determined for each location. Land surface elevations were determined to the nearest 0.1 foot for soil borings and permanent monitoring wells. Top of casing elevations were also determined for each permanent well. Land surface elevations were not determined for each temporary well because they were abandoned after samples were collected. Vertical elevation data was surveyed to an accuracy of 0.01 feet and horizontal position data to an accuracy of 0.1 feet. Top of well casing elevation data was used, in conjunction with depth to water in each well, to determine the elevation of the water table.

3.3.8 Hydraulic Data Collection and Conductivity Testing

Multiple rounds of groundwater level measurements have been collected from the Site during the RI. Groundwater elevation data for the monitoring wells have been used to construct groundwater elevation contour maps for the most recent measurement event and to determine the direction of groundwater flow. Groundwater elevation information and groundwater flow beneath the Site is discussed in Section 4 of this report.

During Phase II, aquifer performance tests (slug tests) were performed in 12 monitoring wells at the Site. The wells utilized in the testing included six shallow zone and six corresponding intermediate zone wells: MW-2, MW-2I, MW-3, MW-3I, MW-5, MW-5I, MW-6, MW-6I, MW-10, MW-10I, MW-20, and MW-20I. These well pairs were selected to ensure evaluation of aquifer characteristics across a broad portion of the Site.

Falling head and rising head (slug) tests were performed on each of these wells. To perform a falling head test, a solid piece of pipe of known volume was lowered into a well below the water surface. The insertion of this slug causes a rapid rise in the water level. The change in water level over time, as it fell to the original or static level, was measured and recorded using a transducer that was placed in the well prior to the test. A rising head test was also performed following the falling head test. The rising head test was performed by removing the solid pipe from the well, which caused the water level to drop rapidly. The recovery of the water level back to static conditions was then recorded by the transducer. The water level changes recorded using the transducers were evaluated using published techniques to provide the data needed to calculate the horizontal hydraulic conductivity of the aquifer units. The results of the hydraulic conductivity testing are discussed in Section 4.4.2.2. The hydraulic conductivity testing evaluation forms are included in **Appendix E**.

3.4 Surface Water Investigation

Surface water investigation efforts included sampling of two tributaries that bound the northern and southern portions of the Site. Tributary 1 lies on the north side of the Site on the Dickert property. Surface water samples have been collected on multiple occasions from this tributary at locations SW-1, SW-2, and SW-3. These locations were sampled during Pre-RI efforts and Phase I of the RI; however during Phase II of the RI, this tributary was dry during multiple visits, so samples could not be collected. Tributary 2, located on the south side of the Site on the Shealy property, was sampled during Phase II of the RI. Samples were collected from this tributary at locations SW-4 and SW-5. **Table 3-10** lists the surface water samples collected during the investigation at the Site.

Methods used to collect the surface water samples are in general accordance with the procedures described in the USEPA SESDPROC-201-R3 and Section 3.2.4 of the Phase II RI Work Plan (AECOM, 2017). Sampling was completed from downstream to upstream locations. This entailed submerging a pre-preserved sample container near the stream/creek mid-point, facing up stream. Surface water was allowed to slowly fill the sample container without displacing the preservative. Water quality parameters (pH, temp, SC, DO, and ORP) were also measured at the time of sample collection.

The locations of the surface water sample points are depicted on **Figure 3-8**. Surface water samples collected during the RI have been analyzed for TCL VOCs. Surface water sample analytical results are discussed in Section 5.4.1.

3.5 Data Validation

General validation was performed on 100 percent of the analytical laboratory deliverables for the RI. All of the data collected prior to the execution of the VCC did not undergo the full validation effort. The general and complete validation process was performed in accordance with the USEPA Region 4's *Data Validation Standard Operating Procedures for Contract Laboratory Program Routine Analytical Services* in association with the USEPA's *Contract Laboratory Program, National Functional Guidelines for Organic Data Review* (USEPA, 1999), Contract *Laboratory Program, National Functional Guidelines for Inorganic Data Review* (USEPA, 2002), and the approved QAPP for the project. The USEPA data validation protocols were used in conjunction with the SW-846 analytical methodologies to determine if data should be accepted without qualification, rejected, or qualified. Data flags, if applied, were consistent with the USEPA validation guidelines cited above. Similar procedures have been used to validate data collected since the SI. A detailed description of the data validation activities is provided in the Phase II RI Work Plan (AECOM, 2017). Sample analysis and data validation are discussed in Section 5.

3.6 Equipment Decontamination

Throughout the RI, re-usable equipment was decontaminated in accordance with the procedures described in the USEPA Region 4 protocol SESDPROC 205-R3) and the Phase II RI Work Plan (AECOM, 2017). Drilling equipment (e.g., hollow stem augers, drill rods, core barrels, etc.) were decontaminated by use of high powered pressure wash and/or steam cleaner in a temporary decontamination area, established on the Facility property. Decontamination materials were containerized in DOT-approved 55-gallon drums, which were temporarily staged on the Facility property until disposal arrangements were made.

3.7 Investigative Derived Waste (IDW)

Soil cuttings, drilling fluids, decontamination wastes, personal protective equipment (PPE), sample tubing, and other investigation related waste were containerized in DOT- approved 55-gallon drums and staged on-site prior to disposal. All IDW has been properly characterized as non-hazardous waste based on sample analytical results. All RI IDW has been transported to, and disposed of ,at licensed disposal facilities in accordance with applicable State of South Carolina and USEPA regulations. Documentation of IDW disposal is not included in this report but can be provided upon request.

4.0 **Physical Characteristics of the Study Area**

A detailed description of the Site setting is included in Section 1.2 of the report. This section describes the physical characteristics of the Site in terms of its topography, surface water hydrology, geology, hydrogeology, and ecology and was prepared using information derived from published reports, and site investigation efforts. The purpose of this section of the RI Report is to provide the framework for the subsequent sections, which discuss the nature and extent of impact (Section 5), and human health and ecological risk assessments (Section 6).

4.1 Surface Features

The Site is centered on the Facility. The facility can be accessed at the southeast and southwest corners. The majority of the facility, including all buildings is surrounded by a chain link fence. The facility is immediately bound to the south by US Highway 76 (Wilson Boulevard) and to the north by CSX rail line, the Dickert property, and the Folk property,

The topography of the Facility property slopes somewhat gradually to the west-northwest. The eastern end of the Facility property has a slightly higher elevation than its central and western portions. The former Facility property appears to have been graded during the construction of the Facility with the western edge sitting an average seven feet higher in elevation than the neighboring Boazman property. Surface elevations range from approximately 562 ft msl on the east side of the facility to 555 ft msl. Storm water collected on the facility is directed, via a series of storm water drains and piping, to a discharge point on the northwest side of the Facility. Storm water discharges to drainage swale on the Boazman property, located to the west of the Facility.

The Dickert and Folk properties, located to the north and northwest of the Facility property, are heavily wooded with planted pine trees. The CSX rail line runs between the Facility property and these properties. These properties slope from south to north, away from the Facility property towards an intermittent stream and wetland area. Elevations range from approximately 550 ft msl at the CSX rail line to less than 520 ft msl at the intermittent stream. The properties slope upward on the north side of the creek to elevations approaching 550 ft msl.

The Boazman, Ringer, and Chapman properties lay to the west of the Facility property, The Boazman property bounds the west side of the Facility property. The Ringer property bounds the west side of the Boazman property. The Boazman and Ringer properties have rolling topography with elevations ranging from a low of 536 ft msl near the southern edge along US Highway 76 to over 550 ft msl back down to less than 535 ft msl on the northern edge of these properties. The Chapman property bounds the west edge of the Ringer property. This property generally slopes downward west of the Ringer property but also increases in surface elevation to the north, similar to the Boazman and Ringer properties.

The Shealy property lies to the south, across US Highway 76, from the Facility property. The Shealy property also has a rolling surface topography and generally slopes to the west and south. The property slopes more drastically to the south to an unnamed intermittent stream. Elevations range from near 550 ft msl near US Highway 76 to less than 520 ft msl at the unnamed intermittent stream.

The intermittent streams from the Dickert and Shealy properties generally flow east to west-southwest. Both intermittent streams discharge to unnamed tributaries that flow southwest to confluences with Reedy Creek.

4.2 Soils

The Site is situated in an area consisting of four soil associations according to the United States Department of Agricultures (USDA) soil survey for Newberry County, SC (USDA, 2008). **Figure 4-1** depicts the soil units within the area including the Site. The soil classification units and the general areas in which they are present are listed below:

CcA – Cartecay Sandy Loam. These soils are typically found in or in the vicinity of streams and wetlands. They are composed of mixture silts and sands. This complex is found beneath portions of the Dickert and Folk properties to the north of the Facility property in what appear to be low lying areas that may contain wetlands or along an unnamed tributary.

HaB and HaC– Hard Labor Sandy Loam. These soils lies beneath the Boazman, Ringer, the majority of the Chapman, and Shealy properties. The HaC complex soils are found primarily along the tributary the runs east to west on the Dickert property.

SaB –Santuc Loamy Coarse Sand. These soils consist of a mixture of coarse grain sands and silts. This unit is encountered mainly beneath the Dickert and Folk properties north of the Facility property.

UsC – Urban Land-Cecil Santuc complex. These soils are found in areas that have been excavated, are covered by buildings or otherwise disturbed by humans. This unit is encountered beneath the Facility and to the east and northeast beneath a portion of the Dickert property.

More detailed descriptions of these soil units can be found in the soil survey for Newberry County, SC (USDA, 2001).

4.3 Geology

This section describes the regional and site specific geology. Regional geologic information has been compiled from various publications. The description of the Site specific geology has been developed based on information collected during the RI and previous investigative efforts.

4.3.1 Regional Geology

Newberry is located within the Charlotte Metamorphic Belt of the Piedmont physiographic province in South Carolina. The Charlotte Belt consists of predominantly Silurian to Devonian aged metamorphic rocks with younger (early Silurian aged) igneous intrusions (Zullo, 1991). The region in which the Site is located is underlain by the igneous intrusion known as the Newberry Granite. The Site is underlain in descending order by severely weathered residuum, saprolite (with relict bedrock fabric), and granite. The severely weathered residuum varies in thickness in the region from less than one foot near areas of bedrock outcrops to as deep as approximately 25 feet. The residuum is underlain by weathered saprolitic soils. The saprolite in this area is underlain primarily by a granite or granitic gneiss bedrock. The bedrock surface is undulating throughout the area, ranging from outcropping at land-surface in eastern portions of the study area to as deep as 95 feet BLS towards the west end of the Facility property.

4.3.2 Site Specific Geology

Over 100 soil and/or well borings have been advanced during the multiple phases of investigation at the Site. Lithologic data collected from these borings has been used to develop a description of the sediments and rock formation beneath the Site. Soil/rock encountered during boring installation were visually examined by field personnel and recorded on soil boring logs. Field personnel used the Unified Soil Classification System (USCS) to characterize and describe the soils encountered during field sampling activities. Lithologic data obtained from these borings has provided information to allow determination of soil and rock layers beneath the Site and correlation of site-specific data with the geologic formations described above.

Four geologic cross sections have been prepared using well and soil boring information obtained during the various phases of investigation. The cross-sections depict the general lithology based on the major component identified in soil cores (sands, silt, clay, etc.). **Figure 4-2** is a site map depicting well boring locations and the orientation of the cross sections. **Figures 4-3** through **4-6** are the geologic cross sections depicting the lithology encountered beneath the Site.

As illustrated on the cross-sections, geologic formations encountered beneath the Site ranged from the residuum to saprolite to bedrock as discussed above. Twenty-four (24) permanent shallow monitoring wells have been installed within the residuum beneath the Site. The shallow soils (land surface to approximately six feet BLS) encountered directly beneath the Facility appear to be fill material placed during construction of the original plant buildings. Shallow residuum related sediments encountered beneath the fill materials on the facility and other areas generally consist of pale brown to reddish brown fine grained sands and silt to silts and silty clay with sand. The thickness of the residuum sediments vary across the Site ranging from as little as three feet to ten feet. These soils have been severely weathered and contain little to no rock fabric texture and consist of varying percentages of sand, silt, and clay.

The residuum interval grading downward to a less weathered saprolitic zone with varying percentages of sands, silts and clay. Twelve (12) intermediate monitoring wells have been installed in the saprolitic zone. Saprolitic soils are differentiated in this area from the residuum by color and visually evident relict rock fabric or structure. The residuum soils are more consistent in color, while the saprolitic soils contain sediments of varying color related to degradation of granitic parent rock minerals (white to pale red – feldspars, gray - quartz, dark gray to black – biotite and hornblende). The saprolitic soils range from one foot to more than ten feet in thickness across the Site.

The saprolitic soils are underlain by bedrock consisting of granite and/or granitic gneiss. Fifteen (15) bedrock wells have been installed during the various phases of investigation at the Site. Rock cores have been collected from each bedrock well bore. As indicated above, each core sample was visually examined by AECOM field personnel. Based on examination of rock core samples collected from the Site, the majority of the study area is underlain primarily by an aphanitic (fine grained) granite (which may also be considered a granodiorite based on percentage of quartz and feldspars). The mineral content of the granite consists of a mixture quartz (gray), plagioclase feldspar (light gray to white), orthoclase feldspar (pink to pale brown), and to a lesser extent accessory minerals including hornblende and biotite (dark gray to black). This is evident in rock cores from the majority of the bedrock wells installed at the Site. Small thin zones of phaneritic (larger-coarse grain) mineral textures are present at multiple depths in cores from RDW-1 (west central portion of Site) and SDW-3 (southern portion of Site).

The bedrock content appears to change to more of granitic gneiss beneath the west-southwest portion of the Site. Cores from SDW-2 indicate the mineral content of the rock contains a much higher percentage of darker colored (black, dark gray) feldspars and hornblende with numerous white to light gray (likely quartz and feldspar rich) dike-like intrusions of varying thickness. This fabric was evident from the depth at which it was encountered (43 feet BLS) to the bottom of the well bore in SDW-2 (88 ft BLS). This same fabric was also encountered in the rock core for MW-19D, located north of SDW-2, but at a much greater depth than at which it was encountered in SDW-2. The gneiss like structure was encountered beneath the aphanitic granite seen throughout other portions of the Site between depths of 95 and 120 feet BLS in MW-19D.

4.4 Hydrogeology

This section briefly discusses the regional and site specific hydrogeology.

4.4.1 Regional Hydrogeology

The Site is located in the piedmont physiographic province of South Carolina. Groundwater is typically encountered in the alluvial deposits and weathered saprolite above the bedrock within the primary porosities of the soils and within the secondary porosity (e.g. faults, joints, and/or fractures) in the bedrock. Groundwater movement occurs within each of these zones. Groundwater movement within the unconsolidated materials (residuum and saprolite) is typically controlled more horizontally by topography and discharge to surface water bodies and vertically with seepage/discharge to underlying bedrock.

4.4.2 Site Hydrogeology

During the investigative efforts completed at the Site, drilling has been conducted to as deep at 163 feet BLS. Temporary and/or permanent monitoring wells have been screened in three depth zones: shallow (or water table/surficial aquifer), intermediate (typically screened in saprolite) and in bedrock. **Tables 3-4** and **3-5** summarize TMW and permanent well depth information.

In general, the water table is encountered in the fine sands and silts to silty clays of the residuum across the Site. Total depths for shallow wells ranged from 12 feet BLS, on top of bedrock beneath the eastern end of the Main Building at the Facility property, to approximately 30 feet at several locations throughout the center portion of the Site. The variation in depth of the shallow wells across the Site is due to differences in land surface elevation and the depth to underlying bedrock. Groundwater has been encountered at depths ranging from approximately two feet BLS in shallow wells near the northern end of the Site on the Dickert property to as deep as approximately 18 feet BLS in wells on the Facility property.

Intermediate wells were installed in the underlying saprolite or at the saprolite-bedrock interface depending on location and the results of field screening as referenced in Section 3.2, above. Intermediate well depths ranged from 23 feet BLS in MW-19I, which is at the top of bedrock to as deep as 55 feet in MW-3I, located at the southwest corner of the Facility property. Depth to groundwater in intermediate wells has ranged from 3.8 feet BLS in MW-19I to 18 feet in MW-9I.

Bedrock monitoring wells were installed either as open hole wells, allowing access to the upper most fracture zone in underlying bedrock, or screened across specific fracture zones at greater depths. Bedrock well depths ranged from 50 feet BLS in MW-17D, located on the Dickert property to as deep as 162.5 feet in MW-19D, located on the Chapman property. Groundwater levels ranged from approximately six feet BLS in RDW-1 to as deep as 69 feet in SDW-2.

4.4.2.1 Groundwater Gradients

To date, multiple rounds of water level measurements have been collected from the entire monitoring well network at the Site. **Table 4-1** summarizes the depth to water and groundwater elevations from the permanent well network during the RI. Groundwater elevations have been used to prepare groundwater elevation contour maps for each zone. **Figures 4-7 through 4-9** are groundwater elevation contour maps for the shallow, intermediate and bedrock zones, respectively, using data from the most recent groundwater measurement event.

As shown in each of the contour maps, the general direction of groundwater flow appears to be to the west-northwest. In the shallow zone, the groundwater flow is to the northwest with a southwest flow component, likely the result of topographic low in this direction (**Figure 4-7**). Groundwater flow in the shallow zone can be interpreted to being the direction of several small unnamed tributaries that lie to the west of the Site. The groundwater flow direction in the intermediate zone is also to the west-northwest (**Figure 4-8**).

Based on elevations determined for the bedrock wells, the direction of flow within bedrock appears to be to the west-southwest. There are several water supply wells located to the west and southwest of the Facility property. Historic use of these wells has likely directed flow within the bedrock fracture system to the southwest (**Figure 4-9**).

The groundwater elevations and flow maps were used to calculate average horizontal and vertical groundwater gradients across the site. The triangulation method was used to calculate horizontal gradients for each zone. This method uses groundwater elevations from upgradient wells on the east side of the Site, side gradient wells, and down gradient wells located west of the Site. Based on the groundwater elevations determined during the June 2018 measurement event, the average hydraulic gradients for the each zone are as follows:

Shallow zone - 0.016 ft/ft to the west-northwest

Intermediate zone – 0.014 ft/ft to the west-northwest

Bedrock zone – 0.013 ft/ft to the west

Horizontal hydraulic gradient calculations are provided in **Appendix E**.

Figures E-1 through **E-3** illustrate the horizontal gradients calculations for each groundwater zone.

Determination of the vertical gradients provides a basic indication of whether contaminants have the potential to migrate vertically from shallower groundwater zones to deeper zones.

Vertical hydraulic gradients were also calculated for this sampling event using the June 2018 data from paired shallow and intermediate well clusters across the Site. The following formula was used to calculate vertical hydraulic gradients at each well cluster:

$$\frac{(GWSW-GWDW)}{(SW-DW)} = Vertical\ Gradient \text{ (ft/ft)}$$

Where:

GW SW - groundwater elevation of shallow well (ft)

GW DW - groundwater elevation of intermediate zone well (ft)

SW - elevation of top of mid-point of shallow well screen (ft)

DW - elevation of top of mid-point of intermediate well screen (ft)

Table E-1 presents the vertical gradient calculations for the June 2018 measurement event.

Based on the calculated hydraulic gradients, it appears that there is a general downward gradient between the shallow and intermediate zones across the site during this event. The vertical gradient between the shallow and intermediate zones for this event was determined to be -0.022 ft/ft in the downward direction.

4.4.2.2 Hydraulic Conductivity (K) Testing

During Phase II of the RI, hydraulic conductivity tests (slug tests) were performed on select shallow and intermediate monitoring wells. Data collected from the slug tests were used to calculate hydraulic conductivity (K), which is a two-dimensional measure of the ability of a square unit of the aquifer to allow the flow of water. The hydraulic conductivity is also used with the groundwater gradient to determine the rate of groundwater flow. The procedures for conducting slug tests are discussed in Section 3.3.7.

Slug tests were performed on seven paired shallow and intermediate wells:

- MW-2 and MW-2I
- MW-3 and MW-3I
- MW-5 and MW-5I
- MW-6 and MW-6I
- MW10 and MW10I
- MW-20 and MW-20I
- MW-21 and MW-21I

Data generated during the slug tests was evaluated using Aqtesolv, a commonly used, commercially available, computer software package. Aqtesolv allows a choice of published methods to evaluate slug test data. Two methods were used to calculate K values: the Bouwer and Rice method (1976 and 1989) and the Hvorslev method (1951) . Initial values as calculated using the Bouwer and Rice method were confirmed by also analyzing the data by the Hvorslev method. Both methods provided similar values for hydraulic conductivity, so only the Bouwer and Rice method is presented here.

Table 4-2 summarizes the data inputs for the hydraulic conductivity calculations. The results of the slug tests for the six shallow wells showed that the K values ranged from 0.13 to 2.19 feet per day with an average K of 0.80 feet/day (**Table 4-3**). K values in the intermediate zone wells ranged from 0.055 to 1.65 ft/day for an average of 0.72 ft/day.

The results of the analysis of the slug test data for the shallow wells are included in **Appendix E** along with the copies of the raw water level data and graphs generated using Aqtesolv software.

4.4.2.3 Groundwater Flow Rates

The hydrogeologic data (hydraulic conductivity and gradient) collected at the Site were used to calculate groundwater flow rates for the shallow zone using Darcy's Law as follows:

$$V = \frac{K \times i}{n}$$

Where:

V = Average Groundwater Flow Velocity

K = Hydraulic Conductivity

i = Groundwater Gradient

n = Porosity

Groundwater flow rates for the unconsolidated formation (water table/shallow zone and intermediate zone) beneath the Site are summarized in the table below.

Hydraulic Property Summary Table
Shakespeare Composite Structures Site

	Hydraulic Gradient	Assumed Effective Porosity	Average Hydraulic Conductivity	Calculated Groundwater Velocity (ft/day)	Calculated Groundwater Velocity (ft/year)
Shallow	0.016	0.25	0.81	0.05	18.8
Intermediate	0.017	0.3	0.72	0.04	14.80
Bedrock	0.013	NA	NA*	NA*	

* Not determined based on variability within screened fracture zones.

4.5 Surface Water Hydrology

Surface water collected on the Facility property is directed, via a series of storm water drains and piping, to a discharge point on the northwest side of the Facility property. Storm water discharges to a drainage swale on the Boazman property, located to the west of the Facility property. Storm water from this portion of the Boazman property drains to the northwest across the Ringer property beneath the CSX rail line and onto the Dickert property via an intermittent drainage swale.

There are a limited number of surface water bodies adjacent to the Site that may have a limited effect on hydraulic and hydrogeologic conditions in the area including two un-named tributaries and a small pond. One tributary could be characterized as an intermittent stream that drains the north central portion of the Dickert property. This tributary flows to the west-northwest where it eventually ties in with Reedy Creek which lies to the west. The second tributary runs from the southeast across the Shealy property to the west where it also ties in with Reedy Creek. Shallow groundwater may discharge to both tributaries during periods of normal to above average rainfall. During periods of normal rainfall these tributaries do contain flowing water and may serve as local discharge points for shallow groundwater. During periods less rainfall these tributaries have been dry within the study area.

There is a small pond located at the west end of the Site on the Chapman property. Shallow groundwater may also discharge to this pond during periods of normal to above average rainfall. During the majority of the RI however, water levels in this pond have decreased.

4.6 Site Ecology

As indicated above, the Site consists of a variety of land uses ranging from pasture lands for livestock/grazing; to residential; to industrial. The Site is a mosaic of gentle rolling dry slopes bounded on the north and south by creeks and limited wetland areas.

4.6.1 Facility Property

The Facility property, as previously discussed, is occupied by several buildings and outdoor, paved staging areas, parking areas, and access roads. Areas that are not paved have a grass cover. There are a limited number of pine trees at the northeast corner of the property. **Figure 1-2** illustrates the layout of the facility property.

4.6.2 North

As previously indicated, the property to the north of the Facility is owned by CSX railroad, and multiple private landowners (**Figure 1-2**). The properties to the north are primarily wooded with re-planted short needle (loblolly pine – *Pinus taedus*) pine trees except the wetland area in the central-eastern portion of the Dickert parcel. This area is suspected to serve as the headwaters for the unnamed tributary that drains to the west across the Folk property. The wetland area contains bulrush and other wetland grasses along with is an open palustrine, seasonal wetland complex containing a mix of grasses, bulrush, cattails (*typha domingensi*), and some oak (*Quercus sp*). This wetland complex may be seasonally saturated and even inundated, depending upon climatic conditions.

4.6.3 West and South

As previously indicated, the Facility property is bounded to the west by three residential properties. The two properties immediately to the west (Boazman and Ringer) are residential with a mixture of pine trees, oak trees and grasses. The Chapman property (west of the Ringer property) is a mixture of open pasture and a residential. There is a man-made pond also located on the Chapman property surrounded by pasture grass. The Facility property is immediately bound to the south by US Highway 76. Property owned by Shealy lies directly to the south of US Highway 76. The Shealy property is primarily pasture land covered by a variety of grasses used for cattle grazing. Three small residential properties are located south of US Highway 76, surrounded by the pasture land (**Figure 1-2**).

5.0 **Nature and Extent of Contaminants**

This section of the RI Report discusses the nature and extent of the contaminants in terms of their occurrence and distribution at the Site.

5.1 Data Compilation and Screening

A total of 484 samples have been collected from the Site during previous investigations and the RI. The distribution of samples collected from each environmental media at the Site during historic and RI related activities is as follows:

- 184 soil samples
- 70 temporary well groundwater samples
- 150 permanent monitoring well groundwater samples
- 11 water well samples
- 8 surface water samples
- 52 passive soil vapor samples
- 7 confirmatory soil vapor samples

Tables referenced in Section 3 list the samples collected from each media, the sample location identification numbers, date collected and analytical parameters for each sample. The analytical results for the samples collected from the investigative efforts are presented as validated data summary tables referenced in this section of the report. Results are presented by media and analyte. The summary tables also include human health (HH) and, where appropriate, ecological (Eco) screening values that allow comparison with sample results.

Discussion of soil sample and surface water sample results focus on the parameter concentrations that were detected above either/or both HH and/or Eco screening values and their distribution in each media. Discussion of groundwater sample results focus on parameter concentrations that exceed State primary drinking water standards (SPDWS) - maximum contaminant levels (MCLs).

Analytical reports for data collected during investigative efforts completed prior to initiation of the RI have been previously submitted to SCDHEC. These reports are included in **Appendix F** on compact disc (CD). Hard copies of the analytical data reports and validation memorandums for samples collected during the RI are included in **Appendix G**.

5.2 Contaminant Summary

Pre-RI and RI sample analyses have indicated that VOCs are the contaminants of interest at the Site. The VOCs reported at the Site for discussion purposes have been segregated based on their suspected use at the former Facility property. The VOCs detected and their respected groups are summarized below:

Chlorinated Volatile Organic Compounds (CVOCs) associated with historical solvent use:

- 1,1 Dichloroethene (1,1 DCE)
- 1,1 dichloroethane (1,1-DCA)

- 1,1,2,2 Trichloroethene (1,1,2,2 TCA)
- Carbon Tetrachloride (CT)
- cis-1,2 Dichloroethene (cis-1,2-DCE)
- Chloroform
- Tetrachloroethene (PCE)
- Trans-1,2 Dichloroethene (trans-1,2 DCE)
- Trichloroethene (TCE)
- Vinyl Chloride (VC)

Organic compounds associated with more current solvent use:

- Acetone
- 2-butanone (methyl ethyl ketone - MEK)
- 4-Methyl-2-pentanone
- 2-hexanone
- Cyclohexane
- Methylene Chloride (dichloromethane)
- Methyl acetate

Aromatic Hydrocarbons, possible historical solvent component:

- Ethylbenzene
- Toluene
- Xylenes
- Methyl-Tert-Butyl-Ether (MTBE)
- Isopropyl benzene

Resin related components:

- Styrene

5.3 Contaminant Occurrence and Distribution

The following sections discuss analytical results for samples collected from the Site. Where appropriate, pre-RI analytical data is utilized to depict contaminant impact of soils in particular.

5.3.1 Soil

A total of 184 soil samples have been collected from 59 borings advanced at the Site. The majority of the borings (53) and samples (138) were advanced/collected during the pre-RI sampling efforts. Initially, soil sampling efforts were focused on locations identified as RECs as part of the Phase II ESA, however the focus shifted to areas of possible impact and identifying possible contaminant source areas as the pre-RI sampling efforts progressed. The majority of the soil samples have been analyzed for TCL VOCs. A limited number of samples were also analyzed for other parameters. The results of these analyses are discussed where appropriate in this section.

Soil sample results have been screened against the USEPA Regional Screening Levels (RSLs) for residential soil and USEPA Soil Screening Levels (SSL) for the protection of groundwater (MCL-based SSLs) (USEPA, May 2018a) to identify contaminants of potential concern (COPCs) and their extent in soils at the areas of interest. The screening levels used for comparison are conservative. For example, residential RSLs were used because they are the most conservative values with respect to potential exposure to persons living at the Site; however, the Facility property is expected to remain an industrial area for the foreseeable future. MCL-based SSLs are based on conservative assumptions [e.g., a dilution-attenuation factor (DAF) of one] and assume little to no attenuation of soil concentrations in the mixing zone. For these reasons, an exceedance of a screening level is not necessarily an indication of unacceptable risk or that remediation is required. Soil sample results are summarized in multiple tables referenced in this section. Results are discussed based on the phase of collection and the areas from which they were collected. Each soil sample summary table lists sample results and includes USEPA RSLs, along with RBSLs and MCL SSLs for comparison.

Twenty-two VOCs have been detected in at least one soil sample collected from the Site. As indicated above, the VOCs that have been detected are categorized in four groups. The VOC groups, compounds reported, and number of detections for each compound in soil samples are listed below:

CVOCs:

- 1,1 DCE – 3 samples
- 1,1 DCA - 1 sample
- 1,1,2,2 TCA – 1 sample
- CT – 1 sample
- Cis-1,2-DCE – 54 samples
- Chloroform – 4 samples
- PCE – 15 samples
- Trans-1,2 DCE – 13 samples
- TCE – 45 samples
- VC – 3 samples

Organic solvents:

- Acetone – 71 samples
- 2-butanone (MEK) – 15 samples
- 4-Methyl-2-pentanone 1 sample
- 2-hexanone – 1 sample
- Cyclohexane – 1 sample
- Methylene Chloride – 13 samples
- Methyl acetate – 1 sample

Aromatic Hydrocarbons:

- Ethylbenzene – 9 samples
- Toluene – 4 samples
- Xylenes – 5 samples
- MTBE – 1 sample
- Isopropyl benzene – 3 samples

Resin related components:

- Styrene – 48 samples

5.3.1.1 Phase II ESA Soil Sample Results

As previously indicated, the Phase II ESA sampling efforts focused on areas of interest identified during a Phase I ESA completed in late 2013. Eighteen soil samples (including one surface and 17 subsurface samples) were collected from 10 RECs (RECs 1 through 10) during the initial stage of the Phase II ESA (**Table 3-1**). The Phase II ESA soil sample locations are illustrated on **Figure 3-1**. Each of the soil samples were analyzed for TCL VOCs. As shown in **Table 5-1**, 13 VOCs were detected in the Phase II ESA soil samples. Samples from locations REC 8 B-12 (Acetone AST), REC 8 B-13 (Hazardous Waste Storage Building), and REC 10 B-16 (Dip Vault- Main building) had the highest number of VOC detections. Six VOCs were detected in REC B-12 including 2-butanone, acetone, cis-1,2-DCE and the petroleum related compounds isopropylbenzene, ethylbenzene, and total xylenes. Ethylbenzene (34,000 ug/kg), was detected above each of the RSLs and SSLs in sample REC 8 B-12. The total xylene concentration in this sample (170,000 ug/kg) also exceeded its RBSL (190 ug/kg) and MCL SSL (9800 ug/kg).

The CVOCs 1,1 DCE, cis-1,2-DCE, and TCE were detected in the sample from REC 8 B-13. The concentrations for each of these compounds exceeded their respective RBSLs in this sample (**Table 5-1**).

The CVOCs TCE, cis-1,2-DCE, Trans-1,2 DCE, and VC. The CVOCs cis-1,2-DCE and TCE were reported above their respective RBSLs in this sample (**Table 5-1**).

Samples collected from RECs 8 (Rec-8 B-13) and 11 (REC-11 B-17) were also analyzed for PAHs, RCRA metals, and nickel. In addition, the soil sample from REC 10 (REC 10 B-16) was also analyzed for PCBs. As shown in **Table 5-2**, a limited number of PAHs and metals were detected in the samples from these locations. None of the reported concentrations exceed their respective USEPA residential or industrial regional screening levels (RSLs). PCBs were not detected in sample REC 10 B-16.

As a result of the detections of VOCs during the initial portion of the Phase II ESA, additional soil investigative efforts were performed, focusing on previous sample locations with numerous detections including REC 8 B-12, REC 8 B-13, and REC 10 B-16. Eleven soil borings were advanced in the vicinity of these original Phase II sample locations. Eight subsurface soil samples (two each) were collected from the four borings (B-12A, B-12B, B-12C, B-12D) installed surrounding location B-12 (in vicinity of above ground acetone storage tank). A limited number of VOCs were detected in these samples including Acetone and cis-1,2-DCE. None of the reported concentrations exceed the compound specific RSLs or SSLs in any of the soil samples collected from the additional B-12 area borings (**Table 5-3**).

Five soil samples were collected from the three additional borings (B-13A, B-13B, B-13C) installed in the vicinity of boring B-13 (within the hazardous waste storage building). A limited number of VOCs were detected in these samples including acetone, 1,1 DCE, Ccis-1,2-DCE and isopropylbenzene. The 1,1-DCE and cis-1,2-DCE concentrations exceeded their respective RBSLs in sample B-13B (3-5 ft). None of the other reported VOC concentrations exceed the compound specific RSLs or SSLs in the samples collected from the Hazardous Waste Storage Building (**Table 5-3**).

Eight soil samples (two each) were collected from four additional soil borings (B-16A, B-16B, B-16C, and B-16D) advanced at locations surrounding B-16 and the Dip Vat Room in the Main building. The results for these samples are included in **Table 5-4** which summarizes the results for soil samples collected from the Main building. As shown in **Table 5-4**, the CVOC cis-1,2-DCE was detected above its RBSL in each of the eight samples collected from these borings. TCE was detected above its RBSL in three samples [B-16C(9-10), B-16C(12-13), and B16D(8-9)] and ethylbenzene was detected above its RBSL in the two samples [B-16D(8-9) and B-16D(12-13)].

5.3.1.2 SI Soil Sample Results

Upon review of the Phase II ESA soil sample and groundwater sample results, Philips expanded its investigation efforts across the Site. The focus of the soil sampling was guided by the results from the previous soil sampling efforts and the results for groundwater samples collected from temporary wells as the investigative efforts at the Facility evolved. The soil investigation included a more elaborate soil sampling program focusing on the Main and Pole Winder buildings in particular with the intent of identifying potential source areas. Twenty nine (29) soil borings were advanced during the Site Investigation (SI) efforts. Multiple soil samples were collected from each of these borings for field screening and chemical analysis. Soil core advancement and collection along with soil sampling was completed in accordance with methods described in Section 3.2.2.1. The depth at which soil samples were collected from the soil borings were determined using a photoionization detector (PID) and field screening efforts completed with the Color Tec kit.

<u>Main Building</u>

Twenty-two borings were advanced within and adjacent to the Main building (**Figure 3-1**). Seventy seven soil samples (including seven surface and 70 subsurface) were collected from the Main building for chemical analysis during this sampling effort. Sample depths varied based on the results of field screening. A description of the soil sample results in this section are based on the areas in and around the Main building from which the samples were collected, not in the numerical order in which the borings were advanced.

Borings B-20 through B-25 were advanced along the west end of the building. B-20, B-21, and B-23 were installed adjacent to a sanitary sewer line and manhole. Nine subsurface soil samples (three from each boring) were collected for analysis. Six VOCs were detected in these samples including the organic compounds 2-butanone, acetone; the aromatic hydrocarbon ethylbenzene; the CVOCs PCE and TCE; and styrene. Ethylbenzene was detected above its MCL SSL of 1.7 ug/kg in samples B-20-11 and B-21-9 at 20 and 2.6 ug/kg, respectively. TCE was also detected above its MCL SSL of 0.18 ug/kg in B-21-15 at 6 ug/kg (**Table 5-4**).

B-22 was advanced west of the former incinerator building. Five VOCs were detected in one sample (B-22-8) collected from this boring. The CVOCs 1,1,2,2 TCA (27 ug/kg) and CT (5.3 ug/kg) were detected above their respective MCL SSLs of 0.03 ug/kg and 0.018 ug/kg, respectively.

Borings B-24 and B-25 were advanced west of the Receiving Department loading dock on the west end of the Main building. As many as 7 VOCs were detected in the four soil samples collected between these two borings. The aromatic hydrocarbon ethylbenzene was detected above its MCL SSL of 1.7 ug/kg in samples B-24-8 (16 ug/kg) and B-25-10 (6.1 ug/kg). cis-1,2-DCE (33 ug/kg) was detected above its MCL SSL of 11 ug/kg in B-24-8. TCE was detected above its MCL SSL of 0.018 ug/kg in B-24-8 (30 ug/kg) and B-25-10 (14 ug/kg).

Boring B-33 was advanced on the north side of the building, east of the Dip Vat Room and the B-16 borings. Four VOCs were detected in each of the three soil samples collected from above the water table depth (approximately 14 feet) in this boring (**Table 5-4**). cis-1,2-DCE was the only VOC detected above any screening value. cis-1,2-DCE was detected above its MCL SSL of 11 ug/kg in B-33-12 and B-33-15 at 12 and 14 ug/kg, respectively.

Borings B-26, B-30, and B-41 were advanced north of a sewer line and former drain line. Up to five VOCs were detected in soil samples from these borings (**Table 5-4**). Only two of the VOCs were detected above any screening values. The CVOC cis-1,2-DCE was detected above its MCL SSL of 11 ug/kg in sample B-26-14 at 13 ug/kg and in sample B-30-10 at 25 ug/kg. TCE was detected above its MCL SSL of 0.18 ug/kg in B-26-14 at 40 ug/kg and in B-30-10 at 100 ug/kg.

Borings B-28, B-31 (TMW-23), B-40, TMW-21, and TMW-22 were advanced through the west central portion of the Main building near a former floor drain line. As many as eight VOCs were detected in at least one of the soil samples from these five borings. This includes the organic solvent compounds acetone and 2-butanone; the CVOCs cis-1,2 DCE, PCE, TCE, and trans-1,2 DCE, the aromatic hydrocarbons ethylbenzene and toluene; and the resin component styrene. The only compounds detected above their respective screening values in these samples were ethylbenzene, Cis-1,2-DCE, and TCE. Ethylbenzene was detected above its MCL SSL of 1.7 ug/kg in sample TMW-21-10 at 6.3 ug/kg. cis-1,2-DCE was detected above its MCL SSL of 11 ug/kg in six samples ranging from 13 ug/kg in TMW-22-8 to 35 ug/kg TMW-21-10. TCE was detected above its MCL SSL of 1.8 ug/kg in nine soil samples collected from these borings ranging from 6 ug/kg in B-31-10 to 180 ug/kg in TMW-22-12.

Borings B-27, B-29, B-32, B-38 (TMW-30), and B-45 were advanced on the southern side of the Main building adjacent to former drain lines. Up to nine different VOCs were detected in at least one of the soil samples from these five borings. This includes the organic solvent compounds acetone and 2-butanone; the CVOCs Chloroform, Ci-1,2 DCE, PCE, TCE, and Trans-1,2 DCE; and the resin component styrene. The only compounds detected above any screening values were the CVOCs chloroform, cis-1,2-DCE, and TCE. Chloroform was detected above its RBSL of 0.061 ug/kg in B-38-8 (1.3 ug/kg) and B-38-12 (5.4 ug/kg). cis-1,2-DCE was detected above its MCL SSL (21 ug/kg) in 11 samples ranging from 25 ug/kg in B-32-7 to 260 ug/kg in B-29-14.

Borings B-29 and B-39 (TMW-31) were advanced beneath the north-central portion of the building. B-29 was advanced near a floor drain and former drain line. B-39 was advanced in a Chemical Storage Room. Only two VOCs were detected in the samples from these borings: acetone and styrene. None of the reported concentrations exceed any respective screening values (**Table 5-4**).

<u>Pole Winder Building</u>

Seven soil borings were advanced in and adjacent to the Pole Winder building (**Figure 3-1**). Nineteen soil samples (including two surface and 17 subsurface) were collected from the Pole Winder building for chemical analysis. Borings B-34 (TMW-25) through B-37 were advanced in the vicinity of an underground wastewater vault system on the north side of the Pole Winder building (REC 5a B-9). As many as four VOCs were detected in at least one soil sample collected from these borings. The organic solvent compounds acetone and 2-butanone along with the CVOCs chloroform, PCE, and TCE were detected in at least one sample collected from these four borings (**Table 5-5**). Chloroform was detected above its RBSL of 0.063 ug/kg in B-34-10 at 1.4 ug/kg. TCE was detected above its MCL SSL of 1.8 ug/kg in B-34-10 (2.6 ug/kg) and B-34-13 (4.3 ug/kg).

Borings B-42, B-43 (TMW-32), and B-44 (TMW-33) were advanced adjacent to ole winding machines within the Pole Winder building. Only three VOCs were detected in the samples from these boring: acetone, 2-butanone, and TCE. Only TCE was detected above any screening value. TCE was detected at 14 ug/kg which is an order of magnitude higher than the MCL SSL of 1.8 ug/kg (**Table 5-5**).

5.3.1.3 Phase II RI Soil Sample Results

During Phase II of the RI, three soil borings were advanced in or adjacent to each building near prior soil vapor sample locations to allow collection of confirmatory soil samples. The locations for the borings were selected based on the results of the passive and confirmatory soil gas surveys and/or historical soil and groundwater data. Borings 47 through 49 were installed in the Main building at confirmatory soil vapor sample locations SVS-31, SVS-45, and SVS-41 respectively. Borings 45PW and 46 were advanced in the Pole Winder building near locations SVS-20 and SVS-23. Boring 50 was advanced at SVS-14, which is located outside the south western corner of the Pole Winder building (**Figure 3-1**). Each soil sample was analyzed for TCL VOCs. **Table 5-6** summarizes the analytical results for the Phase II RI soil samples.

Main Building

Twenty-four soil samples were collected from the three borings advanced in the Main building (**Figure 3-2**). As shown in **Table 5-6**, at least one VOC was detected in all but one of the soil samples collected from the Main building. No VOCs were detected in sample B-46-14.

No more than two VOCs were detected in the samples from B-46 with no VOCs detected in the sample from B-46-14. Only two VOCs were detected above any of their respective screening values in the B-46 soil samples. Ethylbenzene was detected at 4.9 ug/kg in B-46-4 which is above the MCL SSL of 0.78 ug/kg. TCE was detected in B-46-15 at 0.0042 ug/kg which is slightly above its MCL SSL of 0.0018 ug/kg (**Table 5-6**).

As many as eight different VOCs were detected in the samples from B-47 and B-48. These included the organic solvents 2- butanone, acetone and methylene chloride; the CVOCs 1,1 DCE, cis-1,2-DCE, and TCE; the hydrocarbon toluene; and the resin component styrene. Five of the VOCs were reported above their respective MCL SSLs including methylene chloride, 1,1 DCE, cis-1,2-DCE, TCE, and styrene.

The organic solvent methylene chloride was detected above its MCL SSL of 0.0013 ug/kg in 10 samples collected from these two borings ranging from 0.0078 ug/kg in B-48-8 to 0.019 ug/kg in B-48-14. 1,1 DCE was detected above its MCL SSL of 0.0025 ug/kg in one sample B-47-12 at 0.0027 ug/kg. cis-1,2-DCE was detected above its MCL SSL of 0.021 ug/kg in four samples, ranging from 0.023 ug/kg in B-47(10) to 0.029 ug/kg in B-47-12. TCE was detected above its MCL SSL 0.0018 ug/kg in 10 samples ranging from 0.0041 ug/kg in B-47-6 to 0.58 ug/kg in B-47-12. The resin product styrene was detected above its MCL SSL of 0.11 ug/kg in 13 samples ranging from 0.12 ug/kg in B-47-6 and B-47-8 to 0.019 ug/kg in B-48-14.

Pole Winder Building

Twenty four (24) soil samples were collected from the three borings advanced in or adjacent to the Pole Winder building (**Figure 3-2**). As shown in **Table 5-6**, at least two VOCs were detected in each of the soil samples collected from the three borings (B-45PW, B-49, and B-50). These included the organic solvents acetone, 2-butanone, methylene chloride; the CVOCs 1,1 DCE, cis-1,2-DCE, PCE, TCE, and Trans-1,2 DCE; the hydrocarbons ethylbenzene and toluene, and the resin product styrene. Six of the VOCs were reported above their respective MCL SSLs including methylene chloride, 1,1 DCE, cis-1,2-DCE, PCE, TCE, and the resin product styrene.

Methylene chloride was detected above its MCL SSL of 0.0013 ug/kg in two samples, B-49-14 at 0.0079 ug/kg to 0.0069 ug/kg in B-50-10. The CVOC 1,1 DCE was detected above its MCL SSL of 0.0025 ug/kg in four samples collected from B-49, ranging from 0.0029 ug/kg in B-49-8) to 0.0044 ug/kg in B-49-6. cis-1,2-DCE was detected above its MCL SSL of 0.021 ug/kg in each sample collected from B-49 ranging from 0.03 ug/kg in B-49-12 to 0.9 ug/kg in B-49-6. PCE was detected above its MCL SSL of 0.0023 ug/kg in two samples: B-49-4 at 0.011 ug/kg and B-49-8 at 0.0071 ug/kg. TCE was detected above its MCL SSL of 0.0018 ug/kg in 14 samples, collected from the Pole Winder building, ranging from 0.0025 ug/kg in B-50-15 to 1.4 ug/kg in B-49-6.

5.3.1.4 Soil Results Summary

Although several VOCs have been detected in soil samples, the CVOCs TCE and cis-1,2-DCE were the compounds most frequently reported above their respective screening values in soil samples. The human health (HH) portion of the risk assessment (RA) compares soil sample data to USEPA Regional Screening Levels (RSLs). The HH focuses on two depth intervals for evaluation of soil data: surface soil (0-2 ft) based on the ease of potential exposure and subsurface (2-10 ft) based on possible exposure by someone working in the subsurface at this interval (construction worker scenario).

Both TCE and cis-1,2-DCE were detected in a limited number of surface soil samples therefore maps depicting distribution of these compounds were not generated for this depth interval (0-2 ft). However, based on the frequency of their detection above RSLs, results for TCE and cis-1,2-DCE have been mapped to depict their distribution beneath the Site in subsurface soil (2-10 ft). **Figure 5-1** is a map depicting distribution of TCE in the subsurface soil interval. It is important to note that subsurface soil samples were not collected from the same depth in each boring during the SI. As indicated in Section 3.2.2.1, soil samples collected during this phase of work were selected based on field screening results. In some cases, multiple samples were collected from intervals between 2 and 10 ft BLS, based on field screening results. Soil samples collected from the six borings advanced during Phase II of the RI were collected at two foot intervals between land surface and 15 ft bls. TCE and cis-1,2-DCE were detected in multiple samples collected from several of the Phase II RI borings. Therefore, when necessary, the TCE and cis-1,2-DCE concentrations depicted at the boring locations are cumulative, including results from each sample interval collected between 2 and 10 feet bls.

As shown on **Figure 5-1**, the distribution of elevated TCE concentrations is primarily centered underneath the west-central portion of the Main building with the highest concentrations being between B-30 (100 ug/kg), B-49 (2,546 ug/kg), and B-27 (230 ug/kg). There is a small area beneath the south central portion of the Main building centered on location B-38 with a concentration of 131 ug/kg. Based on subsurface soil sample data there also appears to be a small area of elevated TCE concentrations beneath the Pole Winder building between locations B-45PW and B-50.

Figure 5-2 illustrates cis-1,2-DCE concentrations in subsurface soils. As with TCE, the majority of cis-1,2-DCE detected in subsurface soils is centered beneath the west-central portion of the Main building with the highest concentration in B-49 at 1720 ug/kg. There is a small area on the north side of the Main building in the B-16 boring area with elevated cis-1,2-DCE concentrations at B-16 (380 ug/kg) and B-16B (260 ug/kg). There is also a small area of elevated cis-1,2-DCE beneath the Pole Winder building.

5.3.2 **Soil Vapor**

During Phase II of the RI soil vapor samples were collected on two separate occasions. The initial phase of soil vapor sampling entailed collection of samples from 52 locations using a passive sampling system (**Figure 3-3**). Confirmatory soil vapor samples were collected at seven (7) specific passive sample points, selected based on the elevated VOC concentrations reported as a result of the passive sampling effort.

5.3.2.1 Passive Sample Results

The passive sampling effort detected several VOCs in soil vapor. As shown in **Table 5-7** one of at least 20 different VOCs were detected in at least one passive sample. Review of these results indicated multiple areas of elevated VOC concentrations in soil vapor. The aromatic hydrocarbons benzene, toluene, ethylbenzene and xylenes (BTEX) were detected most frequently in the passive vapor samples. Other aromatic compounds detected frequently included isopropylbenzene and 1,2,4-Trimethylbenzene. The CVOCs cis-1,2-DCE, PCE, and TCE were also detected in multiple passive sample locations. The compounds most frequently detected in the passive samples and the numbers of detections are as follows:

- Benzene (33 samples)
- cis-1,2-DCE (13 samples)
- Ethylbenzene (42 samples)
- Isopropylbenzene (31 samples)
- p&m xylene (39 samples)
- PCE (18 samples)
- TCE (15 samples)
- Toluene (50 samples)
- 1,2,4 Trimethylbenzene (13 samples)

The passive sample results were not used for comparison to any regulatory screening values since the results were reported as mass only [nanograms (ng)]. This task served as a screening process. The results of which were used to identify areas where VOCs were present at elevated concentrations and allowed focusing of additional soil vapor and soil sampling efforts that might identify source areas. The Phase II RI soil sampling efforts are discussed in Section 5.3.1.3. **Figure 5-3** depicts the distribution of TCE in soil gas based on the results of the passive survey.

5.3.2.2 Confirmatory Soil Vapor Sample Results

As a result of the passive sampling effort, SCDHEC requested collection of additional soil gas data using an active sample collection method at five of the passive sample locations in the Main building and two locations in the Pole Winder building. These locations were identified for confirmatory sampling by SCDHEC based on the concentrations of chlorinated compounds in each of the corresponding passive samples. Confirmatory soil vapor samples (SVS) were collected using a vapor pin and 1 liter summa canister at passive sample locations SV-31, SV-45, SV-46, SV-49, and SV-54 in the Main building and locations SV-20 and SV-23 in the Pole Winder building. The seven samples were analyzed for the nine VOCs most commonly detected during the passive survey along with the CVOCs trans-1,2 DCE and VC using USEPA Method TO-15.

As indicated above, SVS sampling results were screened against the USEPA Industrial Air RSL [based on a hazard quotient (HQ) of 1] and a Shallow Soil Gas Standard that was calculated from the USEPA RSL using the USEPA Office of Solid Waste and Emergency Response (OSWER) attenuation for shallow soil gas of 0.1. The results are summarized on **Table 5-8** and the laboratory data package is provided in **Appendix G.**

Other than VC, each of the VOCs listed above were detected in at least one of the SVS. The VOCs PCE, TCE, benzene, ethylbenzene, p&m xylene, toluene, and 1,2,4-Trimethylbenzene were detected in four or more of the samples. The highest number of detections and highest concentrations were detected in the sample from SVS-31 (**Table 5-8**). Trans-1,2 DCE was detected in only two of the SVS, while cis-1,2-DCE and isopropylbenzene were also detected in three of the seven samples.

As presented on **Table 5-8,** benzene, ethylbenzene, PCE, TCE, and xylenes were detected above their respective industrial RSLs. The samples from SVS-31 and SVS-49 contained the highest number of detections above screening values with four and five compounds each. The highest VOC concentration detected in the samples was TCE at 1020 ug/m^3 in SVS-31. TCE was detected above its Industrial RSL in six of the seven SVS samples. Benzene and PCE were detected above their respective RSLs in five SVS samples. Ethylbenzene and the xylenes were detected above their respective RSLs in at least two samples. None of the other reported compound concentrations exceed their respective RSLs.

5.3.2.3 Soil Vapor Summary

Soil vapor samples were collected from the Facility property during multiple stages of the Phase II RI. Fifty two passive samples and seven (7) confirmation samples were collected from the Facility property. Results for the passive sample survey detected several VOCs in various locations including several petroleum related compounds, organic solvents, and CVOCs. The compounds most frequently detected during the passive soil vapor survey were petroleum hydrocarbons followed by low concentrations of various solvent related compounds. Although the hydrocarbons and organic solvents were present in several locations, their detections in soil vapor do not necessarily correlate to their presence in soil and groundwater beneath the facility property. Phase II RI boring B-46, was advanced at SV-14, which was in an area with elevated hydrocarbon concentrations in the passive soil gas sample. However, as shown in **Table 5-6**, a very limited number of compounds were detected at low concentrations in the soil samples from this boring.

The CVOCs TCE and cis-1,2-DCE were detected in one third of the passive vapor samples. The locations at which these compounds were detected and their concentrations in soil vapor samples more directly correlate to the areas soil and groundwater beneath the facility. **Figure 5-3** depicts the distribution of TCE in the occurrence of these compounds in soil vapor samples. The areas of highest CVOC concentrations in the passive soil vapor samples are located within the central western portion of the Main building and beneath a portion of the Pole Winder building, which correlate directly with the areas of soil impact and elevated groundwater concentrations. TCE results for the confirmatory soil vapor samples, also depicted on **Figure 5-3**, confirm the areas of the higher TCE concentrations in sub-slab soil vapor.

It is important to note that soil vapor data collected from the downgradient (western and northern) Facility property boundaries have detected a very limited number of VOCs indicating migration of these vapors from the likely source areas off the Facility property is minimal.

5.3.3 Groundwater Quality

Groundwater data has been collected during multiple phases of work beginning with the Phase II ESA. This includes sampling from temporary well borings, permanent monitoring wells, and private water supply wells. **Tables 3-7** through **3-9** list the groundwater samples collected from the TMWs, permanent monitoring wells, and private water wells during the investigative efforts. This section summarizes the results of the historic and RI related groundwater investigative efforts. This section includes a brief summary of the groundwater results from pre-RI related efforts. Maps depicting pre-RI data are have not been included in this report. This section of the report focuses more on the most recent RI related data.

The majority of the groundwater samples collected from the Site have been analyzed for TCL VOCs. A limited number of samples were also analyzed for TCL VOCs and/or specific biogeochemical parameters used to evaluate natural attenuation potential. **Tables 5-9** through **5-14** summarize analytical results for groundwater samples collected from the site and allow comparison of results to MCLs.

5.3.3.1 Historic Groundwater Investigation Results

<u>Groundwater - Phase II ESA</u>

During the Phase II ESA, several temporary wells (TMW-1 through TMW-8) were installed at many of the locations identified as RECs in the Phase I ESA (**Figure 3-4**). Analytical results from the Phase II ESA indicated that TCE, and its degradation compounds (cis-1,2-DCE and VC) were present above their respective drinking water standards (MCLs) in groundwater primarily in temporary wells located in the central and western portion of the Facility property (**Table 5-9**) . TCE was the most commonly detected CVOC above its MCL in the initial groundwater samples collected from the Site.

As a result, nine additional TMWs (TMW-9 through TMW-18) were installed at locations on the Facility property. Nine permanent monitoring wells (MW-1 through MW-9) were also installed and sampled during the latter portion of the Phase II ESA. The TMW and corresponding permanent replacement well results are grouped together (i.e. TMW-3 / MW-4) in **Table 5-9**. Groundwater samples collected from these wells were also analyzed for TCL VOCs. A shown in **Table 5-9** the data for many of the permanent wells confirmed the results originally detected in the original TMWs including limited to no impacts to groundwater to the east and the presence of TCE and other CVOCs in groundwater beneath the west-central portion of the Facility property.

Groundwater - Site Investigation

Upon review of the Phase II ESA groundwater results, five additional temporary wells (TMW-19, TMW-20 and TMW-26 through TMW-28) and 10 permanent shallow monitoring wells (TMW-21 through TMW-25, and TMW-29 through TMW-33) were installed at the facility (**Figure 3-4**). Groundwater samples collected from each of these wells were also analyzed for TCL VOCs. As shown in **Table 5-10**, analytical results for the temporary and permanent monitoring wells indicated a more expanded presence of CVOC concentrations exceeding their respective MCLs in shallow groundwater, extending to the western facility boundary. TCE was the CVOC most frequently detected above its MCL. Degradation compounds cis-1,2-DCE and VC were also detected above their respective MCLs in the shallow groundwater samples collected during the SI.

In addition, groundwater samples from the permanent wells MW-1, MW-6, MW-7, and MW-8 were also analyzed for biogeochemical analyses to determine attenuation conditions beneath the Site. The results of this sampling are discussed later in this section.

Groundwater – Expanded Investigation

Upon review of the results for the Phase II ESA and SI efforts, a more extensive assessment (Expanded Investigation – EI) of groundwater quality was initiated at the Site. This included installation and sampling of several TMWs screened at multiple depths on properties adjacent to the Facility property and installation of additional permanent bedrock monitoring wells. **Figure 3-4** illustrates the locations of TMWs installed at the Site.

As indicated in Section 3.3.2.3, this phase of work included a more elaborate investigation of groundwater quality in multiple depth zones at locations on- and off-Site using the AQR Color-Tec field screening tool in an attempt to delineate the extent of CVOCs in groundwater. Color-Tec field screening results were used to guide the sampling efforts both vertically and horizontally. This portion of the investigation traced elevated CVOC concentrations off the Facility property to the north and west. **Table 3-6** summarizes the results of the Color-Tec field screening results for groundwater data collected during this phase of the investigation and identifies sample points from which confirmation samples were collected for laboratory analysis.

Confirmation samples were collected from several of the TMWs and analyzed for TCL VOCs (**Figure 3-4**). The results for the temporary well confirmation samples along with permanent monitoring well samples are summarized in **Table 5-11**. As shown in **Table 5-11**, CVOCs (including TCE) were detected at several locations off-site indicating migration patterns both to the north and west-southwest.

In addition to the TMW sampling efforts, seven bedrock wells were installed on the Facility property (MW-2D, MW-3D, MW-6D, and MW-7D) and on properties to the west (RDW-1 and RDW-2) and southwest (SDW-1) (**Figure 3-7**). Each of these wells were sampled for TCL VOCs. **Table 5-12** summarizes the analytical results for samples collected from bedrock wells installed at the Site. The results depicted in this table include those from the initial sampling event (EI) as well as the results from both phases of the RI. As shown in **Table 5-12**, the CVOC TCE was detected above its MCL (5 ug/L) in several of the bedrock wells, ranging from 40 ug/L in MW-3D located at the southwest corner of the Facility property to 210 ug/L in MW-6D located in the middle of the Facility property.

5.3.3.2 Groundwater Investigation - RI Phase I

As indicated in Section 2.5, upon completion of the EI, Philips and SCDHEC entered into a VCC which specified an RI was to be completed at the Site. Phase I of the groundwater portion of the RI included installation of several permanent shallow, intermediate and bedrock wells on the facility and at locations to the north, west, and southwest of the Facility. RI Phase I groundwater investigation results are discussed in this section.

<u>Shallow Zone</u>

Sixteen (16) shallow monitoring wells were installed during this phase of the RI. Each of these new wells and the 18 shallow wells installed during previous phases of work were sampled for TCL VOCs. **Table 5-13** summarizes the groundwater sample results for all shallow zone monitoring wells sampled since the inception of the RI efforts. The results are grouped based on the locations of the wells at the Site.

As many as nine VOCs were detected in at least one groundwater sample collected from the shallow wells during the Phase I RI effort. The only compounds reported above their respective MCLs in the shallow well samples collected during Phase I of the RI, were the CVOCs PCE, TCE, cis-1,2-DCE, and VC. PCE was detected above its MCL of 5 ug/L in two shallow well samples collected during Phase I: MW-8 at 8.4 ug/L and TMW-21 at 7.2 ug/L. TCE was detected above its MCL of 5 ug/L in 16 of the 34 shallow well samples collected during Phase I. Elevated TCE concentrations reported during Phase I ranged from 7.4 ug/L in MW-18 to 1200 ug/L in TMW-24. cis-1,2-DCE was detected above its MCL (70 ug/L) in three samples collected during Phase 1: MW-6 at 64 ug/L, MW-7 at 110 ug/L, and MW-8 at 78 ug/L. VC was detected above its MCL of 2 ug/L in two samples collected during Phase I: 3.6 ug/L in MW-7 and 15 ug/L in MW-6 (**Table 5-13**).

<u>Intermediate Zone</u>

Ten intermediate wells were installed and sampled during Phase I of the RI (**Table 3-6**). As discussed in Section 3.3.2.4, the intermediate wells were constructed at depths, determined by Color-Tec field screening efforts to contain little or no CVOCs. Color-Tec field screening results for the intermediate wells are summarized in **Table 3-6**. Intermediate well depths are summarized in **Table 3-5**.

As many as 11 VOCs were detected in at least one groundwater sample collected from the seven intermediate wells (**Table 5-14**). TCE was the only VOC detected above its MCL (5 ug/L) in any of the samples, ranging from 17 ug/L in MW-21 to 890 ug/L in MW-10I. The highest TCE concentrations in the Phase I RI intermediate zone samples were detected in wells located near the west central and northern portions of the Facility property.

Bedrock Wells

As previously indicated, seven bedrock wells were installed at the Site prior to the RI and three other wells were installed during Phase I of the RI. Each of the ten bedrock wells (MW-2D, MW-3D, MW-6D, MW-7D, RDW-1, RDW-2, SDW-1, SDW-2, and MW-9D) were sampled during Phase I of the RI. As many as six VOCs were detected in these samples. TCE was the only VOC detected above its MCL of 5 ug/L. Elevated TCE concentrations ranged from 16 ug/L in the downgradient well SDW-1 to 250 ug/L in MW-6D (**Table 5-12**).

5.3.3.3 Groundwater Investigation – RI Phase II

After completion of Phase I of the RI, SCDHEC requested additional groundwater investigative efforts at the Site including the installation and sampling of additional downgradient shallow wells, intermediate wells, and bedrock wells. The Phase II RI drilling and sampling efforts resulted in the installation of four additional downgradient shallow monitoring wells (MW-26 through MW-29), collection of additional groundwater samples from temporary intermediate sample points [MW-14I, MW17D(38-44 ft), TMW-118, and MW-19I(19-23ft)] and newly installed monitoring wells (MW-12I and MW-19I) and collection of additional groundwater samples from temporary bedrock fracture sample intervals [MW-12D(71-81 ft), SDW-3 (56-66 ft), SDW-3 (84 ft), and SDW-3 (133 ft)] and newly installed bedrock monitoring wells (MW-12D, MW-17D, MW-19D, and SDW-3). RI Phase II groundwater investigation results are discussed in this section.

Shallow Zone

As part of the Phase II efforts, each of the 34 previously installed shallow wells along with the four wells installed during this phase were sampled for TCL VOCs. The results for the shallow zone samples are summarized in **Table 5-13**. The results are grouped based on the locations of the wells at the Site.

As many as seven VOCs were detected in at least one groundwater sample collected from the shallow wells during the Phase II RI effort. The only compounds reported above their respective MCLs in the shallow well samples collected during Phase II of the RI, were the CVOCs TCE, cis-1,2-DCE, and VC. TCE was detected above its MCL of 5 ug/L in 20 of the 38 shallow well samples collected during Phase II. Elevated TCE concentrations reported during Phase II in shallow well samples ranged from 7.3 ug/L in MW-18 to 1400 ug/L in TMW-31.

The CVOC degradation compound cis-1,2-DCE was detected in several shallow zone samples collected during the Phase II RI. However, cis-1,2-DCE was detected above its MCL (70 ug/L) in only a limited number of samples (MW-6 at 430 ug/L and MW-8 at 74 ug/L).

VC is the only other CVOC detected above its MCL (2 ug/L) in Phase II RI shallow zone groundwater samples (**Table 5-13)**. VC was detected at 8.1 ug/L in the sample from MW-6. Intermediate Zone

Ten existing intermediate wells, two newly installed intermediate wells (MW-12I and MW-19I) and multiple temporary intermediate sampling locations [MW-14I, MW17D(38-44 ft), TMW-118, and MW-19I(19-23ft)] were sampled during Phase II of the RI. The results for the intermediate zone samples are summarized in **Table 5-14**.

As indicated in Section 3.3.2.5, during the Phase II efforts groundwater samples were collected from temporary intermediate zone locations MW-14I (20-24 ft), MW-17D (38-44 ft), TMW-118, and MW-19I (19-23 ft) for confirmatory analysis by the analytical lab. TCE was detected in the sample from MW-14I at 47 ug/L. This sample was collected from the 21 -24 feet BLS, atop bedrock, at a depth very similar to the shallow well MW-14 located to the north. Although TCE was detected above its MCL in this sample, due to the shallow depth to bedrock, a permanent intermediate well was not installed at this location. MW-17D (38 to 44 ft) was collected from a temporary sampling point installed just above the saprolite-bedrock interface in the pilot boring for MW-17D. The groundwater sample from this location contained limited number of VOCs at very low concentrations. None of the reported concentrations exceed any respective screening levels or MCLs. TMW-118 was collected from a temporary sampling point advanced south of MW-17D. This sampling point was advanced to refusal in the saprolite zone (30-34 ft). Only one VOC was detected in this sample at a very low estimated concentration (acetone – 12J ug/L). MW-19I (19-23 ft) was collected from the saprolite-bedrock interface in the pilot boring for MW-19I. As shown in **Table 5-14**, acetone was also the only VOC detected in this sample, at a concentration (6.5 J ug/L) well below any screening value.

As many as 11 VOCs were detected in at least one intermediate zone permanent monitoring well sample collected during Phase II of the RI. The VOCs cis-1,2-DCE and TCE were the only compounds detected above their respective MCLs in these samples. TCE was detected above its MCL of 5 ug/L in eight intermediate zone samples ranging from 10 ug/L in MW-6I to 1000 ug/L in MW-10I. cis-1,2-DCE was detected above its MCL of 70 ug/L in the sample from MW-7I at 140 ug/L(**Table 5-14**).

<u>Bedrock Zone</u>

Ten existing bedrock wells, four newly installed wells (MW-12D, MW-17D, MW-19D, and SDW-3) and multiple temporary sampling locations [MW-12D (71-81 ft), SDW-3 (56-66 ft), SDW-3 (84 ft), and SDW-3 (133 ft)] were sampled during this phase of the RI. The results for the bedrock monitoring wells and temporary sampling points are summarized on **Table 5-12**.

Sample MW-12D (71-81ft), MW-19D (45 feet) and the three samples from SDW-3 (56-66 ft, 84 ft, and 133 ft) were collected from fracture zones identified during vertical profiling efforts in bedrock well pilot boring advancement. As shown in **Table 5-12**, a limited number of VOCs were detected in the samples collected from these intervals. TCE was detected above its MCL in only one sample, MW-12D (71-81 ft) at a concentration of 7.8 ug/L.

Up to six VOCs were detected in at least one bedrock monitoring well groundwater sample collected during Phase II of the RI. However, the only compound detected above its MCL in bedrock zone samples during the Phase II sampling efforts was TCE. Elevated TCE concentrations ranged from 10 ug/L in the downgradient well SDW-1 to 160 ug/L in MW-6D located on the north side of the Main building.

5.3.3.4 Biogeochemical Analyses

During the Phase II ESA, four shallow wells (MW-1, MW-6, MW-7, MW-8) were sampled for additional biogeochemical parameters to determine if subsurface conditions indicate natural attenuation or degradation is taking place (**Table 3-5**). The results of the initial biogeochemical sampling indicated degradation and attenuation processes were occurring beneath a portion of the Site. As shown in **Table 5-13**, degradation is evident in the samples from MW-6 and MW-7 in particular shown by the presence of TCE daughter compound cis-1,2-DCE and VC at elevated concentrations along with other indicators including the dissolved gases ethane, ethene, methane, and carbon dioxide.

During Phase II of the RI, these same four wells along with two other shallow wells (MW-10 and MW-20) and three intermediate wells (MW-9I, MW-10I, and MW-20I) and one bedrock well (MW-6D) were sampled for the biogeochemical parameters listed in Section 3.3.6. This section briefly summarizes the results for the samples collected during Phase II of the RI. The results for these parameters are summarized in **Tables 5-12** through **5-14**. Results from periodic future sampling events will be compared to the values presented in this report.

Electron Acceptors

The electron acceptor parameters in this analytical suite include ferric iron, total manganese, and sulfate. Each of these parameters were detected in samples from the shallow and intermediate wells. Ferric iron was detected in each of the five shallow well samples and three intermediate well samples, ranging from 0.077 mg/L in the upgradient well MW1 to 8.4 mg/L in MW-9I. Manganese (total) was detected in each of the shallow and intermediate samples ranging from 0.011 mg/L in MW-10I to 0.42 mg/L in MW-20. Sulfate was detected in each of the shallow zone samples and two of the intermediate zone samples, ranging from 0.59 mg/L in MW-20I to 5 mg/L in MW-9I. Sulfate was the only electron acceptor detected in the sample from the bedrock well MW-6D (at 1.2 mg/L).

Degradation Compounds

The degradation indicator compounds in this analytical suite included the inorganic compounds ferrous iron, dissolved manganese, sulfide, and chloride along with the dissolved gases ethane, ethene, methane, and carbon dioxide. Several of these compounds were detected in samples collected during Phase II of the RI. The metal ferrous iron was detected in two shallow samples, and each of the four intermediate samples. Dissolved manganese was detected in each of the shallow, intermediate and bedrock samples collected in June 2017. Dissolved manganese concentrations ranged from 0.0086 mg/L in MW-10I to 0.18 mg/L in MW-6I. Chloride was also detected in each of the 10 samples; ranging from 2.2 mg/L in MW-1 to 56 mg/L in MW-10. Sulfide was not detected in any of the 10 samples collected in June 2017.

Each of the dissolved gases was detected in the samples collected in June 2017. Ethane was detected at concentrations ranging from 0.009 mg/L in MW-20 to 0.084 mg/L in MW-6. Methane was detected at concentrations ranging from 0.45 mg/L in MW-20I to 560 mg/L in MW-6. Carbon dioxide was detected at concentrations ranging from 26,000 mg/L in MW-9I to 260,000 in MW-6. Ethene was detected at concentrations ranging from 0.0047 mg/L in MW-1 to 0.049 mg/L in MW-9I.

Biological Indicators

In addition to the geochemical parameters, ten samples collected during Phase II of the RI were also analyzed for the five biological parameters listed in Section 3.3.6. Each of these parameters was detected in the sample from MW-6 (**Table 5-13**). None of the parameters were detected in the intermediate wells sampled in June 2017 (**Table 5-14**). Only one of these parameters, *dehalobacter* (SPP), was detected in the sample from MW-6D (**Table 5-12**).

5.3.3.5 Natural Attenuation Evaluation

The biogeochemical data collected during the RI data has been used to perform a preliminary evaluation of the intrinsic biodegradation processes using the methodology presented in *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (USEPA, 1998). This methodology involves comparing groundwater analytical data to criteria that are indicative of the presence of anaerobic biodegradation of CVOCs (e.g., reductive dechlorination). Monitoring wells are ‘scored’ based on measured geochemical conditions relative to the criteria, and are assigned a qualitative ranking of the likelihood of reductive dechlorination. Wells can be scored as having inadequate, limited, adequate or strong evidence for the anaerobic biodegradation of chlorinated solvents.

During the Phase II of the RI, groundwater samples from several wells were collected and analyzed for various natural attenuation (NA) parameters to evaluate the potential for VOCs at the Site to intrinsically biodegrade under natural conditions. The NA parameters are listed in Section 3.3.6. The results of these analyses are presented in **Tables 5-13** and **5-14**. The wells sampled for these parameters during Phase II of the RI included MW-1, MW-6, MW-6D, MW-7I, MW-8, MW-9I, MW-10, MW-10I, MW-20, and MW-20I. MW-1 is an upgradient well therefore data collected from this well was used as a background well for this evaluation.

Review of the limited amount of geochemical parameter and degradation by-product information supports a conclusion that natural attenuation via biodegradation is evident beneath portions of the Site. Based on these parameters, there is evidence of the presence of electron acceptors (sulfate, iron, manganese, etc.). Reduced species of these acceptors (sulfide, ferrous iron, soluble manganese, etc.) are present to indicate reducing conditions. Additionally, the DO and ORP are low, indicating anaerobic groundwater conditions, which also supports reductive dechlorination. The results of the screening protocol are presented in **Table 5-15**. As shown in **Table 5-15**, four of the wells (MW-6, MW-6D, MW-8, and MW-9I) exhibit adequate evidence of reductive dechlorination. Five (5) wells (MW-7I, MW-10, MW-10I, MW-20 and MW-20I) exhibited limited evidence of anaerobic biodegradation.

The products of TCE degradation observed at the Site include cis-1,2-DCE and VC, which were present at relatively low concentrations in some of the monitoring wells. The ratio of parent compounds (PCE and TCE) to the degradation products in several wells was also analyzed (**Table 5-16**). Reviewing the ratio of parent to daughter products showed that wells MW-6 and MW-7I have significant concentrations of daughter products (greater than 25 percent). Of the DCE isomers, cis-1,2-DCE is predominant and indicative of reductive dechlorination of TCE. This evidence suggests that NA is occurring beneath a portion of the Facility property, however it does not appear to be widespread.

The rate of intrinsic biodegradation has not yet been calculated, as sufficient data has not yet been collected. Several groundwater monitoring events are necessary to establish a firm estimate of intrinsic biodegradation rates. In the absence of this data, the ability of natural attenuation processes to limit the downgradient transport of CVOCs is currently unknown. Continued periodic monitoring events will provide data necessary to estimate biodegradation and attenuation rates.

5.3.4 **Water Supply Wells**

During the SI a groundwater sample was collected in June 2014 from the private water supply well located on the Boazman property that bounds the west side of the facility. The initial water well sample collected from the Boazman well contained TCE at a concentration of 270 ug/L which is above the MCL of 5 ug/L. As a result of the detection of TCE in the initial sample from this well, SCDHEC requested collection of groundwater samples from private water wells surrounding the facility (**Figure 3-8**). Eight private water wells have been sampled to determine if VOCs are present. **Table 3-9** lists the water well samples collected during investigative efforts.

As indicated in **Table 5-17**, TCE was detected in the initial sample from the Boazman well (270 ug/L) and PW-2 (64 ug/L). Because both concentrations exceed the MCL for TCE of 5 ug/L, Philips installed carbon filter systems and then municipal water lines to the homes utilizing these wells.

Table 5-17 summarizes analytical results for the Boazman well (PW-2) and other water wells sampled during the investigative efforts. TCE is the only compound detected above its MCL in any of the water well samples collected during the investigation. As indicated, TCE was detected in the initial sample from PW-2 at 64 ug/L, and in PW-5 (livestock well on the Shealy property) at 15 ug/L. The degradation compound cis-1,2-DCE has also detected at low concentrations in the initial sample from the Boazman well (7.7 ug/L) and the initial samples from PW-2 (6.9 ug/L) and PW-5 (0.94 ug/L).

It is important to note that since use of the Boazman well has ceased following installation of the municipal water line, the TCE concentrations detected in samples from this well have decreased substantially. As shown in **Table 5-17**, the TCE concentration in the sample from the Boazman well from the most recent sampling event was 1.1 ug/L. It is suspected that this decrease is in direct correlation with ceasing to use this water well as a source of drinking water.

Due to the detections of TCE in samples from the Boazman and Chapman (PW-4) wells, SCDHEC has requested continued periodic monitoring of these wells.

As mentioned in Section 3.3.5, a dual packer system was used to collect samples from multiple depth intervals in wells PW-2 and PW-8. As shown in **Table 5-17**, TCE was detected in each depth interval in both wells above its MCL. TCE concentrations in the PW-2 samples ranged from 16 ug/L at 140 ft. to 79 ug/L at 84 ft. TCE concentrations ranged from 9.8 ug/L at 182 ft to 150 ug/L at 155 ft in PW-8. PW-4 (Chapman well) has been sampled on multiple occasions with only trace concentrations of TCE reported in these samples. No VOCs were detected in the samples collected from PW-1, PW-6, and PW-7 (**Table 5-17**).

5.3.5 **Groundwater Summary**

As previously indicated, multiple temporary, permanent, and water well sampling events have been performed at the Site. Data collected from the most recent monitoring well network sampling efforts have been used to develop isoconcentration maps for the CVOCs driving the investigative process at the Site: TCE, cis-1,2-DCE and VC. The isoconcentration maps include analytical results from the most recent sampling event for a well or sample point.

As shown in **Figures 5-4**, **5-5**, and **5-6** TCE is the most widespread of the CVOCs detected in the groundwater zones. The highest concentrations are found in shallow wells beneath the Main building (TMW-21 at 890 ug/L and TMW-31 at 1400 ug/L) and Pole Winder buildings (MW-10 – 570 ug/L). The area of TCE impacted groundwater extends semi-radially from the Main building to the west and from the Pole Winder building to the north-northwest. This distribution of TCE in the shallow zone appears to be consistent with groundwater flow direction which is generally to the northwest.

As shown in **Figure 5-5**, the distribution of TCE in the intermediate zone is similar to that depicted beneath the facility property. The extent of TCE impacts to west-southwest is slightly more widespread than in the shallow zone, but less than that to the north. The distribution to the west is thought to be the result of historic pumping in the Boazman well and wells located on the Shealy property (PW-2, PW-5, and PW-8).

TCE impacts in the bedrock zone extends farther to the southwest than either the shallow or intermediate zones. This is thought to be due to the historic use of private water supply wells, screened in the bedrock, located to the south and west of the facility (**Figure 5-6**).

Figures 5-7, 5-8, and **5-9** illustrate the extent of the degradation compound cis-1,2-DCE in groundwater as detected during the Phase II RI sampling event . These figures indicate that the area of cis-1,2-DCE impacted groundwater generally mimics the TCE plume but is less widespread. The highest cis-1,2-DCE concentrations are also found in wells located on the Facility property near the Main building and towards the northwest corner of the Facility property.

Figure 5-10 illustrates the extent of VC in shallow groundwater, as detected during the Phase II RI sampling event. The presence of VC in groundwater indicates that existing conditions do support the natural degradation of the chlorinated compounds in a limited area at the Site. VC has been found in the vicinity of the Main building near a suspected source area. As shown on **Figure 5-10**, the presence of VC is limited in the shallow zone to wells located to the west, northwest and north of the Main building and indicate a potential primary source area.

As illustrated on these figures, the extent of impact in each groundwater zone has basically been delineated in all directions. Slightly elevated TCE concentrations are evident along the eastern portion of the investigation area on the Dickert property in the shallow zone, but based on groundwater flow data, it appears that the overall flow component in this interval is more to the northwest, therefore groundwater is expected to migrate in this direction over the long term as opposed to the east. As long as the water wells located west of the Facility property are no longer utilized, additional migration of the impacted groundwater in this directions should be limited.

5.3.6 **Surface Water**

A total of 8 surface water samples have been collected from the Site. This includes multiple samples from locations SW-1 through SW-3, located on the Dickert property, and one round of samples from locations SW-4 and SW-5, located on the Shealy property. Each sample was analyzed for TCL VOCs. **Figure 3-9** depicts the surface water sample locations. **Table 3-10** lists the surface water samples collected from the Site.

As shown in **Table 5-18**, a limited number of VOCs have been detected in the surface water samples. The primary CVOC of concern TCE and its daughter compound cis-1,2-DCE have been detected in samples collected from location SW-2 on multiple occasions. TCE was also detected in the sample collected from SW-5, located on the Shealy property. The reported concentrations do not exceed their respective surface water screening criteria. As indicated in Section 4, and based on the intermittent detection of Site related constituents in each of the tributaries, it appears that groundwater will periodically discharge to the tributaries to the north (on the Dickert property) and to the southwest (on the Shealy property). The interaction between groundwater and surface water in these tributaries is based on rainfall and groundwater elevations with discharge of groundwater occurring during periods of normal to above average rainfall.

A more thorough understanding of the nature of surface water /groundwater interaction can be accomplished following of future periodic groundwater monitoring events performed at the Site.

5.4 Conceptual Site Model

The information summarized above has been used to develop a pictoral conceptual site model (CSM) and a more detailed 3-dimensional (3-D) model for the Site. Both versions of the CSM depict the extent of TCE since it is the compound most commonly detected above screening values at the Site. **Figure 5-11** is the pictoral CSM for the Site. This version of the CSM provides a cross-sectional view of the Site from the south-southwest. As shown on **Figure 5-11**, the source for the TCE related impacts appears to be via the historic release of chlorinated solvents and other site-related materials through the former floor drain system beneath the Main building (and to a lesser extent the Pole Winder building). The solvent and other process-related components emanating from the floor drain system migrated vertically through subsurface soils into underlying groundwater. As shown in **Figure 5-11**, once in the groundwater, the organic compounds continued to migrate downward through the unconsolidated soil intervals (residuum and saprolite) to underlying granitic bedrock. In addition to the vertical migration in groundwater, the compounds moved horizontally with the groundwater flow direction to the northwest.

Pumping from water wells to the west of the Facility property pulled impacted groundwater in this direction. **Figure 5-11** primarily focuses on the migration pattern from the Facility to the west-southwest, however it also indicates there is a groundwater flow component to the northwest towards an unnamed tributary on the Dickert property.

As shown on **Figure 5-11**, the organic compounds have also migrated into the fractured intervals within the underlying granitic bedrock. Horizontal and vertical migration in groundwater particularly to the west was enhanced by pumping in several privately-owned water supply wells. The approximate locations of the Boazman and Chapman (PW-4) private water wells are illustrated on **Figure 5-11**.

An electronic copy of the 3-D version of a CSM is included on compact disc (CD) in **Appendix H**. This model can be manipulated to allow views from multiple directions and angles. The 3-D model provides a more detailed depiction of the extent of TCE impact to groundwater both vertically and horizontally. It also allows viewing of the extent of concentration ranges including values just above the MCL for TCE of 5 ug/L; values above 50 ug/L and values above 500 ug/L.

The 3-D model illustrates the dimensions of the TCE plume indicating it has migrated vertically, below shallow zone monitoring wells to the west, likely as a result of historic pumping from water supply wells located to the west and southwest. The model also illustrates the shallow zone of impact to the north beneath the Dickert property.

6.0 **Risk Assessment**

In accordance with the VCC, a Baseline Risk Assessment (BRA) has also been performed for the Newberry Site. The principal components of this BRA are a Human Health Risk Assessment (HHRA) and an Ecological Risk Assessment (ERA). The results of this BRA for the Site can be used to determine if additional data or additional steps in the BRA process are needed and to identify remediation levels protective of receptors if determined to be at risk. This section briefly summarizes results of the HHRA and ERA. The complete versions of the HHRA and ERA are included as **Appendix I** of this RI Report.

6.1 Human Health Risk Assessment

The purpose of the HHRA portion of a BRA was to evaluate chemicals detected in Site-related media, including surface and subsurface soils, shallow/intermediate and bedrock groundwater, surface water, and subslab vapors. The HHRA characterized the potential for carcinogenic risk and noncarcinogenic hazard to human receptors exposed to Site-related contaminants under current and hypothetical future land use conditions if no remedial action is performed.

The preliminary steps of the HHRA included an evaluation of the exposure setting, development of a preliminary conceptual site model and associated exposure pathway diagram (EPD), and conservative screening of existing data. Contaminants determined to have the potential to pose risk or hazard to human receptors are identified as human health chemicals of potential concern (COPCs). Information from the preliminary steps of the HHRA supports risk management decisions regarding the need for additional data or additional steps of the HHRA at the site.

The HHRA process for the Site included several steps. Each is briefly summarized in the following sub-sections.

6.1.1 Identification of Chemicals of Potential Concern

The selection of COPCs evaluates appropriate analytical data in order to identify the chemicals present in each media that are Site-related and that have the potential to pose risk or hazard to human receptors. The process evaluated compound concentrations in surface soil, subsurface soil, surface water and groundwater. This process identified a limited number of compounds including 1,1 DCE, benzene, chloroform, cis-1,2-DCE, PCE, TCE, VC, iron, and manganese as COPCs in groundwater only. **Tables I-2** through **I-7** in **Appendix I** summarize the results of the COPC evaluation for the HHRA.

6.1.2 Exposure Assessment

The exposure assessment portion of the HHRA addressed the potential pathways by which human populations could be exposed to the COPCs identified above. Both current land uses and future, hypothetical land uses on the Site and surrounding areas were considered in identifying principal pathways of exposure. The exposure assessment describes exposure scenarios, develops information on exposure pathways, estimates the concentrations of COPCs at points of human exposure, and calculates receptor intakes. The exposure assessment process identified a future resident as the only receptor evaluated for risk after the COPC screening efforts.

6.1.3 **Toxicity Assessment**

This section of the HHRA provides an overview of the human health toxicity of those chemicals identified as COPCs for the Site. The objective of the toxicity assessment is to weigh available evidence regarding the potential for each chemical to cause adverse health effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure and the severity of the adverse effects (USEPA, December 1989). The toxicity assessment focused on the COPCs identified above. The two compounds that were evaluated more thoroughly based on their carcinogenic potential were TCE and VC.

6.1.4 **Risk Characterization**

This section presents the results of the HHRA. These results include estimates of the potential for excess lifetime cancer risks and noncancerous health effects for the current land use and hypothetical future land use scenarios for the Site. Seven exposure groups (shallow/intermediate groundwater, bedrock groundwater, groundwater from four individual drinking water wells, and groundwater based on risk to indoor air) and one exposure scenario (future residents) were evaluated for the Site.

6.1.5 **HHRA Summary**

Based on initial screening, COPCs were not identified in four environmental media: surface soil, subsurface soil, surface water, or subslab vapors. As a result, these media and two receptors potentially exposed to them (current/future industrial worker and future construction worker) were <u>not</u> evaluated further. Potential risks to human health under hypothetical future land use scenarios were quantitatively evaluated. In accordance with risk assessment guidance and procedures adult and child residents assumed to live on the Facility and off the Facility were evaluated as future receptors. Both on-Facility and off-Facility residents were evaluated based on exposure to groundwater used as potable water, while the on-facility resident was also evaluated for exposure to shallow/intermediate groundwater via vapor intrusion.

COCs were identified in the Risk Characterization based on the risk and hazard calculations. The human health COCs identified for each receptor were the following:

- Current and Future Industrial Worker – no COCs identified
- Future Construction Worker – no COCs identified
- Future On-Facility Resident (Adult) –

  chloroform, cis-1,2-dichloroethene, trichloroethene, and vinyl chloride in shallow/intermediate groundwater
- Future On-Facility Resident (Child) –

  cis-1,2-dichloroethene and trichloroethene in shallow/intermediate groundwater
- Future Off-Facility Resident (Adult) –

  1,2-dichloroethane, chloroform, and trichloroethene in bedrock groundwater; and

  trichloroethene in drinking water wells PW-2 and PW-8

- Future Off-Facility Resident (Child) –

  trichloroethene in bedrock groundwater;

  trichloroethene in drinking water wells PW-2, PW-5, and PW-8.

HH COCs were identified based on very conservative assumptions including use of currently inactive private water supply wells, a hypothetical future on-Facility resident, an off-Facility resident assumed to regularly consume and use groundwater. Each of these assumptions is unlikely to occur due to the current use and future availability of municipal water.

6.2 Ecological Risk Assessment

The ERA component of a BRA evaluated whether unacceptable risks are posed to ecological receptors from chemical stressors in the environment. The ERA identified contaminant levels that would not pose unacceptable ecological risks and provides information for risk management decisions regarding the need for, and extent of, potential remedial action (USEPA, November 2001). The process followed in performing the ERA was based on the current USEPA model for conducting ecological risk assessment, as described in the *Ecological Risk Assessment Guidance for Superfund* (ERAGS): *Process for Designing and Conducting Ecological Risk Assessments* (USEPA, June 1997) and *The Role of Screening-Level Risk Assessments and Refining Contaminants of Concern in Baseline Ecological Risk Assessments* (USEPA, June 2001). Additional risk assessment guidance considered in developing the ERA process includes the *Guidelines for Ecological Risk Assessment* (USEPA, April 1998) and the *Region 4 Ecological Risk Assessment Supplemental Guidance* (USEPA, March 2018c).

The ERAGS process is the principal model for ERAs in USEPA Region 4. The eight steps of the ERAGS process in Region 4 are as follows:

<u>Screening-Level Ecological Risk Assessment (SLERA)</u>

Step 1: Initial Problem Formulation and Effects Evaluation

Step 2: Exposure Estimation and Risk Calculation

<u>Baseline Ecological Risk Assessment</u>

Step 3: Baseline ERA Problem Formulation

Step 3a: Problem Formulation and Refinement Screening

Step 3b: Additional Problem Formulation

Step 4: Study Design and Data Quality Objectives Process

Step 5: Field Verification of Sampling Design

Step 6: Site Investigation and Data Analysis

Step 7: Risk Characterization

Step 8: Risk Management

In conjunction with these steps, the ERAGS process also requires interim decisions and deliverables following several steps in the process. These scientific/management decision points (SMDPs) are defined as points in the process at which risk managers evaluate the work completed to a given step and either approve the work and the planned approach or redirect additional work (i.e., decide whether or not the ERA should continue to the next step in the process). Up to six SMDPs potentially may be incorporated into the eight-step ERAGS process, depending on the number of ERA steps required at a particular site and circumstances specific to the site. SMDPs typically occur after Steps 2, 3, 4, and 7 of the ERAGS process, with a possible SMDP within Step 3 and another after Step 5 if approval is required for needed changes to the sampling design. The ERA for this Site concludes with SMDP 1.

The evaluation determined that there are no chemicals in Site media with the potential to pose significant risk to ecological receptors. Therefore, none of the chemicals in Site media warrant designation as COPECs, and further evaluation of ecological risk in a Baseline ERA is not needed for this Site.

7.0 Summary and Conclusions

7.1 Site Hydrogeology

The Site lies within the west-central portion of South Carolina, within the Charlotte Metamorphic Belt of the Piedmont physiographic province. Locally, the water-table surface subtly mimics 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.

The Site geology has been subdivided into two general geologic zones. The upper zone consists of severely weathered residuum/residuum consisting of clayey sands, silty clays, and silty clays. This is underlain by a saprolitic zone consisting of tight silty clays and clayey sands with relict rock fabric and severely weathered bedrock. The upper zone is underlain by weathered/severely fractured to competent granitic bedrock.

Groundwater flow beneath the Site is generally east to west with flow components to the northwest and southwest. The primary horizontal groundwater flow direction in the shallow portion of the upper zone is inferred to be toward the west-southwest beneath the Shealy property with a component to the north-northwest beneath the Dickert property. This flow pattern is consistent with regional topography and drainage.

The inferred direction of horizontal groundwater flow in the saprolite/intermediate zone has components to the south-southwest towards the Shealy property and to the north-northwest beneath the Dickert property. The flow direction in the saprolite zone to the southwest historically may have been influenced by usage of several private water supply wells located to the west and southwest of the Facility.

The flow direction in the bedrock zone appears to be to the southwest. It is evident that this flow pattern within the bedrock fracture system was influenced by the pumping of several water supply wells located to the west-southwest of the Facility property.

A slight downward vertical gradient exists between the shallow aquifer zone and the underlying intermediate zone. Vertical flow between these two zones may be impeded due to the tightness of the silt/clay component of the saprolite.

Prior testing provided estimates of the horizontal hydraulic conductivity of 0.8 ft/day in the shallow zone and 0.7 ft/day in the saprolite zone. Using the gradient from the groundwater elevation contour maps generated as part of the RI, the horizontal groundwater seepage velocity in the shallow aquifer zone was estimated to be 0.05 ft/day or about 18.8 ft/year. The horizontal groundwater seepage velocity in the saprolite zone was estimated to be 0.040 ft/day or about 14.8 ft/year.

A downward gradient exists between the shallow aquifer zone and the underlying deep aquifer zone. However, the higher silt and clay content of the saprolitic zone may limit the vertical flow between these two zones in the northern portion of the Site.

7.2 Environmental Quality

Samples of environmental media (soil, groundwater, surface water and sub-slab vapors) were collected and analyzed during the several phases of investigation to further characterize the Site and determine risk to potential receptors.

7.2.1 **Soil**

Surface and subsurface soil samples were initially collected to evaluate areas for possible impact by site-related activities. The soil sampling program evolved to focus on identifying source areas and delineation of extent of impact. The summary below is limited to compounds that exceeded the preliminary screening criteria (MCL-based SSLs and Residential RSLs). The MCL SSL is a very conservative screening value and is used for comparison only. The USEPA Residential RSL is a conservative screening value utilized in the HHRA for the Site.

7.2.1.1 Main Building

Eleven surface and 114 subsurface soil samples were collected from locations in and around the Main building during the investigative efforts. Several organic compounds were detected above their respective MCL SSLs in the surface and/or subsurface soils including the VOCs acetone, ethylbenzene, 1,1 DCE, cis-1,2-DCE, styrene, TCE, and VC. However, based on the results after the HHRA evaluation none of the compounds detected in surface or subsurface soil samples collected from the Main building area exceeded their respective USEPA RSLs.

7.2.1.2 Pole Winder Building

Four surface and 62 subsurface soil samples were collected from locations in and around the Pole Winder building during the investigative efforts. Several VOCs were detected above their respective MCL SSLs in samples collected from the Pole Winder building. These included methylene chloride, cis-1,2-DCE, styrene, and TCE. Based on the results of the HHRA, none of the compounds detected in surface or subsurface soil samples collected from the Pole Winder building area exceeded their respective USEPA RSLs screening values.

7.2.2 **Soil Gas**

Soil vapor and sub-slab vapor was collected from over 50 passive sampling points and seven confirmation sampling points and analyzed for VOCs. Four confirmation samples were collected from beneath the Main building. Three confirmation samples were collected from the Pole Winder building. The results of the vapor analyses were screened against the USEPA Industrial Air RSL and a calculated shallow soil gas standard to identify compounds of interest in soil gas.

Benzene, ethylbenzene and TCE were detected above their respective USEPA Industrial RSLs in at least three of the confirmation soil vapor samples. However, the HHRA evaluation determined that the concentrations of these compounds in the subslab soil vapor did not pose a risk to potential receptors. The remaining detected VOCs were detected at concentrations below their respective screening criteria.

7.2.3 **Groundwater**

The groundwater investigative efforts have included installation and sampling of numerous temporary and permanent monitoring wells along with sampling of private water supply wells during several phases of work. This included advancement and sampling of 118 temporary monitoring wells, installation and sampling of 39 shallow, 12 intermediate (saprolite), and 14 permanent bedrock wells. Groundwater from all new and existing monitoring wells was sampled for laboratory analysis of VOCs and select monitoring wells were sampled for biogeochemical parameters and MNA parameters. Analytical results were screened against MCLs to identify PCOIs in groundwater beneath the Site.

7.2.3.1 Shallow Aquifer Zone

Concentrations of TCE, cis-1,2-DCE and VC exceeded their respective MCLs in one or more samples of shallow groundwater. TCE was the compound detected most frequently above its MCL in samples from the shallow monitoring wells. The extent of TCE concentrations exceeding its MCL in the shallow zone extends from the Main building on the Facility property to the north beneath the Dickert property.

cis-1,2-DCE was also reported at elevated concentrations in several shallow well samples, with the highest concentration being in the middle portion of the facility property.

7.2.3.2 Intermediate (saprolite) Zone

TCE and cis-1,2-DCE exceeded their respective MCLs in one or more samples collected from the wells screened in the intermediate (saprolite) zone. TCE is also present most frequently above its MCL in the samples collected from this interval. Elevated TCE values in the intermediate zone extend from the east central portion of the facility property to the north beneath the southern portion of the Dickert property to the west-southwest beneath the Boazman property.

cis-1,2-DCE was also reported at elevated concentrations in several of the intermediate zone wells along the western edge of the facility.

7.2.3.3 Bedrock Zone

TCE concentrations exceed the MCL in samples from several of the bedrock wells located at the Site. A limited number of elevated TCE values have been detected in bedrock wells to the north of the Facility property. Elevated TCE values were also reported in several wells located to the west and southwest of the Facility property. It appears that historical usage of water supply wells located to the southwest of the Facility have influenced migration of impacted groundwater in this direction.

Several private water supply wells surrounding the Facility property were sampled as part of the investigative efforts. Four of the wells located to the west-southwest of the Facility property were found to contain TCE values above the MCL. As a result, Philips coordinated the installation of a municipal water supply to each of the properties that had impacted water wells.

7.2.3.4 Monitored Natural Attenuation Parameters

Groundwater quality/biogeochemical parameters were collected from five shallow, four intermediate and one bedrock monitoring well. Groundwater samples were analyzed for electron acceptors, degradation compounds, dissolved gases, and biological indicator parameters.

Several monitoring wells located in the central portion of the Facility property exhibited evidence of natural degradation of CVOCs including elevated dissolved gas concentrations, and elevated biological counts. However, the area of adequate degradation is not widespread and natural conditions overall may inhibit natural degradation processes beneath the entire Site.

7.3 Baseline Risk Assessment

7.3.1 Human Health Risk Assessment

An HHRA was conducted for the Site to evaluate potentially Site-related chemicals detected in environmental media. Potential risks to human health under current and future land use scenarios were quantitatively evaluated. COCs were identified in the Risk Characterization based on the risk and hazard calculations. The human health COCs identified for each receptor were the following:

- Current and Future Industrial Worker – no COCs identified.
- Future Construction Worker – no COCs identified.
- Future On-Facility Resident (Adult) –

  chloroform, cis-1,2-dichloroethene, trichloroethene, and vinyl chloride in shallow/intermediate groundwater

- Future On-Facility Resident (Child) –

  cis-1,2-dichloroethene and trichloroethene in shallow/intermediate groundwater

- Future Off-Facility Resident (Adult) –

  1,2-dichloroethane, chloroform, and trichloroethene in bedrock groundwater;

  trichloroethene in existing drinking water wells PW-2 and PW-8

- Future Off-Facility Resident (Child) –

  trichloroethene in bedrock groundwater;

  trichloroethene in existing drinking water wells PW-2, PW-5, and PW-8.

HH COCs were identified based on very conservative assumptions including use of currently inactive private water supply wells, a hypothetical future on-Facility resident, an off-Facility resident assumed to regularly consume and use groundwater. Each of these assumptions is unlikely to occur due to the current use and future availability of municipal water.

7.3.2 Ecological Risk Assessment

An Ecological Risk Assessment (ERA) was performed to evaluate whether potentially Site-related chemicals in the environment pose unacceptable risks to ecological receptors. None of the chemicals in Site media were found to warrant designation as COPECs, and further evaluation of ecological risk in a baseline ERA is not needed.

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FIGURES

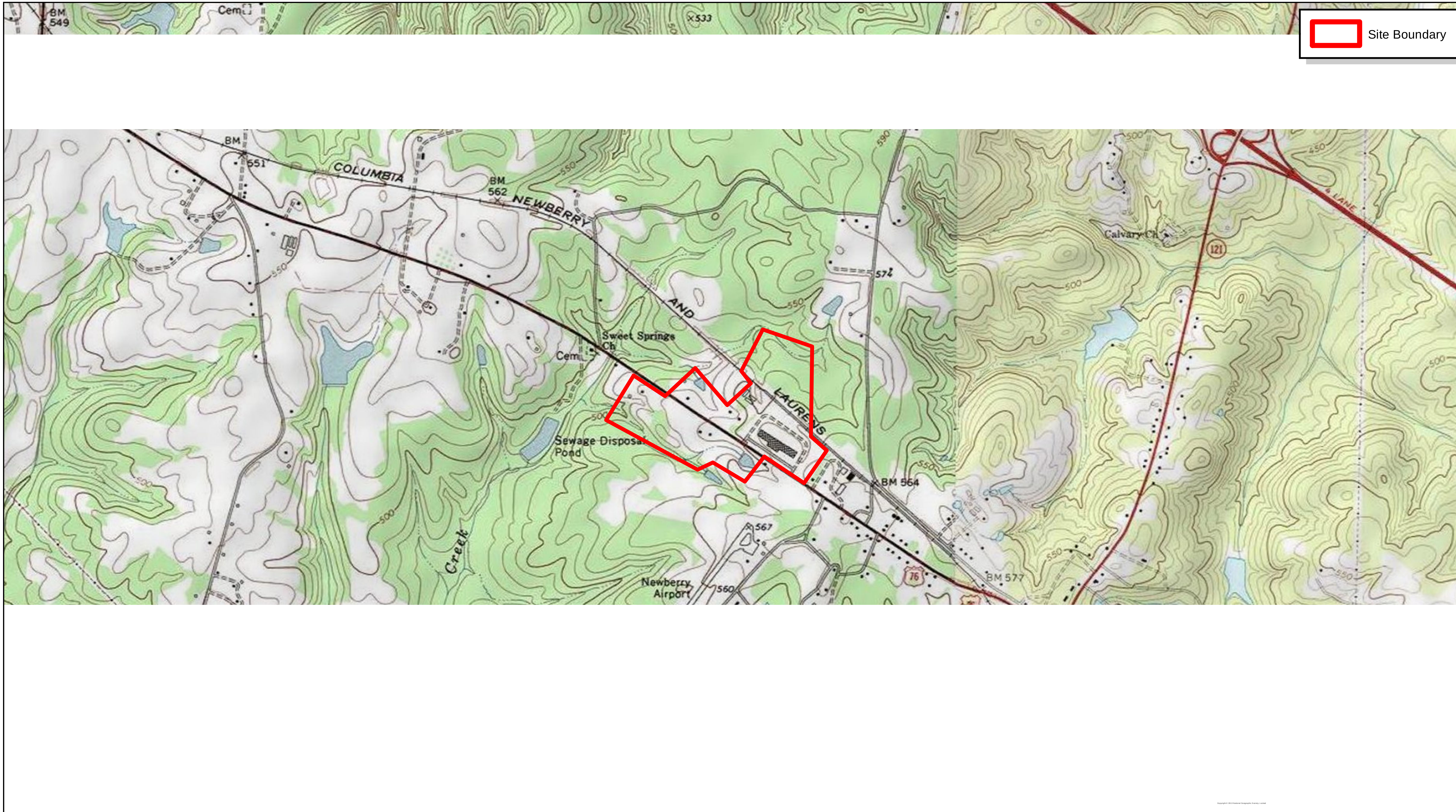

Figure 1-1: Site Location Map

Shakespeare Composition Structures
Newberry, South Carolina

Project No.: 60534283; Prepared by: JG; Date: 5/10/2018.

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