Basis of Design Report (30% Design Stage)
Operable Unit Two (OU2)
Standard Chlorine of Delaware Superfund Site

New Castle, New Castle County, Delaware

PREPARED FOR

U.S. Environmental Protection Agency
4 Penn Center
1600 John F. Kennedy Boulevard.
Philadelphia, PA 19103-2029

Design and Engineering Services (DES) Contract No. 68HE0318D0002
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Acronyms and Other Abbreviations

3-D	three dimensional
°C	degrees Celsius
°F	degrees Fahrenheit
AECOM	AECOM Technical Services, Inc.
AMP	Air Monitoring Plan
amsl	above mean sea level
APC	air pollution control
ARAR	Relevant and Appropriate Requirement
ASTM	ASTM International
BERA	baseline ecological risk assessment
bpf	blows per foot
bgs	below ground surface
BODR	Basis of Design Report
BRA	baseline risk assessment
BTU	British thermal unit
BTU/hr	British thermal unit per hour
CADD	computer-aided drafting and design
CB	chlorobenzene
CETCO	Colloid Environmental Technologies Company
CIP	cast-in-place
CLP	Contract Laboratory Program
cm/sec	centimeters per second
CoC	Chain Of Custody
COC	Contaminant of Concern
COPEC	Contaminants of Potential Ecological Concern
CS	carbon steel
CSI	Construction Specifications Institute
cVOC	chlorinated volatile organic compound
CY	cubic yard
DAR	Design Analysis Report
DCRC	Delaware City Refining Company
DE	Delaware
DHG	dissolved hydrocarbon gas
DNAPL	dense nonaqueous phase liquid
DNREC	Delaware Natural Resources and Environmental Control
DRE	destruction and removal efficiency
ECC	evaporative cooling chamber
EPA	U.S. Environmental Protection Agency
ERH	electrical resistance heating
EVS	Earth Volumetric Studio
EXES	Electronic Data Exchange and Evaluation System
FEMA	Federal Emergency Management Agency
FFS	Focused Feasibility Study
ft^2	square feet
FTL	Field Team Leader
GAC	granular activated carbon
GETS	groundwater extraction and treatment system
GPS	Global Positioning System
HDPE	high-density polyethylene
HGL	HydroGeoLogic, Inc.
HHRA	human health risk assessment
IC	institutional control
IPaC	Information for Planning and Consultation
IP-LTTD	in pile low temperature thermal desorption
ISS	in situ stabilization
ISTR	in situ thermal remediation
K	Kelvin
kg	kilogram
kW	kilowatt
kWh/yd^3	Kilowatt hour per cubic yard
lb	pound(s)
LEL	lower explosive limit
LiDAR	Light Detection and Ranging
LiMWA	Limit of Moderate Wave Action
LTTD	low temperature thermal desorption
$MBTU/yd^3$	Million British Thermal Unit per cubic yard
Metachem	Metachem Products, LLC
mg/kg	milligrams per kilogram
mil	one-thousandth of an inch
mm	millimeter
MMBTU	one million British thermal units
MMSCF	million standard cubic feet
mph	miles per hour
MS/MSD	matrix spike/matrix spike duplicate
ND	not detected
NGS	Next Generation Sequencing
NMFS	National Marine Fisheries Services
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NWI	National Wetland Inventory
OM	organic matter

ORP	oxidation reduction potential
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PCB	polychlorinated biphenyl
PEM	palustrine emergent
PID	Photoionization Detector
PFO	palustrine forested
PFT	Paint Filter Test
PPE	personal protective equipment
ppm	parts per million
PRG	preliminary remediation goal
PRP	potentially responsible party
PSD	particle size distribution
psi	pounds per square inch
psia	pounds per square inch absolute
PTU	primary treatment unit
PTW	principal threat waste
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RA	Remedial Action
RAL	Remedial Action Level
RAO	Remedial Action Objective
RD	Remedial Design
RI	remedial investigation
RI/FS	Remedial Investigation/Feasibility Study
RK-LTTD	Rotary Kiln Low Temperature Thermal Desorption
ROD	Record of Decision
RTD	resistance temperature detector
SCD	Standard Chlorine of Delaware, Inc.
ZVI	zerovalent iron
SCFH	standard cubic feet per hour
SCFM	standard cubic feet per minute
SPLP	synthetic precipitation leaching procedure
SDG	Sample Delivery Group
SEE	steam enhanced extraction
SPLP	Synthetic Precipitation Leaching Procedure
SPT	standard penetration test
S/S	solidification/stabilization
SVOC	semi-volatile organic compound
SWPPP	Stormwater Pollution Prevention Plan
T&D	Transportation and Disposal
TBD	to be determined
TBC	total benzene and chlorobenzene
TCH	Thermal Conductive Heating
TCLP	toxic characteristic leaching procedure
TDU	thermal desorption unit
TCH	thermal conductive heating
TMP	temperature monitoring point
TO	Task Order
TOC	total organic carbon
TTZ	thermal treatment zone
tVOC	total volatile organic compound
UCS	unconfined compressive strength
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VFA	volatile fatty acid
VOC	volatile organic compound
Weston	Roy F. Weston, Inc.
W/ft	Watts per foot

1 Introduction

The U.S. Environmental Protection Agency (EPA) is managing the cleanup of the Standard Chlorine of Delaware, Inc., Superfund Site (Standard Chlorine or the Site) under four operable units (OUs). The OUs and their status are listed in **Table 1-1**.

Table 1-1: Operable Units and Status

Operable Unit	Description	Status
OU1	Interim action for groundwater including groundwater extraction and treatment system (GETS)	Interim action for groundwater. This remedy (barrier wall and groundwater pump-and-treat system) was constructed by EPA in 2007 and is being operated by EPA. The interim action for groundwater will be continued until a final groundwater remedy (OU4) is selected.
OU2	Final action for spill pathway soil and sediment	Final action for spill pathway soil and sediment. OU2 is the subject of this BODR that was prepared by AECOM under an EPA contract design task order (TO).
OU3	Former facility area	Facility decommissioning, demolition, and capping remedy has been constructed and is maintained by DNREC.
OU4	Final groundwater remedy	Final groundwater remedy. The future remedy will address both the Columbia aquifer and underlying Potomac aquifer.

EPA issued a Record of Decision (ROD) on March 9, 1995 (EPA, 1995a). Amendment No. 3 to the ROD (Amendment) was issued in September 2022 (EPA, 2022). The Amendment identified excavation and on-Site treatment via low temperature thermal desorption (LTTD), in-situ enhanced bioremediation (in the form of a “biobarrier”), and metals stabilization, as the selected remedy for the spill pathway soils and sediment, now referred to as OU2. EPA contracted AECOM Technical Services, Inc. (AECOM) to perform the Remedial Design (RD) for the selected OU2 remedy via Task Order (TO) Number 68HE0323F0050. The TO was issued under AECOM’s Design and Engineering Services Contract 68HE0318D0002 with EPA.

1.1 Purpose

The purpose of this BODR is to describe the basis and criteria to be used in the design of the selected remedy. The selected remedy for OU2 includes the following five major elements: (1) excavation, (2) on-Site LTTD treatment of excavated soils, (3) stabilization of treated soils to reduce metal leaching, (4) in-situ enhanced bioremediation (in the form of a biobarrier), and (5) backfilling of excavations with treated soils and restoration of wetlands. This report describes the remedy elements and also concepts, general sequence, and design criteria.

1.2 Scope

The RD includes engineering reports, documents, specifications, and drawings that detail the steps that will be taken during the remedial action (RA) to meet the goals established in the ROD. The RD will be consistent with EPA's Remedial Design/Remedial Action Handbook (EPA, 1995b) and the Scope of Work provided by EPA.

The typical RD process involves up to four design stages (30%, 60%, 90%, and 100%). However, the design scope for this project is limited to two design stages: Preliminary Design (30% design) and Pre-Final/Final Design (100% design), reflecting the expedited nature of the RD. Additional meetings are planned to bridge the gap between the Preliminary Design and Pre-Final/Final Design stages.

After AECOM was awarded the RD contract, EPA entered into an Interagency Agreement with the U.S. Army Corps of Engineers (USACE) for remedy implementation. Thus, the design documents will be reviewed by both EPA and USACE. Review comments provided on the Preliminary Design will be incorporated into the Pre-Final Design. The Pre-Final/Final Design will also incorporate recommendations from a Value Engineering Study conducted between the Preliminary and Pre-Final/Final Design stages.

Several treatability studies were planned to support the Preliminary Design, but due to delays in the fieldwork, the majority of the planned treatability studies have been delayed. As a result, several details intended to narrow the process options that were initially planned to be part of the Preliminary Design will now be included in the Pre-Final/Final Design stage.

1.3 Report Organization

This BODR is organized as follows:

- Section 1 – Introduction: Purpose, scope, and report organization
- Section 2 – Site and Project Background: Site history, Site setting, and conceptual site model
- Section 3 – Remedy Summary and Design Basis: Remedial Action Objectives (RAOs), Contaminants of Concern (COCs), selected remedy, and regulatory requirements
- Section 4 – Pre-Design Investigation: Wetlands and vegetation surveys, topographic survey, data gap investigation, geotechnical investigation, and treatability studies; the BODR appendices provide additional details
- Section 5 – Development of Soil Excavation Boundaries: Environmental Visualization System (EVS) modeling, preliminary areas/volumes, and contaminant mass estimates

- Section 6 – Preliminary Process Flow: Various remedy elements and their preliminary sequencing
- Section 7 – Site Preparation Basis of Design: Various Site preparation activities, excavation and soil handling, utilities, and general site management
- Section 8 – LTTD Basis of Design: Various thermal process options, thermal modeling results, treatability study results, and process design parameters
- Section 9 – Metals Stabilization Basis of Design: Reagent options, mixing methods, process options, and design criteria for stabilization and backfilling
- Section 10 – Biobarrier Basis of Design: Reagent options, mixing methods, process options, and design criteria for biobarrier construction
- Section 11 – Residuals Management: Management of waste streams resulting from the remediation processes
- Section 12 – Restoration Design: Restoration requirements and options for excavation areas in the wetlands and the restoration of upland areas disturbed by remediation process siting
- Section 13 – Baseline and Performance Monitoring Plan: Approach to establishing pre-remediation conditions within OU2 and a plan to support the long-term evaluation of remedy effectiveness
- Section 14 – Project Delivery: Information needed for planning and procurement for the RA
- Section 15 – References
- Appendices (see the list in the Table of Contents)

2 Site and Project Background

The Site history and regulatory background are summarized in documents such as EPA (1995a) and EPA (2022). The information in this section is based on these documents but has been updated to reflect recent Site background and other relevant documents listed in the current Administrative Record.

2.1 Site Location and Description

The Site is on Governor Lea Road near the intersection with River Road approximately 3 miles northwest of Delaware City in New Castle County, Delaware (see **Figure 2-1**). The Site is surrounded by a mixture of industrial facilities, farmland, and undeveloped properties. There are residential and commercial properties to the north and west within 1 mile of the Site.

The Site covers approximately 145 acres of mixed developed and undeveloped upland areas and wetland, including a 23-acre fenced area that is the former location of a chlorobenzene manufacturing facility that was owned and operated by SCD until December 1998 and subsequently by Metachem Products, LLC (Metachem) until 2002. The total property (Property) owned by SCD and Metachem is roughly 63 acres and includes the 23 acres where the facility was formerly situated, a grass covered upland area and wooded steep slopes to the north, and portions of wetlands within the Red Lion Creek watershed.

2.2 Site History

The facility was built in 1965 on approximately 46 acres of farmland that SCD purchased from the Diamond Alkali Company. Chlorobenzenes were manufactured at the facility from 1966 until its closure in 2002, and chlorinated nitrobenzene was manufactured in the expansion of the facility from the early 1970s until the late 1970s.

In 1998, SCD was sold to Charter Oak Partners, which reorganized as Metachem Products, LLC (Metachem). SCD and Metachem were identified as potentially responsible parties (PRPs). However, Metachem closed the facility on May 4, 2002, and abandoned the Site on May 14, 2002, after declaring bankruptcy. EPA and the Delaware Department of Natural Resources and Environmental Control (DNREC) have had custody and control of the Site since 2002 and have been cooperating since then to implement emergency cleanup and Remedial Actions (RAs) and develop an approach for the long-term rehabilitation of the Site.

2.2.1 Regulatory History

The facility manufactured chlorobenzenes by combining chlorine and benzene purchased from adjacent industrial facilities, reacted and then distilled them at high temperatures, and prepared and stored them prior to sale. Some of the chlorobenzenes were stored in aboveground, heated, steel storage tanks.

Multiple releases resulted in the contamination of Site media as follows:

- Leakage from pipes and tanks accumulated in the drainage system sumps, including Catch Basin #1, which released chlorobenzenes from a crack in its base. The crack was discovered and repaired in March 1976.
- In 1981, approximately 5,000 gallons of chlorobenzene was released during railcar-loading activities. EPA conducted an initial Site inspection and preliminary assessment of the Site and assembled a Hazard Ranking System package based on the inspection and assessment, which resulted in adding the Site to the National Priorities List (NPL) on July 22, 1987.
- In 1986, before the Site was formally listed on the NPL, a tank collapsed and damaged surrounding tanks, resulting in a release of approximately 569,000 gallons of dichlorobenzenes and trichlorobenzenes. The release impacted portions of the facility as well as the underlying groundwater, drainage pathways, the surrounding wetlands, and Red Lion Creek. An Administrative Order on Consent between DNREC and SCD requiring SCD to conduct a Remedial Investigation/Feasibility Study (RI/FS) of the Site was issued on January 12, 1988, and amended on November 14, 1988 (DNREC, 1988). The initial RI/FS was conducted to address the spill pathways, groundwater, and off-site contamination (Weston, 1992; 1993).

EPA issued an initial Record of Decision (ROD) for the Site groundwater and spill pathway soils and sediments on March 9, 1995 (EPA, 1995a) and issued an Administrative Order for an RD and RA on May 30, 1996 (EPA, 1996). Metachem filed a bankruptcy petition on May 10, 2002, and abandoned the Property on May 14, 2002, to the custody and control of EPA and DNREC. From 2002 through 2006, EPA and DNREC completed an emergency removal action that included the sale and disposal of hazardous chemicals, decontamination of process equipment, and oversight of the dismantlement of the former facility.

EPA designated Operable Units (OUs) at the Site (see **Table 1-1**) to make the cleanup more manageable.

Based on the OU designations, the following RODs were issued:

- The 1995 ROD addressed OU1 and OU2 (EPA, 1995a).
- The 2004 ROD (1995 ROD Amendment 1) selected off-site thermal treatment (incineration) as the remedy for the bulk liquid wastes that were left on the Site when the facility was abandoned (EPA, 2004). The off-site thermal treatment was completed by December 31, 2009.

- The 2010 ROD addressed OU3 (EPA, 2010).
- The 2016 ROD (1995 ROD Amendment 2) addressed OU2 (EPA, 2016).
- The 2022 ROD (1995 ROD Amendment 3) identified the selected remedy for OU2 soil/sediment (focus of this BODR) (EPA, 2022).

A ROD for OU4 has not been issued.

The additional RAs for OU1, OU2, and OU3 are summarized below.

The OU1 interim action for groundwater was implemented in 2006 and 2007 and includes a subsurface barrier wall surrounding approximately 33 acres of the Site and a groundwater extraction and treatment system (GETS). The subsurface barrier wall was installed to an average depth of 70 feet bgs around the majority of the upland portion of the Site, including the former manufacturing area. Within this area is a groundwater extraction and treatment system designed to contain and treat contaminated groundwater within the Columbia Aquifer. The GETS is being used to lower the groundwater elevation within the vertical barrier wall and limit/prevent the spread of contamination from the impacted Columbia aquifer to the underlying Potomac aquifer.

During the construction of the vertical containment barrier as part of the OU1 interim action for groundwater, the waste pile soils that are referenced in the original remedy in the 1995 ROD (EPA, 1995a) were relocated to an area within the containment barrier referred to as the Temporary Soil Staging Area (TSSA). The bottom of the TSSA was lined with a coated polyester geomembrane. The 2016 ROD (EPA, 2016) established containment of these former waste piles underneath the OU3 multilayer cap to reduce/eliminate the flow of groundwater contamination to Red Lion Creek.

OU3 was the subject of a 2010 ROD and addressed the contamination of the vadose zone soils (soils above the water table) and soil gas in the former facility area through capping, soil gas collection and treatment, and institutional controls (EPA, 2010). The OU3 remedy was completed in 2017 and includes a 23.2-acre multilayer protective cap with an incorporated soil vapor recovery and treatment system. The engineered muiltilayer cap was built over the former facility area, the sedimentation basin, and the area between the former facility and the Sedimentation Basin as part of the remedy for OU3. The OU3 cap was constructed with 4% to 4.5% slopes and includes perimeter swales and other surface water control features. The cap is vegetated with a variety of grasses and other shallow rooted plants selected by EPA. The land between the OU3 cap and Red Lion Creek remains undeveloped except for single-lane gravel roads and interim action for groundwater components.

Only the area outside the interim action for groundwater containment barrier remains wooded. Near Red Lion Creek and its unnamed tributary, the terrain slopes sharply downward to wetland areas surrounding these two water bodies. Red Lion Creek located north of the Site, flows east to the Delaware River. Wetlands border the creek along the Site's northern boundary. Wetlands are also present along the Site's western boundary, where the unnamed tributary flows north into Red Lion Creek.

Figure 2-2 shows OU2 and pertinent Site features and Site conditions after construction of the interim action for groundwater (OU1) and the cap (OU3).

OU2, the subject of this BODR, includes remediation of contaminated soils and sediments in the unnamed tributary and Red Lion Creek along the 1986 spill pathways. The soils and sediment have caused surface water and groundwater contamination. The original remedy selected in the 1995 ROD (EPA, 1995a), with respect to soils and sediments, included bioremediation of soils/sediments along the Western Drainage Gully, the eastern drainage ditch, the soils adjacent to Catch Basin #1, those along the railroad tracks and along the unnamed tributary to Red Lion Creek, and soils in the waste piles and in the sedimentation basin. It should be noted that certain media addressed in the 1995 ROD were capped as part of the OU3 remedy including the sedimentation basin, the eastern drainage ditch, Catch Basin #1, the railroad tracks, and the waste soil piles that were combined into the TSSA, and the on-Site soils.

Since 2003, EPA has evaluated additional alternatives to address OU2, including in-situ pilot studies for chemical oxidation and bioremediation. In-situ chemical oxidation was determined to not be a viable remedial alternative. Many advances have been made in the field of bioremediation, and the U.S. Geological Survey (USGS) has done extensive testing at the Site to evaluate various bioremediation techniques to remediate sediment and groundwater. Reports related to work at the Site are included in the Administrative Record.

The OU2 media addressed by this design are:

- Contaminated soils in the Western Drainage Gully and soils located beneath and downgradient of the location of the former waste soil piles.
- Contaminated sediments and underlying unconsolidated soil material in the eastern, northern, and western tributary wetlands.
- Surface water in Red Lion Creek, western tributary, and the surrounding wetlands

As described in the 2022 ROD Amendment 3 (EPA, 2022), the remedy selected in the 1995 ROD (EPA, 1995a), with respect to the OU2 spill pathway soils, was bioremediation, with a contingent remedy of LTTD. Following review of a bioremediation treatability study conducted after the 1995 ROD was issued, EPA determined that bioremediation alone would not be sufficient to remediate the most contaminated spill pathway soils and sediment. As specified in the 1995 selected remedy, the contingent remedy (LTTD), was to be implemented if the bioremediation treatability study demonstrated that bioremediation would not be able to satisfy the cleanup criteria. Therefore, EPA proceeded with the design of an LTTD remedy after the 2022 ROD Amendment 3 was issued (EPA, 2022).

2.3 Physical Characteristics

This section describes the physical features of the Site, including topography and surface water hydrology. Major portions of the information presented in this section are presented in the 2007 and 2016 Remedial Investigation (RI) reports (Black & Veatch, 2007; HGL, 2016). Significant portions of the information presented in those reports were taken from USGS reports prepared by Lorah et al. (2014) and Brayton et al. (2015).

2.3.1 Topography

A topographic map of the Site is presented in **Figure 2-3**. The figure shows roughly two distinct areas: (1) the upland areas within the vertical containment barrier, or slurry wall, which includes the former operating areas and operations-related open space (includes OU1 and OU3) and (2) the low-lying areas along Red Lion Creek, which include OU2 and OU4. With completion of OU3, the Site topography within the slurry wall has been significantly altered in the former manufacturing, storage tank, and railcar areas as well as the former lagoon and uplands that were north of the former facility operations. Elevations in the area surrounded by the vertical containment barrier are approximately +50 feet North American Vertical Datum (NAVD) and include the constructed cap, which creates the highest point on the Site. As with the topography, the surface coverage in the OU3 area has changed substantially with the final cover of the OU3 area being vegetated with a mix of grasses. Land surface elevations beyond the slurry wall in the northern portion of the Site drops steeply to near sea level at Red Lion Creek. The northwestern portion of the Site slopes steeply westward to the nearly north-south unnamed tributary of Red Lion Creek. Another prominent, but less steep, drainage is located to the east. To the south of the Site, topography increases gradually. There is a topographic divide running almost north-south through the Site as discussed in Section 2.3.2.

2.3.2 Surface Water Hydrology

The Site is located on a land parcel between Red Lion Creek, a small unnamed tributary that feeds into this creek on the west, and a topographic depression draining into Red Lion Creek on the east. A topographic divide runs close to the center of the Site; however, surface drainage is collected in a stormwater management system and directed to two outfalls. The western outfall discharges surface water runoff and sediment into the unnamed Red Lion Creek tributary, and the eastern outfall discharges surface water runoff and sediment into the wetlands adjacent to Red Lion Creek. Some drainage from the northern end of the groundwater containment area and north of the slurry wall is not captured by this system.

Flow in Red Lion Creek is controlled by a tide gate located where the creek joins the Delaware, which minimizes the exchange of water between Red Lion Creek and the Delaware River. Fifteen-minute continuous water level data from as early as 2007 are available through the USGS (USGS gauge station 01482320).

2.3.3 Subsurface Infrastructure

The utilities from the former manufacturing facility were decommissioned as part of the demolition of the facility. The only remaining underground utilities are part of the remedial systems installed during OU1 and OU3 activities (see Sheets V-03, V-05, and R-01 through R-04 in Appendix K). These include:

- The subsurface barrier installed as part of OU1 remedy
- Electric utilities for the groundwater extraction wells and groundwater treatment building
- Piping for the groundwater extraction wells and treated water discharge
- Soil venting piping system to remove VOCs from the capped portion of the former manufacturing facility
- Cathodic protection for the soil venting system
- Culverts for surface water drainage from the new stormwater basins installed during the OU3 cap activities

There are no known underground utilities in the proposed excavations for wetland soil and creek sediment planned for the OU2 remedy.

2.4 Site Geology and Hydrogeology

This section describes the geologic and hydrogeologic conditions of the Site. Much of the information presented is based on the interpretations in the HGL RI Report (HGL, 2016) and previously identified USGS reports for the Site (Lorah et al., 2014; Brayton et al., 2015). In addition, 24 geotechnical, sampling, and test locations were advanced as part of the data gap investigation (see Section 4.3). Although water levels were not recorded, any updates to subsurface geologic conditions were updated as needed based on this new information.

2.4.1 Geology

The Site is located in the Atlantic Coastal Plain physiographic province approximately 8 to 12 miles southeast of the fall line, which demarcates the boundary between the Atlantic Coastal Plain physiographic province and the bedrock uplands of the Piedmont physiographic province. The Atlantic Coastal Plain is characterized as a wedge of unconsolidated gravel, sand, silt, and clay sediments that were deposited in fluvial, deltaic, and marine environments and range in age from Cretaceous to Holocene. These sediments dip southeastward at generally less than

1 degree and overlie basement rock comprised of metamorphic, igneous, and consolidated sedimentary rocks. These basement rocks outcrop as a part of the eastern Piedmont along the fall line, while sediments of the Atlantic Coastal Plain thicken toward the Atlantic Ocean.

The Site Is underlain by the Quaternary aged Columbia Formation, followed by the Cretaceous-aged Merchantville and Potomac Formations, and finally a basement of Paleozoic and older metamorphic rock and saprolite (**Table 2-1**). The basement rock is estimated to be approximately 700 feet bgs in the area of the Site (Woodruff, 1986).

Table 2-1: Stratigraphic Correlation Chart of Geologic and Hydrogeologic Units in the Vicinity of SCD

System	Series	Geologic Formation and Unit	Hydrogeologic Unit
Quaternary	Holocene	undifferentiated (Qm)	Silt, clay, and peat
	Upper Pleistocene	Scotts Corners (Qsc)	Surficial aquifer (Columbia aquifer)
		Lynch Heights (Qlh)	
	Middle Pleistocene	Columbia (Qcl)	
Cretaceous	Upper Cretaceous	Merchantville (Kmv)	Merchantville confining bed
		upper Potomac (Kpt)	top sand aquifer (discontinuous
			confining bed
			upper Potomac A-sand aquifer
			confining bed
			upper Potomac B-sand aquifer
			confining bed
			upper Potomac C-sand aquifer
	Lower Cretaceous	middle Potomac (Kpt)	middle Potomac aquifer
		lower Potomac (Kpt)	lower Potomac aquifer
	Lower Paleozoic to Precambrian		Consolidated basement rocks

Source: Brayton et al. (2015)

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The Columbia Formation is a Pleistocene age deposit associated with glacial outwash streams that came down the ancestral Delaware River and its tributaries. It consists of coarse to fine quartz sands with a characteristic orange to yellow color. Varying amounts of gravel are present in the formation and a sand and gravel layer is a key marker bed at the base of the formation. The Columbia Formation has occasional lenses of silty clay or clayey silt, and occasional lithified sands due to iron oxide cements can be observed (Jengo et al., 2013). At the Site, the Columbia Formation ranges from 8 to 84 feet in thickness, with a general decrease in thickness observed moving north toward Red Lion Creek and beyond.

The Merchantville Formation is a shallow marine sedimentary deposit composed predominantly of dark blue-gray to green-gray glauconitic, micaceous clay to silty/sandy clay. The average thickness of the Merchantville Formation on the Site is 10.2 feet, though it is discontinuous and can range in thickness from 0 to 22 feet (Black & Veatch, 2007). An evaluation of the borehole data indicates the absence of the Merchantville Formation over a large portion of the center of the Site. Paleochannels that incised the Merchantville Formation have been identified by Degnan and Brayton (2010), Brayton et al. (2015), and Jengo et al. (2013), both on the Site and to the east and west of the Site (**Figure 2-4**). These paleochannels may be attributed to the ancestral Red Lion Creek and its tributaries to the ancestral Delaware River, as well as a large north-south trending erosional channel locally called the Reybold paleochannel (Jengo et al., 2013). In these areas, the Merchantville Formation is absent, and the sometimes-deep channels formed into the underlying Potomac Formation have been refilled with Columbia Formation sediment. In these areas the Columbia Formation is directly underlain by Potomac Formation clays and sands.

The Potomac Formation underlies areas of the Columbia and Merchantville formations (**Figure 2-4**). The Potomac consists of nonmarine silts, clays, and sands, deposited in an aggrading alluvial plain creating a heterogeneous, stratigraphically complex layering of sediments where deposits are discontinuous and variable in thickness and extent. The Potomac Formation in the area of the Site has been divided into three subformations designated as upper, middle, or lower formations. Each is approximately 250 feet thick (Brayton et al., 2015). The Upper Potomac Formation consists of variegated red, gray, purple, yellow, and white clays and silts interbedded locally with three relatively thick silty sand units designated “A-Sand,” “B-Sand,” and “C-Sand” (**Figure 2-4**). These sand units are separated by localized confining units.

2.4.2 Hydrogeology

This section describes the hydrogeologic conditions of the Site. Much of the information presented here is based upon the interpretations provided in the HGL RI Report (HGL, 2016) and previously identified USGS reports for the Site. Additional groundwater elevation data were not determined to be a data gap with respect to the removal of OU2 sediment and soils. Therefore, the previously generated hydrogeologic conceptual models for groundwater movement within the areas of OU2 were determined to be sufficient and are reported herein.

2.4.2.1 Regional Hydrogeology

The Atlantic Coastal Plain aquifer system is recharged through rainfall and snowmelt. Most of the water that reaches the water table in the surficial aquifer discharges to local streams (Cushing et al., 1973). Some of the groundwater discharges to larger streams and rivers and, in coastal zones, may discharge to wetlands, tidal rivers, or estuaries (Brayton et al., 2015). A relatively small portion of groundwater recharge becomes part of a deeper flow system that includes confined aquifers that extend downdip toward the Atlantic Ocean (Shedlock et al., 2007).

Most of the regional recharge to the underlying Potomac aquifer occurs to the northwest of the Site where the upper Potomac aquifer subcrops under Quaternary surficial sediments, primarily the Columbia Formation. The regional flow system within the confined aquifers of the Potomac Formation is characterized by slow southeast flow, controlled mainly by hydrostratigraphy. Fleck and Vroblesky (1996) modeled groundwater flow in the Maryland and Delaware Coastal Plain and estimated average regional flow rates of approximately 0.1 to 0.2 feet per day in the aquifers. Pumping of the aquifers affects both flow rates and flow directions. Long-term water use has led to documented regional and local groundwater level decline associated with production wells constructed with the Potomac aquifer system (Martin, 1984). These conditions induce downward vertical flow gradients in the area from the Columbia to the Potomac aquifer, and downward between sand layers within the Potomac Formation. Flow between the Columbia and Potomac Formations is possible where confining units, such as the Merchantville formation, are thin or absent (Brayton et al., 2015).

2.4.2.2 Site (OU2 and OU4) – Hydrogeology

There are four hydrogeologic units of interest at OU2. From shallow to deeper, these are the wetland sediments along the Red Lion Creek tributary and its floodplain, the Columbia aquifer, the underlying Merchantville aquitard, and the Potomac sands of the Potomac Raritan Magothy, i.e., PRM (Potomac Raritan Magothy), formation. This section describes the conditions of these formations that control the movement of groundwater within these units.

Historical drainage and changes to sea level have resulted in the incision of Red Lion Creek into the underlying Pleistocene, i.e., Columbia formation, sediments. This resulted in the incised channel infilling with reworked Columbia formation sediments and silts and clays deposited on the flood plains. These wetland sediments vary laterally in thickness from greater than 30 feet below land surface near the modern Red Lion Creek to approximately 6 feet at the wetland-upland boundary.

Wetland sediments can be grouped into two stratigraphic units, an upper organic-rich unit consisting of root mass and organic matter in a mineral matrix of silt and clay, and a basal unit consisting of clay, silt, and fine sand. The upper, organic-rich unit is typically dark brown to black with scattered gray clay layers, with a median carbon content of 7.7 percent and a maximum carbon content of 24.2 percent (Lorah et al., 2014). Based on the data gap investigation, 10-foot excavations confirmed that wetland sediments are organic rich, sandy to silty clays with low permeability.

Groundwater discharge to the northern marshes occurs at the 1.3-foot-amsl elevation, and local upward vertical gradients from the Columbia aquifer to Red Lion Creek are also present. These localized shallow upward vertical gradients from the Columbia aquifer are a potential source of contamination to Red Lion Creek and the wetlands. Lorah et al. (2014) also estimated the volumetric groundwater fluxes to Red Lion Creek, which indicated that at least half of the net recharge to the subwatershed of tidal Red Lion Creek comes from groundwater, which would be derived locally from the Columbia aquifer. This assessment indicates a potentially significant contaminant transport pathway from the Columbia aquifer to Red Lion Creek. It is noted, however, that bulk gradients between the Columbia aquifer and underlying Potomac aquifer are downward (Brayton, 2015).

Hydraulic conductivity was measured in the wetland sediments and were found to be about 1 to 5 feet per day (ft/d) (Lorah, 2014). Previous studies of hydraulic properties of wetland sediments in a similar Coastal Plain setting in Maryland showed hydraulic conductivity estimates ranging from 0.0003 to 0.04 ft/d in peat-dominated sediments and 0.0008 to 0.04 ft/d in clay-dominated wetland soils (Lorah et al., 1997). Slug tests were performed where responses to induced gradient were measurable; therefore, these estimates of hydraulic conductivity within the wetland sediments may be biased slightly high. However, estimates of hydraulic conductivity are within the range of values reported for non-peat wetland soils to moderately to slightly decomposed, northern peatland sediments (Mitsch and Gosselink, 1993).

The Columbia aquifer, consisting of sands and gravels of the Columbia Formation, is the uppermost aquifer at the Site. The upper boundary of the Columbia aquifer represents the localized water table and occurs at depths ranging from near ground surface (near the wetlands and tributaries to Red Lion Creek) to approximately 45 feet bgs in the former operating area (Black & Veatch, 2007). Across much of the Site, the Columbia Formation is underlain by clays and silts from the Merchantville and Potomac formations. These clays and silts form a shallow aquitard, but they are thin or absent from certain areas of the Site, including areas to the northeast of the containment barrier, as depicted in **Figure 2-4**. The elevation of the top of the shallow aquitard, which consists of both Merchantville and Potomac Formation clays and silts, is also shown on **Figure 2-4**.

The saturated thickness of the Columbia aquifer at the Site varies between 10 and 40 feet (HGL, 2016) and groundwater within the unconfined Columbia aquifer conforms to topography under natural conditions, with flow moving north toward Red Lion Creek (**Figure 2-5**). The average groundwater hydraulic gradient under natural conditions in the Columbia aquifer ranges from 0.003 to 0.007 foot to the north-northwest (Black & Veatch, 2007). Site water levels may fluctuate slightly due to seasonal precipitation changes. Only minimal tidal influence has been observed in shallow Columbia aquifer wells near Red Lion Creek (Lorah et al., 2014).

The Columbia aquifer hydraulic conductivity is estimated to range from 5 to 134 feet per day but has been observed as high as 184 to 441 feet per day (Black & Veatch, 2007). The water level in Red Lion Creek is lower than the adjacent groundwater table in the Columbia aquifer (+4 feet amsl), indicating that there is discharge from the Columbia aquifer into Red Lion Creek and the unnamed tributary (Black & Veatch, 2007; Lorah et al., 2014).

Lorah et al. (2014) performed a detailed examination of the hydrology in the area of the wetlands near Red Lion Creek (Lorah et al., 2014). Their investigation found that groundwater discharge to the northern marshes occurs approximately at the 1.3-foot-amsl elevation and that upward vertical gradients from the Columbia aquifer to Red Lion Creek are also present (**Figure 2-6**). These localized shallow upward vertical gradients from the Columbia aquifer represent a potential source of contamination to both Red Lion Creek and the wetlands.

Lorah et al. (2014) also estimated the volumetric groundwater fluxes to Red Lion Creek, which indicated that at least half of the net recharge to the subwatershed of tidal Red Lion Creek comes from groundwater, which would largely be derived locally from the Columbia aquifer (Lorah et al., 2014). This assessment indicates a potentially significant contaminant transport pathway from the Columbia aquifer to Red Lion Creek. It is noted, however, that bulk gradients between the Columbia aquifer and underlying Potomac aquifer are downward.

The Merchantville Formation consists of dark gray to black micaceous clays and silty-clays. Regionally, the Merchantville acts as a confining unit separating the Columbia and upper Potomac aquifers. The Merchantville Formation is absent in some areas of the Site. In these areas the Columbia aquifer is underlain by either clayey sediments of the Potomac Formation or by silty-sand (**Figure 2-4**) material, which is then underlain by interbedded clays, silts, and sands that eventually form the upper Potomac aquifer. The locations of significant communication between the Potomac and Columbia aquifers will be in areas where the Merchantville Formation is absent and the upper portions of the Potomac Formation are permeable (such as in the area near PW-17 and the PW-5 well pair).

Wells screened within the upper Potomac aquifer were installed in 2007. Gamma logs and vertical water-quality profiling were conducted on selected wells (Brayton et al., 2015). At two of the locations, the wells were installed with a screened interval set below existing Merchantville clay, but above Potomac clay. This thin discontinuous sand zone (described by Brayton et al., 2015, as “upper Potomac top sand”) has been found to be similar in water chemistry to the unconfined Columbia aquifer, and water levels have behaved similar to Columbia wells, indicating that the Merchantville clay is not an effective confining unit at that location.

The additional explorations resulted in the identification of three upper Potomac aquifers named by Brayton et al. (2015) as A-Sand, B-Sand, and C-Sand (**Figure 2-4**). The A-Sand ranges in thickness from 10 to 70 feet and is present below the upper Potomac confining unit where present. This upper Potomac confining unit, however, is not present near Red Lion Creek. The B-and C-Sands are noted by Brayton et al. (2014) as being thinner than the A-Sand. The B-Sand is below a second localized Potomac confining unit. This second confining unit has been documented as being between 40 and 60 feet thick. The B-Sand has been found to be 10 to 15 feet thick. The C-Sand lies below a third localized Potomac confining unit and has been shown to be less than 10 feet in thickness (Brayton et al., 2015). There is hydraulic communication between the A-, B- and C-Sands as their confining units are not laterally continuous (**Figure 2-4**).

The potentiometric surface of the upper and lower Potomac aquifers has been lowered by pumping groundwater for industrial and municipal usage around the Site. It has been estimated that the Delaware City Refining Company (DCRC), which is located to the south of the Site, pumps 5.5 million gallons of water per day from the Potomac aquifer (Lorah et al., 2014). These lowered water level conditions make interpretating natural groundwater flow conditions difficult. However, during a period of limited groundwater pumping, owing to a change in the ownership of DCRC, water levels were measured during the RI to estimate natural groundwater flow conditions in the Potomac aquifer. A potentiometric contour map showing these conditions from Brayton et al. (2015) is presented as **Figure 2-7**. As depicted, groundwater flow under close to ambient conditions is generally to the east, toward the Delaware River. **Figure 2-8** depicts the potentiometric conditions in the Potomac aquifer under normal pumping conditions at DCRC. Under these conditions flow is generally toward the south, possible toward pumping wells at DCRC and the City of Delaware City, which are present to the south. Hydraulic heads in the upper Potomac aquifer sands are affected by changes in the stage of Red Lion Creek due to precipitation, as well as minimally affected by tide changes. The tidal influence is further reduced by the tide control structure on Red Lion Creek (Brayton et al., 2015).

Although the Merchantville Formation and upper Potomac clays reduce groundwater flow between the Columbia and upper Potomac aquifers throughout much of the Site, downward vertical gradients exist between the Columbia and Potomac aquifers. Detections of Site-related contaminants in wells screened in the Potomac aquifer to the east, west, and north of the former facility area indicate that dense nonaqueous phase liquid (DNAPL) could be present at a depth of 150 feet and that some transmission between the Columbia and Potomac aquifers has occurred.

2.4.3 Surface Water Drainage

The site drainage has been dramatically changed with the OU3 cap installation. In general, surface water on the site flows from the top of the cap in all directions into the on-cap, grass-lined surface water control berms. The drainage improvements were described in the OU 3 final remedial design (HGL and CH2M Hill, 2012) and are summarized as follows:

- Grass lined on-cap surface water control berms
- Concrete perimeter ditches
- Stormwater pipes and downslope chutes
- Riprap lined spillways at sedimentation basin inlets and the final outfalls
- Two stormwater detention basins (referred to as east and west ponds)

2.5 Surrounding Land Use and Sensitive Receptors

Past investigations and risk assessments have identified potential human and ecological receptors that may have been impacted by past manufacturing operations and the 1981 and 1986 spills. Reports summarizing the findings include the Black & Veatch BRA (Black & Veatch, 2007) and updated from the HGL RI and HGL Focused Feasibility Study (FFS) (HGL, 2016; 2020). These assessments were used to prepare summaries found in the following sections.

2.5.1 Human Health Risk Assessments

In 2007, a baseline risk assessment (BRA) was prepared to evaluate the risks to human health and the environment posed by contaminants in the soil, sediment, surface water, and fish tissue at the Site (Black & Veatch, 2007). The 2007 human health risk assessment (HHRA) Black & Veatch, 2007) concluded that Site contaminants could pose a risk to future residents, future industrial workers, future construction workers, and current trespassers/visitors. Chlorobenzenes were the primary risk drivers. Human health risk drivers also included dioxins/furans and vanadium in sediment, and aluminum, lead, and vanadium in surface water.

Between 2008 and 2014, new surface water, sediment, and fish tissue data were collected. Since completion of the 2007 HHRA, EPA has updated its guidance on exposure assumptions used in the HHRA process and how to evaluate mutagenic chemicals. Human health toxicity values for several chemicals, such as trichloroethene and hexavalent chromium, have changed since 2007. Further, there is new information in the literature on ecological toxicity reference values, bioaccumulation factors, and ecological benchmarks. In addition, Site conditions have changed because much of the contaminated soil surrounding the former manufacturing facility has been capped. The 2007 BRA was updated to account for the changes in Site conditions (the cap), new data, and new information on inputs to the risk assessment process (HGL, 2016; 2020).

The updated HHRA is provided in the FFS (HGL, 2020) and confirms that contaminants in soil outside the cap, sediment, surface water, and fish tissue pose a threat to current and potential future receptors. Both HHRAs identified chlorobenzenes as risk drivers in all media. The updated HHRA identified more risk drivers than the 2007 HHRA. Chromium was added as a risk driver because of the identification of a cancer slope factor for hexavalent chromium in 2009.

The updated HHRA identified pesticides, methyl mercury, and polychlorinated biphenyls (PCBs) as risk drivers for fish tissue: these chemicals were not analyzed in the fish tissue samples collected for the 2007 HHRA.

2.5.2 Baseline Ecological Risk Assessment

The 2007 baseline ecological risk assessment (BERA) concluded that Site contaminants could pose a risk to the aquatic community, benthic invertebrates, soil invertebrates and nutrient cycling, terrestrial herbivores, aquatic insectivores, terrestrial vermivores, and piscivores (Black & Veatch, 2007). The following listed habitats are potentially impacted by migration pathways from source areas at the Site (HGL, 2016):

- Red Lion Creek and its unnamed tributary
- Palustrine emergent wetlands
- Palustrine open water
- Palustrine forested wetlands

Migration pathways between OU4 contaminated areas and these habitats may include surface water runoff and groundwater transmission. Potential ecological receptors that have been identified at the Site by former studies are provided in the following paragraphs.

The unnamed tributary of Red Lion Creek is located to the west of the facility and originates approximately 1,000 feet upstream from the Site (**Figure 2-2**). An open water area and associated wetlands on this tributary have occasionally been created through the construction of a dam by beavers in the area. The tributary is an intermittent stream upgradient of the open water/wetland area. A tide gate is located at the mouth of Red Lion Creek prevents tidal flow in the unnamed tributary. At the time of the two major contaminant releases (1981 and 1986), this tide gate was not operational and contamination from the unnamed tributary entered Red Lion Creek. The tide gate was subsequently repaired after the spills and returned the stream to a freshwater, nontidal system (CRA, 2000). However, the tide gate was again damaged in 2011 by Hurricane Irene. As of March 2024, the tide gate was restored to full operation.

Red Lion Creek is approximately 5 miles long and relatively shallow throughout its length, with depths ranging from 0.3 to 3.3 feet (Weston, 1992). Surface water from Red Lion Creek ultimately discharges into the Delaware River approximately 6,000 feet downstream from the Site.

During field activities conducted in 1999 by the PRP contractor, several species of fish were observed in Red Lion Creek including American eel (*Anguilla rostrata*), carp (*Cyperinus carpio*), white suckers (*Catostomus commersoni*), killifish (*Fundulus* spp.), catfish (*Ictalurus* spp.), bullhead (*Ameiurus* spp.), sunfish (*Lepomis* spp.), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), perch (*Perca flavescens*), shiners (*Notropis* spp.), and crappies (*Poxomis annularis*) (CRA, 1999).

Wildlife species that potentially occur in the Red Lion Creek habitat include various mammal species (muskrats [*Ondatra zibethica*]), reptiles (turtles and snakes), amphibians (frogs), and several bird species (Canada geese [*Branta canadensis*], loons [*Gavia immer*], ducks, gulls, egrets, herons, sandpipers, owls, eagles, ospreys, hawks, and swallows) (CRA, 1999).

The palustrine emergent wetlands are the largest habitat at the facility potentially affected by contaminated groundwater. This area extends from north of the containment berm in the unnamed tributary to the confluence of the unnamed tributary and Red Lion Creek (**Figure 2-2**). Areas of palustrine emergent wetlands occur intermittently south of the containment berm. These wetlands also border Red Lion Creek to the north and south. Dense stands of phragmites (*Phragmites australis*) are dominant in this habitat, with white grass (*Leersia virginia*), common rush (*Juncus effusus*), and various unidentified sedges (*Carex* spp.). The soils in this area are generally gray-brown with mottling, which are characteristic of a hydric soil (Greely, 1997).

Wildlife species that potentially occur in the palustrine emergent wetlands include various mammal species (shrews [*Blarina brevicauda*], voles [*Microtus pennsylvanicus*], beavers [*Castor canadensis*], and mink [*Mustela vison*]), reptiles (turtles and snakes), amphibians (frogs and salamanders), and several bird species (ducks, teals, herons, rails, vultures, and swallows) (CRA, 1999).

Palustrine open water exists intermittently to the south of the palustrine emergent wetlands and near the containment berm along the unnamed tributary. This habitat was created by a beaver dam. The ponding behind the dam has killed several trees and has eliminated emergent vegetation in the deeper areas of the open water.

The palustrine forested wetlands are immediately upgradient of the palustrine open water. Vegetation within this habitat consists of mature forest dominated by red maple (*Acer rubrum*) and black willow (*Salix nigra*), with a well-developed scrub/shrub layer dominated by spicebush, (*Lindera benzoin*) and silky dogwood (*Cornus amomum)*. A series of small, braided channels flows through the wetlands, forming the headwaters of the unnamed tributary to Red Lion Creek (Greely, 1997).

Wildlife species that potentially occur in the palustrine open water and forested wetland habitats include various mammal species (beavers and muskrat), reptiles (turtles and snakes), amphibians (frogs and salamanders), and several bird species (ducks, teals, herons, rails, vultures, and swallows) (CRA, 1999).

The 2007 BERA concluded that Site contaminants could pose a risk to the aquatic community, benthic invertebrates, soil invertebrates and nutrient cycling, terrestrial herbivores, aquatic insectivores, terrestrial vermivores, and piscivores.

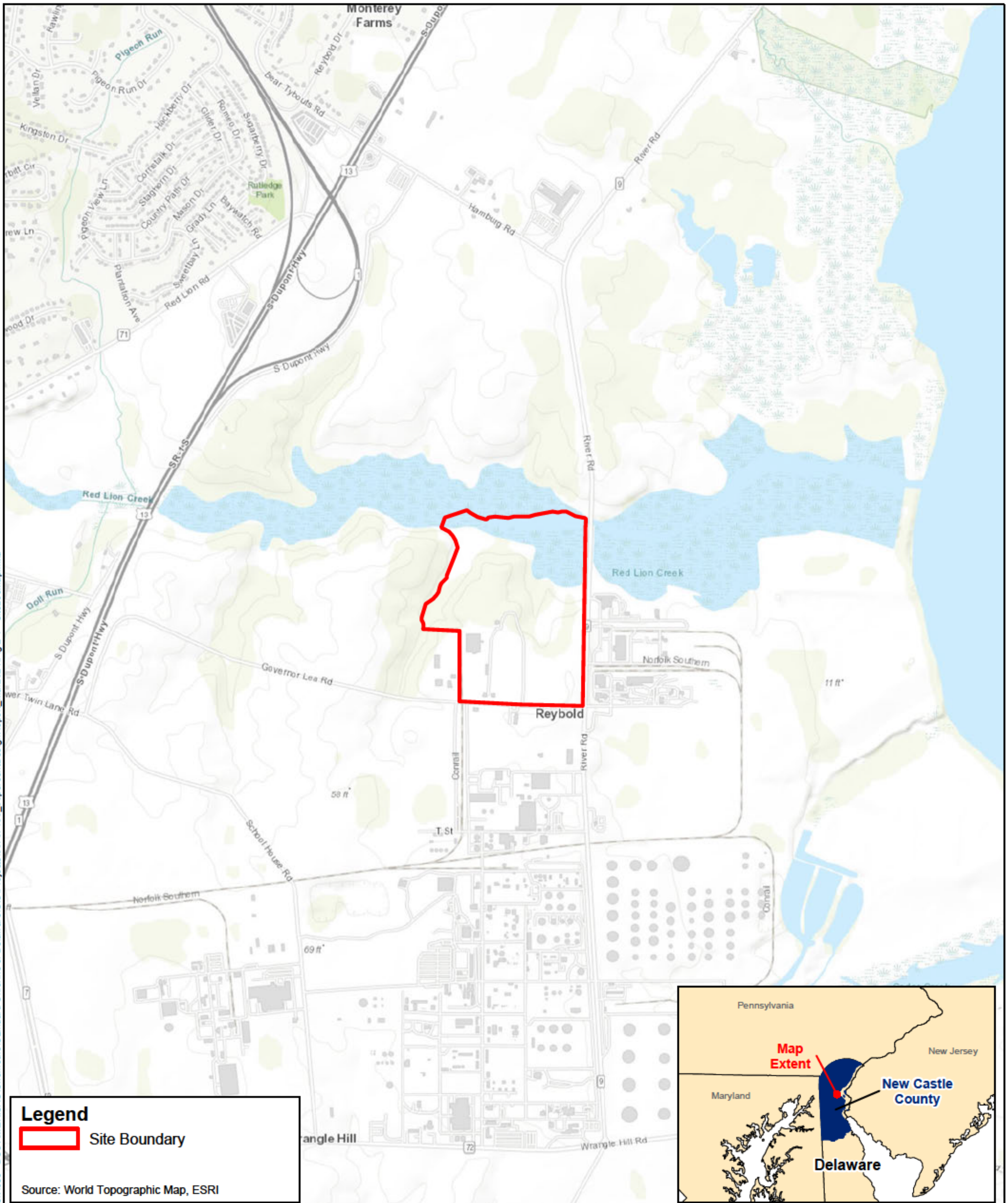
The updated BERA was provided in the HGL FFS and confirmed that Site contaminants could pose a risk to the aquatic community, benthic invertebrates, soil invertebrates and nutrient cycling, aquatic insectivores, terrestrial vermivores, and piscivores (HGL, 2020). The updated BERA did not identify any risks for terrestrial herbivores because much of the historical soil contamination had been covered by the cap. The updated 2020 BERA identified fewer risk drivers in soil than did the 2007 BERA. Through a combination of the cap and updated benchmarks, the polynuclear aromatic hydrocarbons and most metals were eliminated as ecological risk drivers for soil. Endrin and PCBs were added as risk drivers in soil. Through a combination of new data and benchmarks, the updated BERA added multiple chemicals to the list of ecological risk drivers for sediment identified in the 2007 BERA. The changes in the surface water risk and fish tissue risk drivers reflect these new data.

2.5.3 Sensitive Ecological Receptors

Sensitive ecological receptors must be considered in the final remedial design and the development of construction sequencing and schedule. Threatened and endangered species consultations with federal and state resource agencies (USFWS, NOAA-NMFS, DNREC) have not been completed. Once these agencies have identified sensitive species that may potentially be affected by remedial activities, the need to implement species-specific restrictions will be summarized, considered, and updated. These may include time-of-year restrictions on construction activities during the breeding season of migratory birds or fish.

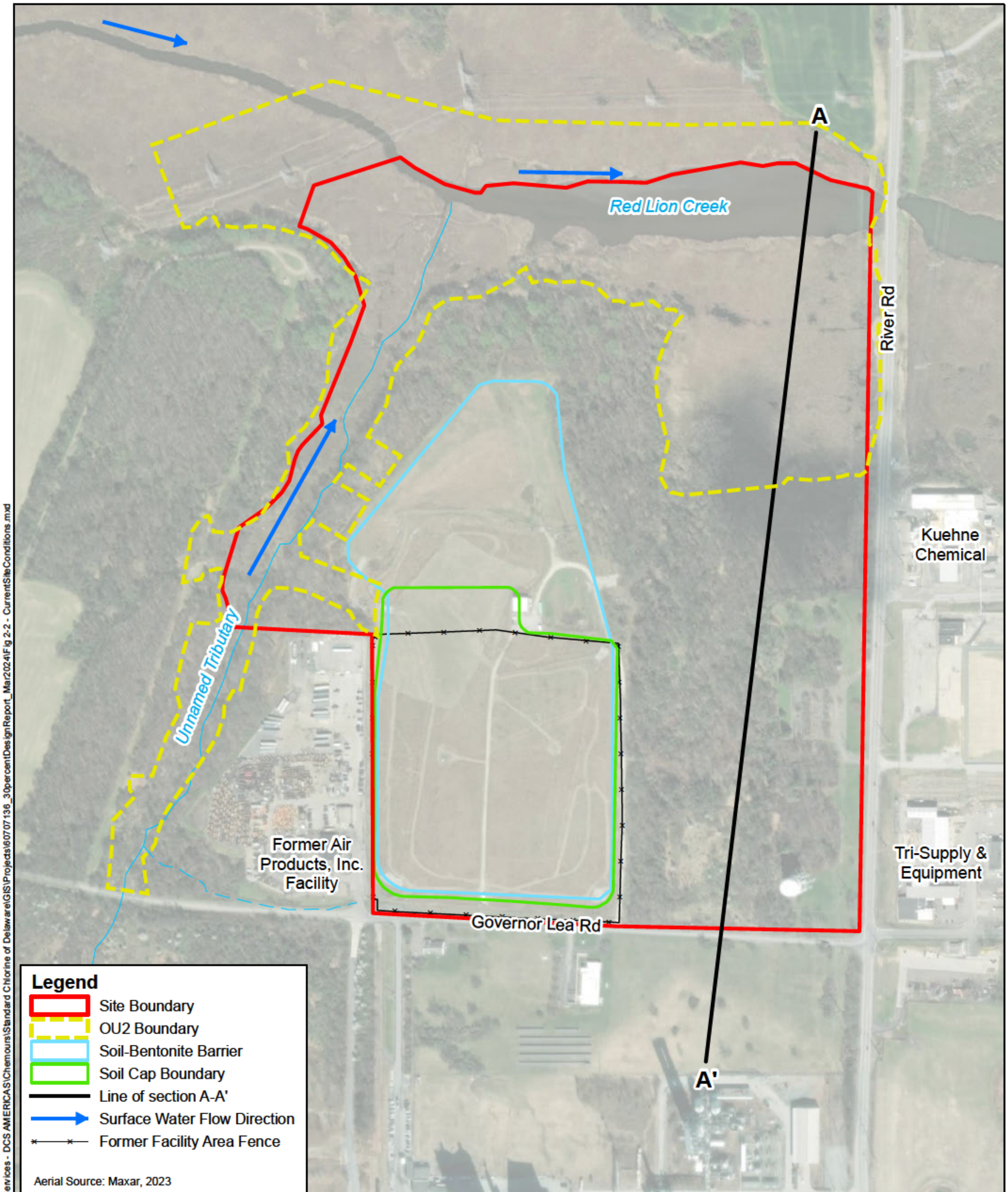
2.6 Conceptual Site Model

A Conceptual Site Model (CSM) is designed to integrate in a functional description (1) the major constituents of concern, based on previous Site investigations and the history of Site operations; (2) the potential on-Site and off-Site sources of these constituents; and (3) the possible exposure pathways of these constituents to potential human health and ecological receptors. The CSM for the Site has been updated using the updated risk assessments presented in the FFS (HGL, 2020) to reflect the fate and transport analyses, exposure pathways and receptors. An updated conceptual model summarizing the OU2 sediment and soil potential exposure scenarios is presented as **Figure 2-9**. The OU2 remedy described in this document will address the soil/sediment direct exposure scenario and direct exposure to groundwater scenario by removing and treating impacted sediments/soil. It will also address food chain exposure scenarios (i.e., fish/biota consumption) by removing and treating impacted sediments/soil, which serve as a source of contaminants for these exposure pathways. The final remedy for groundwater will be addressed later as OU4.



Path: C:\Users\tanaseg\AECOM\EC GIS Services - DCS AMERICAS\Chemours\Standard Chlorine of Delaware\GIS\Projects\60707136_30percentDesignReport_Mar2024\Fig 2-1 - SiteLocMap.mxd

N W E S 0 1,000 2,000 Feet 1 inch = 2,000 feet MAP FORMATTED FOR "A" (8.5" X 11") SIZE SHEET. SCALE NOT VALID FOR DIFFERENT PAGE SIZE.	TASK NUMBER: 6.3.3 DESIGNED BY: S. MORGAN DRAWN BY: G. TANASE DATA QUALITY CHECK BY: S. MORGAN	AECOM AECOM 248 Chapman Road Suite 101 Newark, DE 19702	Site Location Map 30% Design Report Standard Chlorine of Delaware, Inc. Superfund Site, New Castle, Delaware	PROJECT NUMBER: 60707136 DATE: 3/27/2024 FIGURE NUMBER: 2-1



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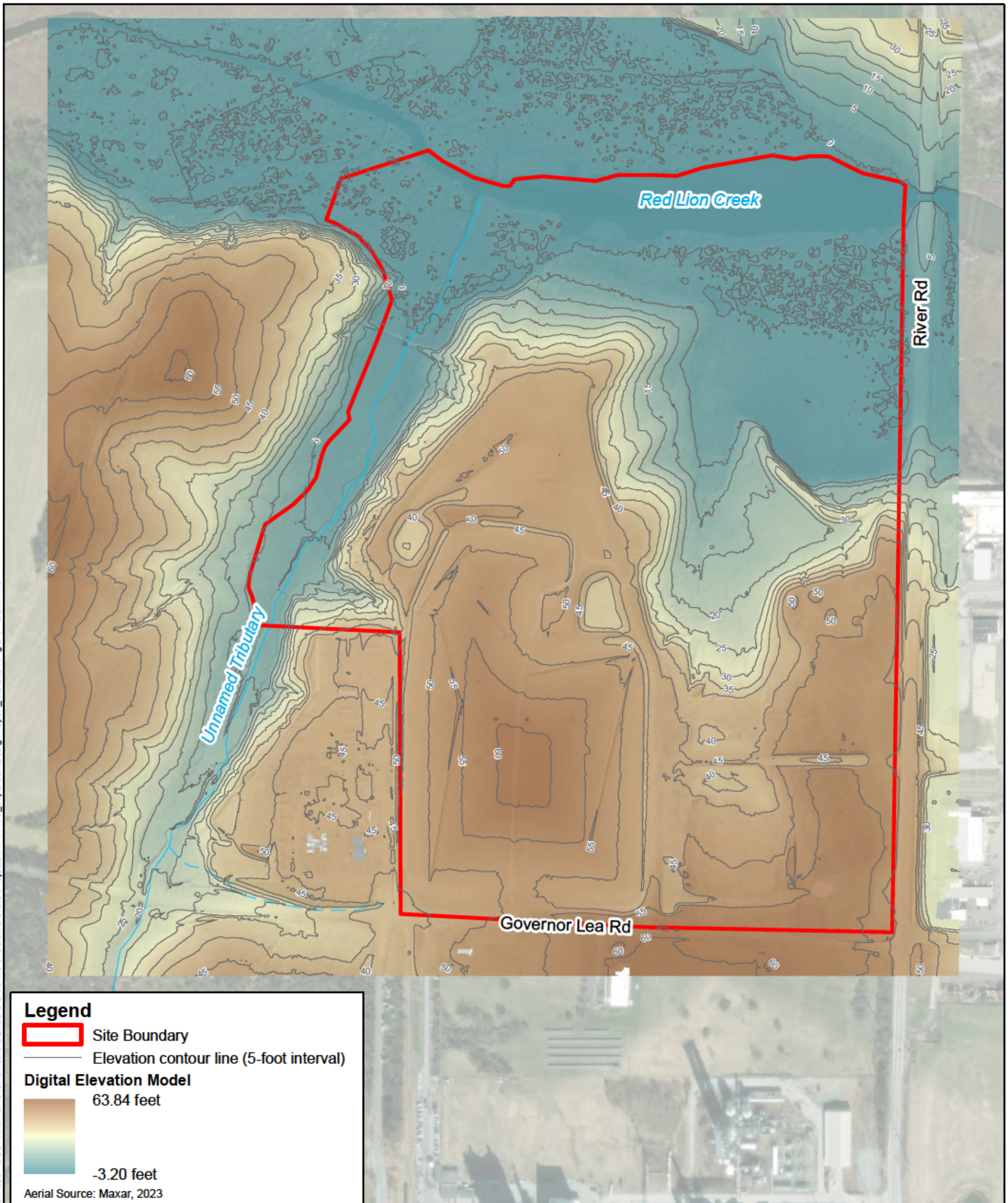
DESIGNED BY: S. MORGAN	AECOM 248 Chapman Road Suite 101 Newark, DE 19702	30% Design Report Standard Chlorine of Delaware, Inc. Superfund Site, New Castle, Delaware	DATE: 6/13/2024
DRAWN BY: G. TANASE			FIGURE NUMBER: 2-2
DATA QUALITY CHECK BY: S. MORGAN			



Legend

Site Boundary

Elevation contour line (5-foot interval)

Digital Elevation Model

63.84 feet

-3.20 feet

Aerial Source: Maxar, 2023

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1 inch = 500 feet

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TASK NUMBER:	6.3.3
DESIGNED BY:	S. MORGAN
DRAWN BY:	G. TANASE
DATA QUALITY CHECK BY:	S. MORGAN

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248 Chapman Road
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Newark, DE 19702

Digital Elevation Model

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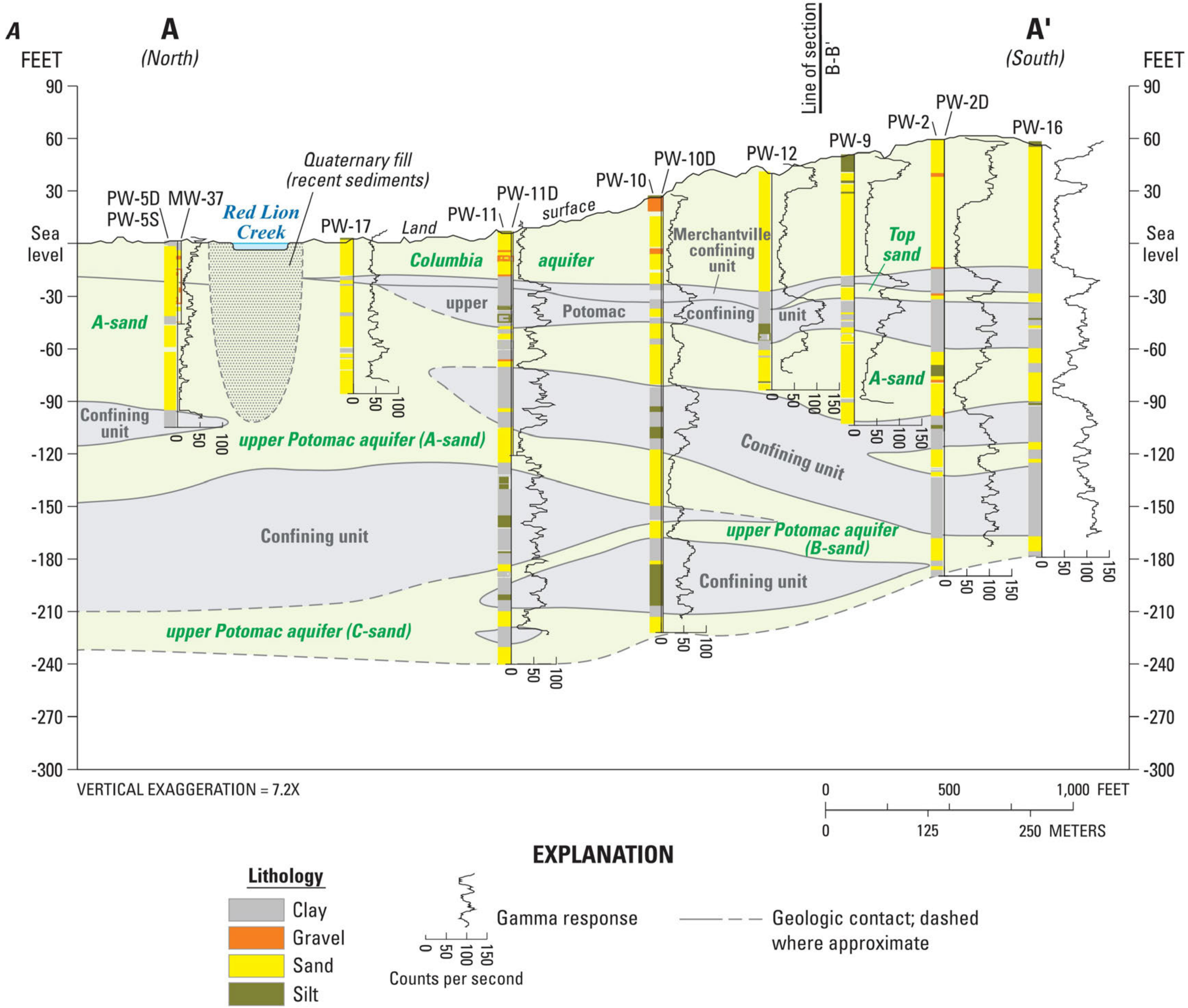
Standard Chlorine of Delaware, Inc.
Superfund Site, New Castle, Delaware

PROJECT NUMBER:	60707136
DATE:	3/27/2024
FIGURE NUMBER:	2-3

Path: C:\Users\tanaseg\AECOM\EC GIS Services - DCS AMERICAS\Chemours\Standard Chlorine of Delaware\GIS\Projects\60707136_30percentDesignReport_Mar2024\Fig 2-3 - DEM.mxd



Note:
From Brayton, et al., 2015

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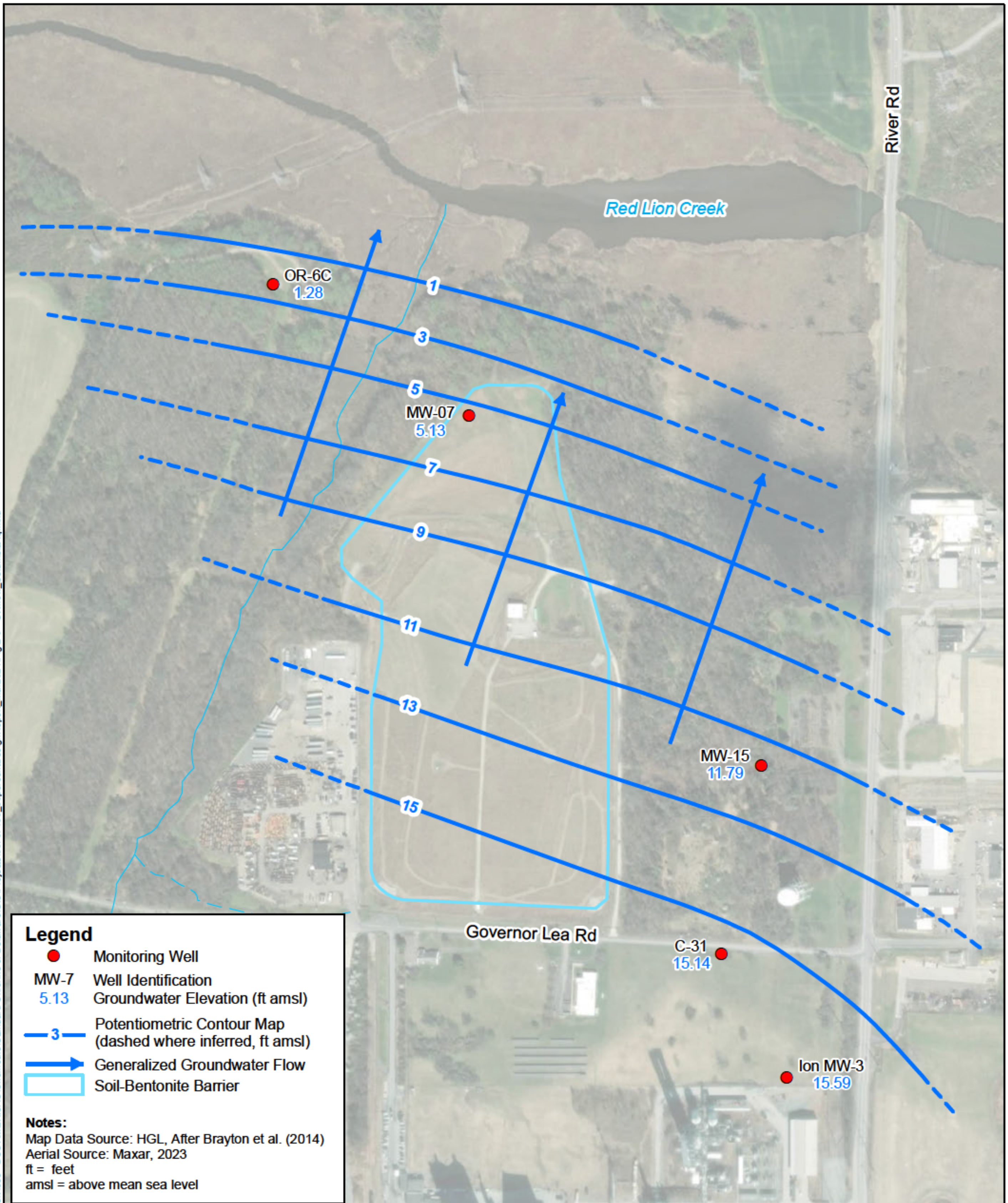
AECOM
248 Chapman Road
Suite 101
Newark, DE 19702

Hydrostratigraphic Conceptual Site Model for the Former Standard Chlorine Site

30% Design Report
Standard Chlorine of Delaware, Inc. Superfund Site
New Castle, Delaware

TASK NUMBER: 6.3.3	PROJECT NUMBER: 60707136
DESIGNED BY: S. MORGAN	DATE: 3/27/2024
DRAWN BY: G. TANASE	FIGURE NUMBER: 2-4
DATA QUALITY CHECK BY: S. MORGAN	



Path: C:\Users\tanaseg\AECOM\EC GIS Services - DCS AMERICAS\Chemours\Standard Chlorine of Delaware\GIS\Projects\60707136_30percentDesignReport_Mar2024\Fig 2-5 - GWflow_ColumbiaAq.mxd

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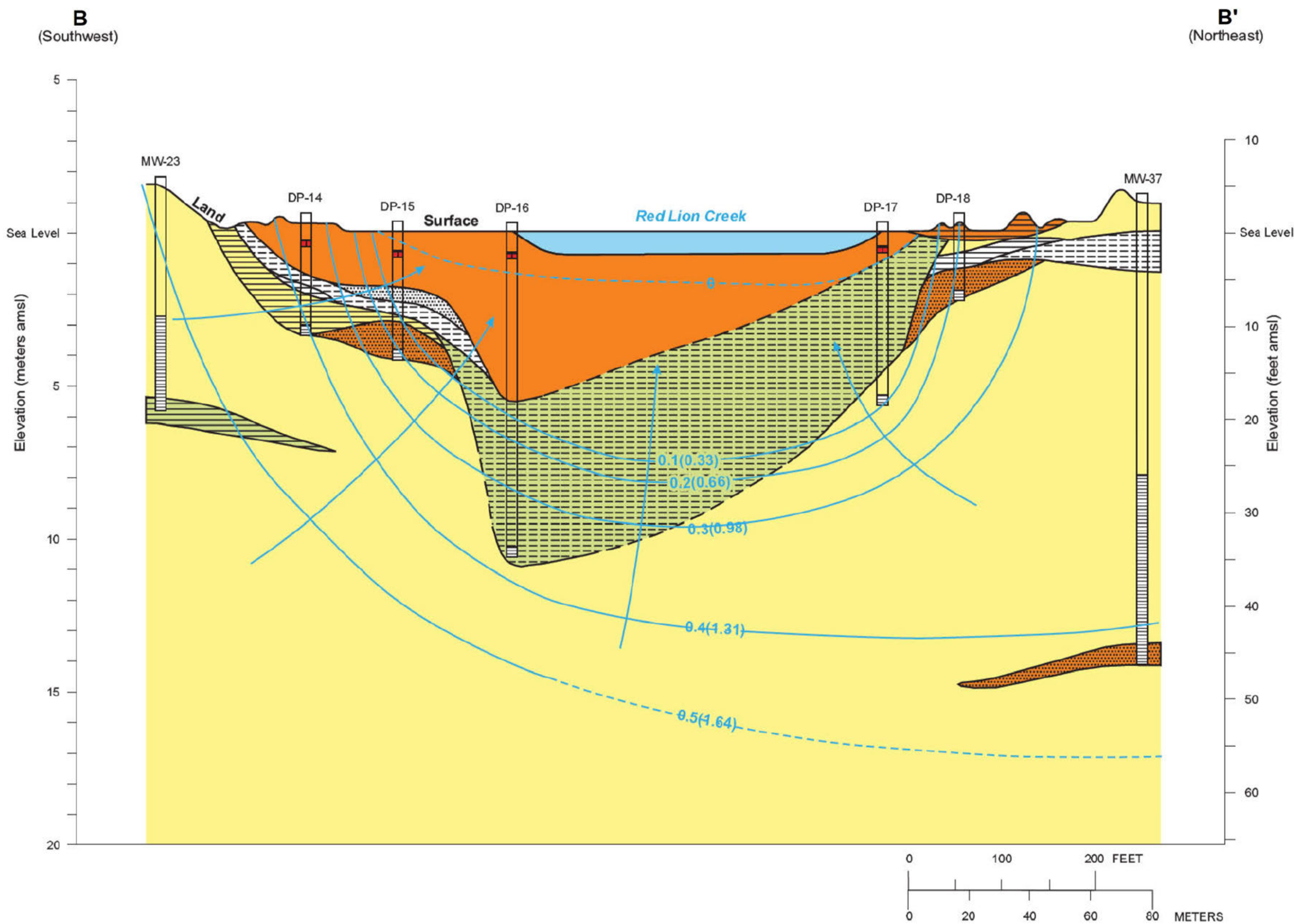
TASK NUMBER: 6.3.3
DESIGNED BY: S. MORGAN
DRAWN BY: G. TANASE
DATA QUALITY CHECK BY: S. MORGAN

AECOM
248 Chapman Road
Suite 101
Newark, DE 19702

Groundwater Flow - Columbia Aquifer
May 13, 2006

30% Design Report
Standard Chlorine of Delaware, Inc.
Superfund Site, New Castle, Delaware

PROJECT NUMBER: 60707136
DATE: 3/27/2024
FIGURE NUMBER: 2-5



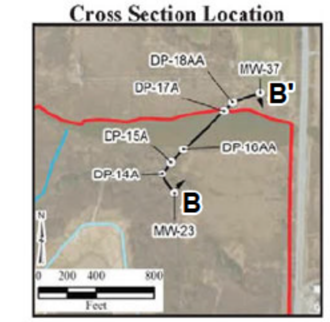
Notes:
Piezometric Head values originally expressed as meters in Lorah et al. (2014)
Vertical exaggeration is 10.
amsl=above mean sea level

From Lorah et al. (2014)

Legend

MW-37 Well/Soil Boring ID
Well Boring/Drive-Point/Screened Interval
Generalized Groundwater Flow Direction
Geologic contact (Dashed where inferred)
Line of Equal Head in meters (Dashed where inferred)
0.3/(0.98) Piezometric Head - meters/(feet) (August 8, 2012 Data)
Clay
Clay/Sand
Clay/Silt
Gravel
Organics
Organics/Clay
Sand (Columbia Formation)
Sand/Clay
Sand/Gravel
Silt
Silt/Clay

Cross Section Location



Note:
From Lorah, M.M., Walker, C.W., Baker, A.C., Teunis, J.A., Majcher, E.H., Brayton, M.J., Raffensperger, J.P., and Cozzarelli, I.M., 2014.

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AECOM

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248 Chapman Road
Suite 101
Newark, DE 19702

Potential Vertical Seepage
to Red Lion Creek

30% Design Report
Standard Chlorine of Delaware, Inc. Superfund Site
New Castle, Delaware

TASK NUMBER: 6.3.3	PROJECT NUMBER: 60707136
DESIGNED BY: S. MORGAN	DATE: 6/14/2024
DRAWN BY: G. TANASE	FIGURE NUMBER: 2-6
DATA QUALITY CHECK BY: S. MORGAN	

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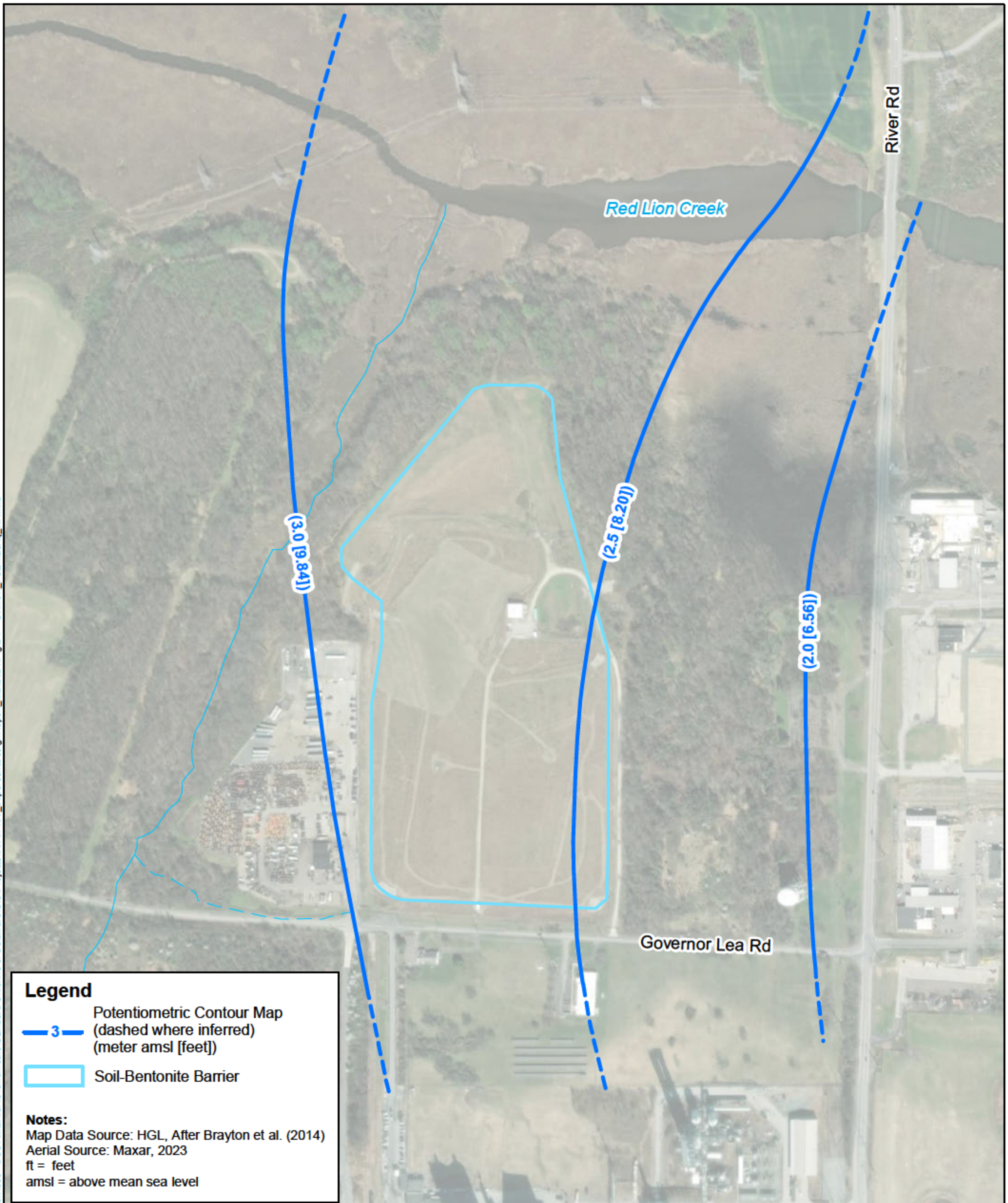

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Feet

1 inch = 500 feet

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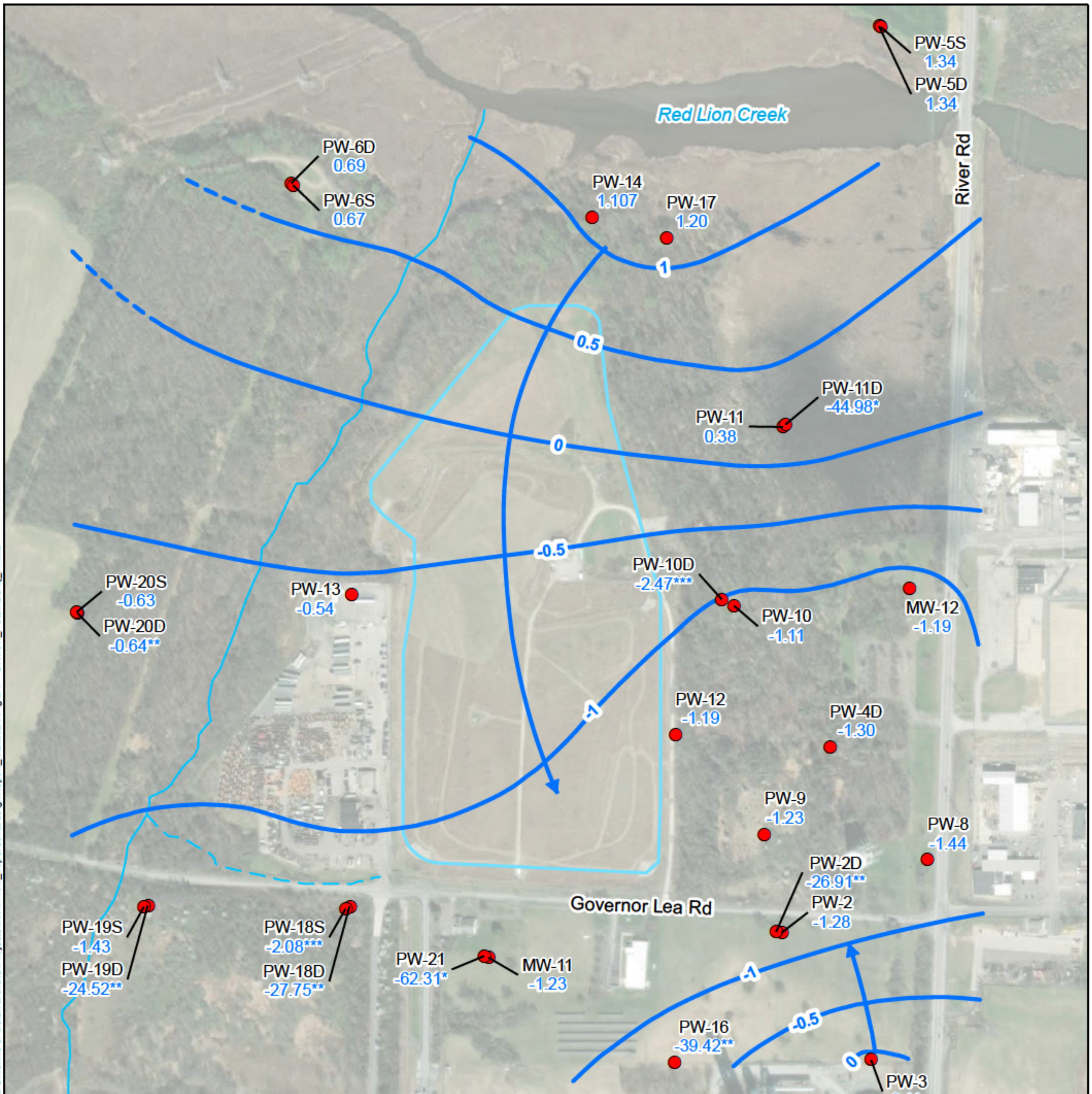
TASK NUMBER: 6.3.3	AECOM 248 Chapman Road Suite 101 Newark, DE 19702	Groundwater Flow - Potomac Aquifer - Non-Pumping September 14, 2011	PROJECT NUMBER: 60707136
DESIGNED BY: S. MORGAN			DATE: 3/27/2024
DRAWN BY: G. TANASE		30% Design Report Standard Chlorine of Delaware, Inc. Superfund Site, New Castle, Delaware	FIGURE NUMBER: 2-7
DATA QUALITY CHECK BY: S. MORGAN			

Path: C:\Users\tanaseg\AECOM\EC GIS Services - DCS AMERICAS\Chemours\Standard Chlorine of Delaware\GIS\Projects\60707136_30percentDesignReport_Mar2024\Fig 2-7 - GWflow_PotomacAq_NP.mxd



Legend

- Monitoring Well
- MW-11 Well Identification
- -1.23 Groundwater Elevation (ft amsl)
- Potentiometric Contour Map (dashed where inferred, ft amsl)
- Generalized Groundwater Flow
- Soil-Bentonite Barrier

Notes:

Map Data Source: HGL, After Brayton et al. (2014).
Data provided by USGS.
Aerial Source: Maxar, 2023
* = Potomac Aquifer "C" Sand Well. Ommitted from contouring.
** = Potomac Aquifer "B" Sand Well. Ommitted from contouring.
*** = Completed Deep "A" Sand. Ommitted from contouring.
ft = feet
amsl = above mean sea level

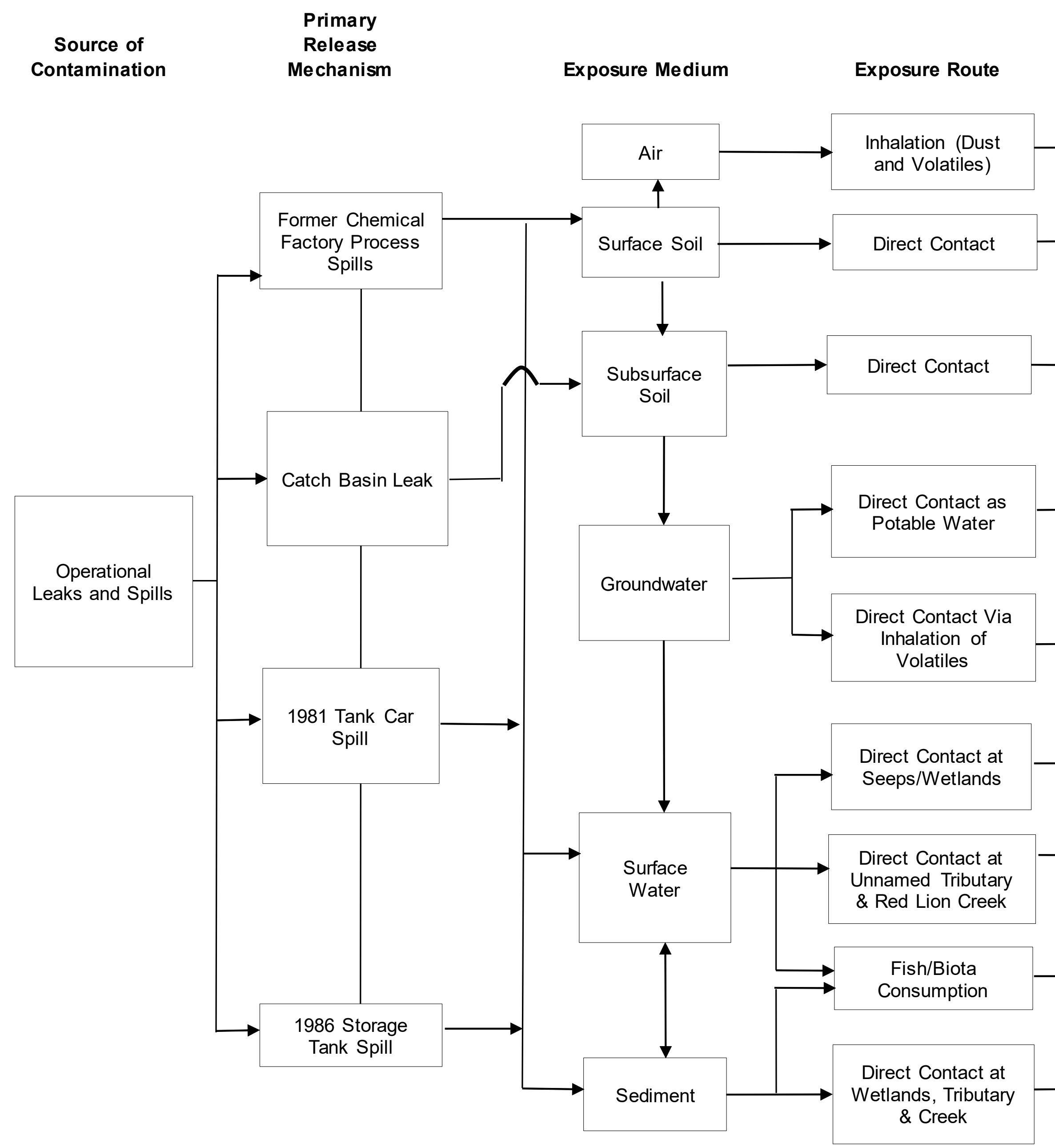
N W E S

0 250 500
Feet
1 inch = 500 feet

MAP FORMATTED FOR "A" (8.5" X 11") SIZE SHEET. SCALE NOT VALID FOR DIFFERENT PAGE SIZE.

TASK NUMBER: 6.3.3	AECOM	Groundwater Flow - Potomac Aquifer - Pumping May 2015	PROJECT NUMBER: 60707136
DESIGNED BY: S. MORGAN	AECOM 248 Chapman Road Suite 101 Newark, DE 19702	30% Design Report Standard Chlorine of Delaware, Inc. Superfund Site, New Castle, Delaware	DATE: 3/27/2024
DRAWN BY: G. TANASE			FIGURE NUMBER: 2-8
DATA QUALITY CHECK BY: S. MORGAN			

Path: C:\Users\tanaseg\AECOM\EC GIS Services - DCS AMERICAS\Chemours\Standard Chlorine of Delaware\GIS\Projects\60707136_30percentDesignReport_Mar2024\Fig 2-8 - GWflow_PotomacAq_P.mxd



	Potential Human Receptors					Potential Ecological Receptors		
	Current/ Future	Future						
Exposure Route	Visitor/ Trespasser	Hunter/ Angler	Outdoor Maintenance Worker	Construction Worker	Resident	Benthic Invertebrates	Fish	Avian and Mammals
Inhalation (Dust and Volatiles)	●	○	●	●	●	○	○	○
Direct Contact	●	○	●	●	●	○	○	○
Direct Contact	○	○	○	●	●	○	○	○
Direct Contact as Potable Water	○	○	●	●	●	○	○	○
Direct Contact Via Inhalation of Volatiles	○	○	○	●	●	○	○	○
Direct Contact at Seeps/Wetlands	⦿	⦿	⦿	⦿	⦿	●	⦿	⦿
Direct Contact at Unnamed Tributary & Red Lion Creek	●	●	○	○	●	●	●	⦿
Fish/Biota Consumption	○	●	○	○	●	○	● (a)	●
Direct Contact at Wetlands, Tributary & Creek	●	●	○	○	●	●	○	⦿

Legend:

- → Migration pathway
- ● Complete exposure pathway
- ○ Incomplete exposure pathway
- ⦿ Potentially complete exposure pathway but likely insignificant.
- (a) Piscivores in Red Lion Creek may eat forage fish.

MAP FORMATTED FOR "B" (11" X 17") SIZE SHEET.
TEXT SCALE NOT VALID FOR DIFFERENT PAGE SIZE.

AECOM

AECOM
248 Chapman Road
Suite 101
Newark, DE 19702

Risk Assessment Conceptual Site Model for OU2, Standard Chlorine Superfund Site

30% Design Report
Standard Chlorine of Delaware, Inc. Superfund Site
New Castle, Delaware

TASK NUMBER: 6.3.3	PROJECT NUMBER: 60707136
DESIGNED BY: B. RUFFLE	DATE: 3/28/2024
DRAWN BY: G.TANASE	FIGURE NUMBER: 2-9
DATA QUALITY CHECK BY: S. MORGAN	

3 Remedy Summary and Design Basis

This section provides details about the desired outcomes of the remediation of OU2 of the Site as presented in the FFS (HGL, 2020) and summarized in the ROD Amendment 3 (EPA, 2022). This section also summarizes the overall RAOs, the cleanup criteria, and the major components of the remedy selected in the ROD by EPA. This summary is followed by an examination of the government requirements or Applicable or Relevant and Appropriate Requirements (ARARs) that will dictate or guide the direction of the remedy.

3.1 Remedial Action Objectives

RAOs are site-specific and are determined by the nature and extent of chemical contamination, current and potentially threatened resources, and the potential for human and environmental exposure (EPA, 1989). RAOs are medium-specific and source-specific goals to be achieved through completion of a remedy that is protective of human health and the environment.

Past and ongoing remediation activities at the Site have addressed or will address contaminated soil, sediment, and groundwater in OU1, OU3, and OU4. However, DNAPL present in the soil and sediment will continue to pose a health risk if it remains a source of contamination to groundwater and soil vapor. The multilayer cap that was constructed as part of the OU3 remedy will prevent contaminated soil within the capped area from acting as an ongoing source. The contaminated soil and sediment outside of OU3 (in the Western Drainage Gully, in upland areas north of the OU3 cap, and in the western, eastern, and northern wetlands) will continue to represent an ongoing source of contamination to groundwater. The groundwater that is impacted by the soils in the portion of upland areas north of the OU3 cap within the OU1 containment area is being addressed under OU1 and OU4.

Investigational data indicated that some Site contaminants have migrated to soil and sediment (including aquifer matrix/deeper sediment) as well as the surface water bodies surrounding the Site. The contaminants at these media were measured at concentrations that could adversely affect the hyporheic community and upper trophic level receptors. Consequently, RAOs were developed for all these media at the Site as generic goals to achieve protection of human health and the environment and limit the further migration of contaminants.

The revised RAOs for OU2 as described in the ROD Amendment 3 (EPA, 2022) are summarized as follows:

- RAOs for Human Health
  - Prevent exposure via inhalation, ingestion, and/or dermal exposure to soil, sediment, and fish tissue with COCs representing an excess cancer risk of greater than 1 $\times 10^{-4}$

and a non-cancer risk of greater than a Hazard Index of 1 for current and future land use.

- RAO for Environmental Protection
  - Reduce unacceptable risks to acceptable levels to ecological receptors exposed to Site-related soil and sediment contamination.
- RAO for Limiting Further Migration of Contaminants
  - Minimize migration of contamination via any of the following major migration pathways:
    - DNAPL to groundwater
    - Soil to groundwater and surface water
    - Sediment to groundwater and surface water

3.2 Contaminants of Concern and Remedial Goals

As presented in the 2022 ROD Amendment 3 (EPA, 2022) and summarized in the Data Gap Memo (AECOM, 2023a), **Table 3-1** summarizes the cleanup criteria and their applicability for OU2 soil/sediment.

As shown in **Table 3-1**, including table foot notes, EPA established a Remedial Action Level (RAL) of 33 mg/kg total benzene and chlorinated benzene compounds for the upper 2 feet below the sediment surface, and soil to a depth of 7 feet in the western drainage gulley and where the former waste pile soils were located. The RAL of 33 mg/kg is the sum of concentrations for a total of 14 COCs as defined in the 1995 ROD (EPA, 1995a) and represents the concentration benchmark, above which, soils are to be excavated and treated in the aforementioned areas.

Preliminary remediation goals (PRGs) were identified for other constituents in the FFS and the updated BRA (HGL, 2020). These PRGs were finalized as Remedial Goals (RGs) by EPA in the ROD Amendment 3 (EPA, 2022). These RGs will apply to treated soil or import soil that is placed within the top 2 feet of the remediated wetlands or Red Lion Creek sediments. The RGs were also used to support the development of the baseline ecological monitoring plan described later in this section and Appendix J.

For soil greater than 2 feet bgs, EPA has identified saturation concentrations for specific compounds indicative of DNAPL for soil/sediment as described later in this section. Soils exceeding these saturation concentrations for any of the indicated compounds will be excavated and treated with LTTD.

The following sections summarize the RGs for OU2.

Table 3-1: Remedial Action Levels and Remedial[(1)] Goals

Criteria	COCs	Value (mg/kg)	Area	Medium	Depth (feet)
Remedial Action Level[(2)]	Total benzene and chlorinated benzene compounds (TBC)[(3),(4)]	33	Wetlands and Red Lion Creek	Sediment	0-2
			Western Drainage Gulley	Soil	0-7
Cleanup Criteria[(2)]	Hexavalent chromium[(5)]	4	Wetlands and Red Lion Creek	Sediment	0-2
Saturation Concentrations for Material Indicative of DNAPL	Benzene	1820	Wetlands	Sediment	> 2
	Chlorobenzene	761			
	1,2-dichlorobenzene	376			
	1,3-dichlorobenzene	170			
	1,4-dichlorobenzene	280			
	1,2,3-trichlorobenzene	150			
	1,2,4-trichlorobenzene	404			
	1,3,5-trichlorobenzene	33			
	1,2,3,4-tetrachlorobenzene	17			
	1,2,4,5-tetrachlorobenzene	2.1			
	Pentachlorobenzene	1.4			
	Hexachlorobenzene	0.06			
	Nitrobenzene	3050			
Remediation Goals (RGs)[(6)]	Chlorobenzene	0.05	Wetlands and Red Lion Creek	Sediment	0-2
	1,2-Dichlorobenzene	0.0165			
	1,3-Dichlorobenzene	4.43			
	1,4-Dichlorobenzene	0.599			
	Sum of dichlorobenzenes	23.6			
	1,2,3-Trichlorobenzene	0.858			
	1,2,4-Trichlorobenzene	2.1			
	Sum of trichlorobenzenes	23.6			
	1,1-Dichloroethene	0.18			
	1,2,3,4-Tetrachlorobenzene	0.702			
	1,2,4,5-Tetrachlorobenzene	1.09			
	Sum of tetrachlorobenzenes	23.6			
	Hexachlorobenzene	0.069			
	Pentachlorobenzene	460			
	Bis(2-ethylhexyl)phthalate	0.68			

Criteria	COCs	Value (mg/kg)	Area	Medium	Depth (feet)
Remediation Goals (RGs)[(6)]	Benzo(b+k)fluoranthene	0.081	Wetlands and Red Lion Creek	Sediment	0-2
	Chrysene	0.46			
	Indeno(1,2,3-c,d)pyrene	0.058			
	Acetone	0.08			
	Benzene	0.137			
	Bromoform	0.654			
	Bromomethane	0.00137			
	Carbon disulfide	0.000851			
	Carbon tetrachloride	0.064			
	Methylene chloride	0.17			
	2-Methylnaphthalene	0.12			
	1,2-Dichloropropane	0.333			
	2-Butanone	0.0424			
	Aldrin	0.013			
	Chlordane	0.0076			
	Endosulfan I and II	0.00214			
	Endosulfan sulfate	0.0054			
	Endrin	0.021			
	Aroclor 1248	7			
	Dioxins/furans and dioxin-like PCBs	0.000025			
	Total PCBs	0.61			
	Copper	69			
	Chromium	4			
	Cyanide	0.32			
	Lead	68			
	Mercury	0.4			
	Nickel	33			
	Vanadium	310			
	Zinc	240			

Criteria	COCs	Value (mg/kg)	Area	Medium	Depth (feet)

Notes:

(1) From 2022 OU 2 Record of Decision (ROD) Amendment #3.

(2) Cleanup Criteria and RGs are also applicable to the treated substrate to be re-used as backfill.

(3) Originally based on toxicity to lettuce seed germination and earthworm survival and based on total COCs (1995 ROD)

(4) Includes the following compounds: benzene, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, hexachlorobenzene, nitrobenzene, pentachlorobenzene, 1,2,3,4-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene, toluene, 1,2,3-trichlorobenzene, 1,2,4-trichlorobenzene, and 1,3,5-trichlorobenzene (1995 ROD and 2022 Amendment 3 to the ROD.

(5) Chromium to be speciated and presence of hexavalent chromium to be determined (2022 OU 2 ROD Amendment #3)

(6) From Attachment 2 – Remediation Goals in 2022 OU 2 ROD Amendment #3; RGs listed on this table includes only sediment Preliminary Remediation Goals (PRGs) from Table 2.2 of the 2020 Focused Feasibility Study, which also has soil and surface water PRGs.

COCs = Contaminants of Concern

mg/kg = milligrams per kilogram sediment (dry weight basis)

DNAPL = Dense Non-Aqueous Phase Liquids

3.2.1 Soil/Sediment Remedial Action Level

The updated baseline human health risk assessment performed specifically for OU2 in the FFS (HGL, 2020) identified PRGs as summarized in **Table 3-1**. EPA designated these as RGs in the 2022 ROD Amendment 3 (EPA, 2022).

The 2022 ROD Amendment (EPA, 2022) indicated the compounds with associated RGs are generally co-located with the COCs listed in the 1995 ROD (EPA, 1995a), which are primarily benzene and chlorobenzenes and include:

- benzene
- chlorobenzene
- 1,2-dichlorobenzene
- 1,3-dichlorobenzene
- 1,4-dichlorobenzene
- hexachlorobenzene
- nitrobenzene
- pentachlorobenzene
- 1,2,3,4-tetrachlorobenzene
- 1,2,4,5-tetrachlorobenzene
- toluene
- 1,2,3-trichlorobenzene
- 1, 2,4-trichlorobenzene
- 1,3,5-trichlorobenzene

In the 2022 ROD Amendment 3 (EPA, 2022), EPA established the RAL of 33 mg/kg total COCs will be applied to the following media:

- Upper 2 feet below the sediment surface
- Soil to a depth of 7 feet in the Western Drainage Gully
- Soil to a depth of 7 feet below where the former waste pile soils were located

EPA expects that remediating soil and sediment exceeding the RAL of 33 mg/kg total concentration for COCs will result in the achievement of the RGs (as summarized in **Table 3-1)** for human and ecological receptors on an area-wide exposure basis. This will be verified by calculating post-remedial exposure point concentrations upon finalization of the excavation prism.

3.2.2 Hexavalent Chrome for Soil/Sediment (0 to 2 feet bgs)

Since issuance of the 1995 ROD (EPA, 1995a), total chromium has been detected at elevated concentrations in soil and sediment samples at the Site. Previous sampling events included total chromium, but samples were not analyzed for hexavalent chrome. As discussed in the FFS, it is unlikely that chromium is primarily in the hexavalent form based on observations of reductive dechlorination of spill compounds as well as measurement of reducing conditions in the wetlands sediments and pore water (Lorah et al., 2014). Under these reducing conditions, most chromium would likely be present in the reduced trivalent state. If this holds true, then chromium would not be a risk driver for sediment (HGL, 2020).

Hexavalent and total chrome analysis was included for soil/sediment samples collected during the 2023 pre-design investigation to evaluate chrome speciation. The hexavalent and total chrome results are presented in Appendix A. These data indicate that total hexavalent chromium was not detected (ND) in the samples. Therefore, chromium was not factored into the determination of excavation limits. However, EPA has indicated a risk-based cleanup level for hexavalent chromium in sediment of 4 mg/kg. Therefore, treated material will be analyzed to confirm achievement of hexavalent chromium cleanup goals prior to backfilling.

3.2.3 Principal Threat Waste Removal of Soil/Sediment (Greater than 2 feet bgs)

The remedy also addresses soil/sediment greater than 2 feet bgs in the wetland that has contaminant concentrations indicative of DNAPL, considered a principal threat waste (PTW). EPA has determined the saturation concentrations in **Table 3-1** will serve as RALs for material indicative of DNAPL.

Soil/sediment exhibiting DNAPL contaminant concentrations for one or more of these compounds will be remediated to the same criteria as shallow sediment. EPA expects that removing and remediating material indicative of DNAPL to the extent practicable will minimize the amount of source material in the wetland and limit the potential for recontamination of remediated sediment.

3.2.4 Baseline Ecological Monitoring Plan

A Baseline Ecological Monitoring Plan is provided in Appendix J. The monitoring plan presents the approach to establishing pre-remediation conditions within Operable Unit 2 (OU2) at the Standard Chlorine of Delaware, Inc. Site. The monitoring described in Appendix J is intended to support the long-term evaluation of remedy effectiveness. Specifically, the baseline monitoring data will be used to establish a point of comparison for assessing post-remedial conditions in the OU2 wetland and aquatic habitats. Long-term post remedial monitoring data will be evaluated relative to the pre-remedial action baseline conditions to assess the degree to which the selected OU2 remedial measures achieved their objectives.

3.3 Summary of Remedy for OU-2

In summary, the remedy will consist of the following activities.

3.3.1 Excavation

Excavation of impacted soil and sediment will be as follows:

- Shallow sediment (up to 2 feet in depth) exceeding the RAL of 33 mg/kg in the wetlands and parts of Red Lion Creek
- Soil in Western Drainage Gully and former waste soil pile (up to 7 feet)
- Deeper sediment (> 2 feet bgs up to 30 feet bgs or to the extent practicable) at saturation concentrations indicative of PTW or potential DNAPL

A specific plan for replacement of treated sediment back into the wetland areas will be developed in the next design phase. In general, excavated sediment will be returned to the same area and depth as originally excavated. The effect on soil volume from thermal treatment, organic amendment, metals stabilization, and biobarrier amendments is not known and will be reevaluated in the next design phase.

3.3.2 LTTD Treatment

The excavated soils will be treated using the following performance requirements established for the thermally treated soils:

- **Primary Requirement** – Meet soil cleanup goals for the COCs, with all sample results at or below the cleanup goal, at a frequency of one sample per every 500 cubic yards of soils treated.
- **Secondary Requirements** – Heat up the soils to the target treatment temperature 250°C (to be updated based on bench testing results), defined by all subsurface temperature sensors reaching a minimum temperature of 225°C (to be updated based on bench testing results) and 95% of the sensors reaching the target treatment temperature 250°C and continue heating, maintaining the target treatment temperature within the target temperature zone, until mass removal has reached diminishing returns, achieved when the mass removal rate is reduced to 10% of the mass removal rate at the peak operation of the system or achieve a linear mass removal rate curve as determined by statistical trend analysis (Mann-Kendall) when applicable based on the thermal treatment process.

Proposed LLTD Soil cleanup goals for each COC are presented in **Table 3-2**.

Table 3-2: Thermally Treated Soil Clean Up Goals

Constituent of Concern	Soil(1)(2) mg/kg
Benzene	0.137
Toluene	TBD
Nitrobenzene	TBD
Chlorobenzene	0.05
1,2 – Dichlorobenzene	0.0165
1,3 – Dichlorobenzene	4.43
1,4 – Dichlorobenzene	0.599
1,2,3 - Trichlorobenzene	0.858

Constituent of Concern	Soil(1)(2) mg/kg
1,2,4 - Trichlorobenzene	2.1
1,3,5 - Trichlorobenzene	TBD
1,2,3,4 - Tetrachlorobenzene	0.702
1,2,4,5 - Tetrachlorobenzene	1.09
Hexachlorobenzene	0.069
Pentachlorobenzene	460

Notes:

(1) From 2022 OU2 Record of Decision (ROD) Amendment #3 (EPA, 2022).

(2) From Attachment 2 - Remediation Goals in 2022 OU 2 ROD Amendment #3; RGs listed in this table include only sediment Preliminary Remediation Goals (PRGs) from Table 2.2 of the 2020 Focused Feasibility Study, which also has soil and surface water PRGs (HGL, 2020).

mg/kg = milligrams per kilogram sediment (dry weight basis)

3.3.3 Metals Stabilization

Concentrations of metals that may present an ecological risk have been detected in some wetland sediment samples. LTTD treatment would not address metals; therefore, thermally treated material that exceeds established criteria for metals will be mixed with a stabilization agent. Metals stabilization agents bind to the media and reduce the bioavailability of metals. The bioavailability of these metals and need for stabilization will be determined during remedial design treatability studies currently in progress. These treatability studies are described in Section 4.

3.3.4 Bio-reactive Barrier

Prior to backfilling the upper portion (approximately the upper 2 feet) of material in the wetland, the treated material will be mixed with organic matter, bio-augmented granular activated carbon (GAC), and other biological amendments to create a bioreactive zone. This bioreactive zone, referred to as a “biobarrier”, will support vegetation and allow for enhanced bioaugmentation to address potential upwelling of groundwater.

Contaminated shallow sediment (considered the upper 2 feet of sediment) that exceed 33 mg/kg total benzene and chlorobenzenes (TBCs) in the wetland would be removed and treated via LTTD. This will include much of the shallow sediment in the western and northern wetlands and limited hot spots in the eastern wetland.

Once backfilling and wetland restoration are complete, institutional controls (ICs) in the form of land use restrictions will be necessary. ICs will include use, access, and deed restrictions for those parcels where Site-related soil and sediment contamination is located. ICs are in place to restrict land and groundwater use for the former facility area and to protect the integrity of the cap cover system and associated remedial components. Additional ICs may be established by EPA and DNREC upon completion of the OU2 remedial action.

3.3.5 Placement of Treated Sediment and Backfilling

A specific plan for replacement of treated sediment back into the wetland areas will be developed in the next design phase. In general, excavated sediment will be returned to the same area and depth as originally excavated. The effect on soil volume from thermal treatment, organic amendment, metals stabilization, and biobarrier amendments is not known. Partial dewatering during backfilling may be necessary to allow placement and to avoid separation of reagents from the soil during placement. Compacting of placed sediment may not be practical. Placement of treated sediment in lifts, allowing settlement, then adding additional lift may be necessary.

3.4 Regulatory Requirements and Permit Equivalency

A number of environmental permits and approvals contain requirements that the project will meet substantively (**Table 3-3**). Submission of permit materials to agencies and receipt of approved permits is not required, as the project is under the authority of EPA. Project materials meeting these requirements will be prepared and submitted to EPA for its review.

Table 3-3: EPA Standard Chlorine of Delaware Permitting Equivalencies Matrix

Permit or Approval	Authority Having Jurisdiction	Permit/Application Summary Overview and Submission Needs	Sources and Notes
		Federal	
RCRA Hazardous Waste Part A Permit	Environmental Protection Agency (EPA)	EPA is required to establish standards for recordkeeping and reporting of hazardous waste for hazardous waste generators, treatment, storage, and disposal facilities. Application submittal entails completing the Hazardous Waste Part A Permit Application for facility-specific information and the RCRA Subtitle C Site Identification Form EPA Forms 8700-12, 8700-13 A/B, 8700-23 OMB# 2050-0024 (Site Identification Form) for detailed site specific information, such as geologic, hydrologic, and engineering data. Forms are submitted to the EPA.	Resource Conservation and Recovery Act (RCRA) / Hazardous and Solid Waste Amendments of 1984 (HSWA) 40 CFR 262.40(b) and (d); 262.41; 264.75; 265.75; and 270.30(1)(9)
Endangered Species Section 7 Consultation	U.S. Fish and Wildlife Service	The USFWS "Information for Planning and Consultation" (IPaC) online tool identifies was completed for the project dated December 1, 2023. One threatened species was identified on the list, the Bog Turtle (*Glyptemys muhlenbergii*). One candidate species was identified on the list, the Monarch Butterfly (*Danaus plexippus*). There were no critical habitats identified within the Project area under the USFWS's jurisdiction. There were no refuge lands or fish hatcheries identified within the Project area. NWI wetlands identified on the IPaC included Estuarine and Marine Deepwater (E1UBL), Freshwater Forested/Shrub Wetland (PFO1C, PFO1A, PFO1R, PSS1R), Freshwater Emergent Wetland (PEM1R), Freshwater Pond (PUB1R), and Estuarine and Marine Wetland (E2EM5P6). The IPaC was submitted to DNREC Wildlife Species Conservation and Research Program to request an environmental review on March 20, 2024. A response has not yet been received.	Endangered Species Act (ESA) – 16 U.S.C. 1531 et. seq. https://ecos.fws.gov/ipac/
Migratory Bird Treaty Act (MBTA) and Bald and Golden Eagle Protection Act (BGEPA)	U.S. Fish and Wildlife Service	The U.S. Fish and Wildlife Service has jurisdiction over migratory birds and bald and golden eagles. Migratory birds and bald and golden eagles, as well as time of year restriction, will be identified and appropriate conservation measures, in accordance with the Nationwide Standard Conservation Measures published by the U.S. Fish and Wildlife Service on April 20, 2015, will be employed at the site.	50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)

Permit or Approval	Authority Having Jurisdiction	Permit/Application Summary Overview and Submission Needs	Sources and Notes
Magnuson-Stevens Act Provisions; Essential Fish Habitat (EFH)	NOAA; National Marine Fisheries Services	The National Marine Fisheries Services will require consultation to determine the impact that the Project may have on Essential Fish Habitat. The Project is located within Essential Fish Habitat for the Atlantic Butterfish (Larvae, Adult), Bluefish (Juvenile, Adult), Black Sea Bass, Longfin Inshore Squid (Eggs), Scup (Juvenile, Adult), and Summer Flounder (Juvenile, Adult). The Red Lion Creek is also within the Shortnose Sturgeon Consultation Area and the Atlantic Sturgeon Consultation Area.	NOAA Fisheries Services - 16 U.S.C. 1801 et seq., and 67 FR 2343; 50 CFR 600
Clean Water Act, Section 404	U.S. Army Corps of Engineers, Philadelphia District	Wetland and stream impacts within the Project site would typically be regulated by the US Army Corps of Engineers (Corps). It is anticipated that the Project would qualify for a Nationwide Permit 38 (Cleanup of Hazardous and Toxic Waste)Permit and project component would need to be consistent with substantive permit requirements. Further coordination with the Corps will be necessary to determine the extent of permitting and the necessary permit components.	Section 404 of the Federal Clean Water Act (CWA) as amended and Final Rule – Reissuance and Modification of Nationwide Permits (Federal Register vol. 86, No. 245, December 27, 2021. p. 73522 – 73583.
EPA 2022 Construction General Permit (CGP) / Delaware National Pollutant Discharge Elimination System	EPA / DNREC	A Stormwater Pollution Prevention Plan (SWPPP) will be prepared with standards and specifications for erosion and sediment control and post construction stormwater management BMPs, including operation and maintenance of those BMPs, for the site and kept up to date throughout construction. The SWPPP will be submitted along with a Notice of Intent (NOI) to EPA for approval prior to construction activities. The SWPPP and all components of design will comply with Delaware regulations regarding the prevention, management and control of pollution from the project.	Section 402 of the Federal Clean Water Act (CWA) as amended, and EPA–HQ–OW–2021–0169; FRL–7877–01–OW https://www.epa.gov/npdes/2022-construction-general-permit-cgp Delaware Administrative Code, Title 7, Chapter 7201, Sections 7 & 8.
		State/County	
FEMA Flood Hazard Act	New Castle County	Substantive requirements of FEMA regulations regarding construction within floodplains and floodways will be complied with in the design of the project. Portions of the site are within the FEMA Mapped Zone AE (EL9 and EL10), which is considered the limits of the 100-year flood. Portions of the Red Lion Creek are within the Limit of Moderate Wave Action (LiMWA). It should be noted that a tide gate located on the Red Lion Creek between the Project site and the Delaware Bay.	Executive Order 11988 https://newcastlecity.delaware.gov/departments/flood-plain-management/ https://www.newcastlede.gov/1425/Flood-Protection#:~:text=Note%20that%20some%20flood%20protection,for%20information%20on%20financial%20assistance.

Permit or Approval	Authority Having Jurisdiction	Permit/Application Summary Overview and Submission Needs	Sources and Notes
Clean Water Act, Section 402Ambient Water Quality	DNREC	Point source discharges related to treated water that is released back into the Red Lion Creek will comply with the requirements of DNREC's Individual NPDES Permit effluent limitations.	https://www.epa.gov/npdes/npdes-application-formshttps://dnrec.delaware.gov/water/commercial-government/npdes/individual/CWA , Section 402:33 U.S.C., Section 1342
Clean Air Act	DNREC	The project will meet the substantive requirements of the DNREC Air Permitting requirements related to emissions of site contaminants as well as systems used to capture and off-gas from the soil during construction activities.	7 DE Admin. Code 1102
Delaware Coastal Management Program (DCPM) Federal Consistency	State of Delaware, Department of Natural Resources and Environmental Control (DNREC) Division of Climate, Coastal, and Energy / NOAA Coastal Zone Management	The Project is within the state of Delaware's Coastal Zone. The Delaware Coastal Program manages Delaware's Coastal Zone Management Federal Consistency reviews. The Project will comply with Delaware's regulations and be designed consistent with Delaware's Coastal Management Program.	6 U.S.C. §§ 1451, 1452, 1453, 1456 Delaware Code, Title 7, Chapter 70, at Section 7002 7003; Delaware Coastal Zone Act Regulations of May 11, 1999, amended on October 1, 2001, Sections A-E Delaware Administrative Code, Title 7, Chapter 5104, Section 2.2
Wetlands and Subaqueous Lands Section Permit	State of Delaware, Department of Natural Resources and Environmental Control (DNREC) Division of Water	DNREC regulates impacts to tidal wetlands and tidal and non-tidal waters of the State of Delaware, including wetlands that include 400 or more contiguous acres. State Wetland Maps indicate that Wetlands mapped as Marsh and Water exist within the Red Lion Creek and its adjacent lands. Impact to these wetlands and waters features require a Wetlands and Subaqueous Lands permit from DNREC. This permit will require an Erosion and Sedimentation Plan, project description, impact description, and property owner verification. Equivalency with these regulations will be met in order to meet the guidelines established for the protection of aquatic life.	7 DE Admin. Code 7401, 7502 and 7504

EPA establishes standards for recordkeeping and reporting of hazardous waste for hazardous waste generators, treatment, storage, and disposal facilities. Application submittal entails completing the Hazardous Waste Part A Permit Application for facility-specific information and the RCRA Subtitle C Site Identification Form EPA Forms 8700-12, 8700-13 A/B, 8700-23 OMB# 2050-0024 (Site Identification Form) for detailed site-specific information, such as geologic, hydrologic, and engineering data. Forms are submitted to EPA.

The submittal of the Hazardous Waste Part A Permit Application requires the following items:

- Item 1 – Facility Permit Contact
- Item 2 – Facility Permit Contact Mailing Address
- Item 3 – Facility Existence Date
- Item 4 – Other Environmental Permits (permit type, permit number, and description)
- Item 5 – Nature of Business
- Item 6 – Process Codes and Design Capacities
- Item 7 – Description of Hazardous Wastes (EPA hazardous waste number, estimated annual quantity of waste, unit of measure, and processes)
- Item 8 – Map (USGS 7.5 min topographic map with extents at least 1 mile beyond the property boundary. Map must show property boundary, serial number of each proposed intake and discharge structure, hazardous waste management facilities, processes identified by process code, underground injection well locations, all spring and surface water bodies in the area, all drinking water wells within a quarter mile of the facility that are identified in the public record or otherwise known, map scale, meridian arrow, direction of current, direction of ebb, and flow of tides.)
- Item 9 – Facility Drawing (Property boundaries; areas occupied by all storage, treatment, or disposal operations that will be used during interim status; the name of each operation; areas of past storage, treatment, or disposal operations; areas of future storage, treatment, or disposal operations; the approximate dimensions of the property boundaries and all storage, treatment, and disposal areas; and process codes listed in Item 6 to indicate the location of all storage, treatment, and disposal areas.)
- Item 10 – Photographs including all existing structures; areas for storage, treating, or disposing of hazardous wastes; and all known sites of future storage, treatment, or disposal operations. Each photograph must have the date it was taken and identify the process codes listed in Item 6 to indicate the location of all storage, treatment, and disposal areas.
- Item 11 – Comments.

The U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Services (NMFS) will need to be consulted to receive clearances with respect to project activities and potential impacts to species of concern under their respective jurisdictions. To date, “Information for Planning and Consultation” (IPaC) online environmental review tool was completed for the project on December 1, 2023, and updated on June 13, 2024. Additionally, online NMFS Essential Fish Habitat (EFH) data were accessed. The results of these inquiries are discussed in Section 3.5. Draft letters of consultation are provided in Appendix B.

Additionally, DNREC clearance with regards to species of concern is needed.

The initial December, 2023 IPaC was submitted to DNREC Wildlife Species Conservation and Research Program to request an environmental review on March 20, 2024 (see Appendix B). A response has not yet been received. The DNREC letter needs to be updated and will be resubmitted after submittal of the USFWS and NMFS letters.

Wetland and stream impacts within the Site would typically be regulated by the USACE. The project is expected to qualify for a Nationwide Permit 38 (Cleanup of Hazardous and Toxic Waste). The project components would need to be consistent with substantive permit requirements. As this remedial action is itself mitigation of an impact with no net loss of wetlands and an improvement of function, it is not expected that a mitigation plan is needed. Further coordination with the USACE will be necessary to determine the extent of permitting and the necessary permit components.

DNREC regulates impacts to tidal wetlands and tidal and non-tidal waters of the State of Delaware, including wetlands that include 400 or more contiguous acres. State Wetland Maps indicate that wetlands mapped as “marsh” and “water” exist within the Red Lion Creek and its adjacent lands. Impact to these wetlands and waters features require a Wetlands and Subaqueous Lands permit from DNREC. Substantive permit requirements will be met. DNREC will require a review of these materials in coordination with EPA and permit material will be provided. Materials to be provided will consist of:

- Erosion and Sedimentation Plan
- Project description
- Impact description
- Alternatives considered
- Restoration plan
- Environmental evaluation of the wetland and its value; habitat; aesthetics; supporting facilities; neighboring land uses; consistency with federal, state, regional, county, and municipal comprehensive plans; economic impact

- Property owner verification

A floodplain permit will be required from the New Castle County Department of Land Use for all excavation activities that take place in the floodplain and substantive permit materials consistent with this permit will be provided to EPA. Portions of the Site are within the Federal Emergency Management Agency (FEMA) Mapped Zone AE (EL9 and EL10), which is considered the limits of the 100-year flood. Portions of the Red Lion Creek are within the Limit of Moderate Wave Action (LiMWA). A tide gate is located on the Red Lion Creek between the Site and the Delaware Bay.

A 2022 Construction General Permit will be required by EPA. A Stormwater Pollution Prevention Plan (SWPPP) will be prepared for the Site, with standards and specifications for erosion and sediment control and post construction stormwater management best management practices (BMPs), including operation and maintenance of those BMPs, and kept up to date throughout construction. The SWPPP will be submitted along with a Notice of Intent to EPA for approval prior to construction activities.

3.5 Environmental and Sensitive Receptor Protection

Environmental receptors include the surrounding wetland complexes, Red Lion Creek and its tributaries, woodlands, and the wildlife communities that reside in these habitats. Sensitive ecological receptors may be particularly amenable to the project site due to its secluded nature. As outlined below, measures have been and will continue to be taken to identify and protect sensitive receptors and their habitats.

An updated IPaC dated June 13, 2024, was generated to identify federally listed threatened and endangered, proposed, and candidate, species that may occur within the boundaries of the project or those that may be impacted by the project. The updated IPaC (Appendix B) indicates the federally threatened bog turtle (*Glyptemys muhlenbergii*); federally endangered northern log-eared bat (*Myotis septentrionalis*); federally proposed endangered tricolored bat (*Perimytosis subflvus)*; nd candidate species monarch butterfly (*Danaus plexippus*) are known to occur near the project site. USFWS National Wildlife Refuge Lands and Fish Hatcheries were not identified.

While no USFWS-designated Critical H abitats for any of the species were identified in the IPaC, suitable habitats may be present and additional assessments will be performed to evaluate potential project impacts to habitat.

The IPaC noted several NWI wetland community types that could be in the project area and potentially habitat for bog turtles. BBog turtles reside in primarily open wetlands dominated by sedges. By answering online questions on IPaC determination keys a technical assistance letter for USFWS Northeast Region species was generated that provided a “may affect” determination for the bog turtle. Further consultation with USFWS and DNREC, in combination with wetland delineations of the project area, will evaluate the nature of any project impacts to the bog turtle.

The monarch butterfly is a species whose numbers have been declining in recent years due to a mix of habitat loss resulting from herbicide use as well as widespread pesticide use. The Site is known to contain milkweed, the monarch butterfly's primary food and breeding habitat. Although this habitat will be temporarily impacted during the construction of the project, reseeding the Site with native herbaceous plants, including milkweed, will restore the habitat to its existing state.

While the original and updated IPaCs do not list specific migratory birds that may be in the project area, it does note that project-related impacts to migratory birds and eagles need to be evaluated and measures be implemented to avoid or minimize potential project-related stressors. USFWS conservation measures developed by its migratory bird program to reduce impacts to birds and their habitats will be reviewed and implemented, as needed, to protect migratory birds if nests are located within a to-be-established buffer. Similarly, the USFWS northeast bald eagle management guidelines will be reviewed and implemented, as needed, to protect eagles if a nest is identified within 660 feet of the project. Seasonal time-of-year restrictions on construction may be needed.

The IPaC does not address sensitive ecological receptors under the jurisdiction of NOAA-NMFS. NMFS will require consultation to determine the impact the project may have on Essential Fish Habitat. The project is located within Essential Fish Habitat for the Atlantic Butterfish (Larvae, Adult), Bluefish (Juvenile, Adult), Black Sea Bass, Longfin Inshore Squid (Eggs), Scup (Juvenile, Adult), and Summer Flounder (Juvenile, Adult). The Red Lion Creek is also within the Shortnose Sturgeon Consultation Area and the Atlantic Sturgeon Consultation Area. A draft consultation letter to NMFS is provided in Appendix B

The Site in 003626 a primarily industrial area close to the Delaware River. The Red Lion Creek and agricultural fields lie to the north of the Site. A mixed use of industrial, open water and marsh and a large electric substation lies to the east of the Site adjacent to the Delaware River. An extensive industrial complex lies to the south of the Site. Agricultural land interspersed with woodlands, streams, and wetlands lies to the west of the Site. The closest sensitive receptor lies approximately 4,500 feet to the west in the form of a mixed community of residential and commercial properties. This community begins just to the west of South DuPont Highway. A childcare center, two religious centers, approximately four residences, and two commercial properties lie adjacent to the highway and are the closest sensitive receptors to the site. These receptors are located far enough away that the noise of construction will be negligible. The odors generated during construction may be noticeable during certain activities, and efforts will be made to control the odor (see Section 7.0). There are no hospitals, elderly housing, or convalescent facilities within the vicinity of the Site. A school is located approximately 8,000 feet to the southwest of the Site adjacent to two large housing developments. These residences and the school are believed to be far enough away that the construction will not affect these sensitive receptors.

4 Pre-Design Investigation

4.1 Wetlands and Vegetation Surveys

A Site survey was conducted from August 28 through September 29, 2023, by AECOM wetland scientists to evaluate the Site for the presence of wetlands and watercourses. Vegetation, soil, and hydrology were sampled to identify wetland characteristics as described in the *Corps of Engineers Wetlands Delineation Manual* (USACE, 1987) and the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region*, Version 2.0 (USACE, 2010). Watercourses were identified by a defined streambed and bank; hydrologically sorted substrate material; observable dimensions, pattern, and profile; and the presence of an ordinary high-water mark. The project site drains to the Red Lion Creek, which is within the Red Lion Creek-Frontal Delaware River Watershed (HUC 020402050703). The portion of the Red Lion Creek within the project area is mapped as a FEMA 100-year floodplain.

Field delineations resulted in the identification of five wetlands totaling 55.16 acres and 14 watercourses totaling 7,653 linear feet. Of the five wetlands, four were categorized as palustrine emergent (PEM) and one as a combination of PEM and palustrine forested (PFO). Of the 14 watercourses, 5 were categorized as ephemeral, 7 as intermittent, and 2 perennial.

The *Wetlands and Other Waters of the U.S. Delineation Repor*t can be found in Appendix C.

In addition to the wetlands/waters delineation a vegetations survey was performed to identify vegetative communities and their species composition. Data were collected along seven transects across the Site and included the species, height, growth habit, health, and percent cover of the vegetation. These data were used to map the communities and vegetation cover types across the parcel. The Vegetation Survey Report is provided in Appendix D. The project site consists of 10 vegetative communities. These vegetative communities consist of mixed hardwood forest, emergent wetland, meadow, open water, forested wetland, maintained right-of-way, agricultural field, scrub shrub, a maintained landscaped area, and urban areas.

Historical data on community composition and habitat structure will be used, in combination with this vegetation survey, to target a restored community that reflects pre-release conditions as much as is practicable. Reference areas will also be used to replicate wetland elevations that support target wetland types. Although the restoration plans will not include non-native species currently existing within these communities, alternative species will be chosen to appropriately restore a native community that appropriately represents the pre-release community as much as possible..

4.2 Aerial and Topographic Survey

Aerial topographic survey and supplemental ground survey to support aerial survey compilation were completed for +/-181 acres of the site encompassing the upland, Western Drainage Gully, western wetlands, northern wetlands excavation areas and adjacent wetlands, and former operating area including the OU3 cap area and extending out to Governor Lea Road. Aerial survey (high definition Light Detection and Ranging [HD-LiDAR]) data of the Site captured on March 4, 2022, by Surveying And Mapping, LLC, formerly AXIS GeoSpatial, for VanDemark & Lynch, was purchased by AECOM and used to create 30 scale planimetric base mapping to include a digital terrain model with 1-foot contours, 0.1-foot spot elevations, in AutoCAD/Civil 3-D format. AECOM performed a ground survey to identify physical features that needed further clarification, identification, or survey accurate elevations, along with additional ground truthing in areas identified as “Obscured.” AECOM also prepared a property boundary retracement survey.

An environmental and wetlands survey was completed to record the locations of wetland delineation and boundaries of Waters of the United States, upland points of interest, and mudflats transition topography. Additionally, survey points were collected at grade changes and flagged intervals along the western stream, running between the top of banks and including the bottom of banks and the centerline/flow line of streams at their lowest point to develop cross sections. Data for seven transects totaling 5,547 feet were collected to support the Site restoration design. Three staff gauges with transducers were also installed in Red Lion Creek.

A bathymetric survey is ongoing for the areas of Red Lion Creek from Route 9 west to the Site limits where accessible by ground personnel or electric propelled boat, and equipped with single beam, survey grade sonar, paired with VRS GPS. Horizontal and vertical coordinate information is being collected on a 10-foot grid. Existing water levels less than 1.5-foot depth, the minimum depth required for Sonar and boat operation, combined with deep mud and weather conditions have impeded the bathymetric survey.

Survey work was supervised by a Delaware Licensed Surveyor and completed in the Delaware State Plane coordinate system NAD83 (2011-epoch 2010)/NAVDg(Geoid 18). The survey of existing conditions is depicted on Sheet V-01 in Appendix K.

4.3 Data Gap Investigation

The data gap investigation was performed at the site between November 6, 2023, and January 23, 2024. A total of 25 locations were sampled via hand augur or direct push drill rig within the Western, Northern, and Upland areas of OU2, with depths ranging from 0 to 20 feet bgs. The sample locations are shown in Figure 2 in Appendix A, Data Gap Investigation Technical Memorandum. Though the full analyte list varied depending on sample depth and location, samples were analyzed for VOCs, SVOCs, PCB homologs and Aroclors, Total Metals, Chromium (III)/Chromium (VI) speciation, Loss on Ignition, heating value (BTU), and proximate/ultimate analysis.

The goal of this sampling event was to assess the final total volume of contaminated material, delineate horizontal and vertical remedial extent, define chromium speciation throughout the OU2 area, and identify soils for Treatability Studies testing. Overall, this investigation found that average site total benzene and chlorinated benzene (TBC) concentrations are similar in concentration and geographical area to those found in historical events, with the average TBC concentration at 4,011 mg/kg, and the main affected volumes present in the Western Wetland north of the containment berm. Discrete interval maxima, however, exceed historical values by an order of magnitude; historical TBC maxima were under 17,000 mg/kg, and the peak exceedance witnessed during this investigation was 176,895 mg/kg. Total chromium contamination was universal through every sample analyzed for metals, though it can be stated that total chromium elevations are due solely to Chromium (III), as all samples analyzed were non-detect for Chromium (VI). Upland areas previously remediated during OU3 operations were found to be relatively free of organic contamination, excluding deeper intervals from 6 to 7 feet bgs.

A more detailed account of the methods, rationale, analytical data, and findings is available in Appendix A.

4.4 Geotechnical Investigation

The geotechnical subsurface investigation was performed at the site between December 5, 2023, and January 3, 2024. A total of 10 borings were drilled to depths of 16 feet to 47 feet bgs. Standard penetration tests (SPTs) were performed during drilling and samples were collected for classification and laboratory testing. Seven borings (GT-01, GT-02, GT-03, GT-03A, GT-04, GT-06, and GT-08) were drilled in the wetland and western gully areas, and three borings (GT-05, GT-07, and GT-10) were drilled in the upland areas. GT-09 was canceled. Boring locations are shown in the Figure 2 in Appendix E Geotechnical Investigation Technical Memorandum.

The selected samples were transported to the soil laboratory, GeoTesting Express, Inc., in Acton, Massachusetts and tested for soil index, compaction shear strength, and consolidation properties. The laboratory test results are included in Appendix E Geotechnical Investigation Technical Memorandum.

Table 4-1 summarizes the subsurface stratigraphy at the site based on findings from the geotechnical subsurface investigation.

Table 4-1: Summary of Subsurface Stratigraphy Based on The Geotechnical Investigation

Ground Cover / Stratum	Encounter Location	Description
Ground Cover	—	Approximately 4 inches of topsoil was noted at the surface of boring GT-05 which was drilled in the wooded area. In other borings drilled in the wetland, western gully, or graded areas, topsoil was not noted. However, type and thickness of ground cover can vary across the project site due to existing structures and trees on the site. It should be noted that the topsoil depths mentioned herein should not be considered as stripping depths as there may be locations around the site that may have larger or smaller thicknesses of topsoil.
Stratum A - Fill	—	Fill material was not noted in the borings. However, considering the previous construction and earthworks at the site, fill materials may be encountered in other locations of the site.
Stratum B - Marsh Deposits (Organic-rich, peaty soils)	Borings drilled in wetlands and Western Drainage Gully	Very soft to soft, Organic Silt (OH), Organic Clay (OH), Elastic Silt (MH), Sandy Elastic Silt (MH), Silt, (ML), Lean Clay (CL), Lean Clay with Sand (CL) with varying organic contents and interlayered fibrous peat soils. Very loose Clayey Sand with Gravel (SC) in GT-04. Range of N-Values: 24-inch penetration with Weight of Rod (WOR/24") to 2 blows per foot (bpf)
Stratum C - Columbia Formation	Borings drilled outside of wetlands and Western Drainage Gully	Very loose to medium dense, Poorly Graded Sand with Clay (SP-SC), Poorly Graded Sand with Silt (SP-SM), Poorly Graded Sand with Gravel (SP), Silty Sand (SM), Silty Sand with Gravel (SM). Sandy Lean Clay (CL) and Lean Clay (CL) at the surface of GT-07 and GT-10, respectively. Range of N-Values: 3 bpf to 23 bpf
Stratum D – Potomac Group (Lean Clay with higher consistency)	Only in GT-03A at a depth of 38 feet bgs	Medium stiff to stiff, Lean Clay (CL), with reduced organics and interlayered Clayey Sand (SC) and Fat Clay (CH). Range of N-Values: 5 bpf to 16 bpf

Auger refusal or bedrock was not encountered during our subsurface investigation. Groundwater was encountered at the ground surface of borings GT-01, GT-02, GT-03, GT-03A, GT-04, GT-06, and GT-08 which were drilled in the wetlands and drainage gully. Groundwater was also encountered in GT-10 at 14 feet bgs during drilling, but not encountered in borings GT-05 and GT-07. The groundwater observations are as indicated on the soil test boring logs included in Appendix E Geotechnical Investigation Technical Memorandum.

4.5 Treatability Studies

Several phases of treatability studies were planned to collect data necessary for the RD as described in the following paragraphs. Additional information on treatability study objectives and design are available in the Treatability Study Work Plan (AECOM, 2023b).

- Phase 1A – LTTD Bench Scale Study: Intended to select a treatment temperature for bulk soil treatment and remedial design deliverables by desorbing site soil samples at multiple temperatures. This thermal approach will examine the ability to achieve PRGs for VOCs and semi-volatile organic compounds (SVOCs) at a lower soil target treatment temperature applied over a longer treatment period.
- Phase 1B – Dewatering Bench Study: Dewatering via mechanical means will be evaluated as a pretreatment measure to enhance the efficiency of LTTD in the remedial design.
- Phase 2 – Off-site Thermal Treatment: A bench study will be conducted to select a treatment temperature for bulk soil treatment and remedial design parameters. This thermal approach will achieve PRGs for VOCs and SVOCs at a high soil target treatment temperature over a very short duration. Then, the bulk soil (two 15 cubic yard batches) required for subsequent treatability phases (soil stabilization and biobarrier studies) will be treated at the fixed facility at the established soil target treatment temperatures to produce treated material for subsequent bench studies.
- Phase 3 – Soil Stabilization Bench Study: This study is designed to test various metal stabilization agents in binding leachable metals and inorganics.
- Phase 4 – Biobarrier Bench Study: This bench study tests multiple microcosm compositions with varied electron donors and solids composition by bioaugmenting the thermally treated, stabilized soils with dehalogenating bacteria culture and amending the soils with granular activated carbon, organic matter, and commercially available materials.
- Phase 5 –Biobarrier Field Pilot: This field pilot is designed to test the efficacy of the highest performing bioreactive components from the biobarrier bench study in-situ and inform the final biobarrier design.

Phase 1A and Phase 1B tests are in progress. Available information from these tests are included in Appendix F and Appendix G, respectively. Due to excessive clay content, the Phase 2 off-site thermal treatment cannot be run without adding amendments such as lime kiln dust or Calcement. AECOM is determining the potential impact of these amendments on subsequent studies. Phase 2 and subsequent studies will proceed once this determination is made. Data from these studies is expected to be included in the Pre-Final/Final Design.

5 Development of Soil Excavation Boundaries

5.1 Contaminant Modeling in Earth Volumetric Studio

AECOM prepared a model of contaminant extent using Earth Volumetric Studio (EVS), formerly Environmental Visualization System software by C Tech Development Corporation. Analytical data used in the model were obtained from 2003 to 2004 metals data and a 2013 to 2014 RockWorks® database provided by EPA. These data were supplemented by 2023 data gap sampling event results conducted by AECOM. Lithology information was exported from the RockWorks ® database file and supplemented with geotechnical borings, data gap samples, and treatability study samples collected by AECOM in 2023.

Data used in the evaluation were filtered to include only COCs with remedial action level, cleanup criteria, and saturation concentrations for material indicative of DNAPL as summarized in **Table 3-1**. Speciation of chromium was completed; however, hexavalent chromium was not detected at the stated reporting limit. Duplicate samples and samples located significantly outside of the modeling boundary (background conditions sampling points), upgradient sampling locations, and locations not representative of a contamination source were excluded from interpolation. Data were assigned to the midpoint of the sampling depth for modeling. The model used an interpolation method called kriging to generate 3-dimensional fields that define the model output as digital solids. Kriging is a statistical method that estimates or interpolates values based on changes in spatial variance between data sample locations. Kriging is a standard method for generating 2- and 3-dimensional models. The solids can be used to calculate volumes and areal boundaries.

The modeling boundary was established using the delineated wetlands boundary with modifications to capture upland areas containing analytical results exceeding the remedial criteria. EVS interpolates beyond this boundary; however, only model outputs within this area are displayed. Constraining points were applied along the 10-foot elevation contour line north of the berm and at the wetland boundary south of the berm, at every 2 -foot depth interval up to 33 feet bgs to prevent an unrepresentative output.

Outputs from the EVS model were imported into Autodesk Civil 3D and are presented in **Figure 5-1** and Sheets C-02 through C-06 in Appendix K. In subsequent design phases, the depth dimension will be depicted, and these outputs will be used to generate excavation prisms for construction.

5.2 Areas/Volumes

The excavation boundary for the top 2 feet of sediment within the wetlands was delineated where the sum of the concentrations for the COCs identified in Section 3.2.1 exceeded the RAL of 33 ppm. Hexavalent chromium was not detected at the stated reporting limit and therefore does not contribute to the excavation boundary and volume. The top 2 feet of wetlands excavation boundaries are shown on Sheet C-02 in Appendix K. The excavation boundary represents approximately 222,627 square feet and an estimated sediment volume of 13,893 cubic yards.

The excavation boundary below 2 feet within the wetlands was delineated based on the saturation concentrations indicative of PTW or potential DNAPL presented in Section 3.2. The wetlands excavation boundaries below 2 feet bgs are shown on Sheets C-03, C-05, and C-06 in Appendix K. The excavation boundary represents approximately 138,718 square feet and an estimated soil volume of 61,790 cubic yards. Approximately 63% of the volume below 2 feet within the wetlands is located at a depth greater than 10 feet bgs.

As modeled by EVS, there is approximately an additional 31,277 cubic yards of soil below the criteria that will need to be excavated above the 75,681 cubic yards of soil above the criteria within the wetlands. The average contaminant concentration of the material below 2-feet depth but overlying the PTW is approximately 49 ppm. The potential consideration to use the soil below the remedial criteria as direct backfill below 2 feet versus sending for thermal treatment will be evaluated and discussed with EPA and the U.S. Army Corps of Engineers (USACE) during subsequent design development.

Three upland areas where known waste storage and spill impact occurred were prescribed to be excavated to a depth of 7 feet bgs. The two northern upland areas were historically used as waste stockpile areas. The third upland area is an existing drainage feature located south of the other two upland areas and is designated as the Western Drainage Gully. The prescribed boundary of the northern-most upland area was expanded eastward based on the sample results obtained during the data gap investigation. The upland excavation boundaries are shown on Sheets C-02 and C-03 in Appendix K. Excavation areas will be field verified for construction practicality. The northern-most upland area is 10,762 square feet and represents an estimated soil volume of 2,812 cubic yards. The second upland area is 15,633 square feet and represents an estimated soil volume of 4,047 cubic yards. The Western Drainage Gully area is 25,720 square feet and represents an estimated soil volume of 6,697 cubic yards.

The quantities indicated represent the minimum excavation of the modeled impacted soil exceeding the remedial criteria. Excavation prisms representing construction considerations will be developed and the associated excavation areas and volumes will be revised during the subsequent design phases. A summary of the estimated excavation quantities is presented in **Table 5-1**.

Table 5-1: Estimated Excavation Volumes

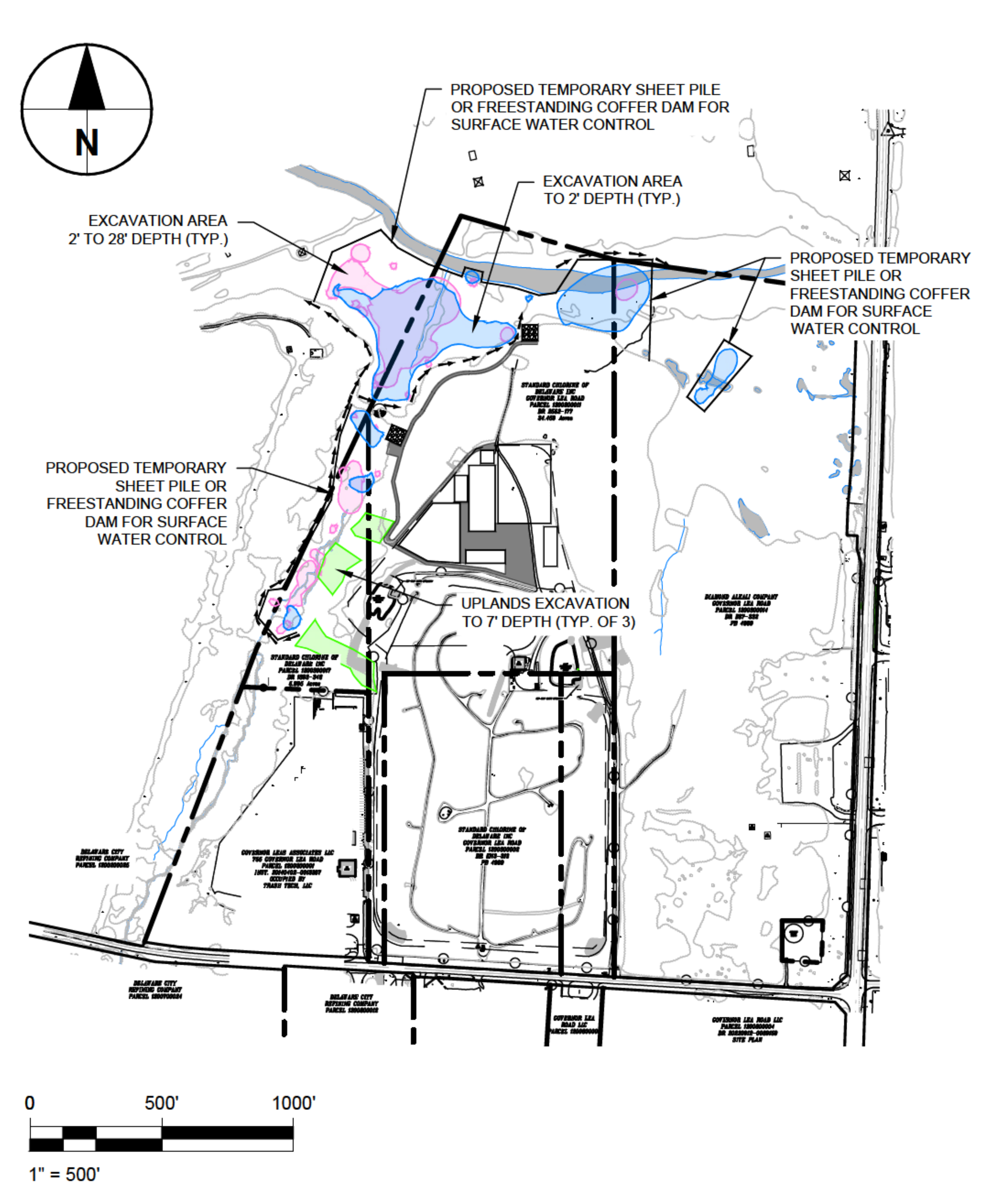
Area Description	Volume (cubic yards)
Wetland soils 0 to 2 feet above criteria	13,891
Wetland soils >2 feet above criteria	61,790
Upland areas	13,556
Soils below the criteria	31,277
Total vertical soil volume	120,514
Total with 25% contingency for excavation lines/regular shapes	150,000 (approximate)

5.3 Mass Estimate (for chlorobenzenes)

AECOM calculated the mass of the combined chlorobenzene constituents exceeding the saturation concentrations indicative of PTW or potential DNAPL segregated by depth from 2 to 10 feet and below 10 feet. Further segregation of mass was determined between the portions north and south of the separation berm in the wetlands. Approximately 156 tons of chlorobenzene constituents indicative of DNAPL is located in the depth between 2 and 10 feet and approximately 272 tons is located below a 10-foot depth. The distribution of chlorobenzene constituent mass is summarized in **Table 5-2.** Approximately 64% of the chlorobenzene constituents' mass below 2 feet within the wetlands is located at greater than a 10-foot depth north of the berm.

Table 5-2: Distribution of Total Benzene and Chlorinated Benzene Compounds (TBC) Mass

Location	Depth (feet bgs)	Volume (cubic yards)	TBC Mass (tons)	Cumulative TBC Mass (tons)	Percent of Total Mass
Upland Areas	0-7	13,556	0.01	0.01	0%
Wetlands	0-2	13,893	11.8	11.81	2.7%
Wetlands	2-10	20,514	155.7	167.51	37.9%
Wetlands	10-15	15,390	174	341.51	77.3%
Wetlands	15-20	10,557	76.2	417.71	94.6%
Wetlands	20-25	7,668	18.3	436.01	98.7%
Wetlands	25-30	4,541	5.2	441.21	99.9%
Wetlands	30-35	386	0.4	441.61	100%
			Total Calculated COC Mass		**429.7**



OPERABLE UNIT TWO (OU2)
STANDARD CHLORINE OF
DELAWARE SUPERFUND SITE
NEW CASTLE, NEW CASTLE COUNTY,
DELAWARE

FIGURE 5-1
OVERVIEW OF EXCAVATION AREAS

AECOM
248 CHAPMAN ROAD, SUITE 101
NEWARK, DELAWARE 19702
302.318.2872 TEL
WWW.AECOM.COM

6 Preliminary Process Flow

The 2022 ROD for the Site calls for excavation of contaminated soil and treatment on-site using Low LTTD. Treated material will be tested to ensure the achievement of RGs defined in the ROD Amendment (EPA, 2022). Treated material will be used to backfill the areas that were excavated. In the wetland, the final 2 feet (approximate) of backfill material will be blended with organic matter and bioaugmented GAC. This bioaugmented GAC will include the addition of microbes that are capable of degrading the organic contaminants present in groundwater. If concentrations of metals in this upper layer are detected at concentrations that exceed ecotoxicity concentrations, the material shall be blended with a metal stabilization agent. Creating a bioreactive zone (biobarrier) on the surface of the wetland will provide for long-term permanence of the remedy via bioremediation of residual contamination from upwelling groundwater.

As further discussed in Section 8, the LTTD process has two possible options: (1) LTTD using an on-site rotary kiln and (2) LTTD using on-site soil pile heating. Overall remedial processes for the Site, with these two primary options are depicted in Drawing G-03 and Drawing G-04 (Appendix K), respectively. These process graphics will be revised with additional details when treatability studies are completed, and as the process options are narrowed down in the design development process.

6.1 Sequence of Activities

The following is a preliminary sequence of activities expected to be carried out to achieve OU2 RAOs and remediation goals. This sequence will be updated as additional analyses are completed and as process options are finalized during design development.

- Site preparation: The following site preparation activities are anticipated to facilitate excavation of contaminated soils from the wetlands, and transport of excavated soils to upland staging and treatment areas for further management/treatment:
- Wetland areas:
  - Install turbidity controls in Red Lion Creek and erosion and sediment controls as needed.
  - Remove phragmites and/or control their growth in the excavation areas to prevent organic content of excavated soils and potential for future regrowth following restoration.
  - Install sheeting/shoring to support excavations deeper than 10 feet. As discussed in Section 5.0, PTW were detected as deep as 30 feet below grade.

- Install flood protection and channel bypass in the wetlands areas immediately adjacent to and partially encroach into the channel of Red Lion Creek as described in Section 7.3.
- Install excavation dewatering systems as needed.
- Install stormwater run on and runoff controls and systems to manage stormwater entering the excavations.

- Upland areas:
  - Install erosion and sediment controls in accordance with DNREC Title 7, Section 5101 Sediment and Stormwater Regulations.
  - Install utilities (electric, gas, water/sewer) needed for LTTD treatment process, water treatment, off-gas treatment, and discharge of treated water.
  - Improve existing aggregate haul roads to facilitate transportation of excavated sediment and soil to the treatment area.
  - Construct material loading/unloading areas, staging areas, sediment dewatering areas, treatment pads, and decontamination pads.
  - Mobilize and install all equipment needed for treatment.
  - Install material conveyance structures such as enclosed conveyors (as needed).
  - Install a temporary fabric structure to enclose untreated soil staging areas to prevent fugitive vapor emissions. Install air handling system to collect and treat vapor from the fabric structure.
  - Install a water treatment system to treat water collected from excavation dewatering, any stormwater runoff collected from material handling areas, and water produced from sediment dewatering operation.
- Site-wide
  - Mobilize odor/vapor monitoring and controls prior to beginning any excavation and handling of any contaminated materials on site.
  - Install additional security measures such as temporary construction fences to enclose excavation and staging areas outside of the existing fenced areas.
  - Separate phragmites root mat from soil intended for treatment, stage on site for composting and further management or transport off site for disposal.
  - Excavate an estimated 150,000 cubic yards of sediments and soils exceeding 33 mg/kg RAL from wetland and upland excavation areas organized in pre-determined

cells. Pending further evaluation, it is estimated that the excavation production rate of approximately 650 cubic yards a day.

- Transport excavated sediment/soils to upland staging/treatment areas.
- Screen/dewater/amend soils as need to be processed using LTTD using a rotary kiln. Dewatering and amendment would not be needed for soils, if treated using soil pile heating process.
- Collect and convey co-produced water from the dewatering process or from the underdrains in the soil pile for treatment and disposal.
- Collect and treat off-gas produced by the LTTD process for the duration of LTTD operation. Off-gas treatment is expected to include a baghouse to remove particulates, a thermal or catalytic oxidizer to treat the vaporized contaminants, followed by a wet scrubber to remove acid gases.
- Operate LTTD process to treat sediment/soil. Collect one sample from each 500 cubic yards of treated soil to ensure the soil meets the RGs established for the organic COCs. Re-treat and re-sample soils not meeting the RGs until treatment is complete.
- Move soils meeting the RGs to cool and further process or backfill the excavation.
- Backfill and compact each excavation cell to approximately two feet below final grade. Off-site backfill may be needed to offset the loss of soil volume resulting from the organic content burn off during the LTTD process.
- Mix pre-determined metals stabilization compound into cooled soils if sampling results indicate that metal stabilization is required for soils to be used in the installation of a biobarrier in the top 2 feet of the excavation.
- Mix pre-determined quantities of organic material and bioaugmented GAC amendments into metals-stabilized soils to prepare for installation of a biobarrier in the top 2 feet of the excavation.
- Backfill and compact the amended soils in the top 2 feet of the excavation to form the biobarrier. Complete wetland restoration in accordance with the approved restoration plan and stabilize the graded surfaces with approved vegetation.
- Demobilize remaining equipment and materials from wetlands, and remove all temporary controls (e.g., sheet piling, flood protection, turbidity curtains) upon achieving proper stabilization.
- Decontaminate and demobilize all equipment, deconstruct equipment pads, and restore the upland portion of the Site in accordance with the upland restoration plan.

– Institute the Long-term Operations, Maintenance, and Monitoring Plan (this plan will be developed in the Pre-Final/Final Design).

6.2 Design Elements

The foregoing discussion identifies the following design elements for further design development:

- Site preparation
- Thermal treatment process
- Metals stabilization and backfilling
- Biobarrier
- Residuals management
- Restoration design
- Baseline and performance monitoring Plan

The Preliminary Design stage analysis for these elements is addressed in the following sections.

7 Site Preparation – Basis of Design

This section describes the design basis, assumptions, and technical considerations for the Site work to support the excavation and treatment activities, comply with regulatory requirements for stormwater and erosion control, minimize impact to adjacent land use and occupant activities, and implement construction industry standards and methods.

7.1 Phragmites and Root Mat Removal

Most of the wetlands are covered in vegetation, which includes large, dense stands of Phragmites (*Phragmites australis* subsp. *Australis*). Given the potential detrimental impacts to the thermal treatment process, the biomass and root mat will need to be managed, removed, and separated from the sediment and soil. A combination of methods to accomplish the phragmites, and root mat removal will be considered.

Control measures for Phragmites typically include the following methods:

- Burning: Using prescribed burns to remove Phragmites stands.
- Mechanical cutting and root removal: Mowing the Phragmites followed by digging out the roots and rhizomes to help prevent regrowth and disrupt the plant’s spread.
- Herbicide application: Spraying with herbicides approved by EPA for use in wetlands often sprayed from helicopters when Phragmites have colonized large areas.
- Flooding: Secondary method following mowing or burning of Phragmites stands to help control regrowth and encourage native plant recolonization. Flooding will not likely be practicable for this project.

Prescribed burns reduce the density of Phragmites and prevent its spread. Trained professionals with expertise in wetland management conduct prescribed burns usually during late summer or early fall when the reeds are dry. Prescribed burns require proper planning, safety precautions, and consideration of ecological impacts. The fire consumes the above-ground vegetation, including the dry reeds. The primary benefit of burning with respect to this project is the reduction of biomass that requires separation from the thermal treatment stream. The other typical benefits of controlled burning, including improving space for native plant species growth, improving habitat conditions for wetland fauna, and enhancing wetland health and biodiversity, will not be realized due to the ultimate excavation of the underlying soils. Following the burn, the Site will need to be monitored for regrowth prior to commencement of excavation activities.

Mechanical removal is conducted through the cutting of Phragmites by large (e.g., Truxor, Marsh Master) or small (e.g., weed whacker) mechanical equipment. This control method is effective with dense hard-to-access stands and can be used as a preparatory step for other control methods. This method does not reduce the amount of biomass that needs to be managed either on Site or removed for disposal.

Herbicide application is commonly used and has a high success rate. Herbicides approved for wetland use, such as Rodeo® (53.8% glyphosate), are sprayed or hand applied on Phragmites stands. This method does not reduce the amount of biomass that needs to be managed either on Site or removed for disposal. Herbicide application typically requires multiple applications over an extended period to eradicate well-established Phragmites stands, which could impact the effectiveness with respect to this project's schedule.

Disposal of the biomass and root mat can be accomplished by burial, stockpile composting, burning, or transporting to a designated disposal facility. Effective burial requires a minimum of 27 inches of soil over the Phragmites and the sediment must be dry to prevent the Phragmites from re-sprouting. Burial within the deeper excavations within the wetlands should be considered for disposal provided the biomass and root mat meets the remedial criteria and burial is acceptable to EPA.

Compost stockpiling will require the biomass and root mat to be removed from the wetland and placed in a dry area to prevent re-sprouting. The stockpiles should be placed on a clean aggregate pad and covered to keep the piles dry. Placing the material in piles and crushing the stems with equipment will accelerate decomposition. The decomposed material would be sampled for conformance with the treatment criteria and disposed of on the Site or at an approved disposal facility.

Phragmites control and disposal options will be evaluated further in subsequent design phases.

7.2 Excavation Support System

As indicated by the EVS model, most of the excavation for chlorobenzene constituents within the wetlands is located at greater than a 10-foot depth. Maximum indicated excavation depths could approach 30 feet bgs. Based on the geotechnical investigation (Appendix E), Stratum B is expected to be encountered throughout the excavation depth within the wetland areas. Stratum B consists of soft marsh deposits with varying amounts of organic material and interlayered peat soils. Surface water and groundwater is expected to be present throughout the depth of excavation in the wetlands.

The excavation contractor, as part of its means and methods of construction, may consider the use of sheet pile support of excavations. Typically, sheet pile is advantageous for support of excavations because they can be installed before excavation begins, require minimal additional work during excavation, and allow safe excavation below the water level. Considerations for sheet pile support of excavations include the ability of the sheet pile to withstand all applied loads, the ability of the formation supporting the sheet pile to remain stable during construction, the ability to manage water entering the excavation, and appropriately sizing the excavation support area for the intended construction work.

Sheet pile support of excavation will typically retain marsh deposit materials with varying amounts of organic material and interlayered peat soils. However, due to the deep excavations potentially required and the low SPT standard penetration resistance values (N-values) observed, cantilever sheet pile support of excavation might not be feasible. Temporary sheet pile support of excavation might need to be designed to be braced or anchored for stability considerations.

Excavation to a depth of 10 feet below ground surface was successfully accomplished during collection of treatability sample material. Feasibility of excavation methods below 10 feet and excavation support will be further evaluated upon determination of design excavation depth. The potential for a test installation of sheet piling and excavation to depth will be considered for future design phases or as part of the SATOC seed task.

Excavation and grading at the Site must be performed according to the Occupational Safety and Health Administration (OSHA) guidelines and local code requirements. Where deep excavation is required for the proposed remediation, the contractor should provide adequate bracing or shoring systems to maintain safe work conditions. The actual means and methods of excavation support will be selected and designed by the contractor.

7.3 Protection from Flooding

Stormwater management for this project consists of collecting and redirecting runoff in a non-erosive manner from areas upland and upstream of the excavation areas to the downstream side of the excavation areas and the Red Lion Creek channel on the northern side of the wetlands. A portion of the wetlands excavation will be immediately adjacent to and partially encroach into the channel of Red Lion Creek, requiring isolation of that section of the creek and redirecting or bypass of the channel flow around the excavation area. The excavation contractor, as part of its means and methods of construction, may consider the use of sheet pile, freestanding temporary coffer dams, stream diversion channels, and construction of temporary berms to redirect surface water and stormwater away from the excavations. Design for the diversion of the Red Lion Creek, its unnamed tributaries, and drainage channels within the excavation area will be developed in subsequent design phases and performance and delegated design criteria for construction contractor selection of means and methods of construction will be included in the project specifications. Criteria for design components delegated to the remediation construction contractor will include that the design be signed and sealed by a licensed engineer and provided as a submittal for review prior to construction.

Additional stormwater and erosion control best management practices will be necessary to minimize runon into and runoff from the treatment process areas and material stockpiles. Stormwater management is not expected to be a concern for the linear construction of utility services and the water treatment conveyance piping installation due to the limited disturbance and intent to restore these areas to their pre-construction topography. Stormwater calculations will be completed during design development to assess the post-construction Site runoff conditions for the design storm events specified in the Delaware Sediment and Stormwater Regulations. The stormwater calculations will be completed using the Soil Conservation Service's hydrology models (TR-55) and Autodesk Civil Engineering Design hydraulics software (Hydraflow). Peak flows for the storm events will be computed with TR-55 and ditch computations calculated with Hydraflow.

The proposed conceptual design minimizes construction disturbance on the slopes transitioning from the upland former operating facility areas to the wetlands except for the three upland excavation areas. Construction activities on the slope will be limited to controlled access areas for equipment into the wetlands. If disturbance of the slope becomes necessary, erosion control blankets will be placed on each slope that is steeper than 25% (4H:1V) to control erosion until the vegetation is established. In addition, temporary erosion controls such as silt fence, diversion ditches/berms, and sedimentation traps will be used, as necessary, during construction. The erosion and sediment control measures will be selected in accordance with the BMPs specified in the *Delaware Erosion and Sediment Control Handbook* (DNREC, 2019). Routine maintenance of the vegetative cover is the only erosion control practice anticipated once vegetation is established.

Stormwater management and erosion and sediment control design will be presented in subsequent design submittals.

7.4 Excavation Dewatering

Based on observations during the geotechnical investigation, surface water and groundwater are expected to be present throughout the depth of excavation in the wetlands. Groundwater was observed at an approximate depth of 14 feet bgs in the uplands areas and is not expected to be encountered in the upland excavations. Perched water conditions might be encountered at different depths during construction, especially after periods of heavy rainfall.

Regional vertical groundwater gradients are downward to the upper Potomac aquifer. There is a horizontal gradient in the Columbia aquifer from southwest to northeast, towards Red Lion Creek. Groundwater is nearly at ground surface within the wetlands and is the surface expression of the shallowest aquifer. For excavations within the southwest portion of the wetlands, this is the Columbia water table aquifer within the Pleistocene Age Columbia formation. Permeability of the Columbia Formation is reported to range from 4 feet per day to over 50 feet/day (1.4E-3 to 1.8E-2 cm/sec). The area is generally underlain by the Upper Potomac confining unit. However, the consistency of presence, depth, and characteristics of the aquitard are unknown.

Excavations within the northern portions of the wetlands are within the floodplain of the Red Lion tributary channel and abut Red Lion Creek. Red Lion Creek is in an ancient erosional channel that is incised into the Potomac formation and is filled with post-Columbia formation alluvium, which consists of marsh mat interbedded with sand, silts, and clay. Unlike the southern portions of the wetlands, this location is not completely underlain by an aquitard and the total depth of the alluvial sediments was not determined during the geotechnical investigation. Wetland sediments are expected to have a low permeability (1 to 5 feet/day), but areas of Columbia and upper Potomac aquifer sands could be considerably higher (4 to 50 feet/day). In addition, areas where the Columbia and Potomac aquifer subcrop beneath the area of excavation could create upward gradients that would need to be controlled to limit the possibility of upwelling. Preliminary excavation dewatering calculations are provided as Appendix H.

The excavation contractor, as part of its means and methods of construction, should consider the use of temporary dewatering measures consisting of well points, submersible pumps in gravel sumps, collector trenches, or other dewatering methods to maintain stable excavations and safe work conditions. The initial surface water removed prior to removal of the existing vegetative root mat may be pumped through sediment bags to downslope areas stabilized with erosion control measures. Water collected from excavations will be conveyed to the selected water treatment process. Criteria for construction contractor delegated design of excavation dewatering means and methods will be developed in subsequent design phases and will be based on the determination of the extent practicable of excavation depth. Performance and delegated design criteria for construction contractor selection of means and methods of construction will be included in the project specifications. Criteria for design components delegated to the remediation construction contractor will include that the design be signed and sealed by a licensed engineer and provided as a submittal for review prior to construction.

7.5 Staging and Processing Areas and Haul Roads

Construction of haul roads using low ground pressure equipment will be necessary for excavation equipment and haul trucks to access the excavation areas within the wetlands. Stabilized construction entrances will also need to be constructed to transition from the wetlands to the uplands area at access points. Existing aggregate haul roads within the uplands areas of the Site will be improved to facilitate transportation of excavated sediment and soil to the treatment area. The conceptual layout of haul roads is provided on Sheet C-01 Site Plan in Appendix K. Details for construction of new haul roads and improvement of existing roads will be provided in the subsequent design phase.

A bermed, lined off-loading area will be installed adjacent to the temporary frame-supported membrane structure. A screening plant and conveyor system will be installed on the off-loading area. The facility/conveyor system will screen large debris from the sediment and soil and then transfer sediment and soil from the off-loading area into the temporary frame supported membrane structure covering the sediment and soil stockpile area. Once inside the temporary frame-supported membrane structure, the designated sediment and soil will be loaded into cells lined with concrete bin blocks for dewatering as described in Section 7.8. The stockpile area will also be lined. Dedicated collection sumps and piping will convey decanted water to the water treatment system.

The temporary frame-supported membrane structure will cover the entire stockpile area footprint. It consists of a fabric skin over steel frame truss sections and a steel I-beam concrete bin block foundation. A series of air handling units will maintain a negative air pressure inside the temporary frame-supported membrane structure. Off gas from the air handling units will be treated prior to discharge to the atmosphere.

The water treatment pad will be bermed and lined with 40-mil high-density polyethylene (HDPE) and asphalt. Water collected from excavation dewatering, the sediment off-loading area, the dewatering process, and other collection areas will be collected in sumps and transferred to the temporary construction water treatment system. The design will address process water treatment from the selected material dewatering and thermal treatment processes and will be developed in subsequent design phases. Performance and delegated design criteria for construction contractor selection of means and methods of water treatment will be included in the project specifications. Water samples were collected from the treatability study rolloffs to aid in characterization of potential process water parameters to develop delegated design specifications. Selection of combined or separate water treatment for dewatering and thermal treatment streams will also be determined in subsequent design phases.

An approximately 200-foot by 300-foot processing area will be required to accommodate the thermal treatment system. An additional 200-foot by 200-foot processing area will be required to accommodate the metals stabilization and biological barrier material mixing operations. Representative sizing and locations of the unit treatment processing areas are shown on Sheet C-01 Site Plan in Appendix K. Variations in temperature and precipitation will be considered as part of the design development for each of the treatment processes, and details of the material processing and support facilities will be provided in subsequent design phases.

7.6 Soil Handling

The loading and conveyance of impacted sediment and soil will need to be performed in a manner that minimizes the potential for the release of odors. The excavation contractor, as part of its means and methods of construction, may consider the use of triaxle or articulated off-road dump trucks or enclosed material handling conveyors for transporting material between the excavation areas and the material processing area, between unit treatment processes, and for return of treated material back to the wetlands. Enclosed conveyors will be installed to transfer material into and out of the temporary frame-supported membrane structure. The location and extent of the excavation areas might preclude the use of material conveyors for transferring excavated materials to the treatment processing area.

The sediment and soil excavated from the wetlands will generally have moisture contents exceeding 20% and will likely have free water present. These conditions are not conducive to the use of mechanical material conveying equipment without dewatering prior to loading the conveyors. Likewise, sediment should be allowed to drain before being loaded onto trucks to control tracking of material on the haul roads to the treatment processing area.

The contractor will be required to set up a loading area that keeps trucks clean during loading to minimize the need to decontaminate the outside of the truck. Each truck will be inspected prior to leaving the loading area to ensure no sediment is adhered to the outside of the truck. Control measures to minimize tracking, dropping, or depositing of soil or any other material onto Site roads will be implemented and any materials spilled on haul roads will be cleaned up immediately.

Trucks suitable for hauling high moisture content materials should be selected by the excavation contractor, and loads should be tarped prior to trucks leaving the loading area to assist with odor control. The sheets will be of sufficient length and width to cover the interior bed of the truck with no seams. Use of the liner minimizes the need for decontamination of the truck after contaminated soil is dumped at the disposal or treatment facility and provides containment for any residual liquids that may be associated with wet soils.

7.7 Odor Control/Suppression

Fugitive odors can be generated from a variety of activities, including the remediation processes themselves and from the temporary staging of materials for loading into conveyance equipment, prior to dewatering operations, prior to thermal treatment, during metals stabilization and biological barrier material preparation, and preparation for placement as backfill. Odor emissions will result from the atmospheric exposure of impacted materials. Odors might be associated with both the excavated sediment and soil, and water decanted from the excavated materials. The constituent concentrations associated with Site VOC odors may be less than the levels that potentially pose a health risk because the odor threshold of COCs is typically less than health-based action levels.

Remedial activities can generate fugitive emissions through equipment operation, the disturbance and exposure of impacted materials, and the transfer and transport of materials. The installation of sheet pile for water control or excavation stabilization will likely be installed under water, so odor generation from this activity is anticipated to be minimal and non-problematic. Odors are likely to be generated during excavation and sediment and soil management operations. BMPs to be implemented to address odors during these activities are as follows:

- Implementation of the remediation contractor's odor control plan
- Implementation of a Community Air Monitoring Plan (CAMP)
- Use of enclosures, such as the temporary frame-supported membrane structure and shrouds on conveying equipment for storage and load-out of impacted sediments
- Use of odor-suppressing foams and odor-neutralizing or masking agents, as needed
- Maintenance of clean and orderly work areas

The activities with the highest potential to result in unacceptable odor generation will occur during excavation of sediment and soil, loading for transport, and off-loading and conveyance to the temporary frame-supported membrane structure. Typically, the use of odor-suppressing foams will provide the best mitigation of fugitive odors during these activities. However, the use of foam additives to excavated soil might impact thermal treatment efficacy or efficiency and will need to be evaluated further during subsequent design phases. Odor-suppressing foams can be used on exposed excavation surfaces upon completion of sediment removal. Application of granular or misting odor-neutralizing or masking agents adjacent to excavation activities or at the Site perimeter can potentially control or cover nuisance-level odor emissions.

To minimize the potential for fugitive emissions, sediment and soil will be conveyed from the off-loading area to the frame-supported membrane structure via an enclosed conveyor belt through an opening in the temporary frame-supported membrane structure. This will allow minimal disruption to the contained atmosphere within the temporary frame-supported membrane structure as opposed to requiring trucks to enter and exit the structure for unloading, thereby minimizing the potential for fugitive emissions to escape the temporary frame-supported membrane structure. Once conveyed to the frame-supported membrane structure, odors will be contained and managed within the frame-supported membrane structure using ventilation and air treatment equipment that will be designed in subsequent design phases. Material stockpiling, dewatering, and amendment addition will be conducted within the frame-supported membrane structure under negative air pressure. Management of sediment with low VOC content outside the structure and following completion of thermal treatment may occur provided the odor minimization and air quality goals set forth in the CAMP are met. Tarps and odor-neutralizing or masking agents will provide primary odor control for sediment and soil managed outside of the frame-supported membrane structure and during placement in the thermal treatment cells if the pile treatment method is selected. Any smaller stockpiles outside the structure will be covered if left inactive for a period of more than 2 hours.

The water treatment system is a closed system and is not expected to present an odor problem. Processed sediment and soil will be loaded into transport trucks for placement as backfill in the original excavation areas. Once trucks are loaded, they will be covered with tarps to control fugitive emissions. Odor-suppressing foams may also be applied to the surface of the sediment after loading, if required to control odors.

The following odor-suppressing agents have been identified for potential use, but additional agents may be used or substituted.

Odor-suppressant foam has been successfully utilized on similar sites. It is presented in this plan as an option for exposed surfaces that will not require thermal treatment and for materials that have completed treatment. Odor-suppressant foam can provide immediate, localized control of VOC and odor emissions. The foam is created by the injection of air into a foam concentrate and water mixture using a pneumatic foam unit. The foam is applied via a hose to cover source areas to a depth of 3 to 6 inches. Foam (Rusmar or equivalent) is a short-term remedy and can be actively used to control VOC and odor emissions from active excavations or stockpiles and during the loading of trucks. It is shipped as a concentrate and diluted with water at the Site. Under normal conditions, this foam can last for several hours. However, it can degrade quickly in direct sunlight or precipitation, so it must be applied liberally and frequently to all areas that require odor control. Details regarding the foam and application units will be provided in the Specifications in subsequent design submittals.

BioSolve® can be used as an alternative to or in conjunction with foam, as necessary. The dilute solution can be sprayed directly onto newly exposed soil surfaces or stockpiles of contaminated material where volatilization is taking place. BioSolve® creates an emulsion with the residuals suppressing vapors, allowing work to continue safely without disruption to workers or neighbors.

All sediment will be conveyed from the offloading area into and out of the temporary frame-supported membrane structure through an enclosed conveyor. Tarps will be used to control emissions from trucks after they are loaded. All trucks will be lined with 10-mil polyethylene sheeting. The liners will be large enough to overlap and fully cover the top of the load. Additional automatic mesh tarps may be used to secure the liners.

Additional actions might be necessary when the controls identified have been exhausted and either ambient concentrations of emissions continue to exceed the site-specific action levels, or nuisance odors become problematic. These additional control actions have the potential to significantly affect the schedule and production rate of remedial action activities. These delays may be required periodically to ensure that acceptable levels of fugitive emissions are maintained and are preferable to a complete work cessation to control an emission event.

Reducing the excavation rate may be necessary to reduce the surface area of disturbed material or to slow the generation rate of stockpiles. These activities would result in smaller source areas that could be more effectively controlled using odor control techniques. Efficient scheduling and coordination of operations can also limit the impact of active emission sources. Close coordination of excavation activities can decrease the surface area of disturbed material, thereby reducing the size of the emission source. A smaller source area can facilitate the implementation of additional controls, if required. Under extreme conditions, such unfavorable prevailing wind direction, high ambient temperatures, and handling of sediment with higher impact concentrations, temporarily ceasing operations may be necessary until more favorable conditions exist.

7.8 Soil Dewatering/Conditioning

The objective of the hydric soil and sediment dewatering treatability tests was to assess the efficacy of several passive and mechanical approaches to dewater dredged material for suitable feedstock for LTTD treatment or other potential dewatering alternatives. Dewatering studies were focused on sediment removal with a mechanical dredge and ex-situ dewatering techniques including gravity stacking, mechanical dewatering (e.g., belt filter press and plate and frame press), stabilization reagent admixtures and various combinations to meet moisture goals (< 20 percent [%] moisture). The complete report is attached as Appendix F that provides an overview of the methods employed for treatability testing, results of the data collected, supporting figures, documentation, photo logs and provides overall recommendations. Key findings from each of the activities performed as part of this technical summary are presented below.

7.8.1 Physical Characterization

- In situ solids content ranged between 18.1% (DG-02) to 71.3% (DG-08).
- Mean particle size diameter was 55.1 μm and ranged between 26.6 μm to 131.9 μm.
- Average density was 1.51 g/mL and ranged between 1.13 g/mL to 1.78 g/mL.
- Average carbon content was 11.6% and ranged between 4.1% to 25.1%.
- DG-02-1, DG-08-1, and DG-08-2 failed PFTs after homogenization at in-situ conditions. All other samples passed.
- All sediments samples passed a PFT after 48-hr conventional gravity stacking. Solids content ranged from 23.4% to 73.5%.
- Based on the physical characterization, addition of chemical conditioning chemicals (e.g., polymers) to facilitate separation of water and solids in a slurry is likely needed prior to mechanical dewatering due to greater than 10% organic carbon concentration.

7.8.2 Mechanical Dewatering

- All filter cake generated from trials (6) run with a plate-and-frame press failed PFTs. Solids content resulting from each test ranged from 4.0% to 37.9%.
- Sediment slurried and conditioned with polymer yielded the best results during belt-filter press testing.
    - Final solids content ranged from 35.4 to 68.9%.
    - All filter cake samples post belt-filter press tests passed a PFT after 24-hr gravity stacking.
    - All filter cake samples post belt-filter press tests achieved greater than 90% solids after 72-hr gravity stacking.

Upon initial project review, mechanical dredging appeared to be the recommended dredge approach. Due to the high moisture content, small diameter particle size distribution (i.e., clays and silts), and greater than 10% organic carbon concentration addition of polymers are likely needed prior to mechanical dewatering. In addition, polymer conditioning would improve solids capture rates and limit overflow from the filters on the press and mitigate higher TSS concentrations in the filtrate water.

The plate-and-frame press would be limited in field application due to the high organic material and sand content. If chosen for full-scale application, the sediment would need to be rehandled to screen out such materials prior to plate-and-frame pressing. In addition, there would be a need to dilute samples in the field to prevent pump clogging. The materials would have to be loaded as a slurry composed of more than 50% water with no bench-scale testing to guarantee the moisture goals (< 20 percent [%] moisture).

7.8.3 Solidification/Stabilization

- 20% Calciment™ and quick lime increased the unconfined compressive strength (UCS) of in-situ sediment to 1,343 and 1,420 lb/ft^2 (52% and 51% moisture), respectively for sample DG-02.
- 5% Calciment™ increased the UCS of in-situ sediment to 3,827, 1,740, and 1,692 lb/ft^2 (27%, 23%, and 40% moisture) for samples DG-05, DG-08, and DG-12, respectively.
- 5% quick lime increased the UCS of in-situ sediment to 4,791, 1,374, and 2,141 lb/ft^2 (26%, 24% and 39% moisture) for samples DG-05, DG-08, and DG-12, respectively.

7.8.4 Recommendations

Based on the initial sediment characterization and bench testing, mechanical dredging followed by gravity stacking and stabilization (if necessary) is the recommended sediment dewatering process. This recommendation assumes that there is access to the dredge prism(s) with appropriately sized equipment and suitable space is available for ex-situ sediment and filtrate water management.

A scalper or comparable screening system is required to remove vegetation and debris prior to gravity stacking in order to expedite sediment processing and handling before LTTD treatment. In addition, vacuum boxes, shaker screens, drying fans, and other mechanical technologies may be used to expedite the passive dewatering process. As the sediment and soil is primarily fines with a high concentration of organic content, gypsum (48-h to 96-h cure time) may be used to complete the dewatering process and achieve the < 20% moisture target. Augers, pug mills, conveyors and other mechanical mixing equipment may also be integrated in order to save time and space for this initial processing step.

Mechanical dewatering via belt-filter presses is feasible, however, the complexity involved in homogenizing the influent slurry for polymer conditioning, the additional volume of water required for dewatering and subsequently treatment, utilities requirements, and operation and maintenance time, make this alternative cumbersome and less cost effective than the passive dewatering alternative.

7.8.5 Mass Balance Calculations

110,000 CY of in situ sediment dewatered and stacked (72-h) and subsequently amended with gypsum would result in 80,326 tons (59,672 CY) for LTTD treatment.

7.9 Community Air Monitoring Plan (CAMP)

The proposed remedial activities have the potential to generate fugitive emissions in the form of vapors or dust. Given the volatile nature of the contaminants and potential for generation of dust, a Community Air Monitoring Plan (CAMP) has been developed to characterize ambient air quality at the perimeter of the Site to identify periods when additional levels of fugitive emission controls may be required to be protective of the surrounding community. A copy of this CAMP is included as Attachment I.

The CAMP details the requirements for the characterization of ambient levels of total volatile organic compounds (tVOCs), PCBs, and respirable dust during remedial activities, including excavation and material handling. Real-time monitoring for these parameters will be conducted on a continuous basis at fixed locations around the perimeter of the Site, with supplemental data provided on an as-required basis using handheld equipment.

The results from the monitoring will be evaluated with regard to the alert and action levels established in the CAMP. The exceedance of an alert limit will trigger a response action (e.g., the use of odor-suppressant foam or water spray); while an exceedance of an action limit will require a temporary work stoppage to facilitate the implementation of a corrective action. The alert/action limits are not intended to suggest the existence of a health hazard, but rather to serve as a proactive screening tool. The draft CAMP (Appendix I) document provides a discussion of the following procedures and schedules:

- Continuous real-time characterization of tVOCs and respirable dust at perimeter locations
- Supplemental monitoring of tVOCs and respirable dust using hand-held equipment
- Observational monitoring of odor and visible dust
- Monitoring for PCBs in dust and vapor
- Meteorological monitoring
- Monitoring schedules

In addition, the final AMP provides a discussion of the evaluation of potential emissions from the temporary fabric structure proposed to be used as an engineering control (if needed) for the management of excavated soil/sediment.

7.10 Existing Utility Assessment

A utility assessment was completed to evaluate the availability and capacity of nearby gas, electric, water, and sanitary sewer services. The findings of the assessment are summarized below and shown on Drawing C-02 and V-03 (Appendix K).

7.10.1 Gas

There is no existing gas service to the Site. There is a 6-inch steel gas main in Governor Lea Road across from the Site. A previous service was installed in 1965 but was abandoned in 2006.. The line is owned by Delmarva. Delmarva requires submission of a Commercial Application to begin the process of constructing a new gas service. Corbin Cullen is the point of contact with Delmarva Gas and can be reached at corbin.cullen@exeloncorp.com.

7.10.2 Electric

There are two 277/480 volt three-phase transformers on Site that receive service from overhead lines along Governor Lea Road. Electric is routed to the on-site treatment system via overhead lines along the Site access road. Delmarva requires submission of a Commercial Application to begin the process of constructing a new electric service. Shaun Woodington is the point of contact with Delmarva Power and can be reached at (667) 313-1986 or shaun.woodington@exeloncorp.com.

7.10.3 Water

There is a 2-inch water service to the on-site water treatment system from a curb box near the Site entrance and a 16-inch water main in Governor Lea Road. The main is owned by Veolia. A new service is not permitted to run across parcel boundaries. Veolia requires submission of a

Water Customer Data Sheet to begin the process of constructing a new water service. Terri Blum is the point of contact with Veolia Water and she can be reached at (302) 252-3012 or teresa.blum@veolia.com.

7.10.4 Sewer

There is no sanitary sewer connection for the Site and the closest connection point is approximately 2.5 miles away. The primary function for sanitary sewer service would be treated effluent discharge from the remedial process. Residual management is covered in Section 11.

7.11 Site Security, Access, and Oversight

7.11.1 Site Access

Site access is available from public roads. Any damage to these roads by the Contractor's vehicles shall be repaired without cost to the Government.

Because of the proximity to land owned by the Delaware City Refinery, access agreements should be established prior to mobilization. Detailed drawings of the excavation area and schedule should be provided to the Delaware City Refinery in addition to copies of the subcontractor’s information and insurance. Notification of work should also be provided to EPA’s active subcontractors.

Rudimentary gravel roads on Site will need to be regraded, widened, or otherwise maintained through the duration of the remedial work. Additional on-Site access roads will be established as necessary, though effort will need to be made to reduce the impact on the OU3 cap and existing facilities.

Old and young growth trees are predicted to hinder access to the northern and southwestern wetlands, as will steep grades and tributaries flowing to Red Lion Creek. While effort to retain old growth trees (trees with diameters exceeding 12 inches) should be made, the remediation subcontractor may need to utilize a combination of the following methods to safely access excavation locations:

1. HDPE wetland mats or equivalent mats rated for the weight of the selected excavation equipment
2. Significant regrading and traction control
3. Vegetation clearing and tree removal
4. Stream and creek management and/or temporary damming

Shoring and additional excavation prism needs are described further in the previous sections.

7.11.2 Site Security

Site access is currently restricted by a standard 6-foot chain fence and barbed wire. Site personnel include EPA staff and their subcontractors and their access is permitted through a series of locked gates. While these gates are considered secure, effort should be made to limit the key personnel with knowledge of the access codes.

Because the current fence line does not extend beyond the OU3 cap footprint into wetlands aside from security fencing present along the eastern property line, staging areas and remedial treatment systems must be secured by additional lengths of 6-foot chain fence and barbed wire. Gates secured with a Site universal combination lock should be installed at the access point of these areas. Historical reports of trespassing by hunters or other unauthorized persons on foot will require routine checks of these gates and maintenance of newly implemented fencing.

There are two security cameras mounted on the northeast and southwest corners of the groundwater treatment system building to monitor the driveway and parking lot. The site currently has no telecommunication services. Historically the groundwater treatment system used phone lines for alarm notifications, but those lines are no longer serviceable. The system currently uses Verizon wireless for communications.

Telecommunications needs for future work include communications for site trailers and remote monitoring for process and treatment equipment. These needs could be met wirelessly or by running a new service to the work area. The remedial contractor will be required to secure the work area with temporary and/or permanent fencing during construction. A security guard for non-working hours is advisable to prevent theft, vandalism, and trespassing.

7.11.3 Oversight

The Site Supervisor reports directly to the project management team and will confirm that field personnel conduct operations at the Site in accordance with project specifications and in a systematic manner using proven operating methods and techniques. Project responsibilities include:

- Managing on-Site manpower and equipment necessary to safely conduct the fieldwork
- Appointing task and field leads on a regular basis
- Coordinating on-Site field activities to minimize impacts to productivity and to confirm compliance with the Accident Prevention Plan
- Directly interfacing with and relaying safety and health concerns to the Project Manager
- Keeping record of all Site visitors
- Preparing and submitting a detailed accounting of activities performed each workday

7.11.3.1 Site Safety and Health Officer

The Site Safety and Health Officer (SSHO) supports the Construction Manager/Site Supervisor in providing a safe work environment. The SSHO ensures OSHA and project-specific health and safety management guidelines are being met and is responsible for implementing and enforcing the safety and health requirements. The SSHO reports to the Project Manager. Project responsibilities include:

- Being present during operations to implement the safety standards and monitor compliance with Site safety measures
- Inspecting the site for compliance with OSHA safety standards procedures during regular field audit inspections
- Continuously monitoring construction operational risks, hazards, and safety requirements
- Coordinating with Site Supervisor to review Task Hazard Analysis/Activity Hazard Analysis with the work crew
- Coordinating changes/modifications to the Site health and safety plan with the Safety Health Environment Manager and field team
- Developing and implementing corrective action plans to eliminate or mitigate hazards
- Maintaining an Inventory of Hazardous Materials and Safety Data Sheets for hazardous materials present on Site
- Conducting and documenting daily safety inspections and weekly safety audits
- Conducting project-specific training, including an initial safety orientation meeting, and documented daily safety meetings for Site personnel
- Checking that all Site personnel and visitors have received the proper training, orientation, and medical clearance prior to entering the Site

8 Thermal Basis of Design

8.1 Ex Situ Thermal Remediation Description

Two methods of Low Temperature Thermal Desorption (LTTD) were considered for the site COCs: (1) In Pile Low Temperature Thermal Desorption (IP-LTTD) using Thermal Conductive Heating (TCH), Electrical Resistance Heating (ERH), or Steam Enhanced Extraction (SEE) and (2) Rotary Kiln Low Temperature Thermal Desorption (RK-LTTD). If applicable/necessary, a combination of these thermal methods/technologies can be implemented to achieve the Site cleanup goals.

8.1.1 Thermal Conductive Heating

TCH using heater wells installed vertically or horizontally raises the temperature of the soils in the treatment pile through conductive heat transfer. Heat is applied to the soil through conduction from thermal wells in direct contact with the soil. The heating elements in these wells operate at up to 700°C (1,300°F). The heater wells are typically electric or gas-powered. The high temperatures induce volatilization of the soil moisture and contaminants. Heat spreads radially from the thermal wells until the desired treatment temperature is attained throughout the soil in the treatment pile. Chemical reactions including hydrolysis, pyrolysis, and oxidation proceed at accelerated rates under high temperatures, also contributing to contaminant removal. Vacuum is applied above or within the thermally heated zone to capture steam and liberated contaminant vapors generated in the pile.

The recovered vapors are partially condensed above grade, separated, and the resultant VOC-laden liquid and vapor streams are treated prior to discharge.

The primary advantage of TCH is that very high temperatures can be achieved, facilitating the removal of compounds with high boiling points. To achieve temperatures above the boiling point of water, the moisture content of the soil in the pile would be completely boiled off. A disadvantage of TCH is that a relatively large amount of energy is required, especially if the goal is to achieve temperatures greater than the boiling point of water.

8.1.2 Electrical Resistance Heating

ERH using vertically or horizontally installed electrodes heats the soil in the pile using its resistance to electric current. Electrodes are placed in the soil and a voltage is applied to them so that an electric current flows through the soil moisture in the pore spaces. Resistance to electron flow by the soil releases energy as heat. The heat generated by ERH vaporizes the soil moisture from the soil in the pile, sometimes requiring the addition of water to maintain adequate electrical conductivity. For this reason, the maximum temperature that can be reached is the boiling point of water. The soil in the pile is heated to the desired temperature and the temperature is maintained until project goals are met. As with TCH, volatilization and degradation rates are enhanced by the high temperatures, and vaporized contaminants are recovered via extraction wells and partially condensed above grade, separated, and the resultant VOC-laden liquid and vapor streams are treated prior to discharge.

The advantage of using ERH is that less energy is required compared to other thermal technologies. The inability to exceed the boiling point of water limits its usefulness in some situations. If the natural resistivity of the subsurface is non-uniform, then ERH currents will follow preferential pathways and the technology cannot distribute heat evenly. Variations in electrical resistivity tend to be more significant than variations in thermal conductivity, so non-uniformities in the subsurface limit the effectiveness of ERH relative to TCH.

8.1.3 Steam Enhanced Extraction

SEE using vertically or horizontally installed steam injection wells uses injected steam to conduct heat through the soil pile to reduce the viscosity and density of the organic contaminants. Vaporized contaminants are recovered via extraction wells and treated prior to discharge to the atmosphere. The flow of the injected steam also displaces and mobilizes nonaqueous phase liquid (NAPL) (if present), while simultaneously providing a stripping effect thereby enhancing volatilization. The soil in the pile is heated to the desired temperature and the temperature is maintained until project goals are met. The vapors are recovered via extraction wells and partially condensed above grade, separated, and the resultant VOC-laden liquid and vapor streams are treated prior to discharge.

SEE is capable of achieving target temperatures above the boiling point of water. Steam is generally considered effective for liquid organic compounds having boiling points up to 175°C (347°F), while in laboratory settings even higher boiling point compounds have been treated. Its effects on NAPL viscosity and density make it favorable for sites with large quantities of free-phase product. The main disadvantage of steam is that it generates large volumes of contaminated water that must be contained within the subsurface, extracted, and treated.

8.1.4 Rotary Kiln LTTD

RK-LTTD uses a mobile rotary kiln and subjects the excavated soil to temperatures ranging from 200 to 1000°F (~94 to ~538°C) to remove soil moisture and volatilize and remove COCs from the soil. The condensate water and off-gas are captured and treated as needed prior to their discharge to the environment. Each batch of soil will be treated in the rotary kiln at an expected soil target treatment temperature of up to 932°F (500°C), required to desorb VOCs, SVOCs, TOC, metals, and some PCBs. If either batch has not reached the site clean-up criteria for VOCs and SVOCs, then the soil will be re-treated, and confirmation samples will be collected.

With the soil target treatment temperatures expected to exceed 570°F (300°C) at a higher rate, this approach is most cost-effective, but may have a greater negative impact on soil quality and TOC loss.

8.2 Thermal Remedy Evaluations

The thermal methods described in Section 8.1 were considered viable options for the treatment of the excavated soils to achieve the soil RGs for the Site COCs and therefore further bench testing was conducted to determine the optimal treatment temperatures. The use of IP-LTTD using TCH, ERH, or SEE would likely achieve the RGs for the Site COCs at a lower soil target treatment temperature (100 to 400°C / 212-752°F) but would require a longer duration of heating to reach the soil target treatment temperatures, and the duration temperatures need to be maintained. Additionally, a target treatment temperature of 100°C may pose challenges in achieving RGs for the least volatile COCs. While RK-LTTD would require a higher soil target treatment temperature for a shorter duration (20 to 30 minutes) but require the soil moisture content to be between 18% and 25% without the use of an additive (e.g., lime, kiln dust, quik lime), which would reduce the moisture content but possibly affect metal stabilization/biobarrier effectiveness due to elevated pH that would be present in the treated soils. For either approach as the soil target treatment temperatures approach/exceed ~300°C (572˚F), TOC will break down, affecting the soil quality; therefore, the volume reduction and change of TOC also needs to be evaluated. The results of the bench testing are preliminary and are discussed in the following sections; the final results will be presented in the 90% DAR, along with detailed information about the LTTD process (i.e. pretreatment requirements, production rates).

8.2.1 TCH Evaluation and Bench Test Results

Soil collected during the direct-push survey during the Treatability Study, performed by AECOM in 2024 (see Appendix A), were screened to obtain subsamples of material at various COC concentrations to mimic Site conditions and expected excavation concentrations to include hotspots as well as lesser contaminated soils. Approximately 9 gallons (~34 liters) of material was shipped to TRS laboratories for pre-treatment screening and subsequent thermal desorption testing.

After allowing the excavated soils from the test pits to drain for up to 4 days; nine 1-gallon (~3.8-liter) paint cans of soil, packed to the top with minimal head space to avoid volatilization losses during shipping, were collected and shipped to a TRS laboratory for thermal desorption testing. During the soil collection and packaging, a soil sample from each can was collected (total of four samples) and analyzed for VOCs, SVOCs, TOC, metals, PCBs, moisture content, BTU, proximate/ultimate, and loss on ignition to establish baseline concentrations of the soils leaving the Site. Before testing at the TRS laboratory, each of the four soil samples underwent thorough homogenization and each sample was divided into five subsamples (total of 20 samples). Four out of the total 20 samples served as a control group for each soil sample that is not subjected to heating. Subsequently, the homogenized control soil samples (total of four) were analyzed for VOCs, SVOCs, TOC, metals, PCBs, moisture content, BTU, proximate/ultimate, and loss on ignition to establish baseline concentrations prior to the thermal desorption treatment. The remaining 16 soil samples were grouped into four sets for heating to the respective temperatures of 212°F, 482°F, 617°F, and 752°F (~100°C, 250°C, 325˚C, and 400°C). The soil volume was insufficient to perform moisture content, BTU, proximate/ultimate, and loss on ignition testing on each test sample. As a result, one sample at 482°F (250°C) from each test pit (total of four samples) was tested for moisture content, BTU, proximate/ultimate, and loss on ignition in addition to VOCs, SVOCs, TOC, metals, and PCBs.

The samples were placed in a stainless-steel soil cell in a temperature-controlled oven equipped with an air pump that pulled a small amount of flow through the soil cell to remove the volatilized contaminants. Temperature probes were placed inside the oven and soil cell to measure the temperature, and a data logger recorded the temperature every minute during the 48-hour test. During desorption, the vapor passed through a condenser, chilled by an ice-bath water, to remove the condensate that was collected for analysis (if a sufficient volume of condensate was recovered) and then allow the soil vapors to pass through a carbon filter for analysis. For condensate sampling, the samples collected were composite from each treatment temperature, while the vapor sample was a composite sample collected during all four tests. A total of four condensate (aqueous) composite samples and one soil vapor (carbon filter/gas) sample were collected to evaluate mass removal and off-gas/liquid treatment options and sizing. The draft bench test report is included as **Appendix G.** Further analysis of the final bench test results will be evaluated and included in the 90% DAR.

This thermal approach would achieve RGs for VOCs and SVOCs at a lower soil target treatment temperature 212-752°F (~100 to 400°C) but would require a longer duration of heating. As the soil target treatment temperatures approach/exceed 572˚F (~300°C), TOC will break down, affecting the soil quality, and therefore the volume reduction and change of TOC at lower temperatures needs to be evaluated. A separate thermal bench study using alternative desorption methods will be conducted by Clean Earth using a higher temperature for a shorter duration. Details are provided in Section 3.4.1. Although both methods could result in the removal of organic COCs, the TRS bench study achieves PRGs for VOCs and SVOCs at lower soil target treatment temperatures over a longer time, while the Clean Earth methodology achieves PRGs for VOCs and SVOCs at high soil target treatment temperatures over a very short period. These two different approaches are intended to collect data needed to evaluate different process options for thermal desorption.

8.2.2 Rotary Kiln Evaluation and Bench Test Results

Approximately 15 cubic yards of soil was excavated from each of the two test pits (total 30 cubic yards). The excavated soils were homogenized and then a composite sample with proper matrix spike/matrix spike duplicate (MS/MSD) and a field replicate was collected from each 15 cubic-yard pile (two samples total). These samples were composted laterally and horizontally across the 15-cubic -yard pile. The soil piles were then placed into two separate 20 cubic-yard vacuum-assisted dewatering boxes for each of the two batches (eight total) and were allowed to drain for several days. Soil moisture samples were collected to ensure he soils achieved 20 to 25% moisture content or at a minimum pass a paint filter test to ensure that no freestanding water was present in the soils shipped to Clean Earth. Water recovered from the dewatering operation was treated in the on-site groundwater treatment system. The two composite samples collected were analyzed on a 3- to 7-day turnaround for VOCs, SVOCs, TOC, metals, PCBs (1668), Dioxins, TCLP, moisture content, BTU, proximate/ultimate, and loss on ignition to establish baseline conditions of the soils leaving the Site and for permitting purposes.

On February 29, 2024, and March 13, 2024, Clean Earth representatives came to the Site and inspected the soils in the roll off containers, to determine or confirm, that the soils were suitable for treatment at the Fort Edward, NY, facility. Based on the visual inspection, approximately 10% of organic material was present in one of the roll-off containers, but both containers consisted of 70 to 80% clay material, which would not be suitable for treatment by a RK-LTTD. Due to the high clay content, the material would not be able to be fed into the facility’s Grizzly bars, and mechanical shredding or processing through a pugmill would not change the consistency of the material to make this soil treatable as is. AECOM is evaluating the use of amendments (Calciment™, quick lime, Portland cement, and gypsum) to make the clay material easier to handle and process through the kiln without affecting the metal and biobarrier process.

Once a path forward is agreed upon, then a Contained in Determination will be obtained from the New York State Department of Environmental Conservation to allow the material to be shipped to Clean Earth’s Fort Edward Facility, 304 Towpath Lane, Fort Edward, NY 12828.

8.2.3 Thermal Remediation Selection

Based on the present understanding of the Site, the COCs, and lean up goals, the preliminary TCH bench testing results discussed in **Section 8.2.1**, the results of the technology evaluations conclude in pile thermal desorption (IP-LTTD) using TCH is the optimum technology for this project. The ability for RK-LTTD to achieve the same levels of treatment and corresponding treatment temperature is still being evaluated. While PI-LTTD using TCH, has the ability to attain target treatment temperatures greater than 100°C and achieve the soil clean up goals for the Site. ERH and SEE methods were determined not viable for this Site because they cannot achieve target treatment temperatures above 100°C (212 °F). Therefore, IP-LTTD using TCH should be considered as the primary thermal technology selected for the full-scale design and estimating purposes, while the use of a mobile RK-LTTD is further evaluated.

8.3 COC Characteristics

COCs for the Site are chlorinated volatile and semi-volatile organic compounds (SVOCs). The COCs are summarized in **Section 3.2**. The COCs include the following compounds taken from the 1995 ROD.

- Benzene
- Toluene
- Nitrobenzene
- Chlorobenzene
- 1,2-Dichlorobenzene
- 1,3-Dichlorobenzene
- 1,4-Dichlorobenzene
- 1,2,3-Trichlorobenzene
- 1,2,4-Trichlorobenzene
- 1,3,5-Trichlorobenzene
- 1,2,3,4-Tetrachlorobenzene
- 1,2,4,5-Tetrachlorobenzene
- Pentachlorobenzene
- Hexachlorobenzene

The physical and chemical properties of these COCs are relevant to the thermal design and are discussed in the following sections.

8.3.1 Vapor Pressure

The primary removal mechanism for thermal remediation is volatilization, which is controlled by the vapor pressure of each COC. Vapor pressures increase with temperature, but are also affected by interactions with other solid, liquid, and gaseous components. Boiling of a compound occurs when its vapor pressure is raised above the pressure of its surrounding environment, and boiling results in rapid volatilization rates. Nevertheless, any temperature increase, even if it is below the boiling point of a compound, increases its vapor pressure and therefore its concentration in the vapor phase, improving its removal from the subsurface. Both boiling and sub-boiling volatilization can occur during thermal remediation implementation, so it is useful to consider the vapor-liquid equilibrium behavior of each COC over a range of temperature and pressure conditions, while simultaneously accounting for interactions with soil, moisture, and other COCs.

Pure component vapor pressures are of primary importance. Higher vapor pressures represent more volatile compounds, which are removed more effectively. Vapor pressures of the Site COCs at ambient temperature (68°F) are presented in **Table 8-1**.

Table 8-1: Physical Properties of Site COCs

Site COC	Physical Property								
	Normal Boiling Point (ºF)	Melting Point (ºF)	Specific Gravity	Solubility (mg/L at 77ºF)	Vapor Pressure (mm Hg at 68ºF)	Henry's Law Constant (M/atm)	Antoine Coefficient A (K)	Antoine Coefficient B (K)	Antoine Coefficient C (K)
Benzene	176	42	0.88	1,790	75	0.172	4.02	1,204	–53.23
Toluene	232	–139	0.87	526	22	0.152	4.14	1,378	–50.51
Nitrobenzene	411	42	1.20	2,090	0.17	64.8	4.22	1,728	–73.44
Chlorobenzene	270	–49	1.11	499	9.0	0.274	4.11	1,436	–55.12
1,2-Dichlorobenzene	357	1	1.31	156	1.0	0.689	4.20	1,650	–59.84
1,3-Dichlorobenzene	343	–13	1.29	125	1.5	0.345	4.20	1,630	–57.33
1,4-Dichlorobenzene	345	127	1.46	81	1.3	0.456	4.12	1,575	–64.64
1,2,3-Trichlorobenzene	425	127	1.45	30	0.30	0.638	5.24	2,634	11.77
1,2,4-Trichlorobenzene	416	63	1.46	49	0.30	0.243	4.64	2,111	–30.72
1,3,5-Trichlorobenzene	407	146	1.46	6.0	0.36	0.182	4.61	2,067	-32.27
1,2,3,4-Tetrachlorobenzene	489	114	1.70	5.9	0.030	1.32	4.52	2,132	–53.92
1,2,4,5-Tetrachlorobenzene	471	282	1.83	2.2	0.13	1.82	7.14	4,653	133.7
Pentachlorobenzene	531	187	1.83	0.83	0.0029	1.42	5.44	2,790	–36.20
Hexachlorobenzene	612	444	2.04	0.0047	0.0036	1.93	6.91	4,598	82.81

atm = atmospheres M = Molarity, mol/L
K = Kelvin mm Hg = millimeters of mercury

The relationship between temperature and vapor pressure also varies with each chemical compound and is described semi-empirically by the Antoine Equation:

$$log_{10}\, p = A - \frac{B}{C+T} \qquad \text{(Eq. 8-1)}$$

Where:

p = the vapor pressure;

T = temperature; and

A, B, and C are component-specific constants.

The Antoine constants for the site COCs are also presented in **Table 8-1.**

8.3.2 Raoult's Law and Henry's Law

Given the nature of thermal remediation, site COCs do not exist as pure components but rather as a multiphase matrix consisting of a liquid mixture with solid soil media, so additional corrections must be applied. In an ideal liquid mixture, the vapor pressure of an individual component behaves according to Raoult's Law, which states that the partial pressure of each component in the mixture is equal to the vapor pressure of the pure component multiplied by its mole fraction in the liquid phase, as shown in Eq. 8-2.

$$p_i = p_i^* x_i \qquad \text{(Eq. 8-2)}$$

Where:

p_i = the partial pressure of component i

p_i^* = the pure component vapor pressure of component i

x_i = the mole fraction of component i in the liquid mixture

Interactions between molecules in the vapor phase are typically small, but in the liquid phase they become significant. Ideal liquid mixtures only occur when interactions between unlike molecules are of similar magnitude to interactions between like molecules. Many organic compounds, including CVOCs, are generally nonpolar and exhibit significant nonideality in their behavior with highly polar water molecules. This nonideality can result in poor agreement between Raoult's Law predictions and real vapor pressures for compounds in the dissolved phase. Fortunately, the solubility of chlorinated solvents in water is generally very low, so dissolved phase organic compounds form dilute aqueous solutions in the pore water. At these dilute concentrations, the relationship between a component's vapor pressure and its concentration in the water is relatively linear and can be approximated using an empirical coefficient known as Henry's constant, as stated in Henry's Law (Eq. 8-3):

$$C_i = H * p_i \qquad \text{(Eq. 8-3)}$$

Where:

C_i = the aqueous concentration of component i

H = the Henry's constant for component i

p_i = the partial pressure of component i

Henry's constants for the site COCs are also presented in **Table 8-1**.

8.3.3 Pure Component Boiling Point

Below boiling point temperatures, volatilization only occurs at the surface of the liquid and is limited by vapor-liquid equilibrium, liquid-phase mass transfer, and vapor-phase mass transfer. Conversely, above boiling point temperatures, when vapor pressures exceed the pressure of the surrounding environment, vapor formation occurs throughout the liquid column and produces greater volatilization rates, limited only by heat input to the system and vapor-phase mass transfer. The normal boiling point of a pure component is a good measure of its volatility and its amenability to thermal treatment. The normal pure component boiling points of the site COCs are included in **Table 8-1**.

Boiling points are also of interest in thermal remediation applications because a liquid cannot be heated above its boiling point. Once the boiling point is reached, any heat that is transferred to the liquid goes into the phase change from liquid to vapor, and the temperature no longer rises. Even if greater rates of heat are transferred, the result is only greater rates of volatilization. This makes the boiling point an important performance criterion because it represents a maximum temperature that can be achieved without complete vaporization of the pore water. Once boiling point temperatures are achieved, additional heat transfer goes only into the latent heat of vaporization of COCs and pore water, not the sensible heat of temperature rise. Higher temperatures are physically impossible until all the liquids have been boiled off.

8.3.4 Boiling Point Due to Hydrostatic Head

Because a compound's boiling point is related to the pressure of its surroundings, pressures greater than atmospheric have the effect of increasing the boiling point. The remediation of saturated soils involves positive pressures that vary with depth due to the hydrostatic pressure of the pore water. This relationship is described by the Antoine Equation (Eq 8-1). For ex situ thermal remediation where soils are excavated and placed into piles, the impact of hydrostatic head is no longer applicable unless water accumulates in the pile.

8.3.5 Azeotropic Boiling Points

The nonideality of contaminant-water interactions creates repulsive forces in the liquid phase. As a result, volatile compounds more readily escape from the liquid phase to the vapor phase, producing higher vapor pressures and lower boiling points. The magnitude of this effect depends on the composition of the liquid mixture.

Azeotropic mixtures are of practical interest because of the effect that they have on vapor pressures and boiling points. For mixtures of nonpolar organic compounds and water, intermolecular forces are typically repulsive and result in higher vapor pressures, and lower boiling points. These are referred to as positive azeotropes or minimum boiling point azeotropes.

In some cases, this effect is practically significant. The azeotrope formed by water and perchloroethylene has a normal boiling point of 191.5ºF, more than 20 degrees below pure component's normal boiling point. Furthermore, because the azeotrope is a stable condition, a mixture of these two compounds that is subjected to an external heat source will dilute or enrich itself at the interface between the two components until the azeotropic composition is formed and boiling occurs. As a result, a wide range of starting compositions of water and azeotrope-forming COCs are all capable of being boiled at the azeotropic boiling point.

8.3.6 Target Treatment Temperature

While azeotropic boiling can help improve removal and volatilization of contaminants under certain conditions, in many cases, the effect can be rather minimal and modeling contaminant removal assuming ideal conditions (Raoult's Law and Henry's Law) can produce adequate results. Additionally, trying to account for azeotropic boiling is quite difficult and involves gathering difficult-to-find vapor-liquid-equilibrium data. It's also possible to overstate the effect of azeotropic boiling which results in a design that is not conservative enough to achieve the desired treatment goals.

For these reasons, Raoult's Law and Henry's Law are used here for modeling expected contaminant removal rates. The expected removal rates are compared to treatment goals to determine what a reasonable target treatment temperature should be.

8.3.7 Heating Duration

From AECOM and vendor case studies, thermal remediation systems typically heat the soil at a rate of 1.5 to 2 °C per day following startup. The heat-up rate depends on a multitude of factors including the dimensions of the pile, the site's geology and hydrology, and the heater well design and layout. For ex situ remediation (such as Standard Chlorine), the dimensions of the pile and materials used (such as concrete walls and insulation around the pile) can have a large impact on the heat-up rate.

Once the target temperature is reached, peak temperatures are generally maintained for a prolonged period, often around 60 days or longer. At this point, contaminant volatilization rates and decomposition rates (where applicable) are accelerated by the high temperatures, but the boiling of any pore water consumes a substantial portion of the applied energy because of the large latent heat of water and the usually high ratio of total pore water mass to contaminant mass. Contaminant recovery rates decline as the bulk of the contaminant mass is removed, while energy consumption remains elevated. The appropriate duration for maintaining peak temperatures is a function of site cleanup goals and the declining cost effectiveness of the thermal remediation application.

8.4 Soil Pile Heating Thermal Modeling

For the Site, a pile size of 200 feet wide, 300 feet long, and 15 feet deep was used. This corresponds to a treatment volume of 33,333 cubic yards. Contaminated soil will be excavated from the wetland and placed into the pile.

For modeling purposes, it was assumed that the pile is constructed of concrete with a 2-foot-thick foundation and 2-foot-thick walls to contain the soil. Additionally, it was assumed that the sides of the pile are insulated (R-14) and the top and bottom are also insulated (R-28). The configuration of the pile is likely to vary between contractors. For example, precast concrete blocks may be used with a thicker profile than what was assumed for modeling. In that case, the 2-foot-thick concrete walls would provide a more conservative estimate for heat loss compared to thicker concrete blocks.

The above assumptions provide a basis for evaluating heating requirements and energy usage. However, it is understood that the thermal contractors bidding on the job are likely to have different approaches and technologies. The assumptions used for modeling aren't intended to be prescriptive but instead provide a basis for comparison. Additionally, the thermal model will be refined further in the Pre-Final/Final Design.

8.4.1 Thermal Modeling

To estimate the time to heat up the IP-LTTD treatment cell for a given heater configuration, a two-dimensional unsteady-state heating model was used. The base level model consists of 40 cells arranged in eight rows and five columns. The initial conditions for each cell must be specified.

Cell dimensions from specified layer thicknesses, column widths, and modeled length based on the volume to be treated in the pile and its estimated depth(s) are specified.

The distinction whether the cell represents the vadose zone or a fully saturated condition:

- For saturated cells, hydrostatic pressure is accounted for when determining the boiling point of the pore water at depth.
- The material composition of each cell (volume fraction quartz, clay, organic matter, rock, air, water). Other materials can be specified as well (for example, mineral wool, perlite, and concrete). For soils, the material composition is based on site-specific geology as well as porosity and saturation data.
- The initial temperature of each cell.

- The number of heaters and power output of the heaters within each cell.

A visual representation of the model for a generic ex situ remediation system is shown in **Figure 8-1**. In addition to the soil vapor flows, the model can account for steam or water injection. With the initial configuration established, the model is run incrementally at sufficiently small-time steps to determine the heat-up rate and temperature profile for the target treatment zone. For each time step, a mass and energy balance is performed at each cell.

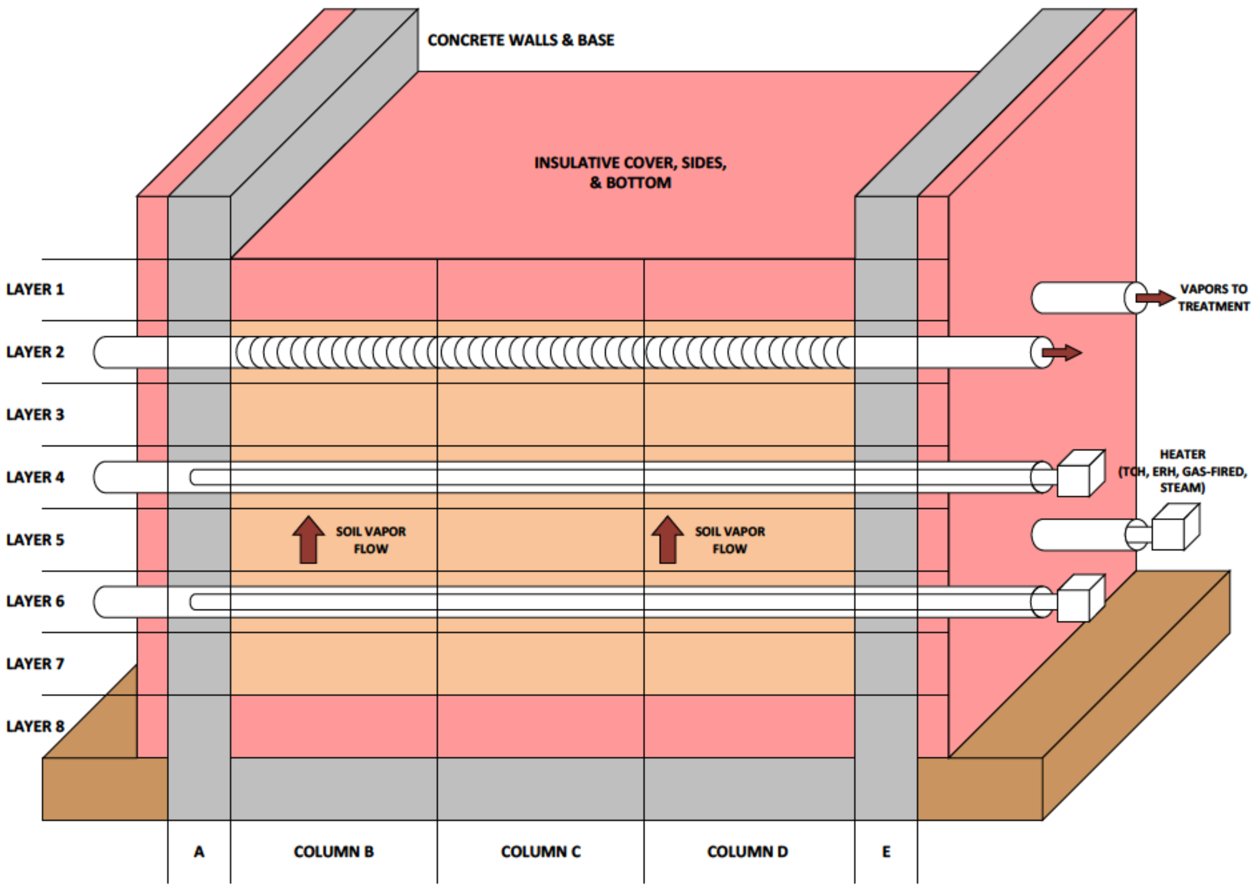


Figure 8-1: Representation of the 2D Unsteady-State Heating Model (Ex Situ Pile)

Note: Figure above is a general representation of how the model can be configured and does not represent a configuration specific to this site.

The mass balance is summarized below (see Eq. 8-5):

$$M_{STM} + M_{INJ} + M_{VAP,IN} - M_{WAT,OUT} - M_{VAP,OUT} = M_{PORE} \quad \text{(Eq. 8-5)}$$

Where:

M_{STM} = Steam injection, lb/hr
M_{INJ} = Injected water, lb/hr
$M_{VAP,IN}$ = Soil vapor being pulled into the cell, lb/hr
$M_{VAP,OUT}$ = Soil vapor extracted from the cell, lb/hr
$M_{WAT,OUT}$ = Water flow out of the cell, lb/hr

M_{PORE} = Pore water added or removed from the cell, lb/hr

The pore water flow is an accumulation term and accounts for water that is already initially present in the cell. Pore water can be removed from the model through vaporization from heating. In certain cases, pore water can be added to a cell. For example, hot moisture-laden vapor from a nearby cell may condense if it is pulled into a cooler cell.

In addition to the mass balance, an energy balance is performed around each cell at every time step. This energy balance is described by the following equations:

$$H_{IN} - H_{OUT} + Q_{HTR} - Q_{SIDES} - Q_{TOP} - Q_{BOT} = Q_{SEN} \quad \text{(Eq. 8-6)}$$

$$H_{IN} = H_{STM} + H_{INJ} + H_{VAP,IN} \quad \text{(Eq. 8-7)}$$

$$H_{OUT} = H_{VAP,OUT} + H_{WAT,OUT} + H_{PORE} \quad \text{(Eq. 8-8)}$$

Where:

H_{STM} = Enthalpy of injected steam, British Thermal Units (BTU)/hr
H_{INJ} = Enthalpy of injected water, BTU/hr
$H_{VAP,IN}$ = Enthalpy of soil vapor being pulled into the cell, BTU/hr
$H_{VAP,OUT}$ = Enthalpy of soil vapor being extracted from the cell, BTU/hr
$H_{WAT,OUT}$ = Enthalpy of water flowing out of the cell, BTU/hr
H_{PORE} = Enthalpy of pore water added or removed from the cell, BTU/hr
Q_{HTR} = Heat input from heaters in cell, BTU/hr
Q_{SIDES} = Heat loss through the sides of the cell, BTU/hr
Q_{TOP} = Heat loss through the top of the cell, BTU/hr
Q_{BOT} = Heat loss through the bottom of the cell, BTU/hr
Q_{SEN} = Sensible heat added/removed to the cell, BTU/hr

The enthalpies of the streams entering and leaving the cell are calculated based on the mass flow rate and specific enthalpies of the fluid. The heat input from the heaters is based on the configuration being modeled (number and power output of heaters within each cell). The cell heat loss at each time step is calculated at every side, top, and bottom of the cell per Eq. 8-9:

$$Q = UA(T_C - T_A) \quad \text{(Eq. 8-9)}$$

Where:

Q = Heat loss, BTU/hr
U = Overall heat transfer coefficient, BTU/hr-ft^2-°F
A = Area of side, top, or bottom where heat loss is occurring, ft^2
T_C = Temperature of cell at time step, °F
T_A = Temperature of adjacent cell or boundary condition, °F

The overall heat transfer coefficient is calculated differently depending on if the heat loss is to another cell or to a boundary condition. For heat loss to another cell, the heat transfer coefficient is calculated based on the thermal conductivity and thickness of the adjacent cell. The thermal conductivity of the adjacent cell is calculated based on the adjacent cell's composition and temperature. For heat loss to a boundary condition, the heat transfer coefficient is calculated based on the boundary condition assumptions.

With the enthalpies in and out of the cell, heater input, and heat losses calculated for the cell at each time step, the sensible heat added or removed from the cell is determined. During initial heating, this term is positive. The temperature increase of the cell due to this sensible heat is calculated from the equation above for a given time step.

8.4.2 Contaminant Fate Model

The output from the two-dimensional unsteady-state heating model is used to estimate the fate of contaminants within the pile. For ex situ remediation, two methods of removal are considered: volatilization and removal through reaction (hydrolysis or other mechanisms).

8.4.2.1 Volatilization

The volatilization of contaminants in the subsurface is modeled as a mass-transfer limited process per Eq. 8-11.

$$W_{vap} = MK_C A(C^* - C) \qquad \text{(Eq. 8-11)}$$

Where:

W_{vap} = Vaporization rate of contaminant, lb/hr
M = Molecular weight of contaminant, lb/pound-mol (lbmol)
K_C = Mass transfer coefficient, ft/hr
A = Mass transfer area, ft^2
C* = Equilibrium vapor concentration, $lbmol/ft^3$
C = Actual vapor concentration, $lbmol/ft^3$

The mass transfer coefficient is estimated from published literature for a bench-scale air sparging system using several VOCs (Braida and Ong, 1998). The mass transfer coefficient is also adjusted for temperature using an empirical fit. The equilibrium vapor concentration is calculated using Raoult's Law for sorbed/free-phase contamination (see Eq. 8-12) and Henry's Law for dissolved contaminants (see Eq. 8-13):

$$Sorbed: C^* = \frac{p^*}{P} x\rho_{M,v} \qquad \text{(Eq. 8-12)}$$

$$Dissolved: C^* = \frac{\rho_{M,l}}{HP} x\rho_{M,v} \qquad \text{(Eq. 8-13)}$$

Where:

p^* = Vapor pressure of contaminant (calculated from Antoine Equation), pounds per square inch absolute (psia)
P = Average pressure in pile (accounting for static head of pore water), psia
x = Mole fraction of contaminant in sorbed or dissolved phase
$\rho_{M,v}$ = Molar density of vapor extracted from pile, $lbmol/ft^3$

$\rho_{M,l}$ = Molar density of aqueous phase (water), lbmol/ft^3
H = Henry's Law constant, lbmol/ft^3-psi

The equation for the vaporization rate of the contaminant can be simplified; the actual vapor concentration extracted from the subsurface is significantly less than the equilibrium vapor concentration and can be assumed to be negligible. It is important to note that the model assumes ideality for the vapor-liquid equilibrium. In reality, many of the contaminants are non-ideal and form azeotropes with water. A discussion on the influence of non-ideality and azeotropes can be found in Section 8.3.5.

The soil total organic carbon (TOC) content has a direct impact on the volatilization rate for sorbed contaminants. The equilibrium vapor concentration for the sorbed mass is proportional to the concentration of the contaminant sorbed to the soil. Higher soil TOC will result in a lower sorbed contaminant concentration and reduce the driving force for volatilization.

8.4.2.2 Reaction

In addition to removal via volatilization and pumping, certain contaminants may be removed in the subsurface through hydrolysis or other types of reactions. The model can account for either alkaline or acid hydrolysis in the dissolved phase. Since the contaminant mass is often sorbed to the soil, it is also necessary to account for mass transfer limitations from the sorbed phase to the dissolved phase. The hydrolysis reactions can be described as follows:

$$Alkaline: \frac{dC}{dt} = -kCC_{OH^-} \quad \text{(Eq. 8-16)}$$

$$Acid: \frac{dC}{dt} = -kCC_{H^+} \quad \text{(Eq. 8-17)}$$

Where:

dC/dt = Change in contaminant concentration over time, lbmol/ft^3-hr
k = Reaction rate constant, ft^3/lbmol-hr
C = Contaminant concentration, lbmol/ft^3
C_{OH-} or C_{H+} = Concentration of hydroxide ion (alkaline) or hydronium ion (acid), lbmol/ft^3

The rate of hydrolysis depends on the contaminant concentration as well as the hydroxide or hydronium concentration. The pH of the pore water is used to calculate the hydroxide or hydronium concentration and it is assumed that the pH remains relatively constant. This assumption may or may not be valid depending on conditions. During heating, acidic byproducts can be generated which depress the pH. The rate of hydrolysis also depends on the reaction rate constant which is a function of temperature and is described by the Arrhenius equation:

$$k = Ae^{-\frac{E_a}{RT}} \quad \text{(Eq. 8-18)}$$

Where:

A = Pre-exponential factor, ft^3/lbmol-hr
E_a = Activation energy, BTU/lbmol

R = Ideal gas constant, 1.986 BTU/lbmol-R
T = Absolute temperature, R

While the above equations can describe the removal rate of contaminant due to reaction, it is necessary to account for mass transfer limitations as well. The hydrolysis reactions take place in the dissolved phase; with mass sorbed to the soil, it is necessary for the sorbed mass to dissolve in the surrounding pore water for the reaction to occur. The mass transfer of sorbed mass from soil particles to the pore water is estimated using the Froessling equation for mass transfer from a sphere (soil particle) into a surrounding fluid (pore water):

$$Sh = \frac{hD}{D_{AB}} = 2 + 0.552 Re^{0.5} Sc^{0.33} \quad \text{(Eq. 8-19)}$$

Where:
Sh = Sherwood number (dimensionless)
h = Convective mass transfer coefficient, ft/hr
D = Particle diameter, ft
D_{AB} = Diffusivity of contaminant in water, ft^2/hr
Re = Reynolds number (dimensionless)
Sc = Schmidt number (dimensionless)

The Froessling equation can be simplified – since the flow of pore water around the soil is relatively stagnant, it can be assumed that the Reynolds number is very low (approaching zero) and the second term is removed. The mass transfer coefficient can then be determined from the soil particle diameter and contaminant diffusivity. The rate at which the contaminant dissolves into the aqueous phase from the soil can be determined by Eq. 8-20.

$$N_{diff} = hA(C^* - C) \quad \text{(Eq. 8-20)}$$

Where:
N_{diff} = Contaminant flow from soil into aqueous phase due to diffusion, lbmol/hr
h = Convective mass transfer coefficient, ft/hr
A = Total surface area of soil particles, ft^2
C* = Equilibrium aqueous concentration of contaminant, $lbmol/ft^3$
C = Actual bulk aqueous concentration of contaminant, $lbmol/ft^3$

The above equation can be simplified by assuming that the actual bulk aqueous concentration of the contaminant is much smaller than the equilibrium aqueous concentration. This is consistent with a mass-transfer limited process: if the dissolution of sorbed contaminant is slower than the hydrolysis reaction, the aqueous concentration will be low – as contaminant dissolves, it will react quickly before it approaches the equilibrium concentration. The equation for the diffusion of contaminant into the aqueous phase is combined with the hydrolysis reaction equation to yield the overall removal rate of sorbed contaminant due to dissolution and subsequent reaction:

$$Alkaline: W_{rxn} = -Mk\Delta thAC^{*}C_{OH^{-}} \quad \text{(Eq. 8-21)}$$

$$Acid: W_{rxn} = -Mk\Delta thAC^{*}C_{H^{+}} \quad \text{(Eq. 8-22)}$$

Where:

W_{rxn}	=	Contaminant removal due to dissolution and reaction, lb/hr
M	=	Molecular weight of contaminant, lb/lbmol
k	=	Reaction rate constant, ft^3/lbmol-hr
Δt	=	Time step size, hr
h	=	Convective mass transfer coefficient, ft/hr
A	=	Total surface area of soil particles, ft^2
C*	=	Equilibrium aqueous concentration of contaminant, lbmol/ft^3
C_{OH-} or C_{H+}	=	Concentration of hydroxide ion (alkaline) or hydronium ion (acid), lbmol/ft^3

The equilibrium aqueous concentration of the contaminant is estimated using a partition coefficient between the soil organic matter and pore water. Since there is little data for the partition coefficient between the soil organic matter and water, the following correlation in EPA's Superfund Soil Screening Guidance Technical Background Document (EPA, 1996) is used:

$$log\,K_{oc} = 0.7919\,log\,K_{ow} + 0.0784 \quad \text{(Eq. 8-23)}$$

$$K_{oc} = \frac{C_{oc}}{C_w} \quad \text{(Eq. 8-24)}$$

Where:

K_{oc}	=	Soil organic matter-water partition coefficient, L/kg
C_{oc}	=	Soil organic matter contaminant concentration, mg/kg
C_w	=	Pore water contaminant concentration, mg/L
K_{ow}	=	Octanol-water partition coefficient

Converting units, the equilibrium aqueous concentration is then calculated as follows:

$$C^{*} = 6.243 \times 10^{-5}\,\frac{C_{oc}}{MK_{oc}} \quad \text{(Eq. 8-25)}$$

Where:

C*	=	Equilibrium aqueous concentration of contaminant, lbmol/ft^3
C_{oc}	=	Soil organic matter contaminant concentration, mg/kg
M	=	Molecular weight of contaminant, lb/lbmol
K_{oc}	=	Soil organic matter-water partition coefficient, L/kg

8.4.3 Model Assumptions

Provided below are key assumptions utilized in the thermal model for Standard Chlorine.

8.4.3.1 Model Thermal Treatment Zone

As described in **Section 8.4**, the pile consists of excavated soil placed into a pile. The pile dimensions are 200 feet wide, 300 feet long, and 15 feet deep. It was assumed that the pile would be contained with a 2-foot thick concrete slab and walls. Additionally, it was assumed that

R-28 insulation would be used above and below the pile along with R-14 insulation on all four sides.

A diagram depicting the configuration of the model's 40 cells for this site is shown in **Figure 8-2.**

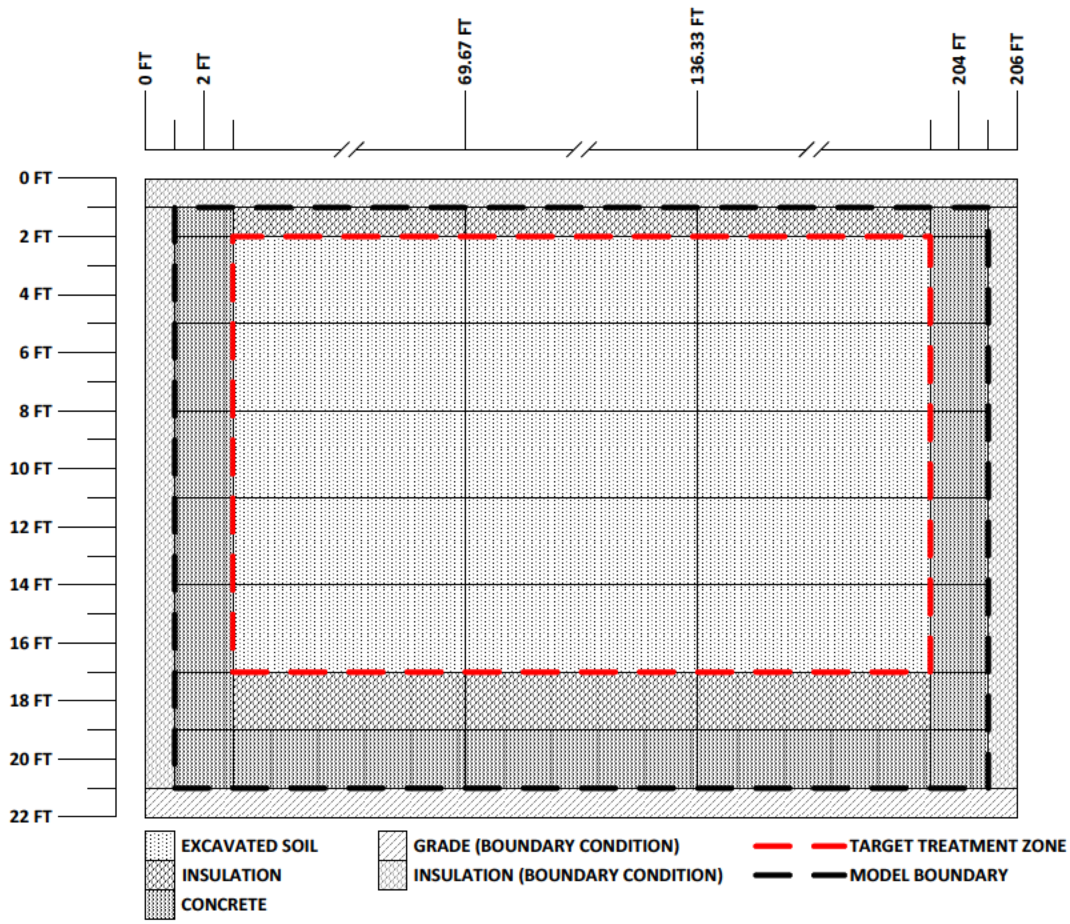


Figure 8-2: Thermal Model Configuration

8.4.3.2 Geology

The site geology is described in **Section 2.4**. The contaminated soils will be excavated and placed into the pile. In the thermal model, the soil is divided into 15 cells (5 rows and 3 columns). Each cell is 3 feet thick and 66.67 feet wide. The five rows of soil correspond to the pile depth of 15 feet and the three columns correspond to the pile width of 200 feet.

The following soil properties were assumed in the thermal model. As the design progresses, these properties will be refined based on data gathered in the field.

- Soil: 50/50 sand/clay soil
- Porosity: 40%
- Saturation: 100%

- TOC: 1.32%

8.4.3.3 Groundwater

Groundwater flow will not be a factor in the proposed remedy since the soils are being treated ex situ. For initial modeling, it was conservatively assumed that the excavated soils will be fully saturated.

8.4.3.4 Initial and Boundary Conditions

Ambient conditions for the site were estimated using ASHRAE climatic design standards. For the design case ambient temperature, the 99th percentile heating dry bulb from the nearest location in the ASHRAE design table was used – this corresponds to 16°F for this site. The 5th percentile extreme annual windspeed was also used from the ASHRAE design table. This corresponded to 18 mph for the site. An initial soil temperature of 50°F was assumed.

Within the model domain, the 2-foot-thick concrete walls are included in the two outer columns of the model (see **Figure 8-2**). Additionally, the 2-foot-thick concrete slab is included as the final row in the model. Above the slab, a 2-foot-thick layer of insulating concrete (R-28) was included to minimize heat losses through the bottom of the pile. Above the insulating concrete is the 15-foot-deep pile of excavated soils. Lastly, a 1-foot-thick layer of insulating concrete was included on top of the pile (note that an additional 1-foot-thick layer of insulating concrete was included as a boundary condition outside of the model domain).

Outside of the model domain, there are boundary conditions with a set temperature. On all four sides of the model, there is a 1-foot-thick layer of insulating concrete (R-14). As previously mentioned, on top of the pile an additional 1-foot-thick layer of insulating concrete was included in addition to the 1-foot layer within the model domain, resulting in an R-28 insulation combined for these two layers. For the ambient air around the pile, the ASHRAE design conditions (16°F and 18 mph) was used to estimate convective heat loss.

It's important to note that the configuration used in the model represents one possible remediation approach and provides a basis for comparison. However, each thermal contractor may have different approaches and techniques to achieve treatment goals.

8.4.3.5 Contaminants of Concern

The contaminants for this site include chlorinated semi-volatile organic compounds (SVOCs). As can be seen from **Table 8-1**, most of the contaminants have normal boiling points above that of water (212°F). The most volatile compounds (benzene, toluene, chlorobenzene) have a normal boiling point range of 176-270°F. The remaining compounds have boiling points ranging fromapproximately 340 to 612°F. These high boiling points will likely require high temperatureoperation.

For sites with contaminants that are more volatile (normal boiling points below around 300°F), it is possible to use a target temperature of the boiling point of water (212°F [100°C]). The vapor pressure for these more volatile compounds is high enough to be stripped from the soil with the steam that is generated as the pore water boils. However, for Standard Chlorine, the elevated boiling points will likely require higher temperatures. To achieve a target temperature above the normal boiling point of water, it is necessary to boil off all pore water.

In addition to volatilization, some compounds can break drown during heating. However, for the contaminants present at this site, decomposition via hydrolysis is not expected. Additionally, even if some of the contaminants were to break down, quantifying the reaction kinetics and mass transfer limitations would prove difficult. As such, it was conservatively assumed that none of the contaminants would undergo decomposition reactions during the remedy.

8.4.4 Model Results

Based on the modeled pile dimensions (200 feet wide x 300 feet long x 15 feet deep), the total treatment volume is 33,333 cubic yards. Since the soils will be treated ex situ, groundwater flow will not be present. Based on the elevated normal boiling points of the contaminants, the high concentrations present in the soil, and the modeled contaminant removal rates, a target temperature of 150°C (300°F) was chosen. The soil target temperature will be updated to 250°C based on the results of the bench scale testing.

8.4.4.1 Heater Configuration

The specific heater design for this site will vary between individual thermal contractors. For the purposes of the model and for preliminary cost estimates, a reasonable configuration based on the pile dimensions described in **Section 8.4**.

To prevent excessive heat loss through the pile, a 1-foot-thick layer of insulating concrete (equivalent to R-14) was assumed to cover all four sides of the pile. Most of the surface area for heat loss is on the bottom and top of the pile. For this reason, a thicker 2-foot layer of insulating concrete (equivalent to R-28) was used below and above the pile. As mentioned earlier, the specific configuration of the ex situ pile will vary between thermal contractors. Different types of insulation may be used and the thermal contractor may use different R-values for the insulation and compensate with varying degrees of heater power input.

For modeling purposes, the heater output was assumed to be 300 W/ft. It was assumed that heater cans would be inserted through the walls of the pile with each heater can spanning the 200-foot width of the pile. Each heater can was assumed to contain two heaters – one inserted from each side. Each heater would be 97 feet long and a 6-foot gap in the middle was used to avoid having the two heaters contact each when the heater element thermally expands. A total of 38 heater cans (76 individual heaters) were arranged in three rows and spaced equally.

It is important to note that the above heater configuration will vary between thermal contractors depending on each specific contractor's heater design. For example, in the modeling, it was assumed that the heaters would be inserted horizontally through the pile wall. This would minimize the number of heaters needed since each heater would span 97 feet across the pile as opposed to just 15 feet if the heaters were installed vertically. However, depending on the contractor's proposed pile configuration, vertical heaters may be preferable.

A summary of the modeled heater configuration is shown in **Table 8-2**.

Table 8-2: Model Heater Configuration

Parameter	Configuration
Number of heater wells	38 heater cans (76 heaters)
Heater spacing	21 feet horizontally and 6 feet vertically along side of pile
Individual heater input	300 W/ft
Total heater input to soil	7,546,000 BTU/hr (2,212 kW)

Note that the heater input does not account for inefficiencies in the heater; it represents the heat that is successfully transferred into the soil. For electric heaters, nearly all the power input into the heaters is transferred into the soil. However, for natural gas heaters, the combustion gases are exhausted after it travels through the heater well. This exhaust gas is still at an elevated temperature and therefore not all the heat is transferred to the soil. To determine the required natural gas input, it is necessary to account for the loss of heat through the exhaust.

The thermal efficiency of a natural gas heater will depend on the heater design (geometry, firing rate, excess air). Assuming a thermal efficiency of 50%, the natural gas requirement would be 15.1 million BTUs (MMBTU)/hr corresponding to approximately 15,100 standard cubic feet per hour (SCFH). The actual gas required will vary based on the selected contractor's design and will need to be confirmed. Although natural gas heaters are not as efficient as electric heaters at the point-of-use, the overall efficiency from point-of-generation to point-of-use is often much higher. This is due to the inefficiencies of electricity generation and transmission.

8.4.4.2 Modeled Heat-Up Rate

The results of the unsteady-state heating model can be seen in **Figure 8-3**. It takes approximately 50 days to heat the pile from ambient to the boiling point of the pore water (212°F, 100°C). The average soil temperature remains at boiling from around Day 50 to Day 125. Once the pore water starts to boil off, the average soil temperature begins to rise again. After approximately 150 days from the start of operation, the target temperature of 150°C (300°F) is reached on average. The model will be updated, utilizing a soil target temperature of 250°C, based on the bench study results. From Day 150 to Day 260, the pile continues to heat up and is maintained above the target temperature. The total modeled operating duration is 260 days; this excludes time for startup, commissioning, post-treatment vapor extraction, and decommissioning. Accounting for these time periods, the total duration is estimated to be around 300 to 320 days.

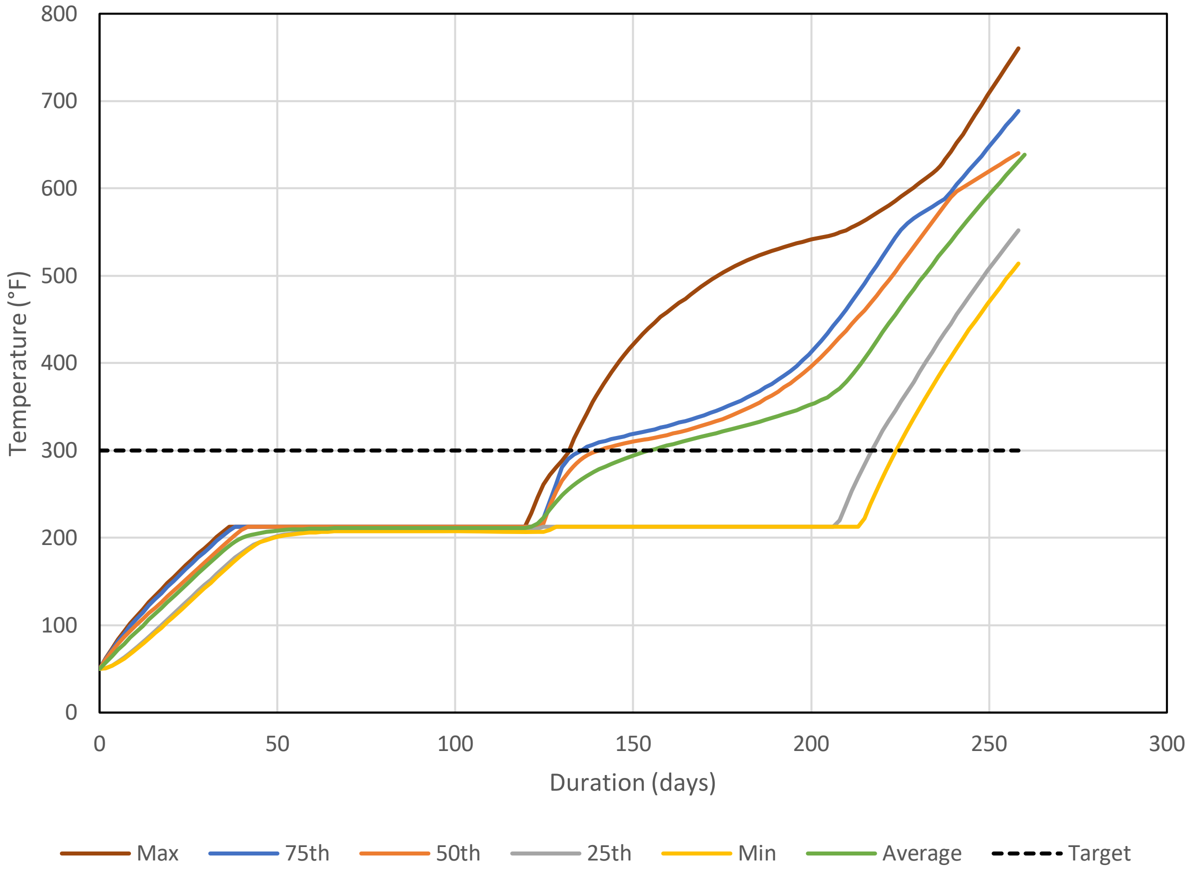


Figure 8-2: Modeled Pile Temperature Distribution

As the pile heats up and reaches boiling, the pore water will start to vaporize into steam. The steam strips contaminants from the soil and is collected in vapor extraction wells. The estimated peak steaming rate from the base case model is approximately 1,800 standard cubic feet per minute (SCFM). The cumulative steam generation over the duration of the project is estimated at around 470 million standard cubic feet (MMSCF). This corresponds to approximately 1,600 pore volumes.

The total energy input into the subsurface over the duration of the project for the base case is estimated at 47,100 MMBTU or 13,800 megawatt hours (MWh); this energy input corresponds to approximately 1,400 MBTU/yd^3 or 414 kWh/yd^3. For gas-fired heaters with a thermal efficiency of 50%, the total estimated natural gas usage is 94 MMSCF (million standard cubic feet).

8.4.4.3 Extraction and Monitoring Wells

During heating, contaminants will desorb from the soil and vaporize. To prevent contaminated vapor from escaping the pile uncontrolled, vapor extraction wells are used to collect vapors and maintain a slight negative pressure in the pile. The configuration of these wells will vary between contractors.

The predicted peak steaming rate from the model is around 1,800 SCFM; to ensure adequate pneumatic control it is necessary to size the vapor extraction system for a higher flow which will pull in additional air through the soil at a slight vacuum. Accounting for an additional 1,700 SCFM of air, the total vapor flow rate from the wellfield is estimated at 3,500 SCFM. Applying 1.5 SCFM of vapor flow per foot of screened interval, 2,340 linear feet of screen is needed. The configuration and number of extraction wells will depend on the specific design utilized by the contractor. Assuming a screened interval that spans across 195 feet of the pile's width, approximately twelve (12) horizontal vapor extraction wells would be needed.

Temperature monitoring points (TMPs) are needed to verify adequate heating of the IPTD target treatment zone. The number of TMPs is a balance between gathering enough to data to confirm performance and cost. Assuming one TMP per 3,000 square feet of pile area, approximately 20 TMPs would be needed. Individual thermocouples/resistance temperature detectors (RTDs) would be placed 1 foot below the top of the soil column (the vertical column of soil), then every 3, with the last one located 1 foot above the bottom of the treatment interval.

8.4.4.4 Contaminant Removal

The fate of contaminants in the pile is modeled using the temperature profile from the thermal model and mass transfer coefficients based on the literature (Braida & Ong, 1998). The temperature profile used to estimate contaminant removal is the average temperature profile within the pile (shown in **Figure 8-3**). Additionally, the average mass transfer coefficient published in the literature was used. Lastly, as discussed in **Section 8.1.1**, any hydrolysis reactions that breakdown contaminants were assumed to be negligible.

The estimated removal for the site COCs is shown in **Figure 8-4** and will be updated once the final mass estimate is completed. The contaminants are removed in waves – with the more volatile compounds being removed first and the least volatile compounds taking the longest. The most volatile COCs (benzene, toluene, chlorobenzene) are removed early on in the remedy. Even at the end of the pore water boiling period (Day 125) when the average pile temperature is still at 100°C (212°F), over 70% of the chlorobenzene is expected to be removed. However, the removal of the less volatile compounds is significantly less at Day 125 (approximately 20 to 30% removal for dichlorobenzenes, 7 to 10% removal for trichlorobenzenes, 2 to 3% for tetrachlorobenzenes, and <1% for pentachlorobenzene and hexachlorobenzene). By boiling off the pore water, it's possible to increase the pile temperature and achieve an expected >99% removal for all COCs by the end of the remedy after 260 days.

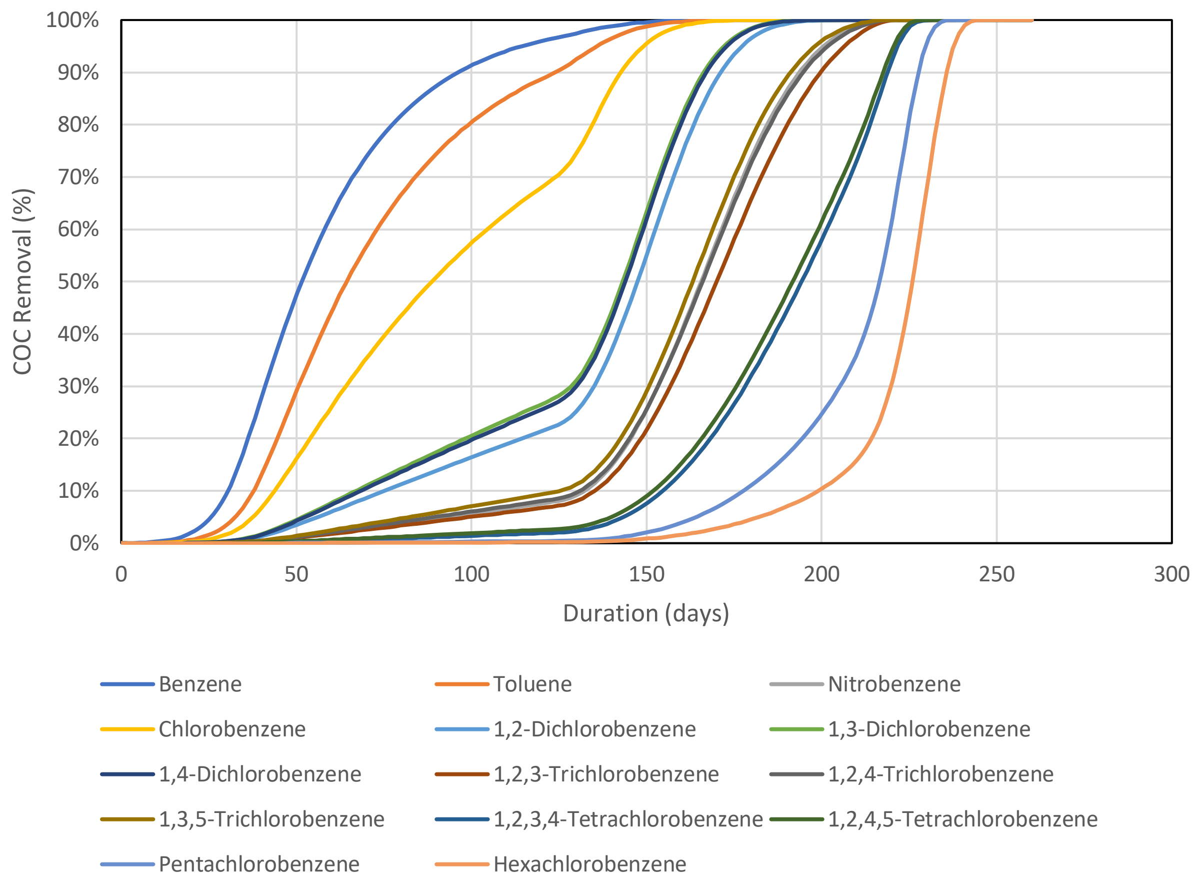


Figure 8-3: Modeled contaminant removal

8.4.4.5 Summary of Model Results

Based on the modeled heat-up rate and contaminant removal, the modeled configuration described in **Sections 8.4.3 and 8.4.4** is adequate to achieve treatment objectives. This configuration includes 38 heater wells with two heaters installed per well (76 heaters total). The resulting power input into the soil is 2,212 kW over 260 days of operation. Near complete removal of the contaminants is expected.

8.4.5 Model Limitations

Both the thermal heating model and contaminant fate model utilize simplifying assumptions to make the modeling feasible. However, these assumptions can introduce uncertainty into the model. Uncertainty is also introduced from the variability in the data used as inputs to the model. The additional uncertainty from the methods used to model the site heat up rate and containment fate are discussed below.

8.4.5.1 Thermal Heating Model Limitations

One of the limitations with the thermal heating model is the fact that it is configured for two-dimensions. The model is divided into 8 rows and 5 columns for a total of 40 blocks. This allows the model to simulate heterogeneity in the subsurface. However, it can only account for heterogeneity in two dimensions. A three-dimensional model would allow for more granularity in specifying the subsurface conditions. However, modifying the model for three-dimensions is not feasible based on the current configuration of the model. Additionally, the added accuracy with a three-dimensional model is entirely dependent on getting enough granularity in the data used as inputs into the model.

Another limitation with the thermal heating model is the selection of appropriate boundary conditions. It is important to specify realistic boundary conditions to accurately estimate heat losses. To limit the variability associated with the boundary conditions, a portion of the pile structure outside the pile is included within the model domain.

8.4.5.2 Contaminant Fate Model Limitations

The output from the thermal heating model (namely, the temperature of the model's 40 blocks) is utilized to model the fate of contaminants within the pile . Two mechanisms for contaminant removal are modeled: volatilization and reaction. To be conservative, it was assumed that any reduction in contaminant mass due to reaction was negligible.

The equations used to model volatilization of contaminants are described in **Section 8.4.2.1**. Volatilization is modeled as a mass transfer-limited process and equilibrium concentrations are calculated assuming ideality (Raoult's Law for sorbed contaminants and Henry's Law for dissolved contaminants). The assumption of ideality is a limitation of the model; as discussed in **Section 8.3.5**, the contaminants can exhibit non-ideality, forming azeotropes. There's also uncertainty in the mass transfer coefficient used to estimate volatilization rates of the contaminants. The mass transfer coefficient was based on literature data in combination with calibration to previous site data. An empirical correlation was utilized to estimate the influence of temperature on the mass transfer coefficient. This empirical correlation was established by finding the best fit to existing vapor-phase concentrations observed at previous sites.

Another limitation of the model is how the pilT temperature and contaminant mass distribution is treated. Unlike the thermal heating model, it was not feasible to model the contaminant fate in all 40 blocks. Instead, the pile temperature and contaminant mass is averaged over the entire soil volume in the pile. This simplification does not account for heterogeneity in the subsurface.

Based on the limitations in both the thermal heating and contaminant fate model, there are significant simplifications and uncertainties. Compounding this uncertainty is the variability in the input data itself. To avoid relying too heavily on the model results, other lines of evidence such as bench scale/pilot tests and experience from similar site should be used as well.

8.4.6 Soil Pile Design

The following sections identify the steps necessary to install the planned thermal remediation system and all its attendant components. Included with system installation are site access improvements, security, well design, vapor and water discharge, treatment components and utility requirements.

8.4.6.1 Soil Pile Preparation

Thermal pile cell perimeter wall subgrades should be observed and approved by a geotechnical engineer prior to wall construction to verify their suitability to provide foundation support, as recommended herein. Where existing fill materials or native weak soils are encountered at the wall subgrade, any localized weak or unsuitable material at the subgrade should be removed and replaced with compacted structural fill, geotextile wrapped washed gravel or crushed stone, such as American Association of State Highway and Transportation Officials (AASHTO) No. 57 stone, or lean concrete. The undercut trenches should extend at least 6 inches on either side of the wall base layout. The geotechnical engineer should monitor and document all undercuts. The final soil subgrade surfaces should be scarified, and the moisture content adjusted prior to compacting, as needed. Once the subgrade is properly prepared and approved, it is recommended that at least 6 inches of No. 57 stone be placed on the compacted subgrade below the wall base.

8.4.6.2 Concrete Block Construction

The concrete block design and construction for building soil pile will be detailed in the 90% DAR once the final volume of soil that needs to be treated has been determined.

8.4.6.3 TCH Well Design

The components of the TCH wellfield design include:

- **Heater Wells:** For preliminary modeling, it was assumed that heater cans would be installed horizontally through the walls of the pile. Each heater can would contain two heaters (one from each side). A 6-foot gap between the ends of the heaters was assumed to allow for thermal expansion. The average spacing for the heater cans was assumed to be around 21 feet horizontally and 6 feet vertically along the side of the pile. A total of 38 heater cans and 76 heaters would be installed in this configuration. Depending on the thermal contractor's pile design, vertical heaters could also be used, although this would significantly increase the total number of heaters since they would only extend the 15-foot depth of the pile.
- **Horizontal Vapor Extraction Wells (HVEWs):** To aid vapor/steam recovery and ensure pneumatic capture, a series of HVEWs would be installed in shallow trenches throughout the pile. Each HVEW will consist of a 2-inch-diameter 20-slot stainless steel well screen

and span across the width of the pile (200 feet, with 195 feet screened length assumed). The HVEWs will be installed at a depth of approximately 2 to 4 feet. Trenches would be excavated to 4 feet below grade, to allow for a either a properly sized silica sand or ¾ inch washed crushed stone bedding to be placed 4 to 6 inches below and above the well screen. The top of the well screen bedding will then be covered a filter fabric, to keep soils out of the well screen, then filled with 1 to 2 feet of dense grade aggregate (DGA) and native soil to grade being compacted in 6-inch lifts.

- **Temperature Monitoring Points (TMPs):** To monitor temperatures within the subsurface, a series of TMPs will be installed throughout the treatment area at a density of 1 per 3,000 square feet. TMPs wells are 1 to 1.5 inches in diameter, therefore the bore hole diameter should be 4-6 inch but may vary per contractor. The borehole annulus of the TMPs should be filled with a temperature grout to grade. Each TMP well will have a thermocouple array consisting of individual thermocouples to monitor vertical temperature distributions throughout the pile. They will each have a thermocouple located one foot below grade, followed by one three feet below grade, with the last one located 1 foot above the bottom of the bottom of the pile. Because temperatures will differ at varying distances from the heater wells and will also be affected by other heat loss processes such as vadose zone air flow, surface loss, temperature sensors deployed within the pile will be evaluated holistically to determine whether target temperatures are generally being met throughout the pile.
- **Pressure Monitoring Points (PMPs):** To ensure pneumatic control within the pile, PMPs will be used to monitor the pressure under the thermal cover. A total of 15 PMPs will be installed within the pile (one per every 5,000 sq ft). The PMPs will be installed to a depth of 6 to 12 inches below grade. PMPs are typically 1/2 to 1 inch in diameter and installed in a 2- to 4 inch-diameter borehole, but the exact size may vary per the contractor. The bottom 6 inches of the well will be screened and the borehole annulus around the screen will include a properly sized silica sand. The sand backfill should extend at least 4 to 6 inches above the top of the well screen and the remainder of the borehole annulus should be grouted with a high temperature grout to grade.

A summary of the wellfield infrastructure is provided in **Table 8-3**.

Table 8-3: Summary of IP-LTTD Well Design

Well Type	Quantity	Material	Depth/Screen	Design Basis
Heater wells	38 (two heaters per well, 76 heaters total)	4-inch CS Sch 40 or 80 Casing	Horizontally installed across 200 feet width of pile	21-foot spacing horizontally and 6-foot spacing vertically
HVEWs	12	2-inch SS 20-Slot Well Screen	Installed in top 2 to 4 feet of pile, spanning width of pile (screened length of 195 feet)	Peak steaming rate from model of 1,800 SCFM plus 1,700 SCFM non-condensables; 1.5 SCFM per foot of screen
TMPs	20	1-inch of 1.5-inch CS Sch 40 or 80	0 to 15 feet, Thermal Couples 3- to 5-foot depth intervals	1 per 3,000 ft^2
PMPs	15	½-inch to 1-inch SS 10-Slot Well Screen	Total depth 24 inches bgs Screened 12 to 14 inches bgs	1 per 52,000 ft^2 within pile

8.4.6.4 Cap Design

To prevent excessive heat loss through the sides, bottom, and top of the pile, insulating layers of material will be needed. It was assumed that insulating concrete would be used for this purpose; however, the selection of the insulation material would depend on the contractor’s design. The bottom and top layers have the most surface area (60,000 ft^2) as opposed to the front/back and sides (3,000 and 4,500 ft^2, respectively). With much more area for heat loss, it was assumed that the top and bottom insulation would be R-28. For the sides, R-14 was assumed.

In addition to the insulation around the pile, it may be beneficial to install an impermeable cover over the top of the pile. This would prevent rainwater from infiltrating the pile, which would cause cooling and require additional heat input. Durable cover material such as thick (20 to 40 mil) HDPE can cover the extents of the pile. To prevent seepage around well penetrations, the cover can be caulked to flashing at each well penetration. It may also be necessary to use sumps to collect accumulated rainwater at low points on the cover.

8.4.6.5 TCH Vapor and Water Discharge

The estimated vapor extraction rate includes 1,800 SCFM of steam plus an additional 1,700 SCFM of air (3,500 SCFM total). Up to 10 gpm of condensate may be generated after cooling the wellfield vapor. Additionally, there will be blowdown flows from the process treatment equipment. These flows could include thermal oxidizer scrubber blowdown, cooling tower blowdown, softener regeneration waste, etc. The number of blowdown streams and their respective flow rates will depend on the specific treatment system utilized by the thermal contractor.

The contaminant mass would largely be treated through the vapor treatment system (likely consisting of a thermal oxidizer with scrubber). The vapor off gas treatment method will be further evaluated once the final mass estimate is completed and will consider utilizing a catalytic oxidizer with chlorine-tolerant catalyst. A small portion of the mass may end up in the condensate and then treated through the liquid treatment system (likely activated carbon). Contaminant loading to the inlet of the oxidizer is expected to be up to 7,500 to 8,000 lb/day at peak conditions. The thermal oxidizer would need to achieve adequate destruction and removal efficiency (DRE) to meet air permitting requirements.

8.4.6.6 IP-LTTD Equipment

The following equipment items are common components of thermal treatment systems:

1. Electrical/Natural Gas services and Control Components to distribute and monitor power/gas delivery to the wellfield.
2. Vacuum blower to generate sufficient vacuum and air flow for recovering steam and vapors from the subsurface.

3. Heat exchangers to reduce temperature and aid in condensing recovered steam. A liquid heat exchanger can be used to recover heat and reduce temperature to comply with discharge requirements.
4. Moisture Separators or knock-out tanks with capabilities to demist entrained liquids from the influent soil vapor being recovered. Knock-out tanks will also separate light and dense NAPL from the vapor stream. The recovered condensate will be treated and discharged to surface water or reused where possible. Accumulated NAPL will be transferred to an oil-water separator to segregate excess water or transferred to a NAPL holding tank.
5. Vapor treatment will likely consist of a thermal oxidizer with scrubber based on the large mass of chlorinated contaminants present in the soil. The scrubber is necessary to remove and neutralize hydrochloric acid generated during combustion of the process vapor through the oxidizer.
6. Liquid treatment equipment such as weir tanks, oil-water separator, and liquid phase granular activated carbon (GAC) units.
7. Vapor monitoring or recovery equipment to document the mass removal of the system and to collect and treat recovered vapors prior to emission.
8. Instrumentation and controls necessary to monitor and operate the equipment continuously, remotely, and safely.
9. Monitoring locations associated with the equipment, and within the thermal treatment zone, to monitor treatment progress and efficiency.

Regardless of the specific thermal design approach implemented, the basis of design assumes equipment or equivalent processes that will efficiently transfer CVOCs in the pile soils to the vapor phase, effectively remove excess moisture as condensate, and then treat the extracted vapor and liquid phases in compliance with air and water discharge requirements. Instrumentation and controls are included to provide adequate control and monitoring of the individual components during continuous operation of the remedy.

A general Process Flow Diagram, will be included in the 90% DAR, which will be used for the purposes of costing, and consist of the following treatment system components:

- Vapor Treatment Train:
  - Wellfield Moisture separator (1st)
  - Heat exchanger (HX) (1st)
  - Post-Condensing Moisture separator (2nd)
  - Condensate transfer pumps from moisture separators to liquid treatment system

  - Cooling tower (CT) or chiller and integral control panel to provide cooling water to the heat exchangers
  - Blower with VFD
  - Thermal oxidizer with scrubber for removal of hydrochloric acid
- Vapor By Pass System
  - Blower with VFD
  - Duct Heater to condition soil vapors
  - Vapor Phase Granular Activated Carbon (VGAC) containers
- Liquid Treatment Train:
  - Weir tank
  - Transfer pump
  - Heat exchanger (HX)
  - Bag filter (1st, to remove emulsified oil)
  - Oil-water separator
  - Bag filter (2nd)
  - Liquid-phase GAC vessels
  - Flow totalizers (for measuring instantaneous and cumulative flows)
  - Transfer pump
  - Light non-aqueous phase liquid (LNAPL) and dense nonaqueous phase liquid (DNAPL) collection tanks
  - Effluent storage tank
- Electrical instrumentation, controls, and remote monitoring capabilities
- Backup generator and automatic transfer switch sized to continue vapor extraction to ensure pneumatic is maintained during power outage

All equipment should be in secondary containment, fitted with high level alarms, to ensure there is no release to the environment.

8.4.6.7 Treatment Equipment Design Considerations

Based on the historical sample data, the soils at the Standard Chlorine site are heavily contaminated. The expected high mass of contaminants poses challenges for the treatment equipment. These challenges include maintaining safe operation below the lower explosive limit

(LEL) of the process vapor and the potential to crystalize contaminants after cooling through the vapor heat exchanger.

Using the anticipated removal of contaminants described in **Section 8.1.3.3**, the estimated flow rate of vapor extracted from the wellfield, and published LEL data for the contaminants, it was possible to estimate the percentage of LEL that could be seen during operation (**Figure 8-5**).

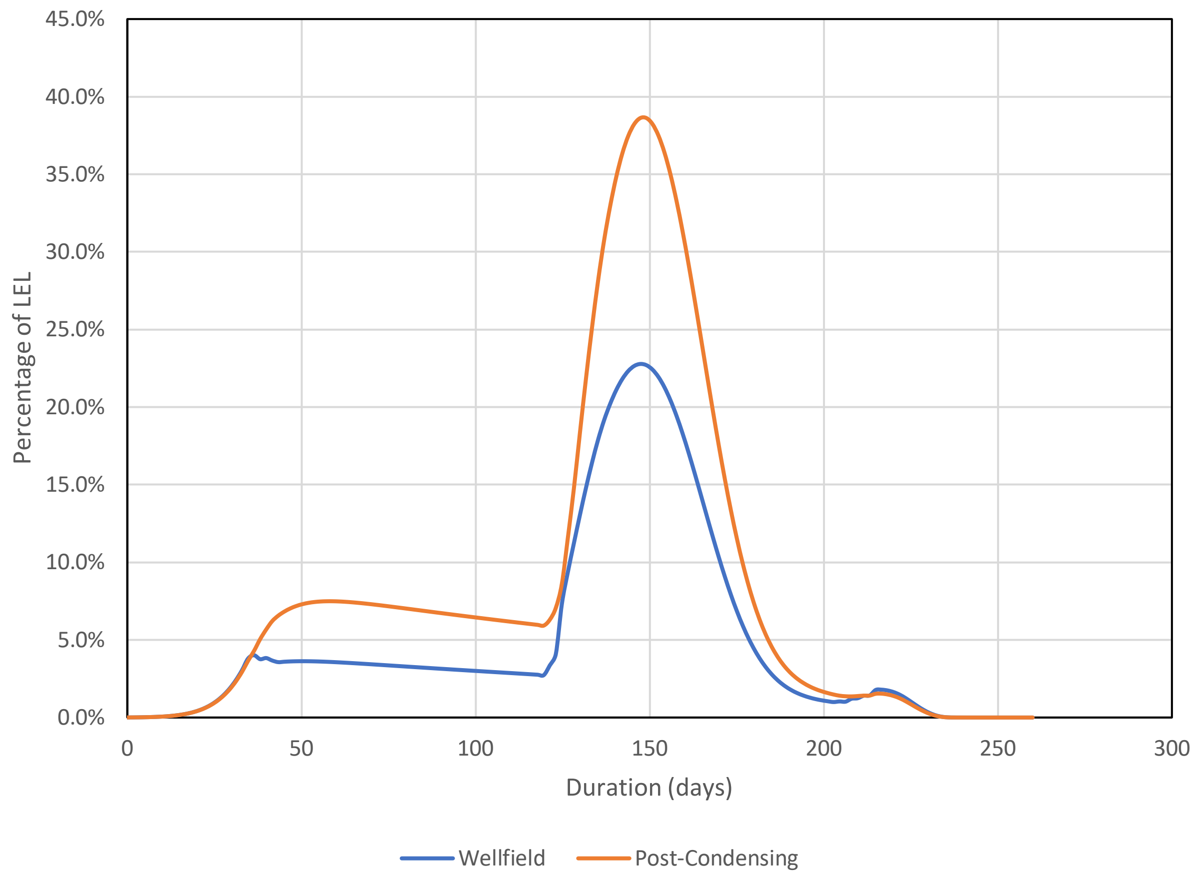


Figure 8-4: Estimated percent of LEL of process vapor

The wellfield LEL shown in the figure accounts for the higher temperature of the wellfield vapor plus the additional vapor flow from the steam that is generated in the pile. After the vapor heat exchanger, most of the steam is condensed which reduces the vapor flow, resulting in higher contaminant concentrations and a higher percentage of LEL. For the post-condensing LEL estimate, it was assumed that the process vapor is cooled to 100°F.

The peak percentage of LEL based on the contaminant mass is approximately 23% at the wellfield and 39% after cooling and condensing the steam through the vapor heat exchanger. It is important to note that the percentage of LEL experienced during operation could be significantly higher than what is estimated here. Since the proposed treatment operates at high temperature, it is possible for naturally occurring organic matter in the soil to breakdown. This may generate volatile and flammable compounds such ketones. It is not feasible to predict how much of the soil will breakdown and the resulting concentration of flammable compounds that are generated. Thus, the estimates reported here should be considered on the low-end and optimistic.

Standards such as NFPA 86 and 91 are applicable to thermal oxidizers in applications where the process vapor is at elevated percentages of LEL. These standards limit the operation of thermal oxidizer to 25% without continuous LEL monitoring or up to 50% with continuous LEL monitoring. Based on the post-condensing LEL estimate of 39%, a continuous LEL monitor would be required for this application.

Due to the uncertainty in the LEL estimate and the possibility of higher LEL percentages from the breakdown of soil organic matter, additional safety measures should be considered. A summary of possible design measures to ensure safe operation are described below. The thermal contractor may use other safety measures or a combination of these; however all mitigation measures used by the contractor should meet NFPA standards and recommended practice.

Addition of Dilution Air

Sizing the thermal oxidizer with enough capacity for the addition of dilution air would help dilute the process vapor and reduce the percent of LEL. An actuated dilution valve could be interlocked to the LEL monitor and once the percent of LEL approaches operating limits, the valve opens to admit dilution air.

Wellfield Isolation Valve

If the percent of LEL reaches the limit of safe operation, an interlock would open the dilution air valve described above and close the wellfield isolation valve. This interlock would be a last resort measure to prevent unsafe operation. By closing the wellfield isolation valve, the pile would no longer be pneumatically controlled. If this were to occur, it may be necessary to stop heating to prevent fugitive emissions from the pile. However, even after turning off the heaters, fugitive emissions may still occur due to the residual heat in the pile.

Flame Arrester

A flame arrester is a device that contains an element designed with small passages to allow the process vapor to pass through but extinguishes a flame. The flame arrestor would be located at the inlet to the thermal oxidizer. In the event of a flame propagating back from the oxidizer, the flame arrester element would prevent transmission of the flame back through the process ductwork. A thermocouple would sense the temperature of the element and if elevated temperatures from the presence of a flame is detected, dilution air would be added and the wellfield isolated. This would be a last resort measure to prevent flame propagation through the treatment system. The vacuum blower would need to be sized accounting for the additional pressure losses associated with this measure.

High Velocity Thermal Oxidizer Inlet

The use of a restricted inlet to the thermal oxidizer can allow for process vapor velocity to exceed the flashback limit. The process vapor velocity should exceed the flashback limit for all possible operating scenarios. A flow/velocity transmitter can be used to ensure adequate velocity and it could be interlocked with dilution air valve to increase flow if velocities are close to the flashback limit. The vacuum blower would need to be sized accounting for the additional pressure losses associated with this measure.

Extended Operation

If the addition of dilution air does not adequately reduce the percentage of LEL, it may be necessary to reduce heater output and extend operation. This has the effect of removing the contaminant mass more slowly and reducing their concentration in the process vapor.

In addition to the operation issues associated with LEL, the removal of semi-volatile compounds from heavily contaminated soils can create issues with the crystallization of contaminants on treatment equipment surfaces – especially at the vapor heat exchanger. From **Table 8-1**, several of the contaminants have melting points more than 100°F. If the contaminants are present in the vapor at high enough concentrations, they can condense from the vapor when cooled. For contaminants with high melting points, they can be deposited as solid crystals on the inside surface of equipment.

With the potential for fouling of equipment (especially the heat exchanger) with crystallized contaminants, it may be necessary to switch between a spare heat exchanger while cleaning the fouled exchanger. Another option may be to forgo condensing of the wellfield vapor and instead keep it at an elevated temperature. However, this would require insulation and high temperature heat trace to keep the temperature high enough to prevent crystallization and fouling. Additionally, the treatment system equipment would need to be sized for the full wellfield vapor flow including steam.

8.4.6.8 IP-LTTD Utility Requirements

The estimated electrical demand for heating the subsurface is approximately 2,212 kW. Alternatively, if natural gas heaters are utilized, an estimated 15,100 SCFH are required assuming a 50% efficiency in gas converted to thermal energy conducted to the subsurface.

8.4.7 IP-LTTD Using TCH Operational Strategy

After one IP-LTTD concrete cell and system has been commissioned the heating process will commence, while a second concrete cell is constructed and filled with untreated soils. Site constraints (i.e. available area) may limit the number of concrete cells and the footprint/volumes, which will be evaluated further in the 90% DAR. It is estimated that the soil will attain the soil target treatment temperature of 150°C (300°F), after the pore water within the pile is boiled off, in approximately 125 days. Then the soil temperature is heated to the target temperature in around 25 days. Once the soil target treatment temperature is reached, it will be maintained for 110 days to achieve the site cleanup goals. The model will be updated with the treatability data as part of the 90% DAR.

During this 260-day operational period, COC recovery will be evaluated, and soil treatment progress samples will be collected based on the rate of mass recovered by the recovered soil vapors, condensation, and NAPL (if recovered). After completing 50-60% of the target treatment temperature duration, progress soil samples will be collected, as discussed in the following section. Based on the progress sampling results, areas that have met the cleanup goals can be turned off, while areas lagging behind should have more energy focused in these areas to achieve the cleanup goals in the defined operating timeframe.

Once the soil target treatment temperature goals are achieved, diminishing returns have been reached, and the Contractor is confident that the soil clean up goals have been achieved, then confirmation samples will be collected to confirm the soil clean up goals for the COCs are achieved. During the confirmation soil sampling event, assumed to take up to one week, the heating process should be maintained in the soil pile if it can be done safely. At a minimum heating should be conducted in areas soil samples are not being collected, to maintain the soil target treatment temperature.

Once the confirmation samples have been collected and submitted for laboratory analysis the heating process will continue for two to four weeks, while the soil samples are analyzed, and results are reviewed to confirm that site cleanup goals have been achieved. If the site cleanup goals are not achieved, then the heating process will continue, and the Contractor will adjust the heating process/area until soil confirmation samples are collected that indicate site cleanup goals have been achieved. Once the site cleanup goals are achieved, the heating can cease, and a two-week cool down period can commence.

During this two-week cool down period, the soil vapor and liquid/condensate treatment systems will continue to operate. Once this cool down period is completed, the IP-LTTD system will be decommissioned and the heating process will commence in the second concrete cell. While the first concrete cell will have the cover removed and crushed for use on-site, the heaters, PMPs, and TPMs will be removed, and the treated soils will be removed from the pile. The treated soils will then be stabilized for metals treatment and mixed for biobarrier placement as discussed in Sections 10.5 and 11.3. Then the concrete cell will be refilled and the process will be repeated until all Site soils are treated. After which the two concrete cells will be removed and the site restored to existing conditions. The details of the concrete cell construction are discussed in Section 8.1.5.

The estimated IP-LTTD schedule is shown in **Table 8-4**.

Table 8-4: Estimated Project Schedule

Project Component	Number of Days
Reach Target Treatment Temp (300°F, 150°C)	150
Operate at 300°F (150°C)	110
Confirmation Sampling Collection	14
Soil Clean Up Evaluation	14
Cool Down	14
Total Days of IP-LTTD using TCH	**302**

The soil target treatment temperature goal is achieved when all the temperature sensors in the TMPs located within the pile at 1 foot bgs, then at a minimum every 3-foot interval thereafter to the bottom of the pile with the last TC 1 foot from the bottom of the treatment interval, have met the following criteria:

1. All have reached a minimum temperature of 140°C (284°F)
2. 95% have reached the target temperature of 150°C (300°F)

Temperature data will be collected at a minimum every ten minutes and a daily average, for each point, will be calculated to determine the average temperature for compliance purposes. The temperature monitoring sensors are assumed to have an accuracy of +/- 2°C (3.6 °F) and due to the dynamic nature of the system, the boiling point will be adjusted to account for hydrostatic pressure or applied vacuum.

8.4.7.1 Impact of Technology of Infrastructure

There are no known utilities present in the proposed location of the two IP-LTTD concrete cells.

8.4.7.2 Phased Sequencing

As part of the 90% DAR, the existing site utilizes will be evaluated to determine if they meet the required demands or if the utilities can be upgraded. Depending on the any limitations it may be necessary to resize the IP-LTTD concrete cell sizes, reducing the utility requirements, and therefore requiring more concrete cells or more treatment cycles.

8.4.8 IP-LTTD Implementation

This section reviews the installation, monitoring, and schedule for the IP-LTTD. It includes reviews of the activity sequencing, analytical monitoring, process monitoring and project schedule.

8.4.8.1 Sequence of Activities

- Design:
  - Generate 30%, 90% drawing packages for construction.
- Pre-Construction:
  - Generate work plans and obtain permits (e.g., discharge permit)
  - Start fabrication of IP-LTTD wells
  - Procurement of long lead equipment
  - Existing equipment testing
  - Programing and testing
- Mobilization/Site Preparation:
  - Bring office trailer (if needed) on site and establish any required storage areas
  - Bring port-a-potty and sink to site
  - Install new security fence and new gate around IP-LTTD concrete cells
  - Begin security monitoring once equipment arrives
  - Establish utility connections and service
    - Temporary Electrical or Diesel Generator: power drop for office trailer etc.
    - Water: required for the IP-LTTD operations
    - Gas: required for the IP-LTTD operations
- Construction:
  - Electrical Service: power drop, transformer installation and pad, diesel or compressed natural gas generators
  - Accept delivery of equipment and materials
  - Protect wells and utilities as needed
  - Construct IP-LTTD concrete cells
  - Install heaters, PMPs, and TMPs

  - Install HVEW runs and thermal cover (if required)
  - Install thermal cover
  - Connect process piping and power feeds/control wiring to above grade
  - Connect TMP system
  - Install vapor and liquid treatment equipment and complete wiring and plumbing
  - Commissioning system by testing system functionality and alarms to be defined by Contractor
- Operation:
  - Heater startup and optimization
  - Daily/Weekly/Monthly performance data collection and sampling
  - Heat to 300°F (~150 days to reach temperature)
  - Continuous operation at or above 300°F (~110 days at temperature)
  - Conduct progress soil sampling to evaluate the remedy progress
  - Conduct soil confirmation sampling event
  - After achieving site cleanup goals and obtaining approval, cease heating
  - Begin 14-day cooldown period consisting of
    - Vapor recovery operations to ensure capture of volatilized CVOCs
    - Liquid extraction operations to treat recovered condensate for the pile
- Demobilize:
  - Remove all the above grade IP-LTTD treatment equipment
  - Remove the thermal cover and SHVEW and dispose of off-site (EPA must approve of the disposal facility prior to off-site disposal)
  - Remove the concrete cells
  - Restore site to pre-construction conditions including grading and reseeding as defined in Section 12.

8.4.8.2 Analytical Monitoring

Performance monitoring of the IP-LTTD soils and mass removal will be assessed by the Contractor through analytical sampling that includes the following media, locations, frequency, and design basis.

- Soil Sampling

- **Progress Sampling** – after operating at the target treatment temperature for 75% of the planned treatment duration, soil samples will be collected to evaluate the effectiveness of the thermal remedy. One boring will be advanced every 8,000 ft2 within the pile for a total of 8 borings. The Contractor needs to ensure that piping, wires, and other IP-LTTD appurtenances are placed with consideration of these sampling locations. Drilling will be conducted using a track mounted geo-probe or hand auger to allow advancement through the vertical extent of the soil pile. Samples will be collected following a "Hot Soil Sampling Protocol," which will be supplied by the Contractor. Samples will be collected starting 1 feet below grade, and then every 3 feet thereafter, with the last sample being collected 1 foot above the bottom of the vertical extend of the soil pile. Therefore, a total of 6 samples, samples will be collected per boring (1, 4, 7, 10, 13 and 14 fbg). Soil lithology will be recorded, cuttings will be screened with a PID, and well logs will be generated. Samples will be collected and submitted for laboratory analysis for COC VOCs, SVOCs, and pH by EPA Method 8260D and 8270E.
- Drill cuttings will be drummed, labeled, and staged inside a containment area within the work area. The drums will be staged on 10-mil polyethylene sheeting until they can be treated on-site or disposed of off-site. A composite sample will be collected from the drums and submitted for laboratory analysis of waste characterization parameters. The drums will then be transported off site under a Bill of Lading (BOL) to an appropriate facility for disposal. During this sampling event, heating should be maintained in as much of the soil pile as safely possible, but these days of operations will not be included toward the required number of days operating at the target thermal treatment temperature.
- **Confirmatory Sampling** – Once the performance criteria have been achieved and the Contractor determines that the thermal treatment has reached site clean-up goals, then borings will be advanced every 5,000 square feet within the pile for a total of 12 borings. The Contractor needs to ensure that piping, wires, and other IP-LTTD appurtenances are placed with consideration of the sampling locations. Drilling will be conducted using a track mounted geo-probe or hand auger to allow advancement through the vertical extent of the soil pile. Samples will be collected following a "Hot Soil Sampling Protocol," which will be supplied by the Contractor. Samples will be collected starting 1 foot below grade, and then every 3 feet thereafter, with the last sample being collected 1 ft above the bottom of the vertical extend of the soil pile. Therefore, a total of 6 samples, samples will be collected per boring (1, 4, 7, 10, 13 and 14 fbg). . Soil lithology will be recorded, cuttings will be screened with a PID, and well logs will be generated. Samples will be collected and submitted for laboratory analysis for COC VOCs, SVOCs, and pH by EPA Method 8260D and 8270E.

  - Soil cuttings will be drummed, labeled, and staged inside a containment area within the work area. The drums will be staged on 10-mil polyethylene sheeting until they can be treated on-site or disposed of off-site. A composite sample will be collected from the drums and submitted for laboratory analysis of waste characterization parameters. The drums will then be transported off-site under a BOL to an appropriate facility for disposal. During this sampling event, heating should be maintained in as much of the IP-LTTD pile as safely possible, and heating will continue after the sampling event is completed until the laboratory analyses confirm the soils have achieved the site cleanup goals, at which time heating can be terminated in the pile. If soil cleanup goals are not met the Contractor should continue operations and/or make modifications (i.e., turn some areas off and focus on others, or add more heaters). The confirmation sampling should be conducted again in the necessary areas.

- Liquid Treatment Monitoring
  - Liquid samples will be collected for use in mass removal tracking, system performance evaluation, and compliance, at the following locations and frequency as follows:
    - Weekly
      - Combined Influent from the pile sumps
      - Combined Condensate
      - LGAC Influent;
      - Discharge, NPDES Compliance Point
    - Bi-Weekly
      - LGAC Mid-fluent to monitor for breakthrough
      - As Needed
      - Samples to assess system performance, assume 10 direct sampling events from three locations
- Vapor Treatment Monitoring
  - Vapor grab samples will be collected in summa canisters for use in mass removal tracking, system performance evaluation, and compliance, at the following locations and frequency as follows:
    - Weekly
    - Influent Soil Vapor, Combined from HVEWs
    - Inlet to thermal oxidizer
    - Vapor Discharge Compliance Point

- Outlet of thermal oxidizer and scrubber

The following on-site equipment will be available on-site at all times and was assumed for the purposes of costing:

- Rental of photoionization detector (PID) fitted with 11.7 eV lamp
- Rental of 4-gas meter: LEL, O2, H_2S, CO
- Tedlar bags for PID readings: 1 per day
- Peristaltic pump: continuous rental in order to collect daily vapor samples in Tedlar bags and measure with PID and 4-gas meter

8.4.8.3 Process Monitoring Requirements

The principal goal is to meet Site soils RGs for the COCs. Mass removal and subsequently the quantity and type of mass remaining will be the primary performance criterion that will be used to judge the success of thermal treatment and when progress and confirmation soil samples will be collected.

Residual Soil Concentration

Following completion of the 300°F (150°C) heating cycle, the Contractor will collect soil samples to determine if the site has attained cleanup goals as described in the previous section above. If significant elevated concentrations are found in exceedance of the cleanup goals identified in **Section 3.1**, further operation may be warranted.

Temperature

The Contractor shall demonstrate that the IP-LTTD system is producing and effectively distributing the heat in the target areas of the subsurface. The Contractor shall propose methods and requirements in their Work Plan that demonstrate that soil temperatures meet contract requirements. For the purposes of costing in this design, horizontal and vertical temperature profiles within the treatment area will be measured at several locations and at three-foot vertical intervals within the vertical extend of the soil pile. The Contractor will demonstrate that the heat in the soil pile is sufficient to treat the contamination. The system shall be capable of maintaining the temperatures until the performance results have been evaluated at both target temperatures.

Heating Duration

Once the target temperature of 300°F has been reached, the Contractor will maintain these temperatures for a specified minimum or base duration of 110 days. The vapor and liquid treatment systems are considered a fully functional system running 24 hours/day-7 days/week excluding normal maintenance/repair periods which do not affect temperature of the treatment zone. A common expectation is at least 95% uptime of the treatment systems, not counting regularly scheduled maintenance. Operation should include routine monitoring and documentation. The period for treatment duration will be followed by a two-week post-treatment period consisting of continued operation of the vapor recovery system.

VOC Removal and Emissions

The Contractor will ensure that VOC recovery rates have dropped to acceptable levels (e.g., assumed to be <10% of the maximum effluent mass maintained over a 2-week period) prior to proposing initiation of soil sampling or system shutoff. The vapor recovery shall be performed throughout the heating operations and additional operating period following the heating shutdown. All recovered vapors shall be treated for removal and/or destruction of VOCs. Contractor will provide equipment to remove the VOCs to permitted levels.

Safety and Environmental Controls

The area surrounding the site is a mix of residential and commercial areas, with the nearest residents approximately 1-mile from the site. The Contractor will ensure that no excessive steam pressure is created in the subsurface, and no migration of the impacted groundwater plume or soil gas vapors will occur to sensitive receptors beyond baseline conditions. There shall be no surface expression of excessive heat such as visible steaming or observable vapors aboveground.

The Contractor is responsible for developing a site-specific health and safety plan and relevant task hazard analyses to cover drilling, construction, restrictions to the operational wellfield, and sampling and monitoring in hot conditions.

Contractor will meet the requirements of local and/or state noise ordinances. This ordinance will be included in the 90% design.

Contractor shall also minimize impacts to quality of life for residents in the vicinity of the site (air quality, lighting, odor, traffic, working hours).

The Contractor will supply a detailed design, as part of the 90% Design, which will be utilized as part of HAZOP, to ensure the system is designed properly and can be safely implemented.

The Contractor will monitor the effectiveness of the IP-LTTD process by documenting the reduction of VOC mass being recovered in the vapor recovery and condensate collection systems. The Contractor shall provide one-week notice prior to the collection of progress and/or confirmation sampling events. The monitoring results will be used by the Contracting Officer Representative (COR) to determine whether any additional (i.e., optional) period of treatment or additional sampling will be required beyond the base treatment.

8.4.9 Performance Criteria

The minimum performance monitoring requirements must be met before IP-LTTD operations are completed, are referred to as primary performance criteria. Sections that follow detail the various criteria to be used and relied upon to predict progress and confirm attainment of cleanup goals.

8.4.9.1 Primary Performance Criteria

As described in **Section 8.4**, IP-LTTD performance for this Site will require reaching and maintaining the soil target treatment temperature for a period of time necessary to achieve treatment goals. The soil target temperature that must be achieved is 300ºF (150°C), and this temperature must be maintained for a minimum of 110 days. This target temperature and duration are estimated to be the minimum requirement for ensuring the site soil cleanup goals are met.

Mass Removal Diminishing Returns

Due to the difficulty of predicting subsurface abnormalities and/or contaminate mass distribution in the soil pile, additional heating time may be required to achieve cleanup goals within the treatment cell. In addition to the primary performance criteria, the Contractor will be required to continue operating the SIP-LTTD system beyond the specified 260 days if asymptotic mass removal conditions have not been achieved. Asymptotic mass removal conditions are defined for this Site as:

- Mass recovery rates in all phases (i.e., lb/day) as measured by analytical samples of recovered liquids and vapors are less than 10% of the peak daily mass recovery rate (e.g., from 100 lb/day to less than 10 lb/day)
- Mass recovery rates remain below 10% of peak mass recovery for at least three consecutive sampling events conducted over a minimum of a 14-day period
- Wellfield flow rates do not vary more than 25% during this 14-day period

Soil Cleanup Goals

Once temperature criteria have been met and mass removal diminishing returns have been confirmed, confirmation sampling may commence as described in **Section 8.5.3**. Soil cleanup goals for the IP-LTTD are summarized in Section 3.3.1, **Table 3-2**.

8.4.9.2 Secondary Performance Criteria

Secondary performance criteria are as follows:

- Vapor Recovery

  - Influent IPSPH-LTTD pile concentrations and influent/effluent points on the vapor treatment system will be monitored daily with a PID and weekly with summa canister samples for laboratory analysis by EPA Method TO-15.
  - Vacuum, flow rate, and temperature will be monitored at the inlet to the IP-LTTD vacuum blower on a daily basis.
- Liquid Treatment
  - Influent from pile sumps and combined condensate flows will be continuously monitored for mass recovery estimates. Effluent from IP-LTTD treatment system will be continuously monitored for discharge compliance.
  - Influent from pile sups and combined condensate streams will be sampled weekly for laboratory analysis of COC VOCs, SVOCs, and pH by EPA Method 8260D and 8270E.
  - Power, natural gas, and potable water use will be tracked using totalizing meters and recorded weekly.
- Pneumatic Control
  - Presence of vacuum or the absence of pressure will be confirmed in pressure monitoring points (PMPs) on a weekly basis. PID or analytical monitoring for COCs may be required if positive pressure is observed in PMPs.
  - Visual observations for escaping steam will be made daily during the work week.
- Air Monitoring
  - Up to five perimeter locations around the pile will be monitored by PID continuously with real-time readings available remotely. Summa canister samples will be collected from three of those locations, one upgradient and two downgradient for laboratory analysis by EPA Method TO-15 monthly until steam production is observed and every two weeks thereafter until shutdown.
  - Within the pile and process equipment area, PID monitoring will be performed daily to observe for loss of pneumatic capture. Odors will be noted during daily inspections.
- Noise
  - Noise levels at the property perimeter will be monitored after new sources of noise are introduced and then monthly during operations, cool down and demobilization activities.

8.5 Mobile Rotary Kiln LTTD

8.5.1 Process Description and Requirements

The ESMI thermal desorption unit (TDU), Model 90-043 manufactured by Astec Industries, Chattanooga, Tennessee, is a direct-fired, hot-configuration thermal desorption system. The TDU consists of seven principal components: feed system; rotary thermal desorption unit (primary treatment unit); pugmill (soil cooling and rehydration) and discharge conveyor; dual cyclone; thermal oxidizer (secondary treatment unit); evaporative cooling chamber; and baghouse. Contaminated solids are heated in the primary treatment unit (PTU) to a temperature pre-determined based upon contaminant characteristics. The PTU, a long rotating steel cylinder, is directly heated by a 42-MMBtu/hour burner located at the feed end of the dryer. The burner can be fueled by propane, natural gas, or fuel oil. Contaminated media is fed into the burner end of the PTU where it is directly exposed to the heat generated by the burner. The temperature of media fed to the PTU increases as it moves along the length of the cylinder. Media temperature is monitored at the discharge of the PTU just prior to the pugmill.

The induced draft (ID) fan located at the end of the baghouse generates a negative pressure on the entire system that is the motive force for the effluent airstream throughout the TDU. Products of combustion combined with desorbed contaminants are introduced to the air pollution control (APC) system upon exiting the PTU. The APC is utilized and designed to meet emissions criteria set forth by regulatory agencies. Larger solid particles that become entrained in the air stream are removed in the dual cyclone by centrifugal force. These solids are conveyed to the pugmill and mixed with the media discharged from the PTU.

The effluent air stream continues through the dual cyclone to the thermal oxidizer (secondary treatment unit; STU) and are reduced to carbon dioxide and water. The air stream is then cooled in the evaporative cooling chamber (ECC) where an air over water system reduces the air stream temperature to allow final particulate removal in the baghouse. The baghouse utilizes high efficiency bags to reduce particulate emissions to acceptable regulatory levels prior to effluent discharge to the atmosphere. Solids captured in the baghouse are conveyed to the pugmill where they are also mixed with solids from the PTU and dual cyclone prior to discharge to the conveyance system.

8.5.2 Treatment Temperatures

The RK-LTTD bench testing will be conducted to confirm the soil target temperatures and will be included in the 90% DAR.

8.5.3 Compliance Sample Requirements

Treated soils will be separated in piles of approximately 1,000 cubic yards, three samples will be collected for each pile, and sent to a laboratory for analysis COC VOCs, SVOCs, and pH by

EPA Method 8260D and 8270E . Each sample will be compared to the RGs for the COCs, with no results being two times the RG, with the average of the three samples below the RGs for each of the Site COCs.

8.5.4 Mobile RK-LTTD Utility Requirements

The mobile RK-LTTD utility requirements will be determined once the bench testing is completed, the final volume of soil to be treated is finalized, and a mobile kiln that meets the site requirements has been identified. This will be detailed in the 90% DAR.

8.6 Project Required Utilities

The utilities required to allow for the implementation of this project and/or the availability to upgrade or install new services to the Site, will be included in the 90% DAR.

8.7 LTTD Technology Comparison

Table 8-5 provides a comparison of the LTTD options under consideration for the Site. The table compares the feasibility, costs, and feasibility considerations for each technology option. For this comparison, feasibility refers the availability of the required utilities and land area, that dewatering needs can be met for each option, and that the final treated material is compatible with both the metals stabilization and biobarrier designs where a low buffering capacity is required, and pH is a critical factor (ideal pH lies between 5.5 and 7.5). Based on this comparison, a recommended IP-LTTD approach is suggested. This will be further discussed with USEPA and USACE before proceeding with the next phase of design.

Table 8-5: Technical and Cost Comparison Matrix for the Proposed LTTD Technologies

Comparison Criterion	Rotary Kiln LTTD	In-Pile LTTD	In-pile LTTD with Additional Real Estate
Feasibility			
Effectiveness	99%	99%	99%
Removal efficiency	Not tested but results should be similar at 250 deg C	99.999% @ 250 deg C	99.999% @ 250 deg C
Achievement of PRGs for COCs	Not tested but all RGs should be meet at 250 deg C	All RGs Meet at 250 deg C	All RGs Meet at 250 deg C
Implementability	Electrical/Gas/Water All Available Near Site	Electrical/Gas/Water All Available Near Site, Sensitivity analysis needs to be conducted to determine the required load to optimize schedule	Electrical/Gas/Water All Available Near Site Very high electrical demand to be met Sensitivity analysis needs to be conducted to determine the required load to optimize schedule

Comparison Criterion	Rotary Kiln LTTD	In-Pile LTTD	In-pile LTTD with Additional Real Estate
Min of three vendors available?	Nelson, Clean Earth, Clean Harbors, Republic Services	TRS, Cascade, Mc2, Geo	TRS, Cascade, Mc2, Geo
Power requirements (KW)	1,000 kW, 480 V, 3 Phase, Delta or Wye	3,750 kW, 480 V, 3 Phase, Delta or Wye	11,250 kW, 480 V, 3 Phase, Delta or Wye
Power upgrades needed	Yes, new transformers	Yes, new transformers	Yes, new transformers
Gas requirements (MM BTU/ hr)	94	10	10
Gas upgrades needed	Yes, no gas service	Yes, no gas service	Yes, no gas service
Plant/organic content limitation	less than 5-8% vegetation by volume	less than 5-8% vegetation by volume	less than 5-8% vegetation by volume
Moisture content limitation	18%	None	None
Soil/sediment physical suitability	Low	Low	Low
Biobarrier amenability	Low	Moderate	Moderate
Water requirements	~90 gpm @ 100 PSI (booster pump required)	~20 gpm make up water for cooling towers	~20 gpm make up water for cooling towers
Water upgrades needed	Yes	Yes	Yes
Real Estate Needs	No	No	Yes
Process and Operation			
Dewatering method	Gypsum (10%)	None	None
Treatment temperature	250 C	250 C	250 C
Continuous/Batch?	Continuous	Batch	Batch
Throughput or batch size	Assumed processing 30 tons/hr for 5.5 days per week, 24 hrs per day	1 cell, 50,000 CY per cell, soil to be treated in consecutive bathes, assumed 100 days to empty and refill cell between batches.	3 cells, 50,000 CY per cell, soil to be treated in concurrently.
Post-treatment pH	7-9	4-6	4-6
Pretreatment staging	**Gravity Dewatering SDA [2 x 1 acre]. Reagent mixing pad** [4 x 0.25 acre pads]. Excavator and loader operating space.	**Gravity Dewatering SDA [2 x 1 acre].** Excavator and loader operating space to load into cell.	**Gravity Dewatering SDA [2 x 1 acre].** Excavator and loader operating space to load into cells.
Pretreatment storage	**Dewatering feed material storage pad** with underdrain sized for 1 week of dewatering processing production. **Reagent addition feed material storage pad** sized to accommodate differential between dewatering and reagent processing rates plus FS=2. **Reagent material stockpile area** sized for 2 weeks	Mechanical dewatering, direct load into treatment cell	Mechanical dewatering, direct load into treatment cell

Comparison Criterion	Rotary Kiln LTTD	In-Pile LTTD	In-pile LTTD with Additional Real Estate
	reagent processing production. **Kiln feed material storage pad** partitioned and sized for 2 weeks of kiln treatment production plus TAT for physical property conformance testing.		
Pretreatment process	Mechanical dewatering, Reagent [gypsum] addition, physical property conformance testing	Mechanical dewatering, direct load into treatment cell	Mechanical dewatering, direct load into treatment cell
Treatment process	100 x 100 ft.	300 X 300 ft.	3 X 300 X 300 ft.
Post-treatment staging	**Metals stabilization reagent addition feed material storage pad** sized to accommodate differential between kiln and stabilization processing rates plus FS=3.	**Metals stabilization reagent addition feed material storage pad** sized to accommodate up to 50,000 CY	**Metals stabilization reagent addition feed material storage pad** sized to accommodate up to 50,000 CY
Water treatment	Additional capacity required for mechanical dewatering filtrate.	Additional capacity required for mechanical dewatering filtrate.	Additional capacity required for mechanical dewatering filtrate.
Operational Timeline			
Preparation Schedule	0.33 year	0.5 year	1 year
Treatment Schedule (Heating Only)	1.25 year	3.25 years	1.25 years
Post pH Adjustment Schedule	0.5 year	0.5 year	0.5 year
Rough Order of Magnitude (ROM) Costs			
Additional real estate	None	None	Yes
Natural gas extension	Additional easements needed	None	None
Utility usage - power (KW/hr)	4,500,000	52,557,120	52,557,120
Utility usage - gas (MM BTU)	750,000	250,000	250,000
Water Usage (gallons)	43,500,000	28,500,000	28,500,000
Pretreatment (vegetation removal)	[redacted]	[redacted]	[redacted]
Pretreatment (gravity dewatering)	[redacted]	[redacted]	[redacted]
Pretreatment (reagent conditioning)	[redacted]	[redacted]	[redacted]
Treatment (including mobilization, utilities, treatment, and demobilization)	[redacted]	[redacted]	[redacted]

Comparison Criterion	Rotary Kiln LTTD	In-Pile LTTD	In-pile LTTD with Additional
Total Estimated +50%/-30%	(b) (4) [redacted]		
		Environmental Impacts	
Additional handling	High	Moderate	Moderate
Energy consumption	High	Moderate	High
VOC emissions	High	Moderate	High
Worker exposure	High	Moderate	Moderate
Carbon footprint	High	Moderate	Moderate

Each thermal treatment option is viable to meet the Site remediation goals as identified in the ROD. Rotary kiln treatment has a cheaper mobilization and startup but requires significant infrastructure and a higher potential for cost increase due to high natural gas input requirements and additional handling to achieve the requisite 18% moisture on soil feed. The need to add gypsum (10%) to the rotary kiln feed material to achieve 18% moisture poses significant implementability issues for subsequent technologies, such as metals stabilization and biobarrier construction, due to pH increase. The rotary kiln also requires constant maintenance, feeding, and operators on site, which increases potential human exposure and increases operational cost. Additionally, because of expected utility easements and constant operational costs, the rotary kiln option has a larger risk of cost variation.

In-Pile LTTD technology would require larger staging areas and have a larger operational footprint but would not require the high level of operation oversight and material preparation necessary for the rotary kiln. Additionally, because the in-pile heating options can be enclosed, they offer additional community benefits in the form of vapor control, less worker exposure, and lower natural gas usage. In-pile heating is less advantageous from a time and cost perspective, especially if additional real estate is required for the potential construction of three in-pile cells rather than one. Though additional real estate costs are currently unknown, both in-pile cell LTTD options are currently within 10% of the rotary kiln LTTD cost. Adding additional or larger thermal treatment cells can also reduce in-pile operation times, placing the completion timeframe of in-pile heating within one to two years of the completion time predicted for rotary kiln processes.

Due to material handling difficulties, pretreatment requirements, higher potential for cost variations, and increased potential for worker exposure for the Rotary Kiln LTTD option, it is AECOM's professional opinion that in-pile heating should move forward in future design deliverables as the selected thermal treatment technology. Time disadvantages of in-pile heating should be further addressed after treatment volumes are finalized and the availability of additional real estate can be determined.

9 Metals Stabilization and Backfilling

9.1 Overview and Metals Treatment Goals

As stated in the ROD, Amendment 3 (EPA, 2022), the primary human health and ecological risk at the Site is from chlorobenzenes. The primary remedial actions focus on chlorobenzenes and include excavation and thermal treatment of sediments and placement of a biobarrier. Metals may also pose a risk to human health and/or ecological receptors. The ROD has set goals for metals. The goals are presented in **Table 9-1**.

Table 9-1: Sediment and Surface Water Goals for Inorganics (Metals and Cyanide)

Constituent	Sediment Goals in ROD (mg/kg) Applies to Top 2 Feet	Receptor	Comparison Criteria for Leaching after Stabilization[3] (ug/l)
Copper (Cu)	69	Macroinvertebrate Community	11
Hexavalent Chromium (Cr+6)	4 or 35[1]	Trespasser	40
Trivalent Chromium (Cr+3)	None stated	None stated	Not applicable
Cyanide	0.32	Macroinvertebrate Community	Need to determine what form of cyanide we have and if thermal will remove or transform
Lead (Pb)	68	Macroinvertebrate Community	5
Mercury (Hg)	0.40	Macroinvertebrate Community and Piscivores	0.031 What form? Organic? Thermal may remove this
Nickel (Ni)	33	Macroinvertebrate Community	
Vanadium (V)	310	Trespasser	62
Zinc (Zn)	240	Macroinvertebrate Community	240
Barium (Ba)	None stated		None stated
Beryllium (Be)	None stated		None stated
Thallium (Tl)	None stated		None stated

(1) Cr goal based on assumption that all is hexavalent Cr, no standard set for trivalent, test will include determining if Cr is tri or hexavalent.

(2) Surface water goals were in the FS and Ecological Risk Assessment but don't appear to be in the latest ROD.

(3) Need to determine a specific test (synthetic precipitation leaching procedure [SPLP] with site water for example) and goal after stabilization that we can use to determine success of stabilization

The need for metals treatment will depend on the presence, leachability, and bioavailability of metals after thermal treatment and after incorporation into the biobarrier. The ROD includes a metals stabilization component as a contingency in case metals treatment is necessary.

Components of the overall remedy and how they may affect the metals stabilization are as follows:

- **Excavation**: Excavation is not likely to significantly affect the concentration or state of metals in the sediment. Some change in oxidation state is possible but unlikely to be significant.
- **Dewatering**: Bench studies are underway to determine the need for and approach to dewatering. Some metals in the pore water may be removed by gravity dewatering or press filters, although the effect is likely to be minor. Addition of reagents such as lime kiln dust (if used) could have a significant effect on metals solubility. For example, the increase in pH from the use of lime kiln dust may mobilize some metals and possibly immobilize other metals.
- **Thermal Treatment**: Thermal treatment will change the soil structure and possibly the concentration of metals or solubility of metals. The bench studies include testing of soils before and after thermal treatment to determine conditions after thermal treatment.
- **Organic Material Amendment**: This is an optional element in case the thermally treated soil has a low organic carbon content which would adversely affect the restoration of the wetland. For some metals, adding the organic amendment may reduce solubility. The organic amendment would apply to soil below 2 feet. Soils above 2 feet will have an organic amendment as part of the biobarrier.
- **Biobarrier**: The top 2 feet of backfill will be a biobarrier. The biobarrier will consist of thermally treated soil, granular activated carbon, organic carbon additives, and bioaugmentation (microbes known to degrade chlorobenzenes). The biobarrier may change the solubility and bioavailability of metals.

A series of bench studies are underway to determine the condition of soil after thermal treatment and to test prospective metals stabilization reagents for thermally treated soils. The biobarrier studies will also include metals testing to evaluate if the biobarrier amendments will reduce metals leachability.

At the time of the ROD, sediments at the Site had not been tested to determine if the chromium was in the trivalent or hexavalent form. The most recent testing demonstrates that the natural condition of the sediments is trivalent and treatment for chromium will not be required. After thermal treatment the soil will be tested for hexavalent chromium. If hexavalent chromium is present above 4 mg/kg after thermal treatment, stabilization will be required. In this circumstance, the stabilization agent will be designed to convert the hexavalent chromium to the less mobile and less toxic trivalent form.

Metals stabilization will not remove metals from the soil. Thus, the goals in the ROD in terms of total metals present would still be exceeded. Goals for treated soil will be based on conducting leachability testing. Leachability will be tested in the bench studies using the synthetic precipitation leaching procedure (SPLP) method 1312. For this test the soil is placed in a vessel with water at a 20:1 ratio of solution to solid. The water from this preparation (the leachate) is then tested for concentration of metals. For the purposes of the Preliminary Design, SPLP results will be compared directly to the surface water goals (see **Table 9-1**) without a dilution/attenuation factor. This initial comparison directly to the surface water goals is overly conservative. Furthermore, reducing the leachability result to below the surface water goals may not be technically feasible. The bench studies will show which metals require stabilization after thermal treatment and will provide a basis for determining achievable leachate results. Results from the bench studies will be considered by the ecological assessment group which may recommend toxicity testing, development of an attenuation factor, or other means to establish appropriate treatment goals for stabilized material. This information will be used to establish a leachate treatment goal for specific metals that is protective of human health and ecological receptors.

The ROD specifies that the criteria in **Table 9-1** apply to the top 2 feet of sediment. Thus, thermally treated sediment that is placed deeper than 2 feet will not require metals stabilization. The logistics and practicality of designating treated sediment for replacement at specific depth intervals is discussed in Section 9.5.

The metals stabilization, if required, is assumed to apply only to excavated sediments. The footprint and depth of excavation is being determined based on achieving the RGs for CB. An evaluation of metals remaining after the chlorobenzenes remediation may be conducted later.

9.2 Design Criteria

Bench studies are underway to select the best reagent and dose for metals stabilization. Criteria for selection of reagents are:

- Must be safe to handle in field environment.
- Must immobilize metals present in site material. Preliminary goals for leachability after treatment are provided in **Table 9-1**.
- Ensure the metal stabilization reagents do not impact aquatic flora/fauna nor cause nutrient depletion or extreme pH conditions. Toxicity data from the manufacturer will be reviewed and evaluated by the project ecologist. A pH range (after mixing) of 6 to 9 is

recommended. Toxicity data will be provided to EPA for review by the EPA ecological risk assessor.

- Must be compatible with other reagents added during the biobarrier treatment phase.
- Must be cost-effective and readily available.

Factors to consider in developing the mixing process are:

- The process must be safe to implement in the field environment.
- Footprint of processing area must be consistent with available space for staging, mixing, and storing after mixing and before backfilling.
- The production rate for the metals mixing process must be designed to keep pace with the rotary kiln thermal treatment process(if that process is selected).
- If possible, the mixing process should be designed to be conducted outside without a rain cover.

9.3 Reagent Options and Bench Testing

Additional metals sampling of Site soils has been conducted. The purpose of this sampling was to provide better delineation of the metals, determine the valence state of chromium (trivalent or hexavalent), and determine the best locations to collect soil for the bench studies. Results from the 2023 sampling were similar to previous sampling in that most metals samples were below or less than 10 times the criteria in **Table 9-1**.

- Chromium: All the chromium results were below the reporting limit for hexavalent chromium. While in some cases the reporting limit is above 4 mg/kg due to matrix interferences, the chromium results provide firm evidence that in-situ sediments do not contain hexavalent chromium. Total chromium was present in untreated soils at levels above 100 mg/kg. The effect of thermal treatment on the valence state of chromium will be determined in the bench studies (not yet complete).
- Mercury: Mercury results range from 0.4 to 1.4 mg.kg. The highest result was at location DG-01. The bench studies will provide an indication of the degree to which mercury is removed by thermal treatment.
- Lead: Lead results ranged from 68 to 110 mg/kg. The highest result was at location DG-05.
- Copper: Copper results ranged from 1.9 to 73 mg/kg with the highest result at location TS-08.
- Nickel: Nickel results ranged from 1.6 to 130 mg/kg with the highest result at location TS-08.

- Zinc: Zinc results ranged from 3.8 to 440 mg/kg with the highest result at location DG-13.

Bench scale studies are underway in accordance with the approved Bench Study Workplan. At this time, it is not known which metals will require treatment. Soils will undergo thermal treatment prior to being submitted to the treatability laboratory for stabilization testing. Baseline sampling of thermally treated soils will include analysis of total metals as well as leachable metals (SPLP test). The metals results will be reviewed and then the best reagents for metals stabilization selected.

A preliminary list of reagents being considered for the stabilization studies is provided below. Other reagents may be considered based on review of the baseline data (after thermal treatment).

9.3.1 Metafix

Metafix developed by Evonik is a proprietary reagent that consists primarily of iron sulfide, iron oxide, and zerovalent iron (ZVI), which can be tailored to site specific conditions (Evonik, 2021). The primary mechanisms of immobilization are adsorption, precipitation, and conversion to stable sulfide and iron-sulfide precipitate. The key benefits of Metafix are that it is non-dependent on alkalinity for removal of metals. Another advantage is the ZVI component would be expected to reduce hexavalent chromium to trivalent chromium. This reagent was identified in the Feasibility Study as a possible reagent for metals treatment.

9.3.2 MercLok

MercLok is a recently developed and commercially available brominated activated carbon composite sorbent used in removal of mercury in contaminated soils and industrial wastes. In theory, MercLok can stabilize various mercury species such as elemental, ionic, and methylated mercury. AECOM has conducted a series of bench-scale treatability studies for previous remediation projects in collaboration with the technology vendor in which preliminary results show substantial immobilization of mercury in solid matrices (contaminated soils) when in-situ stabilization (ISS) is applied with MercLok. Due to these successful results for mercury immobilization, AECOM recommends evaluating this product for the stabilization if mercury is determined to be a primary driver of contamination after thermal treatment. It is also possible that MercLok may be used in conjunction with the biobarrier remedy due to possible compatibility between brominated activated carbon and bioaugmentation components.

9.3.3 FerroBlack

FerroBlack is a proprietary reagent that contains soluble and insoluble sulfides. The product is a mackinawite structured iron sulfide-based reagent that can remove multiple metals in various valence (redox) states. The reagent works using various mechanisms such as dissolution/precipitation, occlusion, mixed crystal formation, physical entrapment, surface adsorption, and electron transfer (Redox Technology Group, LLC, 2023). The equilibrium between soluble and insoluble sulfide enables immediate treatment of available heavy metals by the soluble sulfides, while the insoluble sulfides can be left in place to create long term stabilization. AECOM has used FerroBlack to reduce hexavalent chromium to trivalent chromium and then bind the reduced metal into the mineral structure. In addition, the reagent has shown to contain oxidized and elemental mercury in a solid waste. AECOM has previously conducted independent bench-scale treatability studies (ISS, leachability, and column tests), pilot studies, and full-scale applications of FerroBlack. The pH of the standard formulation of FerroBlack is basic in nature and is not typically suitable for use in the wetland; however, if FerroBlack appears to be viable after review of baseline data, AECOM will work with the vendor to customize the formulation to reduce the potential toxicity to wetland fauna and flora.

9.3.4 Organoclay MRM

Another option for metals solidification is Organoclay MRM, a reactive clay from CETCO (CETCO, 2022). In addition to absorbing NAPL and dissolved low solubility organics, specially formulated sulfur impregnated Organoclay sequesters mercury (Hg0, Hg+1, and Hg+2) and arsenic (As+5) from water. Other metals such as lead may also be treated. To prevent altering the permeability of the soil when backfilling, sand will be added to the soil mixture. During the treatability study in the lab, the clay-to-soil-to-sand ratio will be evaluated to ensure the permeability remains unaltered.

The amendments being used as part of the biobarrier may also provide stabilization of certain metals. Effluent from the biobarrier will be tested for metals. At the conclusion of testing the soils in the biobarrier will be tested for total and leachable metals.

The bench studies will provide the following key design data:

- Need for metals stabilization and specific metals requiring treatment
- Effect of biobarrier materials on stabilization of metals
- Reagent and recommended dose
- Estimate of limits of treatment (what percent reduction in metals leachability is practical)
- Data that will be used to establish specific goals for metals leachability

9.4 Mixing Methods and Process Options

This section provides an outline of procedures for implementation of the metal stabilization component of the overall remedy. The objective of this write-up is to provide a viable approach which can be used for preliminary planning. The remedial contractor may propose alternative approaches provided the work is done safely, meets the performance goals, and matches the necessary production rate.

9.4.1 Preliminary Requirements for Site Preparation and Equipment

Mixing equipment and a mixing area will be necessary for the organic carbon amendment and biobarrier preparation. It should be possible to use the same area and equipment for the metals stabilization. Depending on the reagent selected for metals stabilization and time for reaction, it may be possible to add the stabilizing agent at the same time blending for the biobarrier is conducted. This would save space and time.

A preliminary estimate of space required for blending is 200 by 200 feet. The area must be flat and covered in gravel or other material to allow for heavy equipment traffic and to drain easily during rainfall events. Soil erosion features around the perimeter of the mixing area will be required in accordance with the Soil Erosion and Control Plan. Work inside a sprung structure or similar structure should not be necessary. Room is needed for storage of reagent, storage of soil prior to blending, and storage of blended soil for testing prior to backfilling. The reagent is typically delivered in 1-cubic-yard sacks that can be kept outside if covered in plastic. Soil piles will also be kept covered when not in active use. After thermal treatment, storage of soil on a liner or concrete pad should not be necessary. An evaluation of the need to mitigate freezing of soil piles will be made after observing the condition of thermally treated soil and after the blending process is full defined.

Equipment for blending will depend on the methods selected by the remediation contractor. A period of trial and error is expected before an efficient operation is realized. A preliminary list of equipment is as follows:

- One or two front end loaders for moving soil.
- Fork attachment for lifting sacks of reagent.
- One or two excavators for digging into soil piles.
- Front end loaders may be equipped with scales or blending ratios may be determined by volume estimates (number of buckets of a known volume).
- Pug mill, concrete mixer, or similar equipment for pre-blend and final blending. Ancillary equipment may include material hoppers and conveyors. An alternative approach would be to construct a mixing trough and use an excavator with bucket and/or rake attachment and/or blending attachment.
- Water source and sprayer may be required. This depends on condition of soil after thermal treatment. It may be necessary to water the soil to reduce dust or to facilitate blending.

9.4.2 Process Flow, In-Process Control, and Verification Testing

The primary process driver will be thermal treatment. The metals stabilization work must be designed to keep pace with the thermal treatment to avoid shutdowns due to lack of space for soil piles. It may be necessary to allow the thermally treated soil to cool down before beginning the metals stabilization blending.

Batches of sediment (500 cubic yards for example) will be tracked from excavation, through thermal treatment, through organic amendment, metals stabilization, biobarrier blending, and placement back into the wetlands at specific locations and depths. Soils being placed below a depth of 2 feet below the final surface will not require metals stabilization or biobarrier blending (organic amendment may still be necessary). Some soils will likely not require metals stabilization depending on the excavation location, in-situ metals concentrations and speciations, or post thermal treatment metals testing. These soils should be tracked separately.

An example tracking sheet for metals stabilization is provided as **Table 9-2**.

Table 9-2: Example Metals Stabilization Tracking Sheet

Soil Batch ID (excavation grid/depth)	Approx Mass (Tons)	Target Reagent Dose (tons)	Actual Reagent Dose Added (tons)	Blending Time (minutes)	Field Mix Verification (pass or fail)	Lab Verification Result (if required)	Checked by (initials/date)	Backfill location (grid/depth)

Observations during the bench study will establish an approximate mixing time. Having a simple field test to verify mixing during the full-scale application would be very useful. Depending on the reagent selected, uniform blending may be visually apparent, apparent under microscope, or, in the case of reagents with iron, can be verified with a magnet test.

The first few batches may require some adjustment in the mixing methods and mixing parameters. Once a uniform process has been established, the initial batches will be sent for laboratory analysis to confirm treatment meets goals. After several batches have passed the laboratory verification tests, the laboratory verification test could be dropped or decreased in frequency.

9.5 Placement of Treated Sediment and Backfilling

A specific plan for replacement of treated sediment back into the wetland areas will be developed in the next design phase. In general, excavated sediment will be returned to the same area and depth as originally excavated. The effect on soil volume from thermal treatment, organic amendment, metals stabilization, and biobarrier amendments is not known. Partial dewatering during backfilling may be necessary to allow placement and to avoid separation of reagents from the soil during placement. Compacting of placed sediment may not be practical. Placement of treated sediment in lifts, allowing settlement, then adding additional lift maybe be necessary.

10 Biobarrier

10.1 Description and Requirements

Migration of residual DNAPL in sandier deep wetland sediments not treated during excavation and LTTD processes poses a risk for the Columbia and Potomac aquifers and overlying surface waters due to upward hydraulic gradients at the wetland/creek interface (HGL, 2020). Ongoing site remedies and treatments in OUs 1, 3, and 4 will continue to address contaminated soils, sediments, and groundwater across other site areas, but it is noted in both the 2020 FS and ROD Amendment 3 that dissolved contamination concentrations from remaining DNAPL in these deep sediments could re-contaminate the backfilled sediments and surface water in the wetlands of Red Lion Creek.

A passive bioreactive zone, referred to as a “biobarrier” has shown promise via historic on-site testing in using commercially available cultures and native site bacteria in aerobic and anaerobic bioremediation of chlorobenzenes (Lorah, 2014). Mixing thermally treated material with additives like organic matter, nutrients, and electron donors restores soil quality and suitability for bioaugmentation. Finally, the addition of GAC will provide a matrix for growth of chlorobenzene-degrading microorganisms as well as sequestering contaminants on the carbon’s surface, bringing them into contact with the microbial population and increasing the biobarrier’s retardation capacity (Ghosh et. al, 2011).

Ultimately, contaminant loading, biobarrier design, and bioremediation kinetics in the biobarrier must be sufficient to achieve the PRGs in **Table 10-1**:

Table 10-1: Surface Water Preliminary Remediation Goals for Aquatic Communities

Contaminant of Concern	PRG(1)	Unit
Benzene	410	µg/L
Chlorobenzene	17	µg/L
1,2-Dichlorobenzene	9.5	µg/L
1,3-Dichlorobenzene	310	µg/L
1,4-Dichlorobenzene	62	µg/L
1,2,3-Trichlorobenzene	33	µg/L
1,2,4-Trichlorobenzene	76	µg/L
Phenol	110	µg/L
Chloroform	5.7	µg/L

Source: HGL (2020)

(1) Preliminary ecological remediation goals (PRGs) for surface water are presented here as they are more conservative than human-risk based surface water remediation goals. These goals are not presented in the 2022 ROD Amendment 3, though they are given in the 2020 FS.

10.1.1 Bench Scale Evaluation

Bioreactive components are considered based on previous studies performed by the USGS (USGS, 2020) and recommendations for commercially appropriate reagents by the proprietary bacteria culture facility, SiREM.

Recommended amendments include GAC, a select metals stabilization reagent (Section 9.3), organic material (topsoil, mulch, humic acids), and both a slow-release electron donor (e.g., Tersus EDS-ER®) and a soluble electron donor (e.g., sodium lactate).

All the treatment microcosms will be amended with GAC and/or one of two to be determined metal stabilizing reagent to target approximately 5% by weight of the thermally treated soil/sediment. The GAC to be tested will be selected in consultation with AECOM, and AECOM will evaluate the local availability, effectiveness, and cost of biochars as a replacement for or in addition to the use of GAC in the biobarrier tests. The metal stabilizing reagents to be tested will be selected from: Metafix (Evonik), MercLok (Albemarle), FerroBlack (Redox Technology Group LLC), or Organoclay MRM (CETCO) based on the results from Section 8 testing. Select treatment microcosms will also be amended with a to be determined (TBD) organic material (OM) as needed to evaluate if the addition of supplemental OM to support the regrowth of intrinsic Site microbial population will impact the sorption and degradation of the chlorinated volatile organic compounds (cVOCs) and SVOCs. While chitin additions were considered, ultimately it was determined in conjunction with SiREM that emulsified vegetable oil products would provide sufficient longevity (up to five years) to the biobarrier treatment until natural vegetative degradation can support continued biodegradation.

The biobarrier bench study will also be used to evaluate the compatibility between soil amendments to be used for metals stabilization and the biobarrier based on literature reviews. This evaluation will be supplemented by incorporating two of the metals stabilization agents into two experimental compositions in the biobarrier bench test to determine the effect of metals stabilization on biobarrier design. In addition, analysis will be conducted for metal leachability during the biobarrier test phase to evaluate the effects of biobarrier amendments on metal leachability.

A slow-release electron donor (e.g., Tersus Environmental, LLC, Electron Donor Solution – Extended Release [Tersus EDS-ER®]) and a soluble electron donor (e.g., sodium lactate) will also be evaluated. The concentration of electron donors will be based on the vendor’s recommendations. After reducing conditions are achieved (typically 2 to 4 weeks after electron donor addition), one set of each of the electron donor amended treatment microcosms will be amended with KB-1® Plus WBC-2 formulation to assess the ability of the culture to promote or accelerate complete reductive dechlorination in the Site materials. KB-1® Plus WBC-2 formulation is a natural microbial consortium containing Dehalococcoides (Dhc), Dehalogenimonas (Dhg), and Dehalobacter (Dhb), bacteria that are known to dechlorinate cVOCs. It is thought that the Dhb can specifically degrade chlorobenzenes. Controls and treatments will be constructed in duplicate as detailed in **Table 10.2**.

Table 10-2: Experimental Design for Biobarrier Bench Study

Treatment/Control		Description
1	Anaerobic Sterile Control	Autoclaved and amended with mercuric chloride and sodium azide
2	Intrinsic Control	No amendments
3	GAC and organic matter (OM) Amended	Amended with a TBD OM and GAC to target 5% weight in geologic material
4	GAC/MSR 1 and Soluble Donor Amended/KB-1®Plus Bioaugmented	Amended with GAC and/or a TBD MSR to target a total 5% weight in geologic material and a soluble electron donor followed by bioaugmentation with KB-1® Plus WBC-2 Formulation
5	GAC/MSR 2 and Soluble Donor Amended/KB-1®Plus Bioaugmented	Amended with GAC and/or a TBD MSR to target a total 5% weight in geologic material and a soluble electron donor followed by bioaugmentation with KB-1® Plus WBC-2 Formulation
6	OM and Slow-Release Donor Amended/KB-1® Plus Bioaugmented	Amended with a TBD OM and a slow-release electron donor followed by bioaugmentation with KB-1® Plus WBC-2 Formulation
7	OM and Soluble Donor Amended/KB-1® Plus Bioaugmented	Amended with a TBD OM and a soluble electron donor followed by bioaugmentation with KB-1® Plus WBC-2 Formulation
8	GAC, OM, and Slow-Release Donor Amended/KB-1® Plus Bioaugmented	Amended with a TBD OM, GAC to target 5% weight in geologic material, and a slow-release electron donor followed by bioaugmentation with KB-1® Plus WBC-2 Formulation
9	GAC, OM, and Soluble Donor Amended/KB-1® Plus Bioaugmented	Amended with a TBD OM, GAC to target 5% weight in geologic material, and a soluble electron donor followed by bioaugmentation with KB-1® Plus WBC-2 Formulation

Initial data collected between Days 0 and 49 will be used to inform the composition of up to five biobarrier pilot test plots. Tests will be maintained through the scheduled 112 days to evaluate the long-term efficacy of each experimental condition.

10.1.2 Pilot Study Design

Up to five approximately 5-foot x 5-foot x 2-foot (1.5 m x 1.5 m x 0.6 m) test plots will be excavated by a subcontractor within the Site area as part of the remedial design. Site selection will be determined following the receipt of pore water sampling results of the Data Gap Investigation but effort will be made to consider a range of Site representative hydrologic conditions. Pilot test locations will be selected in areas with sufficient groundwater upwelling and representative COC contamination present in the pore water.

Plot composition will mirror the design of the two most successful treatments from the bench test, and each treatment will be tested in duplicate or with minor changes (**Table 10-3**).

Table 10-3: Experimental Design for Biobarrier Pilot Test

Plot	GAC	Thermally Treated Material	Additional Organic Material	Amendments	KB-1® Plus WBC-2
Pilot Test Plot 1	5%	≤95%	TBD	TBD	TBD
Pilot Test Plot 2	5%	≤95%	TBD	TBD	TBD
Pilot Test Plot 3	5%	≤95%	TBD	TBD	TBD
Pilot Test Plot 4	5%	≤95%	TBD	TBD	TBD
Control Plot 5	0%	100%	0%	0%	0%

An unamended site control composed only of thermally treated material will also be evaluated. Test plots will be amended with 5% GAC, at a minimum. Plots requiring additional amendments will be amended upon installation. If the plot requires bioaugmentation, KB-1® Plus WBC-2 will be added by weight percent as recommended by SiREM with KB-1® Primer with a target culture concentration of 1×10^7 cells/L as an anaerobic slurry to the test plots. The primary makeup of the injection slurry will be KB-1 plus, KB-1 primer dosed as recommended, and sterile deionized water. The application methods (bioaugmented GAC versus slurry injection) for field pilot test plots will be further evaluated once we receive biobarrier bench results and can evaluate the microbial growth rates. Furthermore, the kinetics determined within the test plots will be used to evaluate the final design criteria including biobarrier thickness, minimum residence time, and total mass reduction achieved.

10.2 Mixing Method

Mixing methods may vary based on bench and pilot study results but will have the following requirements:

1. The final mixed material must be >95% homogenous.
2. The integrity of the final selected biobarrier reagents must be preserved.
3. The reagent rations must be maintained according to bench study and vendor specifications.

A storage area for treated thermal material adjacent to the thermal process would allow for increased efficiency and decrease material transfer and the potential for material loss. Thermal treatment and metals stabilization additives are limiting to the mixing rate, as is the final excavation and preparation of the backfill area. Biobarrier mixing may not commence until (1) a sufficient volume of thermally treated and stabilized material is obtained and (2) the excavated material has been sufficiently backfilled to a sub 2-foot grade such that the biobarrier will comprise a ~2-foot thickness and bring the surface of the treatment zone to the required grade.

Depending on the results of bench and pilot testing, it may be necessary to bioaugment the reactive barrier material with commercially available bacteria cultures. Given the sensitivity of these cultures to air, anaerobic storage tanks equipped with nitrogen are required to sustain anaerobic conditions until application.

Additionally, it may be recommended from the pilot test that GAC be inoculated in a dilution of these commercial microbial cultures. GAC soaking tanks made anaerobic via nitrogen bubbling which hold volume capable of providing dosages recommended during the bench study may also be required. Inoculated GAC would then be fed into the pug mill and blended to the specified ratio with thermally treated soil and the other recommended reagents.

The secondary application method to be evaluated during the pilot test involves direct injection to the applied biobarrier with the diluted commercial microbial culture. In this scenario, only anaerobic storage tanks equipped with nitrogen are required, though their placement relative to the installation footprint needs to be considered.

Additional reagents and commercial additives recommended during the bench study may be stored in supersacs prior to their incorporation into the thermally treated material. Continuous mixing methods suggested include either a pug mill or a concrete mixer, with the addition of hoppers and secondary containment as necessary. The recommended reagents should be fed into the pug mill or concrete mixer via a hopper or similar equipment. Mixing times and feed rates will be determined following the bench and pilot studies. Storage of the mixed material may be necessary, but those specifications are contingent on the final application method of the bioaugmentation culture.

Quality tests will be performed for every batch produced or every 500 cubic yards (whichever is smaller) of material mixed to assess the microbial population density, pH, and soil chemistry as defined by the minimum treatment criteria in the bench and pilot study. Material not meeting these criteria will be remixed to achieve the minimum recommended composition.

10.3 Application

The biobarrier will be placed to mirror the excavation footprint and areas with groundwater upwelling or seeps. Final mixed material will be backfilled to an approximate 2‑foot thickness, though this thickness is subject to change following the results of the bench and pilot studies. The material should be compacted by vibrating, tamping, or a combination to 95% of the Maximum Standard Proctor Density.

If bioaugmentation is deemed necessary, and the most suitable approach is decided to be via injection, pressurized injection rigs will be used to apply the bioaugmentation culture across the approximate 2-foot thickness in spacings that are determined during the pilot test and through hydraulic modeling.

Following the biobarrier installation, Site restoration and replanting will be used as the primary erosion control.

It is also assumed that up to an additional 50% of the biobarrier will be reinstalled 5 years after the initial installation to replace any loss of bioreactive material due to erosion or other processes. Quality sampling of the biobarrier for microbial population densities, health, and pore water geochemistry across the installation footprint will be performed to a sampling depth of 2 feet to determine the extent of this need, and if necessary, the bioreactive reagents will be mixed with imported clean fill in lieu of thermally treated material, assuming that no thermally treated material will be available following the initial backfill and installation.

11 Residuals Management

Residual wastes generated during remediation will be treated and disposed of in accordance with applicable local, state, and federal requirements.

11.1 Water Discharge

Sanitary sewer service is not available to the site. Currently the on-site water treatment system discharges to Red Lion Creek. The treated effluent is required to meet Delaware's NPDES permit equivalency standards shown in **Table 11-1**.

Table 11-1: NPDES Permit Equivalency Standards

Parameters to Be Monitored	Waste Load Allocation (ppb)	Monitoring Frequency	Avg. Limit (ppb)	Maximum Limit (ppb)
Treated Groundwater				
Copper, Total	15	Monthly	6.2	15
Zinc, Total	128	Monthly	50	130
Lead, Total	72	Monthly	30	70
Hardness (as CaCO3)	—	Monthly	—	—
Benzene	—	Quarterly	—	—
Chlorobenzene	—	Quarterly	—	—
Ethylbenzene	—	Quarterly	—	—
1,2-Dichlorobenzene	—	Quarterly	—	—
1,3-Dichlorobenzene	—	Quarterly	—	—
1,4-Dichlorobenzene	—	Quarterly	—	—
Hexachlorobenzene	0.033	Quarterly	—	—
Nitrobenzene[1]	—	Quarterly	—	—
Stormwater Runoff				
Iron, Total	2,000	Annual	—	—
Copper, Total	16	Annual	—	—
Zinc, Total	138	Annual	—	—
Lead, Total	44	Annual	—	—
Hardness (as CaCO3)	—	Annual	—	—

AECOM will request similar permit equivalency standards from the DNREC NPDES permitting division. The standards will be based on Delaware's surface water quality standards and anticipated constituents and concentrations.

AECOM will evaluate the construction of a new effluent line with a discharge point to Red Lion Creek versus tying into the effluent line for the on-site treatment system. This will depend on capacity of the existing pipe and sampling/compliance point locations.

11.2 Air Emissions

The DNREC Division of Air Quality requires permitting for air emission sources of criteria pollutants above 0.2 lb/hr and a control device for emissions above 10 lb/hr. Hazardous air pollutants require modeling to ensure reduction to 1% of the threshold limit values. Emissions sources within 100 m of each other will be assessed cumulatively.

Components of the remediation that will require air permitting include the rotary kiln, soil piles, and emissions from a treatment system. In a low mass scenario, the primary treatment mechanism would be GAC. In a high mass scenario, an oxidizer would be used to treat the VOC, but would lead to hydrochloric acid (HCl) generation. An acid scrubber would be added to remove HCl.

The first step in the application process is to complete a stationary source impact analysis. Emissions modeling software is required to quantity emissions. AERSCREEN is the EPA recommended screening level air quality model. Following issuance of the permit, DNREC will conduct field verification testing, which may include stack testing.

11.3 Other Wastes

Dumpster and portable toilet services will be used for municipal and sanitary waste generated during remediation. Facilities will be emptied and cleaned on a weekly basis or as needed to maintain a hygienic environment.

12 Restoration Design

A description of the construction phasing of the restoration and a timeline will be available at the 60% design phase. At that time a list of phases that will require formal review prior to implementation will be provided. These reviews will incorporate changes and/or improvements in best practices for restoration activities and accommodations for unexpected changes in site conditions.

12.1 Wetland Areas

The delineated wetland portions of the remediation area consist of three habitat types – open water, forested wetland, and emergent wetland. Ground, bathymetric, and LiDAR survey data were gathered and used to identify the existing topography. Water elevation data was also obtained and will be used to calculate the average water depth and flow patterns of the open water and streams. Wetland data consisting of soil types, vegetation, and hydrology was obtained and will be used to identify ground water levels within the wetlands. The existing condition data will be compiled in an existing conditions plan and used to develop the restoration plan.

The restoration plan proposes to return the disturbed wetland areas to pre-existing contours and elevations. Stream banks and flow patterns will be returned to pre-existing conditions. The restoration plan will also incorporate a planting scheme to identify types and quantities of trees, shrubs, and herbaceous plants to be planted in the remediation areas. No restoration plantings are proposed in the open water portions of the Red Lion Creek, as there are no pre-existing areas of submerged aquatic vegetation. Some portions of the unnamed tributaries to the Red Lion Creek in the western portion of the Site contain submerged aquatic vegetation in areas where the creek is widened and created a flooded marsh condition. The proposed restoration of these areas will be recreation of the existing bed and banks of the channels. Over time, the natural tendencies of the stream to braid through the marsh will allow population of the adjacent species in the wetland to recreate the aquatic stream communities. Of the palustrine emergent wetlands, three small wetlands located in the upland meadow just off the capped portion of the Site have developed (Appendix C; Figure 4; Sheet 6 (W-JRK-004 and W-JRK-005) and Sheet 7 (W-JRK-003)). These areas are within a maintained meadow and were not originally intended to exist having developed as a result of depressional topography. These three small wetlands will be disturbed during the course of remediation and restoration of the wetlands and will not be restored as wetlands. An upland meadow will be proposed in their place, similar to the existing adjacent meadow. The remainder of the palustrine emergent wetland community will be planted with a combination of woody shrub and herbaceous plants, suitable to the inundated and potentially brackish conditions.

Seed mixes will be used for immediate stabilization across the site as well as for the long-term establishment of native herbaceous plants. Similarly, the palustrine forested portion of the restoration area will be initially planted with a seed mix to obtain stabilization of the soil with subsequent plantings of native trees and shrubs to restore the forested cover. Species suitable for planting in the restoration area will be chosen based on their native status and will be similar or the same as the species identified in the existing communities, as described in the Vegetation Survey Report (Appendix D). Multiple types of seed mixes suitable for the varying hydrologic conditions across the site will be proposed.

Appropriate reference areas will inform the seed mix selections. The plant communities to be restored will be reflective of the existing communities so that the final restored condition of the Site is consistent with the pre-existing conditions to the extent possible with the elimination of existing non-native plant species in the restoration design. Species may be added to the planting schedule based on their native status and their suitability to the existing communities on Site to replace the functions and values contributed by non-native species that will be excluded.

Vegetation best management practices will be detailed in the restoration plan to ensure adequate survival of the species planted on Site. Monitoring and performance requirements, in addition to best management practices, will also be detailed in the restoration plan.

12.2 Upland Areas

Upland areas disturbed during construction including the upland excavation areas, Western Drainage Gully, treatment process areas, and utility construction corridors will be restored with a minimum 6-inch-thick vegetative layer composed of topsoil or suitable manufactured soil if enough natural topsoil is not available to germinate and sustain vegetative growth. These areas consists of mixed hardwood forest, meadow, and scrub shrub, and maintained mowed lawn, A good vegetative stand consistent with the existing native vegetation will be used to restore each habitat type in order to minimize water and wind erosion and increase evapotranspiration, and maintain the existing ecotypes currently existing at the site. The vegetative layer will extend to cover areas disturbed by construction. The disturbed area and adjacent stormwater management features will be seeded with native grasses and forbes to improve Site aesthetics and provide an enhanced habitat for native fauna. Materials and construction procedures required to properly construct this layer will be documented in the Technical Specifications developed during subsequent design phases.

13 Baseline and Performance Monitoring Plan

The Baseline Ecological Performance Monitoring Plan presents the approach to establishing pre-remediation conditions within OU2 wetland and aquatic habitats affected by the 1986 tank failure spill. The monitoring will generate baseline benthic macroinvertebrate community, fish community, bulk sediment, surface water, benthic macroinvertebrate tissue, and fish tissue data sets within OU2 wetland and aquatic habitats. The baseline monitoring data will be used to establish a point of comparison for assessing post-remedial conditions in the OU2 wetland and aquatic habitats. Long-term post remedial monitoring data will be evaluated relative to the pre-remedial action baseline conditions to assess the degree to which the selected OU2 remedial measures achieved their objectives.

The Plan has the following main elements:

- Background for the ecological monitoring in OU2 including the baseline risk assessments and risk driver constituents of concern (COCs),
- Remedial action objectives (RAOs) and Preliminary Remediation Goals (PRGs),
- Baseline monitoring data collection and data quality objectives (DQOs),
- Reporting and use of the baseline monitoring data,
- Baseline monitoring schedule and team organization.

A copy of this draft plan is provided as Appendix J.

14 Project Delivery

The RD for this project will be delivered in two stages: Preliminary Design and Pre-Final/Final Design. Comments received during the Preliminary Design stage will be incorporated into the Pre-Final/Final Design stage. Deliverables include this Preliminary Design BODR, design drawings, technical specifications, cost estimate summary, and a project schedule. Preliminary Design deliverables also include identified potential Seed Task Orders. The following paragraphs describe these design elements.

14.1 Design Drawings

Concept-level drawings showing the key remedy components including general project information, process flow, geotechnical boring information, existing conditions, preliminary proposed locations of material handling and treatment processes, and 2-dimensional and 3-dimensional depictions of the excavation locations from the EVS model are provided in Appendix K. A preliminary list of drawings that will potentially be included in the final design package is included on Sheet G-01 in Appendix K. Interim and final remedial design drawings will be generated in AutoCAD Civil 3D in accordance with the United States National CAD Standard–V6 (NIBS, 2014).

14.2 List of Technical Specifications

Technical specifications will be prepared during subsequent design development phases to serve as a companion to the design drawings by further describing the material and installation requirements for proper remedial measure implementation. Technical specifications will be prepared using SpecsIntact software following up-to-date Unified Facilities Guide Specifications (UFGS). When a guide specification is not represented from the specification sources, a new specification title and section number will be created following the Construction Specifications Institute (CSI) MasterFormat® 2020 edition and inserted in the most appropriate division. A list of anticipated specifications is provided in Appendix L.

14.3 Preliminary Design Cost Estimate

The overall Cost estimate in Appendix M is based on available Preliminary Design Status information. Delays experienced in obtaining treatability sample results have impacted estimate detail and will need to be updated in later design stage submittal as more definitive information becomes available.

The cost estimate in Appendix M is based on Preliminary Design stage information. The estimate has been placed in MII MCASES Traces Software. The estimate breakdown at the present design stage is based on task assumptions involving Site preparation, clearing, grubbing, temporary road installation, utilities including mobilization and demobilization, excavation of 150,000 cubic yards of soil from wetlands and associated on-site LTTD thermal treatment, metals stabilization of 13,018 cubic yards, in-situ bioremediation based on 1,319,760 cubic feet of soil, and offsite disposal of 8,431 tons of soil and backfilling of soils / Site restoration as well as sampling during execution and post-work monitoring.

The cost estimate includes labor cost associated with subcontractor project management, treatment operator, field labor, and per diem as well as AECOM personnel project manager, field crew, and per diem.

Bid scope contingency of 20% has been included for referenced estimate breakdown. Time span of project is assumed to be over multiple years. The estimate has 2 years of LTTD treatment plant operations and post-remedial action involving long-term monitoring and a 5-year review period.

Cost estimates are summarized in **Table 14-1**. Engineering judgement and past project experience were used in the development of the estimate results along with a varying yearly inflation rates. Travel, materials, and labor cost rates assumptions are based on Northeast rates/@joeMII 2023 Cost Book Values. See Appendix M for cost distribution layout.

Table 14-1: Summary of Estimated Costs

Phase/Task	Estimated Cost
Remedial Action (RA)	(b) (4) [redacted]
Site preparation	
Pre-Treatment Vegetation Removal	
Pretreatment (gravity dewatering)	
LTTD treatment(1)	
Rotary Kiln LTTD	
In-pile LTTD, 3 cells, 1 operation	
In-pile LTTD, 1 cell, 3 operations	
Metals treatment	
Biobarrier installation	
Off-site disposal	
Sampling	
Site restoration	
Post-RA implementation	
Long-term Monitoring	
Five-year review	
Subtotal	
Escalation for inflation(2)	

Phase/Task	Estimated Cost
Total Preliminary Cost Estimate	(b) (4) [redacted]

(1) A detailed breakdown of varying thermal technologies is available in section 8. Only one LTTD treatment method is necessary.

(2) A varying yearly inflation rate is used along with a 7% discount rate for present worth cost

14.4 Preliminary Schedule

A preliminary schedule developed for the RA is presented as **Figure 14-1**. This schedule assumes the construction start in early October 2024 with a seed task order well ahead of the final design completion. Based on the current RD schedule, the final design approval is expected on March 3, 2025. This schedule is based on the worst-case scenario of excavating and treating the soils in three sequential cycles with approximately 30,000 cubic yards of soil treated in each cycle. Site preparation, such as tree clearing and grubbing, will be scheduled to occur in segments prior to each thermal treatment cycle. Each cycle is estimated to take approximately 330 days to complete. The overall schedule is estimated to be approximately 1,920 days or approximately 5 years long (10/8/2024 to 11/6/2029). The project duration could be significantly reduced by the availability of additional space for soil handling and treatment. Further analysis to optimize the Site use and project schedule will be conducted in the subsequent design phase.

14.5 Potential Seed Tasks

AECOM identified the potential Seed Tasks that are listed below. The Seed Tasks will be developed into a separate full design package for solicitation/award by USACE under its Single Award Task Order Contract mechanism following the selection of a construction contractor prior to the issuance of the Pre-Final/Final Design package for the entire project.

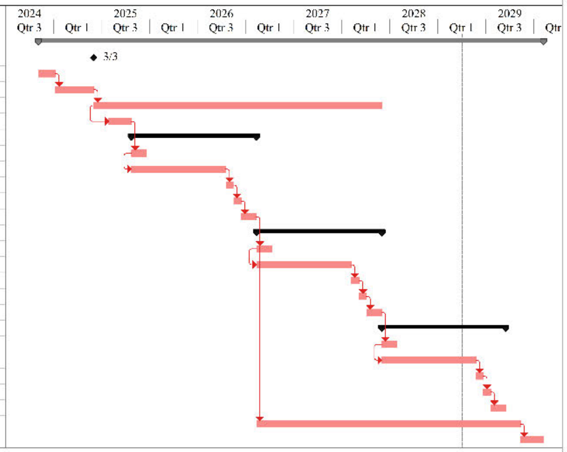
- **Utility Service Installation**: The LTTD options analyzed require high-voltage power supply, water, and potentially gas service to be installed from Governor Lea Road that is currently not available at the Site. Each service would require installation of a metered connection to the utility distribution system and approximately 1,800 linear feet of conveyance to a centralized location on the northern portion of the Site.
- **Site Preparation**: Several site preparation activities including grading of the treatment process area, construction of staging areas and equipment pads, select clearing of trees, and construction of access roads will be required irrespective of the technologies used.
- **Surface Water Control Structures**: Sheet pile coffer dams will need to be installed along portions of the Red Lion Creek to facilitate excavation of target areas encroaching on and adjacent to the creek channel. Temporary stream diversion channels will also need to be constructed to maintain flow around the coffer dam areas. Surface water will also need to be controlled along additional sections of the Red Lion Creek adjacent to the excavation

areas and runoff from upland and upstream of the excavation areas. The selected excavation contractor may elect to expand the installation of sheet pile to include these sections as an alternative to using temporary freestanding coffer dams (e.g., Portadam®).

- **Phragmites Control:** Phragmites control methods typically require multiple events to sufficiently reduce the biomass and regrowth. Mechanical cutting and root removal, herbicide application, and potentially prescribed burning operations can be initiated several seasons prior to execution of the excavation work to reduce the amount of vegetative matter that will need to be managed.
- **On-site LTTD Soil Pile Heating Cell Construction:** The soil pile heating option for thermal treatment will require construction of a concrete block structure(s) that includes a lining and underdrain leachate collection system. Purchasing and delivery of the blocks and underdrain materials can be initiated. Construction of the cell(s) could also potentially be initiated prior to execution of the excavation work.

Standard Chlorine of Delaware Inc. Superfund Site - Preliminary Remdial Action Schedule
Figure 14-1

ID	Task Description	Calendar Day Durations	Duration	Start	Finish
0	**Standard Chlorine of Delaware Inc. Superfund Site - Preliminary Remedial Action Sc**	1920 days	**1334 days**	**8/5/24**	**11/6/29**
1	Final Design Approval	0 days	0 days	3/3/25	3/3/25
2	SATOC Contractor Selection	64 days	45 days	8/5/24	10/7/24
3	Seed Task Order Implementation	147 days	100 days	10/8/24	3/3/25
4	Site Preparation	1094 days	760 days	3/4/25	3/1/28
5	Mobilization	86 days	60 days	4/29/25	7/23/25
6	**Treatment Cycle 1**	**475 days**	**330 days**	**7/24/25**	**11/10/26**
7	Excavation	57 days	40 days	7/24/25	9/18/25
8	Low Temperature Thermal Desorption Operation	359 days	250 days	7/24/25	7/17/26
9	Soil Amendment for Metal Stabilization	26 days	20 days	7/20/26	8/14/26
10	Soil Amendment for Biobarrier	29 days	20 days	8/17/26	9/14/26
11	Backfill	57 days	40 days	9/15/26	11/10/26
12	**Treatment Cycle 2**	**476 days**	**330 days**	**11/12/26**	**3/1/28**
13	Excavation	58 days	40 days	11/12/26	1/8/27
14	Low Temperature Thermal Desorption Operation	359 days	250 days	11/12/26	11/5/27
15	Soil Amendment for Metal Stabilization	29 days	20 days	11/8/27	12/6/27
16	Soil Amendment for Biobarrier	28 days	20 days	12/7/27	1/3/28
17	Backfill	58 days	40 days	1/4/28	3/1/28
18	**Treatment Cycle 3**	**471 days**	**330 days**	**3/2/28**	**6/15/29**
19	Excavation	56 days	40 days	3/2/28	4/26/28
20	Low Temperature Thermal Desorption Operation	358 days	250 days	3/2/28	2/22/29
21	Soil Amendment for Metal Stabilization	28 days	20 days	2/23/29	3/22/29
22	Soil Amendment for Biobarrier	28 days	20 days	3/23/29	4/19/29
23	Backfill	57 days	40 days	4/20/29	6/15/29
24	Site Restoration	1003 days	699 days	11/12/26	8/10/29
25	Demobilization	86 days	60 days	8/13/29	11/6/29



Task | Milestone | Project Summary | Baseline Summary | Critical | Baseline
Split | Summary | Baseline Milestone | % Complete | Critical Split

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Figure 14-1: Preliminary Remedial Action Schedule

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