

Pennsylvania Department of Environmental Protection

# Draft Remedial Investigation Report

**Former Defense Supply Center Philadelphia**

December 2025

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## Acronyms and Abbreviations

°F	degrees Fahrenheit
>	greater than
<	less than
%	Percent
µg/L	micrograms per liter
3D	three-dimensional
Act 2	PADEP Land Recycling Program
amsl	above mean sea level
AO	Administrative Order
AOI	area of interest
AOI 1 RIR	Remedial Investigation Report for Area of Interest 1, Philadelphia Refinery Operations
AOI 11 RIR	Site Characterization/Remedial Investigation Report, Sunoco Philadelphia Refinery, Philadelphia, Pennsylvania
API	American Petroleum Institute
Arcadis	Arcadis U.S., Inc.
ASTM	ASTM International
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, xylenes
BV-BS	biovent-biosparge
CH <sub>4</sub>	Methane
CO <sub>2</sub>	carbon dioxide
COC	constituent of concern
CP	Cleanup Plan
CSM	conceptual site model
CSX	CSX Corporation
DLA	Defense Logistics Agency
DSCP	Defense Supply Center Philadelphia
EC	electrical conductivity
Foster Wheeler	Foster Wheeler Environmental Corporation

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ft	feet or foot
ft <sup>2</sup> /day	square feet per day
HPT	hydraulic profiling tool
HHRA	Human Health Risk Assessment
I-76	Interstate 76
ITRC	Interstate Technology & Regulatory Council
LEL	lower explosive limit
LNAPL	light non-aqueous phase liquid
mg/L	milligrams per liter
MiHPT	membrane interface probe combined with hydraulic profiling tool
MNA	monitored natural attenuation
MSC	Medium Specific Concentration
MSC(r)	Medium Specific Concentration based on residential site use
MTBE	methyl tert-butyl ether
NIR	Notice of Intent to Remediate
NS	near source
O&M	operation and maintenance
O <sub>2</sub>	oxygen (gas)
PA	Pennsylvania
PADEP	Pennsylvania Department of Environmental Protection
PAGWIS	Pennsylvania Groundwater Information System
PAH	polycyclic aromatic hydrocarbon
PARS	PARS Environmental, Inc.
PHA	Philadelphia Housing Authority
PIANO	paraffin, isoparaffin, aromatic, naphthene, and olefin
PID	photoionization detector
PP	preferential pathway
Ppm	parts per million
PRM	Potomac-Raritan-Magothy
Ransom	Ransom Environmental

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refinery	former Sun Oil Company Point Breeze refinery
RIR	Remedial Investigation Report
RSL	Regional Screening Level
SCV	sewer conduit vapor
SEPTA	Southeastern Pennsylvania Transportation Authority
SHS	Statewide Health Standard
Site	Former Defense Supply Center Philadelphia Site
SSDS	sub-slab depressurization system
SSS	site-specific standard
SSSG	sub-slab soil gas
Sunoco	former Sun Oil Company
SV <sub>GW</sub>	Statewide health standard vapor intrusion groundwater screening value
SV <sub>GW(r)</sub>	Statewide health standard vapor intrusion groundwater screening value residential
SV <sub>IA</sub>	Statewide health standard vapor intrusion indoor air screening value
SV <sub>NS</sub>	Statewide health standard vapor intrusion near source screening value
SV <sub>SS</sub>	Statewide health standard vapor intrusion sub-slab soil gas screening value
TBA	tert-butyl alcohol
TDS	total dissolved solids
TGM	Technical Guidance Manual
THQ	total hazard quotient
TR	target cancer risk
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	underground storage tank
VES	vacuum-enhanced skimming
VI	vapor intrusion
VOC	volatile organic compound

## Executive Summary

This Remedial Investigation Report provides a summary of the investigation and current remediation activities completed under the Pennsylvania Department of Environmental Protection (PADEP) Land Recycling Program (Act 2) for the Former Defense Supply Center Philadelphia (DSCP).

The activities described herein have been conducted per the requirements of the Administrative Order dated December 10, 1999, between PADEP and the Defense Logistics Agency. The Administrative Order requires:

- Remedial activities to remove petroleum hydrocarbon light non-aqueous phase liquid (LNAPL) at the Former DSCP Site (Site) to the maximum extent practicable;
- Quarterly reporting to the Southeast Regional Office of PADEP, detailing all measures taken in conformance with this order, and attaching the results of all quantitative measurements taken in the quarter; and
- That the Site meet “one or a combination of the remedial standards set forth in the Land Recycling [and Environmental Remediation] Act [or Act 2] and the regulations found in 25 Pa. Code Chapter 250.”

LNAPL remediation to the maximum extent practicable will entail demonstration of the stability of site LNAPL (i.e., the post-remedial presence of weathered residual LNAPL), specifically through attainment of physical and chemical LNAPL stability criteria. Attainment will be demonstrated via statistical evaluation of:

- LNAPL physio-chemical characteristics and groundwater quality data collected; and
- Data to be collected at specific site point of compliance wells as part of continued remediation performance monitoring events.

LNAPL remediation at the Site began in 1996 using skimmer pumps to remove available LNAPL from the unconfined water table aquifer. A full-scale vacuum-enhanced skimming system was installed in 2005 in response to waning LNAPL recovery rates. Various optimization strategies were subsequently implemented to boost the rate of LNAPL recovery and led to the removal of approximately 1,088,393 gallons of LNAPL through the fourth quarter of 2024. Additional in-situ bioremediation LNAPL cleanup strategies have been implemented to facilitate attainment of LNAPL stability metrics.

A previous risk assessment determined the potential for unacceptable excess lifetime cancer risks and noncancer hazards for construction workers that may come in direct contact with the LNAPL, vadose smear zone soil, and shallow groundwater, and for residents, assuming exposure to indoor and outdoor air as result of subsurface vapor intrusion to indoor air and migration of sewer vapors to indoor and outdoor air. This Remedial Investigation Report includes the results of an updated Human Health Risk Assessment (HHRA) based on a vapor intrusion investigation documented in the HHRA Report.

In addition to LNAPL stability demonstration, site closure under Act 2 (i.e., release of liability) will demonstrate the elimination of potential human health exposure pathways related to residual LNAPL and associated petroleum hydrocarbon impacts as described below. Pathway elimination will be achieved through a combination of engineering and institutional controls as allowed via the site-specific standard approach available under 25 Pennsylvania Code § 250.401:

- Groundwater, via institutional controls (requesting a non-use aquifer determination);
- Soil, via institutional controls (site-specific soil management); and
- Vapor, via engineering controls in specific commercial and residential structures.

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A forthcoming Cleanup Plan will document the existing site engineering and institutional controls and provide approaches to eliminate remaining potential exposure pathways in the context of an updated Conceptual Site Model and the HHRA. Post-remediation care plan elements for each control will be defined in property-specific environmental covenants under the Uniform Environmental Covenant Act.

# 1 Introduction

On behalf of the Defense Logistics Agency (DLA) and with key support from the United States Army Corps of Engineers (USACE) Philadelphia District and PARS Environmental, Inc. (PARS), Arcadis U.S., Inc. (Arcadis) has prepared this Remedial Investigation Report (RIR) for the Former Defense Supply Center Philadelphia (DSCP) facility (i.e., the Site, the limits of which are defined in **Sections 3 and 4**). This report includes required Pennsylvania Department of Environmental Protection (PADEP) Land Recycling Program (Act 2) RIR table of contents elements defined in the Land Recycling Program Technical Guidance Manual (Act 2 TGM; PADEP 2021) and describes the status of ongoing light non-aqueous phase liquid (LNAPL) remediation activities at the Site. Gauging, sampling, operation and maintenance (O&M), and system optimization data presented herein are inclusive of the fourth quarter of 2024.

Remediation of site LNAPL is driven by the December 10, 1999, Administrative Order (AO) mandated by PADEP to DLA. The AO presents findings of fact regarding subsurface hydrocarbon contamination and outlines the requirements to be carried out by DLA. Full text of the AO may be found in **Appendix A**. The AO is the mechanism via which PADEP administers and enforces the Clean Streams Law, Act 2, the Solid Waste Management Act, the Tank Act, and the Administrative Code at the Site. The AO defines the following criteria for eventual site closure (i.e., Act 2 “Cleanup Liability Protection”):

- Removal of petroleum hydrocarbon LNAPL to the “maximum extent practicable”; and
- Attainment of “one or a combination of the remedial standards set forth in the Land Recycling Act and the regulations found in 25 Pa. Code Chapter 250.”

The AO also requires the remediator, DLA, to take the following actions during performance of site cleanup activities until compliance is demonstrated under Act 2 (PADEP 2021):

- DLA shall protect the health and safety of workers, residents, and visitors within the Affected Area regarding risks associated with the area’s contamination;
- DLA shall assume responsibility for operation of the portion of the sewer air filtration system that treats petroleum vapors;
- DLA shall perform risk assessments as necessary;
- DLA shall submit quarterly reports to PADEP;
- DLA shall provide PADEP unrestricted access to the area; and
- All sample analyses shall take place at a qualified laboratory using United States Environmental Protection Agency (USEPA) methods.

To provide a foundation for demonstrating compliance with the cleanup standards and release of liability under Act 2 (PADEP 2021), the RIR proposes the formal Act 2 site boundary within which remediation and attainment of “one or a combination of the remedial standards” and eventual Act 2 release of liability will occur. In support, the RIR:

- Presents the findings of the subsurface characterization work conducted in the context of hydrogeological and human health risk aspects of the Conceptual Site Model (CSM);
- Describes past and current approaches to LNAPL remediation and identifies, in the context of the CSM, the utility and limitations of these approaches;

- Describes the nature and extent of LNAPL and progress of remedial efforts towards the LNAPL cleanup goals of in-situ LNAPL body stability (i.e., achieve low LNAPL solubility and mobility through enhanced weathering and biodegradation);
- Presents the results of an updated Human Health Risk Assessment (HHRA) based on the results of an updated vapor intrusion (VI) investigation that was implemented to evaluate risk to receptors from the residual LNAPL plume; and
- Presents the results of updated groundwater models and an updated fate and transport analysis.

Remediation to site closure under Act 2 (PADEP 2021) is driven by the AO-specific focus on petroleum hydrocarbon LNAPL and related petroleum hydrocarbon impacts to groundwater, soil, and soil vapor. This RIR describes only petroleum hydrocarbon impacts to site media (groundwater, soil, and soil vapor) and proposes an approach to closure for each under Act 2.

This RIR describes the results of characterization activities conducted through the fourth quarter of 2024 on LNAPL and LNAPL-related constituent of concern (COC) impacted groundwater, soil, and soil vapor in the context of a CSM. The CSM provides a geographic and hydrostratigraphic framework for the description of these impacts, the evaluation of potential exposure pathways to each impacted media type, and the associated potential risks to human health. The RIR provides a basis for the proposed elimination of potential human health risk exposure pathways via a combination of media-specific institutional and/or engineering controls and the implementation of an in-situ biodegradation-based approach to remediation of site LNAPL under Act 2 (PADEP 2021).

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### 3 Site Maps

Maps showing the site location and the Act 2 (PADEP 2021) site boundaries, as proposed by the remediator (DLA), are provided as **Figures 1** and **2**, respectively. As shown on **Figure 2**, the area within the proposed boundaries, the “Act 2 Site” (Site), includes the following components:

- The AO-defined “Affected Area,” which includes the Former DSCP Facility and adjacent land areas that were the focus of LNAPL petroleum hydrocarbon characterization and remediation efforts from approximately 1987 to 2005 (see **Section 4**); and
- Additional contiguous properties that contain at least one environmental media (e.g., soil, groundwater, and soil vapor) affected by LNAPL-related COCs.

Liability relief under Title 25 of the Pennsylvania Code (25 PA Code) § 250.707 is tied to specific contaminant impacts and indexed to the land area(s) at which impacts have been revealed through characterization. Thus, as described in the Act 2 TGM (PADEP 2021), there may be multiple (Act 2) sites on a property, or a single (Act 2) site may include all or part of one or more properties (PADEP 2021).

As shown on **Figure 2**, the complete Act 2 Site is the land area bounded by Oregon Avenue to the north, 19<sup>th</sup> Street and 20<sup>th</sup> Street to the east, Penrose Avenue and Pattison Avenue to the south, and South 26<sup>th</sup> Street to the west, covering approximately 267 acres in south Philadelphia, Philadelphia County, PA. An east-west portion of Interstate 76 (I-76) bisects the Site, and along the western side of the Site, parallel to South 26<sup>th</sup> Street, lie elevated railroad tracks located atop fill soil bedding approximately 20 feet (ft) thick. The Site is bordered to the west by the former Sun Oil Company (Sunoco) Point Breeze refinery (refinery), currently owned by Chicago-based Hilco Redevelopment Partners, to the north and east by residential areas, and to the south by the Schuylkill Expressway and the Former Passyunk Homes Property. The Former Passyunk Homes Property is currently the location of the Philadelphia Housing Authority (PHA) Building, with the Siena Place Homes neighborhood farther to the south. Siena Place Homes, a residential development undergoing construction, is located south of I-76, west of Penrose Avenue, and east of the elevated railroad tracks. The land area components of the Site are further described in **Section 4** wherein past and current land usage is presented in the context of AO-driven regulatory history, and corresponding AO-required LNAPL characterization and remediation activities.

## 4 Site Description

### 4.1 Site History and Current Land Use

This section describes the history and current use of the component land areas within the proposed Act 2 Site boundaries. The largest component of the Site, and component of the AO defined “Affected Area,” is the Former DSCP Facility – an 87-acre parcel that was owned and operated by the United States Department of Defense from 1918 to 1999. While in operation, the Former DSCP Facility was responsible for the procurement and distribution of food, clothing, and medical supplies to all branches of the armed forces, as well as other authorized federal agencies and foreign countries (Malcolm Pirnie 1999). Production of finished textile products for the United States Armed Forces also took place at DSCP from the 1940s to 1994 (Environ 2002). Prior to initial construction in 1918, the property was reportedly vacant, unimproved land.

In 1993, the Base Realignment and Closure Commission recommended the closure of the Former DSCP Facility, and in 1999, all remaining administrative operations were relocated to the DLA Troop Support Facility in Northeast Philadelphia. To support post-closure redevelopment, the “air rights” (which are defined as the ground surface to 10 ft below ground surface [bgs]) to the Former DSCP Facility were transferred to the Philadelphia Authority for Industrial Development in October 2001. Due to the presence of LNAPL, first identified in September 1987, the Army retained the subsurface rights deeper than 10 ft. Shortly after the air rights were transferred, Philadelphia Authority for Industrial Development began selling portions of the Former DSCP Facility for redevelopment. In October 2001, Quitclaim Deeds were prepared for the “Eastern” and “Western” parcels of the Former DSCP Facility (**Appendix A**, Subsection Three). The Quitclaim Deeds detail the specific petroleum hydrocarbon impact-related redevelopment restrictions and remediation infrastructure requirements (required by the AO) that occupants of structures on the former DSCP must abide by. These include, but are not limited to, permitting egress for ongoing remediation work, restricting any construction or maintenance activities to a maximum of 10 ft bgs, and restricting property to commercial and industrial use excluding childcare. The buildings on the Eastern parcels of the Former DSCP Facility are owned and managed by a private property management entity that leases parcels to commercial and government (state and federal) interests, with some former facility buildings currently vacant. On the Western parcel portion of the Site (44 acres), a shopping center known as Quartermaster Plaza was constructed in 2004. It currently contains 17 retail stores and four food establishments.

The next largest site component, the AO-defined “Affected Area,” is the Former Passyunk Homes Property – a 55-acre plot that was once a public housing project. Developed in the 1940s, the housing project consisted of 96 apartments in 12 three-story buildings and 778 two-story apartments. These structures were demolished in 2002. In 2009, an 80,000-square-ft office building was constructed on the northern portion of the Former Passyunk Homes Property for use by PHA. Additionally, the construction of new, privately owned residential dwellings (Siena Place Homes) was initiated on the remainder of the property. A total of 313 townhomes are to be constructed as part of this development, which is largely complete at the time of this RIR. An additional six homes with basement garages are currently being constructed on a property located on Hartranft Street directly adjacent to the CSX Corporation (CSX) property and surrounded on three sides by Siena Place. These homes are not part of Siena Place but are shown to be within the site boundary.

The CSX right-of-way and component of the AO-defined “Affected Area” lies between I-76 and the Former DSCP Facility. This land is primarily utilized by CSX for maintenance of the railway itself and for other rail transportation uses. The CSX right-of-way hosts a rail spur that links to the adjacent former refinery, currently owned by

Chicago-based Hilco Redevelopment Partners. This rail spur and adjoining right-of-way have been railroad property since construction of the Former DSCP Facility.

The Steen property, immediately adjacent to the CSX right-of-way and a component of the AO-defined “Affected Area,” is currently the site of a privately held outdoor advertising agency. The property includes an office building, outside storage for materials and supplies, and parking. The use of the property prior to Steen ownership is unknown.

**Table 1** lists the site components, which are also shown on **Figure 2**.

*Table 4 Site Components*

Site Component	Current Land Use	Approximate Area (Acres)	Petroleum Hydrocarbon Impacts
Former DSCP Facility	Commercial: Quartermaster Plaza (Defense Realty, U-Haul, Quartermaster Plaza Cedar Realty Trust, and Brite Star Manufacturing Company) and Sky Management Services, LLC	87	LNAPL, shallow and deep aquifer zone groundwater, soil, and soil vapor
CSX property and Steen property	Commercial: Railroad usage and outdoor advertising agency/billboard assembly laydown area, respectively	30	Shallow and deep aquifer zone groundwater, soil, and soil vapor
Siena Place Homes (Former Passyunk Homes Property)	Commercial: PHA property, and residential Siena Place neighborhood	55	LNAPL (PHA property), groundwater, soil, and soil vapor
Area bounded by 20 Street, Pattison Avenue, and Penrose Avenue and homes being constructed on Hartranft Street not in Siena Place	Residential	56	Groundwater (deep aquifer zone only)
Southeastern Pennsylvania Transportation Authority (SEPTA) southern bus terminal, and ACME	Commercial: Bus maintenance facility and grocery store, respectively	15	Soil vapor
Properties along Penrose Avenue	Commercial: P. Agnes, Hotel, Jim's Ice, Liberty Camera Company, and Leones Computer	30	Shallow and deep aquifer zone groundwater, soil, and soil vapor

## 4.2 Regulatory History

In 1987, DLA notified PADEP of the discovery of petroleum hydrocarbon contamination beneath the Former DSCP Facility and, in 1988, subsurface investigations into the source, nature, and extent of the impacts began. In 1996, the United States and [then] Sunoco entered into a Consent Order and Agreement with PADEP to

collectively remediate the subsurface LNAPL impacts delineated between 1988 and 1995. The December 10, 1999, PADEP-issued AO required DLA to remove petroleum hydrocarbon LNAPL to the “maximum extent practicable,” and to attain “one or a combination of the remedial standards set forth in the Land Recycling Act and the regulations found in 25 Pa. Code Chapter 250” (i.e., enter the Act 2 program [PADEP 2021]). To formally enter the Site into the Act 2 program, a Notice of Intent to Remediate (NIR) was submitted to PADEP in 2004 for a proposed Act 2 Site with a smaller footprint than that shown on **Figure 2**. The 2004 NIR (**Appendix A**, Subsection Two) was superseded by a second NIR (Arcadis 2017) submitted on April 14, 2017 (**Appendix A**, Subsection Four). The 2017 NIR identifies a site-specific standard (SSS), exposure pathway elimination-based path to closure. The standards identified in the NIR reflect the current CSM (**Section 6**).

To comply with the LNAPL remediation requirements of the AO and to enable a path to site closure under the Act 2 program (PADEP 2021), several improvements and optimizations to the Site’s remediation systems and associated remediation strategy have been implemented since the initiation of LNAPL remediation at the Former DSCP Facility (as further described in **Section 4.3**). Additionally, to refine the site remedial approach and to support a comprehensive site path to closure for all media impacted by petroleum hydrocarbons, various subsurface characterization activities have been conducted. Details on remediation system improvements, optimization strategies, and characterization activities as well as updates to the CSM were also reported as part of AO quarterly reporting requirements. In May 2022, a combined RIR and Cleanup Plan (CP) was submitted to PADEP and was subsequently disapproved pending updates to the CSM. Specific CSM elements requiring updates included completion of the soil vapor investigation, characterization of the soil media, and refinement to the groundwater models. These updates to the CSM are included in this RIR.

## 4.3 Remediation History

LNAPL remediation at the Former DSCP Facility began in 1996 with skimmer pumps installed in water table aquifer wells (i.e., shallow aquifer zone wells, as described in **Section 6**). Seven potential onsite source areas were investigated under the Phase II Environmental Site Investigation in 1998. No definitive source of LNAPL was determined during these investigations and all areas were recommended for no further action as part of the Installation Restoration Program (Malcolm Pirnie and Louis Berger & Associates 1998). Subsequently, the 1999 AO established Act 2 (PADEP 2021) as the regulatory framework for remediation activities; set specific cleanup objectives for the shallow aquifer zone (i.e., LNAPL recovery to the maximum extent practicable); and required, for the larger “Site” (refer to **Section 4.2**), that DLA obtain closure by achieving an applicable Act 2 standard or set of standards.

A full-scale vacuum-enhanced skimming (VES) system was installed in 2005 in response to declining LNAPL recovery rates and to continue to support the AO objectives. Several optimization strategies to increase LNAPL recovery have been implemented since 2011. Related results and recommendations have been provided to PADEP in AO-required Quarterly Progress Reports. These results are further detailed in **Section 6**.

Since 2011, site remediation optimization strategies have improved the rate of petroleum hydrocarbon recovery in the vapor phase, as well as subsurface, in-situ destruction of site LNAPL. However, while the strategies deployed since late 2011 have been successful (e.g., the VES system continues to recover between 500 and 1,500 gallons per quarter as vapor), LNAPL extraction and/or in-situ destruction rates remain constrained by the local hydrostratigraphy (e.g., varying water table elevations and stratigraphic inhomogeneity), limitations of VES system design, and continued site redevelopment and construction activities. Concurrently, the rate of recovery of LNAPL as liquid by way of skimming has decreased as a result of the hydrostratigraphic factors discussed above and the

reduced presence of LNAPL in wells. The fixed and modular skimming systems were taken offline in 2019 because the LNAPL thickness in wells was no longer consistently great enough to allow continuous skimming. From 2019 to date, LNAPL recovery in the liquid phase has been accomplished by utilizing manual skimming when present at thicknesses great enough to recover (generally greater than [ $>$ ] 0.3 ft). Still, the rate of LNAPL recovery as liquid has decreased to asymptotic levels (between 0 and 11 gallons per quarter recovered as liquid) compared to the first few years of LNAPL skimming (when recovery ranged from 5,096 to 76,593 gallons per quarter recovered as liquid).

For these reasons, new LNAPL cleanup strategies, including pilot testing of an integrated Biovent-Biosparge (BV-BS) system that operates in tandem with the site VES system, have been explored. A BV-BS pilot study commenced at the Site in February 2019 to test the feasibility of an air injection-based approach to help attain site LNAPL Act 2 cleanup goals (PADEP 2021). Site O&M data and past experience led to the conclusion that oxygen ( $O_2$ ) added to the subsurface would result in the greatest degradation of hydrocarbons in the fringes of the impacted area, where measured LNAPL was not as thick, in areas where the LNAPL is less degraded, and where VES is limited due to the high water table. The installation of the pilot BV-BS system was completed in February 2019 in the northwestern portion of the PHA property, and a six-month pilot evaluation was conducted from March 6, 2019, to September 5, 2019. Following encouraging results from the pilot study, it was determined that additional time was required to operate and monitor the pilot system and evaluate the effect of seasonal changes in the subsurface at the Site. The progress and results of monitoring conducted during the six-month BV-BS pilot study were documented in a BV-BS Pilot Report (Arcadis 2020a), and monitoring of the effectiveness and potential for expansion of the BV-BS system is continuing to date. Since initiation of the BV-BS pilot test, several positive changes have been observed within the pilot study area from the continued operation of the BV-BS system, including abating methane concentrations in the soil gas within the pilot study area as the area has become more aerobic, decreased headspace volatile organic compound (VOC) concentrations in the pilot study area monitoring wells, and reductions of VOC concentrations in groundwater as compared to pre-pilot study baseline conditions in pilot study area monitoring wells.

Documented LNAPL/petroleum hydrocarbon-focused HHRAs (Environ 2002) assumed the Site's subsurface future land use would be restricted to commercial/industrial use. Various engineering controls, such as venting systems and vapor barriers, were designed, constructed, and installed prior to achieving a full understanding of the CSM; knowledge of future land use and redevelopment activities; and publication of the 2017 PADEP Technical Guidance Manual for Vapor Intrusion into Buildings from Groundwater and Soil under Act 2 (VI guidance; PADEP 2017). For these reasons, and because the site commercial structures that rely on these controls are already occupied and in use (e.g., Quartermaster Plaza and Siena Place), specific VI-focused characterization and eventual remediation activities are discussed in **Section 6.5.2**, and characterization of VI risk is included in the HRA Report (**Appendix B**). Conclusions and recommendations regarding a proposed combination of institutional and engineering controls designed to address site petroleum hydrocarbon impacts to soil vapor, subsurface soil (i.e., "smear zone" of the water table/shallow aquifer hydrostratigraphic zone), and groundwater (shallow and deep aquifer hydrostratigraphic zones) will be provided in the CP.

## 5 Selection of Standards

The AO presents findings of fact regarding subsurface hydrocarbon contamination and outlines the requirements to be carried out by DLA. As outlined in the AO, DLA shall demonstrate that the area meets “one or a combination of the remedial standards set forth in the Land Recycling Act and the regulations found in 25 Pa. Code Chapter 250.”

The 2017 NIR (Arcadis 2017) declared the elimination of potential exposure pathways to site LNAPL and LNAPL-impacted media (e.g., groundwater, soil, and soil vapor) to be the goal of an SSS-based Act 2 path to closure, and the basis for site “Release of Liability” as defined in the Act 2 TGM (PADEP 2021) Section 1 (D)(8)(c)(iii):

*“The site-specific standard is an important option when the remediator has determined that, for technical or economic reasons, attainment of either the Statewide health standard or the background standard is not feasible because of the presence of [Separate Phase Liquid] SPL. Attainment under the site-specific standard when SPL is present at the [Point of Compliance] POC is permissible as long as there is no discharge to surface water and there is no unacceptable exposure (based on risk) to the contamination.”*

Based on a comprehensive interpretation of site subsurface data, including boring logs, direct-push/direct-sensing logs, groundwater potentiometric surface elevations, the extent of site LNAPL, and the distribution of petroleum hydrocarbon COCs, the CSM (**Section 6**) separates the site aquifers into "shallow" and "deep" hydrostratigraphic zones. These zones anchor the NIR-defined, SSS-based cleanup goals for site LNAPL; LNAPL-impacted groundwater, specifically dissolved-phase impacts by site LNAPL-related Short List (PADEP 2008) COCs in both the shallow and the deep aquifer zones; and shallow zone LNAPL-related impacts to soil and soil vapor.

The SSS-based path to closure approach described herein identifies and evaluates potential exposure pathways to site LNAPL-impacted media, considers present and future land use scenarios, and supports potential exposure pathway elimination through engineering and administrative land use controls in accordance with 25 PA Code § 250.401 through § 250.410. Additionally, the approach includes remediation of site LNAPL until attainment of specific LNAPL stability metrics (described below) and a combination of engineering and institutional controls for the elimination of potential exposure pathways to residual (post active remediation) LNAPL and related impacts to groundwater, soil, and soil vapor. Proposed LNAPL stability metrics and attainment demonstration procedures (discussed further in **Section 6.6.1.4**) include:

1. LNAPL boiling point and simulated boiling point analysis and trend evaluation indicative of in-situ biodegradation (i.e., chemistry changes resulting in the reduction of lighter molecular weight and generally more soluble and volatile components of the LNAPL).
2. Transmissivity analysis by way of baildown testing of LNAPL-bearing wells over time to demonstrate decreasing LNAPL recoverability in response to ongoing remediation. The process of evaluating LNAPL transmissivity is provided by the Interstate Technology & Regulatory Council (ITRC) and can be found in the ITRC guidance document LNAPL-3 (ITRC 2018) and in the American Petroleum Institute (API) LNAPL Transmissivity Workbook (API 2016). Transmissivity at or above 0.8 square ft per day (ft<sup>2</sup>/day) is considered recoverable, transmissivity in the range of 0.1 to 0.8 ft<sup>2</sup>/day is marginally recoverable depending on the situation, and transmissivity below 0.1 ft<sup>2</sup>/day is generally not recoverable (ITRC 2018).
3. Dissolved-phase petroleum hydrocarbon COC statistical trend analyses (to evaluate the decrease in LNAPL-related COC flux from site LNAPL to groundwater in response to ongoing remediation).

## 6 Site Characterization and Conceptual Site Model

### 6.1 Conceptual Site Model Development Methods

To support site remedial strategy development and path-to-closure decisions per the requirements of the AO and Act 2 (PADEP 2021), historical and current site data have been reviewed to develop a comprehensive CSM. The CSM was developed from the following sources:

- Peer reviewed and published regional and local geologic documents;
- Site investigative database including well installation data, boring logs, well construction logs, survey data, direct sensing data, groundwater liquid level gauging data, groundwater and LNAPL analytical data, and system operation vapor analytical data; and
- Site historical maps and documents detailing the site infrastructure (utilities) development and construction of the site buildings over time.

The site database includes 165 monitoring points, including LNAPL recovery wells (54), monitoring wells (108), “prepack” monitoring points (two), and a piezometer (one). A total of 138 of these wells terminate in the shallow aquifer, 11 are considered intermediate (subsidiary of the shallow aquifer), and 16 reach the deep aquifer. The wells are distributed across the properties discussed in **Section 4.1** and shown on **Figure 2**. Boring and well construction data were compiled into a database for graphical modeling of the CSM (see **Section 6.2**). Database information is provided and tabulated in **Appendix C**. Wells were installed over the following time periods:

- Prior to 2013: Installation of 153 monitoring wells;
- 2013: Installation of monitoring well DSCP-MW-65 and two adjacent prepack wells;
- 2014: Installation of five recovery wells (PH-RW-A2, PH-RW-B2, PH-RW-I2, PH-RW-V2, and PH-RW-W2);
- 2017: Installation of two deep aquifer wells (NOVA-DW-14 and FDR-DW-15) by the USACE Philadelphia District (**Appendix D**); and
- 2019: Installation of two shallow aquifer wells (PH-MW-66 and PH-MW-67) for the BV-BS pilot study.

Hydrostratigraphic data derived from review of site monitoring and recovery well logs were supplemented with data collected via direct push-direct-sensing technology, including a membrane interface probe and hydraulic profiling tool (HPT) (combined MiHPT), electrical conductivity (EC), and fuel fluorescence detector. The integrated data were modeled using Earth Volumetric Studio to create a three-dimensional (3D) subsurface model. Figures were selected from discrete sections of the 3D model for inclusion in this report based on local geologic interpretations, which support the RIR framework and the fate and transport model of shortlist COCs for this report. Direct-sensing events were conducted in:

- 2012: 13 MiHPT borings, two EC borings, and drilling of two visual borings;
- 2013: 15 MiHPT borings and two EC/HPT borings; and
- 2014: Six MiHPT borings and two fuel fluorescence detector borings.

MiHPT data were correlated to known stratigraphic unit properties providing elevation data for contacts of each unit of interest. Refinement of these stratigraphic picks in each well log was completed using lithologic data from the well network and culminated in the creation of a 3D site model incorporating both sets of data. Individual data

points were evaluated for inclusion in the model based on data integrity and general model agreement with existing reports referenced in the sections below.

Throughout the project timeframe, groundwater analytical, water level, and LNAPL thickness data have been obtained during quarterly events conducted at relevant site wells. Data through the third quarter of 2019 are provided in this report. The hydrologic and chemical components of the CSM were built upon these data. Additional methods used to improve understanding of LNAPL and groundwater COC mechanics and plume geometry included LNAPL simulated boiling point analysis, LNAPL baildown testing, respirometry testing, radius of influence testing, and isotopic analysis of LNAPL. The resulting improvements to the site understanding of groundwater and LNAPL behavior gained from these additional activities are summarized in the CSM, and details are noted in later sections of this report.

## 6.2 Land Use and Water Resources

### 6.2.1 Land Use and Stormwater

As described in **Section 4**, the Former DSCP Facility portion of the Site is currently used for a mix of industrial, commercial, and residential purposes. Onsite buildings north of I-76 are currently occupied by various commercial and government (state and federal) tenants. The topography of the Site and surrounding area is relatively flat with a land surface elevation generally less than (<) 25 ft above mean sea level (amsl). The portion of the Site north of I-76 (**Figure 2**) is significantly covered with impervious surfaces including parking lots, streets, and large commercial buildings.

Site stormwater is controlled in a variety of ways. Stormwater from Former DSCP Facility buildings and commercial buildings located north of I-76 is collected in concrete subterranean holding tanks, as shown in **Appendix E**. These structures provide temporary stormwater storage and are intended to minimize hydraulic loading to the local combined sewer system via controlled release, ultimately discharging to the City of Philadelphia combined sewer system (**Figure 2**). These structures are not designed to infiltrate to the aquifers beneath. Stormwater from streets, parking lots, and commercial buildings located north of I-76 flows to catchments within this area. This water is ultimately discharged to the City of Philadelphia combined sewer system.

South of I-76, the site land surface is similarly covered with buildings and paved areas. Within the neighborhood of Siena Place, stormwater is reportedly conveyed to a subsurface storage structure that appears similar in purpose and operation to those described above. This subsurface storage structure is reportedly lined. Stormwater collected in the vicinity of the PHA building is conveyed to a swale that runs along I-76, swales and grass-covered areas adjacent to parking lots, and a retention basin located adjacent to the eastern end of the building. Stormwater connections are shown on **Figure 2**.

A more detailed discussion of the stormwater sewer system is provided in **Section 6.4**.

### 6.2.2 Surface Water Features

Limited exposures of undeveloped pervious ground surface, such as landscaped areas around commercial and residential buildings, along street and highway rights-of-way, above sewer rights-of-way, and in the wooded right-of-way bordering the CSX rail line, are located within the northern and southern site areas (i.e., north and south of

I-76). There are no surface water features at the Site to support natural habitat or terrestrial communities, and there are no exposures expected for potential ecological receptors (further described in **Appendix B**).

### 6.2.3 Groundwater Wells

Previous investigations completed in the area indicated that groundwater was not being utilized for drinking water purposes (Environ 2002) and that there were no active groundwater supply wells located within the immediate vicinity of the Site (Malcolm Pirnie 1999). In addition, based on a well search of the Pennsylvania Groundwater Information System (PAGWIS) conducted in 2017 for the Act 2 (PADEP 2021) project at the former Philadelphia refinery, no potable water supply wells were identified within a 1-mile search of the former refinery site (Stantec 2024).

A more recent search of the PAGWIS (PADEP 2025) online water well database was conducted on August 25, 2025, and included the area extending 1 mile from the site boundaries. PAGWIS search results are shown on **Figure 3** (site wells are excluded), with the tabulated results presented in **Appendix F**.

A total of 637 wells were identified in the PAGWIS search. **Table 2** presents an inventory list of the types of well uses identified in the PAGWIS search:

*Table 2 PAGWIS Well Use Inventory List*

Well Use/Status	Count	Comments
Abandoned	51	
Destroyed	54	
Injection	27	Wells listed as the Sunoco Refinery Area
Monitoring or Observation Wells	314	
Other/Unused	53	Listed as Philadelphia Gas Works or Evergreen (aka Former Refinery) – Listed as Air Sparging/VES
Test Wells	2	Listed as USACE (site wells NOVA-DW-14 and FDR-DW-15)
Unused	9	PGW (one), Colonial Theater (one), Roosevelt Park (one), United States Navy (two), Atlantic Refining Co. (one), George Young Co. (one), City of Philadelphia (one) – a geothermal system, and President Caterers (one)
Withdrawal Wells	87	Associated with former refinery or other petroleum-related companies with the exception of two locations: Preparatory Charter High School at 1928 Point Breeze Avenue (0.63 miles north of the upgradient site boundary) and two wells approximately 0.1 miles south-southwest of the southern site boundary (labeled as MW-2 and MW-3 in the PAGWIS database; PADEP 2025)
Unclassified	40	Entities listed under “Original Owner” are Sun Company (19); PES (11); Sunoco Evergreen Subsidiary (six); Eco Materials, LLC (two); United States Government (one); and City of Philadelphia, Department of Public Property (one)

Based on the most recent review of the PAGWIS database (PADEP 2025) and prior historical well searches, there were no groundwater withdrawal wells identified for domestic use or agricultural purposes within 0.50 miles of the site boundary, with the exception of one location (Preparatory Charter High School). The Preparatory Charter High School well is listed in the PAGWIS database (PADEP 2025) with a note that the well was installed for an onsite laundry. The Preparatory Charter High School is located approximately 0.63 miles to the north of the northernmost site boundary and is in an upgradient orientation with respect to the Site.

When assessing withdrawal wells and the potential for impact by conditions at the Site, the following should be noted:

- Drinking water in the area is supplied by the Philadelphia Water Department.
- Pursuant to Title 6 of the Philadelphia Code (Health Code), Chapter 6-400 – Miscellaneous Standards and Requirements, Section 6.402 – Business, Professional, and Community Controls, Subsection 7 (Water and Ice), Part (a), the following is stated: “No person shall use any water for human consumption, the preparation of food, or for ablutionary purposes with respect to humans, food or food service equipment or utensils except such water as shall come from a public water supply system, approved by the Pennsylvania Department of Health; or which meets such standards as the regulations of the Board may prescribe with regard to the materials, supplies, and methods of treating water supplies, the chemical, physical, bacteriological content or quality of the water, or the design, installation, operation and maintenance of such water supply systems.”

There were no listings under Preparatory Charter School or Preparatory Charter High School (1928 Point Breeze Avenue) in the *Pennsylvania Bulletin* for either a community water system or a noncommunity water system suggesting an active water supply well is in place. And, as noted above, the Preparatory Charter High School is located approximately 0.63 miles to the north, in an upgradient orientation with respect to the Site (see **Section 6.3.3** for a discussion of groundwater flow patterns across the Site). Therefore, it is Arcadis’s opinion that it is unlikely for the Preparatory Charter School/High School to be impacted by conditions observed at the Site, if in fact a groundwater withdrawal well exists.

## 6.3 Geology and Hydrogeology

### 6.3.1 Regional and Local Geology

Broadly, the region around the Site is divided into two distinct physiographic provinces: the Piedmont and the Coastal Plain. The boundary between these two provinces, known as the “fall line,” trends roughly southwest to northeast and is located approximately 2 miles northwest of the Site (Paulachok 1991). The Site lies within the Coastal Plain province and, as such, a generalized stratigraphic sequence for the Coastal Plain region of southeastern PA is shown on Figure 2 of **Appendix C** (Schreffler 2001); a brief description of each of these units and their water-bearing properties is provided in Table 4 of **Appendix C** (Paulachok 1991).

The crystalline bedrock of the Piedmont comprises the late Proterozoic and early Paleozoic age Wissahickon Schist Formation, which forms the basement beneath the Coastal Plain sediments. The bedrock surface dips eastward approximately 90 ft per mile toward the Atlantic Ocean. The surface of the Wissahickon Formation has been scoured by the ancestral Schuylkill and Delaware rivers to form localized troughs and served as the surface into which the overlying Cretaceous and younger sediments were deposited.

Overlying the channeled basement rocks are Cretaceous age and younger strata composed of highly permeable sands and gravels separated by less-permeable layers of silts and clays (Schreffler 2001) that make up the Coastal Plain sedimentary wedge. This sedimentary wedge also dips eastward toward the Atlantic Ocean but at a rate of approximately 40 to 60 ft per mile (Greenman et al. 1961), creating a sedimentary wedge that thickens between 30 and 50 ft per mile toward the southeast. This non-marine clastic wedge was deposited over three major sedimentation cycles, each of which began with a series of coarse detrital deposits and closed with a series of silts and clays (Greenman et al. 1961). Together these Cretaceous age deposits are termed the Potomac-Raritan-Magothy (PRM) aquifer system. The lowermost PRM unit consists of fine gravel and coarse sand grading upward into medium to fine sand with a few layers of clay (Paulachok 1991) and is also referred to as the Farrington Sand. Portions of this unit lie unconformably on the crystalline bedrock, while others are separated from the bedrock by a layer of saprolite (Paulachok 1991). Thickness varies at the Site between 20 and 50 ft, with areas generally thicker near the bedrock trough axes and thinner near the margins.

Six units have been mapped regionally within the PRM: the Lower Sand, Lower Clay, Middle Sand, Middle Clay, Upper Sand, and Upper Clay, which, from bottom to top, form the Coastal Plain sedimentary wedge beneath the Site. Locally, the PRM generally thickens towards the local bedrock trough axes and thins towards their margins. Not all units of the PRM system are present near the fall line or at the Site; some only appear to the south and east. In the vicinity of the Site, two are observed to be absent – previous investigations in the area have mapped both the Upper Clay and the Middle Sand (which divides the Middle and Lower Clay) of the PRM pinching out to the south and east of the Site (Schreffler 2001).

Tertiary age terrace and valley-fill deposits completely cover the PRM in the region. In the vicinity of the Site, the PRM is chiefly overlain by a Pleistocene age deposit referred to informally as the Trenton Gravel. The Trenton Gravel consists of varying amounts of gravel and sand and minor amounts of clay and is of Pleistocene age, likely deposited as a result of glacial meltwaters conveyed by the ancestral Delaware River.

The Lower Clay and Middle Clay layers are laterally extensive and thick enough to be considered important confining units throughout the region, except where they have been removed by erosion and replaced by Pleistocene deposition. This unit separates the unconfined to semi-confined shallow aquifer from the underlying coarser zone that constitutes the confined deep aquifer; however, in discrete areas of the Site, the lateral extent of this layer is mapped as missing (Sloto 2012).

The upper clay of the PRM serves to hydraulically separate the PRM from the Trenton Gravel across most of the region. Locally, this upper clay has been removed by Pleistocene erosion prior to deposition of the Trenton Gravel. Where this clay has been removed, the deposits of the Trenton Gravel contact the PRM units and allow for hydraulic communication between the two; this has been referred to as the “breach,” which is described in more detail in **Section 6.3.2**.

Overlying the Trenton Gravel in the vicinity of the Site and the surrounding area is a layer of Holocene age alluvium including a dense silt layer with varying amounts of sand and clay. The silt layer has been observed across the Site at depths between 0 and 3.5 ft bgs and thicknesses between 1 ft and 12 ft, with an average depth and thickness of 1.5 and 8 ft bgs, respectively. The significance of the silt layer as a risk mitigation feature for vapor-phase hydrocarbon contamination is detailed in the 2002 HHRA (Environ 2002). Its relevance as a protective feature and as part of the site CSM is further detailed in **Section 6.4** and in the updated HHRA Report (**Appendix B**).

Overlying the silt is a discontinuous layer of varying thickness of historical fill materials (ash, brick, soils, etc.). The historical fill material likely was used to level uneven surfaces of the underlying silt layer for building, drainage, and developmental purposes (Paulachok 1991). Across the Site this layer ranges between 3 and 8 ft thick.

### 6.3.2 Historical Soil Investigation Reports

A comprehensive review of available historical soil-related investigation reports was conducted. The review identified site-wide surveys along with investigations of the following historical petroleum handling areas: Building 8 Underground Storage Tank (UST), Building 9 Gas Station, Building 28 USTs and piping, Building 46 UST, Bulk Storage Aboveground Storage Tanks, Oregon Avenue UST, SEPTA Southern Garage, and Sunoco Mini Mart (Verina-Pars JV 2025a). The findings of these reports, which included investigations of both the vadose zone and underlying smear zone, are provided in **Appendix G**. Soil boring locations from these investigations dating to the 1990s are provided on Figure 1 of **Appendix G**, which also includes notations of the aforementioned petroleum handling areas. Tabulated results of these investigations, along with the PADEP Act 2 (PADEP 2021) Medium Specific Concentrations (MSCs), are also provided in **Appendix G**.

As shown on Figure 1 of **Appendix G**, the borings from the various historical investigations cover the Site from Oregon Avenue to the north to south of I-76 (Hartranft Street), and from the former refinery to the west to 20<sup>th</sup> Street. Figure 2 of **Appendix G** depicts the locations that had exceedances of Act 2 MSCs (PADEP 2021) for the compounds analyzed. In summary, exceedances of the MSCs for the site COCs are as follows:

- **Benzene:** Exceedances of the 100x Groundwater MSC from the Aquiver (2009) investigation and from site-wide data (with the caveat of high detection limits noted above).
- **Ethylbenzene:** Exceedances of its MSC in site-wide data.
- **Naphthalene:** Exceedance of its MSC in site-wide data.
- **Lead:** Exceedance of the 100x Groundwater MSC (and generic value) in the Building 9 Gas Station and Bulk Storage Aboveground Storage Tank areas.

Figure 2 of **Appendix G** shows locations with exceedances of the MSCs.

Figures 1 and 2 of **Appendix G** also depict the extent of LNAPL observed in 2002 and the extent of LNAPL observed based on the fourth quarter of 2024 gauging event. A comparison of the 2002 and 2024 observations shows a decrease in the spatial extent of LNAPL. In 2002, LNAPL was observed from the middle of Quartermaster Plaza to approximately 140 ft north of Hartranft Street, and from the refinery to South 20<sup>th</sup> Street. Based on the fourth quarter of 2024 gauging event, the observed LNAPL is primary limited to the area of the "breach" (defined in Section 6.3.1) and bounded by the CSX tracks to the west, Home Depot to the north, the U-Haul building to the east, and the PHA Building to the south, with isolated occurrences beyond this area. An approximate 75 percent (%) reduction in the spatial extent of LNAPL is observed. Additional discussion of LNAPL is provided in **Section 6.6.1.1**.

Soil investigations dating to the 1990s through 2024 indicate that potential source areas (i.e., areas where petroleum-related product was stored) have been identified and assessed with limited detected exceedances of the applicable Act 2 MSCs (PADEP 2021). An addition, as documented in historical reports, the lateral and vertical impacts from former fuel tanks and associated piping were limited in spatial extent, not reaching the water table or the underlying LNAPL, demonstrating that the various historical petroleum-related operations at the former DSCP likely did not contribute to the LNAPL and resulting groundwater impacts.

### 6.3.3 Aquifers and Hydrogeology

Features in the overall regional geology impact the movement of water and contaminants through the local aquifers. Within the regional geologic framework described previously, specifically with the confined Cretaceous middle and lower sand units of the PRM being separated from the overlying unconfined Pleistocene Trenton Gravel by one or a combination of clay aquitards within the PRM, there are two principal aquifers in the region and beneath the Site. The Lower Sand is confined by the combined Lower and Middle Clay units and separated from the water table aquifer consisting of the Upper Sand, Trenton Gravel, Upper Silt, and Fill layers. For the purposes of this investigation and to maintain consistency with previous investigations in the area, these two aquifer zones are termed the "shallow" (Upper Sand, Trenton Gravel, Upper Silt, and Fill) and "deep" (lower PRM sand) aquifer zones. This bifurcation is consistent with the 2017 NIR (Arcadis 2017), in which the separation of these two aquifers is supported by the current CSM and are thus, these aquifers are treated separately within the Act 2 framework and SSS closure pathway identified for the Site (PADEP 2021).

Regionally, the aquifers of the PRM are largely confined, except in isolated areas where Pleistocene sediments are in direct contact with underlying Cretaceous sediments as a result of erosional processes. As such, the Site deep aquifer is also confined outside of any known erosional features (i.e., the "breach"), and groundwater flow within the deep aquifer is generally toward the southeast in the down-dip direction (Rosman 1996). Groundwater flow in the deep aquifer in the area surrounding the Site has historically been controlled by recharge to the aquifer from the outcrop area, the presence of rivers, changes to land use accompanying urbanization, and the presence of large pumping centers located to the east and south of the Site (Schreffler 2001). Removal of water from these pumping centers reportedly pulled groundwater underlying the former refinery and the Site to the east and south toward Publicker Industries and the Philadelphia Naval Shipyard, respectively (Schreffler 2001). Since the cessation of large-scale removal and use of groundwater from the deeper aquifer in recent times, flow in the aquifer has largely returned to more natural conditions, although continued pumping in nearby New Jersey preserves the vertical hydraulic gradients that allow for downward leakage (Paulachok 1991). Since the 1991 report, downgradient withdrawal rates have not been modeled or reported. Rising water-level trend data collected at the Site suggest a continued decrease in downgradient water usage or withdrawals since 1991. Locally, significant recharge from the shallow aquifer occurring through leaky and absent portions of the confining unit (discussed below) may impact this overall flow direction. At the Site, for that portion of the deeper aquifer for which data are available, groundwater flow is largely to the south-southeast.

In addition, as hydraulic heads in lower units dropped below those in upper units, a downward vertical groundwater gradient developed (Schreffler 2001). Although pumping at the naval shipyard was discontinued in the mid-1960s, pumping increased in New Jersey across the Delaware River until approximately 1975. While the rate of groundwater withdrawal in New Jersey has declined since 1975 (Sloto 2012), downward vertical gradients from the shallow aquifer zone to the deep aquifer remain steady at the Site.

Based on the fourth quarter of 2024 gauging event results, groundwater elevations were estimated for both the shallow and deep aquifer zones (**Figures 4 and 5**, respectively). For the fourth quarter of 2024, groundwater elevations in the shallow aquifer beneath the Site range from approximately 8 to -8 ft amsl. As shown on **Figure 4**, based on water level measurements collected during the fourth quarter of 2024 gauging event, groundwater typically flows from the northwest corner of the Site to the southeast and then south with observed mounds and sinks throughout. In the western portion of the Site, groundwater flow is westward in the area of the Steen property and along the western portion of the Siena Place Homes. Shallow groundwater at the Site ultimately exits the Site within the shallow zone to the south, southeast, and southwest or enters the deep aquifer zone through the "breach" of the confining unit (lower/middle clay) (see **Section 6.3.2**). Based on the fourth

quarter of 2024 gauging event results, groundwater elevations in the deep aquifer zone range from approximately -1.69 to 1.68 ft amsl (**Figure 5**). Localized “mounding” is observed at DSCP-DW-12, located in the center of the “breach” and at Steen-DW-08, located along the western edge of the Site, also within the area of the “breach.”

Groundwater gauging is conducted quarterly with observations of groundwater flow patterns reported in Quarterly Progress Reports. Overall, groundwater flow patterns observed in the shallow and deep aquifers have remained relatively consistent to those shown on **Figures 4** and **5**.

### 6.3.4 Connection between Shallow and Deep Aquifers

As described above, the CSM supports separation of the Site aquifers into one “shallow” and one “deep” aquifer zone. This separation is based on observations from well boring logs, direct-push/direct-sensing logs, groundwater potentiometric surface elevations, the extent of site LNAPL, and the distribution of COCs. However, as described above, removal of the lower and middle clay units of the PRM due to Pleistocene fluvial erosion allowed for deposition of the Trenton Gravel directly on top of the water-bearing units of the PRM within paleochannels carved by glacial meltwater flowing through the region. Several of these paleochannels have been mapped along the coastal plain in southeast Pennsylvania, New Jersey, and Delaware (Jengo 1999 and 2006). At the Site, an absence of PRM confining units has been observed and mapped. This allows for hydraulic communication between the upper and lower aquifers and is colloquially termed the “breach” in this report.

The “breach” is illustrated in several cross sections drawn across the Site (**Figure 6**). In Geologic Conceptual Site Model Section BB’ (**Figure 7**), the “breach” is tapering to the east near the SEPTA property and to the west near the CSX train line. The northern and southern edges of the “breach” are shown on **Figure 8** (Geologic Conceptual Site Model Section DD’) being coincident with the limits dashed on **Figure 6**. In the vicinity of the CSX line, the “breach” is mapped diverging into two smaller channels near its westernmost boundary (Geologic Conceptual Site Model Section AA’, **Figure 9**). A cross section of the theorized flow path at the Site is shown on **Figure 10** (Geologic Conceptual Site Model Section CC’), which extends from northwest to southeast across the “breach”. A 3D view of the “breach” extent is presented on **Figure 11** (Geologic Conceptual Site Model Oblique View). The “breach” extent is layered atop various figures in this report to anchor the SSS path to closure elements to this critical component of the CSM, and our proposed remediation concepts therein. The “breach” extent is defined as those areas where the confining bed thickness is <0.5 ft. The areas where the Lower Sand is visible on **Figure 11** (Geologic Conceptual Site Model Oblique View) represent zones of hydraulic connection between the shallow and deep aquifers.

The hydraulic connection of the two aquifers is supported by site-specific data (e.g., observed downward gradients in nested well pairs in the vicinity of the “breach”) as well as data presented in several other independent studies (Greenman et. al. 1961; Paulachok 1991; Schreffler 1997; Sloto 2012) and is represented in the CSM. Site hydrogeologic monitoring supports leakage of groundwater from the shallow aquifer zone to the deep zone through the above-described “breach”. Quarterly groundwater gauging data for the shallow and deep aquifers indicate that a downward hydraulic gradient is present between the shallow and deep aquifers in the “breach” region. This hydraulic connection and downward gradient also allow for chemical and physical communication between the bifurcated aquifer zones below the Site. Gradients are calculated quarterly using measured groundwater elevations for wells within nested shallow and deep aquifer zone pairs (**Appendix H**). The downward gradients are measured in nested well pairs, including:

- DSCP-MW-20D and DSCP-MW-20 (start date March 1, 1995);
- CSX-DW-4 and CSX-MW-7 (start date May 5, 2005);

- DSCP-DW-1 and DSCP-MW-23A (start date May 5, 2005);
- DSCP-DW-6 and DSCP-MW-2B (start date May 5, 2005);
- PH-DW-2 and PH-MWS-15 (start date May 5, 2005);
- PH-DW-3 and EPH-PH-5 (start date May 5, 2005);
- PH-DW-10 and PH-MWS-1 (start date April 2, 2007);
- PH-DW-11 and PH-PH-22 (start date April 2, 2007); and
- DSCP-DW-13 and DSCP-MW-11 (start date April 2, 2007).

In general, the majority of these well pairs display downward vertical gradients for the periods monitored starting as noted above. While seven of the nine pairs displayed downward vertical gradients, the locations of these well pairs showing downward vertical gradients are generally coincident with the approximate reported extent of the “breach” in the base of the Site’s shallow aquifer zone.

This downward gradient is somewhat accentuated by decreased groundwater usage, both in southeastern Philadelphia and New Jersey; a general rising trend in local annual precipitation rates has resulted in rising groundwater elevations within the site shallow aquifer zone, as shown in **Appendix H**, which includes hydrographs for select monitoring wells (DSCP-MW-29, DSCP-MW-32, DSCP-MW-35A, DSCP-MW-36, PH-PH-14, PH-PH-15, PH-PH-18 and PH-PH-20). This increase in water table elevation has reduced the amount of remediation well screen available for free-phase LNAPL recovery and has been the primary factor responsible for the rate of decrease in free-phase LNAPL recovery beginning in 2006-2007 since installation of the site VES system.

At the request of USEPA, an additional hydrogeologic study was performed by the United States Geological Survey (USGS) due to the potential for adverse water quality to result from this hydrologic communication. Mr. Ron Sloto of USGS investigated the migration of benzene into the lower sand member of the PRM following benzene detections in deep well DW-2, 1,300 ft southeast of the Site (Sloto 2012). Mr. Sloto updated an existing MODFLOW groundwater flow model to represent the aquifers beneath the Site to determine possible flow paths for benzene in the system (Sloto 2012). The model simulated the aforementioned “breach” in the confining layer above the lower sand member, located in the southwest portion of the Site. Output generated from the model suggests that, within the vicinity of the “breach”: 1) hydraulic communication between the shallow and deep aquifer zones is occurring; and 2) by way of this communication, COCs have migrated from the shallow to the deep aquifer.

The upper clay unit, which separates the unconfined shallow aquifer from the deeper aquifers, is also not continuous across the entire former refinery (east of DSCP) as shown in the isopach map of the upper clay unit on the Stantec Area of Interest (AOI) 4 Remedial Investigation Report, Figure 4-14 (Stantec 2021). This figure is provided in **Appendix I**. The middle clay is present over much of the southeastern parts of the refinery. However, the clay is absent in the western portion of the refinery closer to the Schuylkill River, as well as in a small portion within AOI 1 along the 26<sup>th</sup> Street sewer, potentially a westward extension of the “breach” or due to anthropogenic activities (construction of the sewer).

## 6.4 Relevant Manmade Site Features

Given the Site’s location in South Philadelphia and recognizing that there has been extensive urban development, repurposing, and expansion over the last century, anthropogenic features germane to the CSM are numerous.

Construction of stormwater basins, building foundations, utility conduits, and sewers has, through localized removal of the silt layer and the confining clay between the upper and lower aquifer units, created potential pathways through which dissolved- and vapor-phase COCs could migrate. While some of the silt layer disturbances occurred in the 1920s, others were created as recently as 2015 and continue to be created via ongoing development of the Site (e.g., Siena Place). Each of these types of features has been included in the CSM as each influences the distribution and movement of site COCs in the LNAPL, dissolved, and soil vapor phases.

The significance of the silt layer cuts is dependent upon the degree to which the silt layer has been compromised and its proximity to the historical LNAPL extent and potential receptors. The presence or absence of the silt layer is important locally for controlling potential exposure to site hydrocarbon impacts. Borehole data for locations near utilities and underground structures is lacking due to risk avoidance and health and safety reasons. As a result, silt layer maps and models (**Appendix I**) likely underestimate the degree to which the silt has been compromised across the Site. According to the 2002 HHRA, a higher estimate of indoor benzene air concentration is associated with modeled buildings under which no silt layer is present (Environ 2002). Presumably, the silt layer effectively blocks soil vapor from entering overlying soil layers and buildings. Where the silt layer is not present, whether naturally or anthropogenically, there may be a higher risk of accumulation of soil vapor in proximal buildings.

Other manmade site features, including abandoned utilities and foundations from old structures, are located under the PHA Building, Siena Place, and the Former DSCP Facility. These features appear on a site map that is included in **Appendix E** and represent the subsurface features that have the potential to represent cuts in the silt layer that lead to preferential VI exposure pathways.

Three major large-diameter sewer lines cross the Site at various locations and orientations and also drain into one another. These include the Former DSCP Facility sewer, the Pollock-Packer Avenue sewer, and the 26<sup>th</sup> Street sewer, as shown in red on **Figure 2**. The Former DSCP Facility sewer (43-inch combined sewer) discharges to the Pollock-Packer Avenue sewer south of Building 9. The Pollock-Packer Avenue sewer flows east to west across the lower-central portion of the Site, where it discharges into the 26<sup>th</sup> Street sewer. The 26<sup>th</sup> Street sewer flows south to north along the western boundary of the Site. As discussed in **Section 6.2**, urban stormwater control is maintained in numerous ways, including catch basins and downspouts that eventually flow to this interconnected sewer network. These manmade features are included in the CSM as they may directly affect groundwater flow and movement of groundwater COCs as well as provide preferential VI exposure pathways of volatilized site COCs to potential receptors. This is further evaluated in **Section 6.6.3** and in the HHRA Report (**Appendix B**).

#### 6.4.1 Former Defense Supply Center Philadelphia Facility Sewer

A main combined sewer outfall (43-inch) is documented to run from Building 9, east of MW-7 on the Former DSCP Facility, and tie into the Pollock-Packer Avenue sewer east of MWS-3, MWS-4, and MH-G on the PHA property, connecting the DSCP sewer system with the Pollock-Packer Avenue sewer (Figure 10 of **Appendix I**; Malcolm Pirnie 2001). In the fall of 2000, in-situ lower explosive limit (LEL) (the minimum concentration of a given vapor that allows for its combustion in air; below this limit, the gas will not burn) measurements of soil vapor were collected south of Building 9. At a depth of approximately 5 ft bgs, the LEL was >100% (Malcolm Pirnie 2001). A cross section of the sewer is provided on Figure 11 of **Appendix I** (Malcolm Pirnie 2001).

Remediation O&M activities required as part of the AO include monthly monitoring of manholes connected to this sewer. Given the absence of elevated in-sewer LEL readings (e.g., AO-required quarterly reports) and those

reported by USACE (**Appendix J**), site remediation has mitigated the occurrence of elevated LEL concentrations in the sewer. However, the potential exposure pathway to the sewer from VOCs and LELs in soil gas remains.

### 6.4.2 Pollock-Packer Avenue Sewer

The Pollock-Packer Avenue sewer is an 8-ft by 10-ft reinforced concrete box culvert that was constructed circa 1919 and has 12- to 15-inch-thick walls with steel rod reinforcements. It currently extends west from Packer Avenue, crossing beneath Siena Place, the CSX property, the Steen property, 26<sup>th</sup> Street, and the former refinery, where it terminates at an interceptor chamber adjacent to the Schuylkill River. It sits at an elevation between approximately -5 ft and -7 ft amsl (approximately 15 ft bgs) with a slope of approximately 0.05 ft per 100 ft of pipe and intersects the shallow groundwater table. In the vicinity of the Site, the Pollock-Packer Avenue sewer also intersects the LNAPL smear zone within the shallow groundwater table.

Excavation for the Pollock-Packer Avenue sewer disturbed or removed the silt layer in some areas (Environ 2002). Backfill for the sewer extends 5 ft from each side. It was also documented in the HHRA Report that the silt layer was absent immediately adjacent to building foundations at the Former DSCP Facility; however, it is not noted which buildings have this potential issue (Environ 2002). The silt layer was also absent at the intersection of I-76 (the Walt Whitman Bridge Approach) and Penrose Avenue and was possibly removed during construction.

Hydrocarbon vapors and LNAPL have historically been observed in the Pollock-Packer Avenue sewer east of the former refinery, beneath the Former Passyunk Homes Property (Schreffler 2001). As part of continued monitoring of subsurface conditions at the Site, the sewer is monitored quarterly for the presence or absence of hydrocarbon vapors at selected manholes. Vapor detections at sewer monitoring points have diminished since 2011, and a sewer entry and inspection conducted on October 14, 2016, revealed no hydrocarbon or explosive vapors nor leaking LNAPL to the sewer. Additional details regarding the Pollock-Packer Avenue sewer are summarized in the Remedial Investigation Report for Area of Interest 1, Philadelphia Refinery Operations (AOI 1 RIR; Stantec 2016).

### 6.4.3 26<sup>th</sup> Street Sewer

The 26<sup>th</sup> Street sewer (also known as the Lower Schuylkill East Side Intercepting Sewer) was constructed circa 1963 using vacuum-processed, 3-ft to 4-ft-diameter reinforced concrete pipe. It is located along the western side of 26<sup>th</sup> Street, approximately 3 ft to 40 ft east of the former refinery fence line. The sewer sits at an elevation of approximately -11 ft amsl (approximately 30 to 40 ft bgs) and flows to the north along a slope of 0.15 ft per 100 ft of pipe. Test boring data from the sewer construction plans presented in AOI 1 RIR (Stantec 2016) confirm that the sewer lies within the shallow aquifer and in places the excavation for the sewer cuts into the underlying confining unit. As discussed in **Section 6.3.4, Appendix I** includes an isopach map of the upper clay unit across the former refinery, which is fairly consistent across much of the property, except where it pinches to zero directly adjacent to the 26<sup>th</sup> Street sewer in AOI 1. A potential connection between the upper and lower aquifers is again discussed in the HHRA CP for the former refinery (Sanborn-Head 2025), which describes a break in the 26<sup>th</sup> Street sewer that's present in the lower portion of AOI 1 and that can act as a point of infiltration from the shallow aquifer and a connection point to reach the deeper aquifer. Remedial efforts at AOI 1 have been implemented to prevent migration of refinery COCs into the compromised section of the 26<sup>th</sup> Street sewer. These reports (Stantec 2016; Sanborn-Head 2025) also discuss that groundwater influence from the 26<sup>th</sup> Street sewer has been observed in both the upper and lower aquifers at the location of the sewer break, further indicating that the confining clay is likely partially removed from either natural or anthropogenic processes in this location.

#### 6.4.4 Siena Place Homes

The following residences within the Siena Place Homes (i.e., [REDACTED] [REDACTED] Roma Drive) are identified as potentially susceptible to VI due to their proximity to the sewer and the connected laterals that serve the residential development. Specifically, review of construction drawings (**Appendix I** Silt Cuts – C305 and C304) indicates that sewer laterals may partially or fully remove the silt. Loss of the silt as well as the emplacement of porous sewer trench backfill created potential preferential pathways for the migration of COC-containing vapor from other sewer areas with documented petroleum hydrocarbon impacts as described in **Section 6.4.2**.

### 6.5 Site Characterization

This section describes the nature and extent of LNAPL contamination present onsite and the resulting impacts to groundwater, soil, and soil vapor. Based on guidance from the AO to remove LNAPL to the maximum extent practicable, remedial investigation activities have centered on the characterization and extent of LNAPL onsite. Proposed site remediation and pathway elimination approaches support release of liability for residual, nonmobile/nonrecoverable LNAPL under Act 2 as required in the AO (PADEP 2021).

#### 6.5.1 Nature and Extent of Contamination

The Site's petroleum hydrocarbon impacts and related potential human health exposure pathways are associated with petroleum LNAPL impacts present above and below the local groundwater table ("trapped LNAPL") and at depths ranging generally from 15 to 40 ft bgs.

#### 6.5.2 Light Non-Aqueous Phase Liquid

Petroleum hydrocarbon COCs and LNAPL are present in the shallow aquifer at the Site. The current distribution of LNAPL appears to be constrained within an elongated area, following an east-west trend. The historical extent of the LNAPL at the Site is depicted on **Figure 12** (originally a Foster Wheeler Environmental Corporation [Foster Wheeler] figure dated October 28, 2002). LNAPL is monitored quarterly at the Site and based on the fourth quarter of 2024 gauging event, the extent and thickness of LNAPL have both decreased, with the revised estimated LNAPL extent depicted on **Figure 12** (SERES-Arcadis JV 2025). As shown on **Figure 12**, the lateral extent of the LNAPL is generally confined within the area of the "breach" with isolated areas within and along the edges of the "breach." The greatest measured LNAPL thicknesses are consistently observed down the center of the "breach" in a narrow linear feature also trending southwest to northeast. The measured LNAPL thins to the northwest and southeast and appears to be bounded by the Pollock-Packer Avenue sewer to the south.

The spatial limits of the Site's LNAPL have been affected by ongoing product removal, natural attenuation, and water table fluctuations. A Foster Wheeler figure, dated October 28, 2002, overlain on **Figure 12** and provided in **Appendix K** shows the maximum reported historical LNAPL extent. Historical LNAPL extent (**Figure 12**; **Appendix K**) reaches north to MW-16, east to MW-12 (a well where LNAPL has sometimes been observed more recently), south to MW-46 (close to Hartranft Street), and west along the Steen property. The historical LNAPL extent has stabilized spatially and has not extended beyond what is shown on the 2002 Foster Wheeler figure mentioned above. This observation supports the argument for the absence of an ongoing petroleum LNAPL source.

The thickness of the Site's LNAPL has also been affected by ongoing product removal, natural attenuation, and water table fluctuations. The record of historical LNAPL thickness includes measurements up to a maximum of 4.98 ft (measured at EPH-MW-39 in 2001), but with site-wide decreases in both average product thickness and the number of wells with any measurable thickness present. During the fourth quarter of 2024, LNAPL was detected in 20 wells, with a maximum observed LNAPL thickness of 1.34 ft measured at DSCP-MW-3A. The minimum LNAPL thickness recorded was 0.01 ft at four locations. The average LNAPL thickness was 0.32 ft, with a median LNAPL thickness of 0.16 ft. Notably, the measurement of LNAPL thickness in monitoring wells is "fraught with uncertainty" (ITRC 2018), and particularly so in the practice of estimating the remaining recoverable LNAPL. Historically, LNAPL thickness is typically observed down the center of the "breach".

Additional LNAPL monitoring results are provided in **Section 6.6.1**. Ongoing LNAPL monitoring aims to show that LNAPL is becoming less mobile, less recoverable, and more stable (i.e., weathered in situ) with time.

### 6.5.2.1 Initial Fingerprinting and Selection of Constituents of Concern

A review of the preliminary characterization data from 1996 to 2003 shows that the LNAPL consists primarily of a complex mixture of hydrocarbons, including benzene, ethylbenzene, 2-methylnaphthalene, naphthalene, toluene, and xylenes. In the previous draft risk assessments, benzene was identified as the chemical contributing most significantly to potential risks (Malcolm Pirnie and Louis Berger & Associates 1998; Malcolm Pirnie 1999).

The historical LNAPL data available for review included information on the concentrations of paraffin, isoparaffin, aromatic, naphthene, and olefin (PIANO) and polycyclic aromatic hydrocarbon (PAH) compounds, petroleum hydrocarbon boiling point ranges, and LNAPL density. PIANO and PAH data were generated by different laboratories for samples that had been collected during different time periods and were not directly comparable without expending considerable effort in normalizing the data sets to a common basis. Therefore, these data were used qualitatively within Arcadis LNAPL composition assessments (Arcadis 2013).

Based on the historical PIANO, PAH, and fingerprinting data through 2006, site LNAPL was determined to be a mixture of compounds derived from refined gasoline and diesel products. While composition appears to vary spatially across the Site, all samples were composed of a mixture, many of which included a small fraction of heavier-than-diesel petroleum hydrocarbons. As a result of the initial characterization data analysis and as discussed with PADEP in progress meetings and published in subsequent Progress Reports, in the third quarter of 2012, the PADEP Short List of Petroleum Products for Leaded Gasoline, Aviation Gasoline, and Jet Fuel (PADEP Storage Tank Program Guidance [2008], Table IV-9) was used to select COCs in groundwater to be analyzed. Comparison of COC concentrations in groundwater to specific PADEP standards (further addressed below in **Section 6.5.2.2**) was performed for relative comparison only, and not to establish quantitative cleanup goals.

The Short List (PADEP 2008) includes the following COCs:

- Benzene;
- Toluene;
- Ethylbenzene;
- Xylenes (Total);
- Cumene (Isopropylbenzene);
- Naphthalene;

- Trimethylbenzene, 1,2,4- (Trimethylbenzene, 1,3,4-);
- Trimethylbenzene, 1,3,5-;
- Dichloroethane, 1,2-;
- Dibromoethane, 1,2-; and
- Lead (dissolved).

To better understand the distribution of petroleum hydrocarbons in LNAPL at the Site, as well as changes over time, boiling point analyses were initially performed in 2003 and 2006. A boiling point analysis provides information on the specific temperatures at which a certain percentage of the petroleum hydrocarbons in a sample has been removed via volatilization or boiling. The data were used to organize samples into general compositional categories (e.g., gasoline, diesel) via boiling point distribution curves, using these approximate boiling temperature ranges:

- Less than 200 degrees Fahrenheit (°F) to characterize light gasoline range compounds;
- 200°F to 400°F to characterize the remainder of gasoline-range compounds; and
- Greater than 400°F to characterize diesel range and heavier compounds.

Results from the 2003 and 2006 boiling point analyses are shown on Figure L-1 in **Appendix L** and are color coded as:

- Yellow: >10% light gasoline range hydrocarbons;
- Green: less than or equal to 10% light gasoline range hydrocarbons and ≤30% diesel and residual range hydrocarbons; and
- Blue: >30% diesel and residual range hydrocarbons.

The figure shows nine wells with the lighter-end characterization (yellow), 11 wells in the middle (green), and seven wells with the heavier-end characterization (blue). LNAPL containing a higher percentage of lighter hydrocarbon compounds appears grouped towards the western end of the area of measurable LNAPL, and LNAPL containing a higher percentage of heavier hydrocarbon compounds is grouped towards the eastern end of measurable LNAPL.

To track remedial performance relative to the LNAPL cleanup goals, samples were again collected for boiling point analysis in 2017 and in 2024. However, as a result of remedial progress as well as hydrostratigraphic limitations of the Site, there were fewer wells containing enough LNAPL to sample. In 2017, six wells were included in a boiling point analysis, and in 2024, only three wells had enough LNAPL to sample. The results of the boiling point analysis were plotted on a map for comparison to Figures L-2 and L-3 in **Appendix L**. As shown on these figures, not only are there fewer LNAPL-bearing wells since the 2003 and 2006 sampling events, but the LNAPL in these wells is more weathered because of both ongoing remediation by the VES and BV-BS systems and natural attenuation processes.

The analytical results from the boiling point analyses were plotted on recovery curves shown as Figures L-4A through L-4I in **Appendix L**. These recovery curves display the percentage recovery of LNAPL versus temperature. As discussed above, the lighter fraction of the LNAPL (i.e., gasoline range) is recovered at lower temperatures (<400°F) compared to that of the heavier diesel range, which is recovered at higher temperatures (>400°F). Overall, the recovery curves show that LNAPL-bearing wells within the area of influence of the vacuum of the VES system show evidence of transitioning from lighter, mostly gasoline range to heavier, mostly diesel range. This is best exemplified by the recovery curves for wells where multiple rounds of analytical results exist

over time such as DSCP-RW-8, DSCP-RW-9, RW-MW-33, and PH-RW-A. These wells have been analyzed several times since 2006 and exhibit significant weathering with the fraction of the LNAPL in the gasoline range, which is significantly reduced as of 2024. DSCP-MW-3A is an example of a well where only skimming was conducted and is not connected to the VES system. In this well, the majority of LNAPL is gasoline range and less weathered than LNAPL under the influence of VES.

### 6.5.2.2 Groundwater

Petroleum hydrocarbon COCs and LNAPL are present in the Site's shallow aquifer zone, and dissolved COCs are present in the underlying deep aquifer zone. As discussed in **Section 7**, the Quick Domenico Groundwater Flow Model starts in the deep aquifer zone at PH-DW-3 where groundwater benzene concentrations have been relatively stable, with the absence of consistent decreasing trends in groundwater. These conditions suggest an input source of dissolved contaminant remains present at the Site (Montrose Environmental Solutions Canada, Inc. 2025). This location (PH-DW-3) is also situated along the downgradient edge of the site boundary in the deep aquifer.

The location of site LNAPL as defined by inferred thickness-based contour maps provided in quarterly reports is coincident with the area where the upper and lower aquifers are hydraulically connected (the "breach"). This spatial relationship is central to the rationale for the type of sampling performed and the planned demonstration of long-term LNAPL stability evaluations, discussed in **Section 6.6.1**.

Shallow aquifer zone dissolved-phase COC data from wells located within the "breach" area indicate stable trends over time. Like LNAPL, the COC distribution suggests a spatially stable shallow aquifer zone impact area composed of lighter end (e.g., gasoline to middle-distillate) constituents above the central and western portions of the "breach", with generally lower concentrations of these constituents elsewhere beneath the Site. These areas are also coincident with an area of the aquifer with downward vertical gradients as indicated by quarterly reported measurements obtained from paired shallow and deep aquifer zone wells (Arcadis 2015 and 2016).

#### 6.5.2.2.1 Groundwater Sampling Results

The most recent site-wide groundwater sampling event was conducted in December 2024, during which 159 of the 165 wells (which include both monitoring and recovery wells) were sampled and analyzed for site-specific target compounds (PADEP Storage Tank Program Guidance Table IV-9; PADEP 2008), the target COCs. Since 2019, site-wide groundwater sampling has been conducted for target COCs on a biennial basis, with the exception of 2023 and 2024, when site-wide groundwater sampling was conducted in November and December 2023 and December 2024. Four wells (CSX-MW-2, CSX-MW-3A, CSX-MW-8, and CSX-MW-9) have not been sampled due to surface-related damage preventing access, and two 1-inch inner-diameter wells (Prepack-1 and Prepack-2) were also not sampled as neither well, due to diameter, could accommodate sampling pumps. An overview of the most recent site-wide groundwater sampling event (conducted during December 2024) is summarized below. These analytical results were previously presented in the Fourth Quarter of 2024 and Calendar Year 2024 Progress Report (SERES-Arcadis JV 2025). Laboratory analytical reports have been submitted to PADEP under separate cover in the Annual Progress Reports, during the periods that the sampling events occurred. Analytical data tables for events prior to the fourth quarter of 2024 site-wide sampling event have also been submitted under separate cover in the appropriate Annual Progress Reports. Data tables for the most recent site-wide groundwater sampling event (i.e., December 2024) are provided herein as referenced below. Data tables for historical site-wide sampling events, dating to 2014, are provided in **Appendix M**.

The target COC groundwater sampling results for the fourth quarter of 2024 are presented in **Table 3A** and are compared to the USEPA Tap Water Regional Screening Levels (RSLs), based on a total hazard quotient (THQ) of 0.1 and a target cancer risk (TR) of 1e-06, the PADEP Act 2 groundwater MSCs (PADEP 2021) based on a residential site use (MSC(r)), and 1/10<sup>th</sup> of the PADEP Groundwater Statewide Health Standard (SHS) Soil Vapor Intrusion Screening Values based on a residential site use (SV<sub>GW</sub>(r)). When screening groundwater for VI, 1/10<sup>th</sup> of the soil vapor groundwater screening value (SV<sub>GW</sub>) is the screening criterion for sites being considered for the SSS. Groundwater results for metals are provided in **Table 3B** and are compared to PADEP Act 2 MSCs based on a residential site use (PADEP 2021).

### 6.5.2.2.2 Volatile Organic Compounds

All of the target COCs analyzed for in the shallow groundwater horizon (benzene, toluene, ethylbenzene, xylenes [BTEX; total], 1,2-dichloroethane, isopropylbenzene [aka cumene], methyl tert-butyl ether [MTBE], tert-butyl alcohol [TBA], 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, and 1,2-dibromoethane) were detected in groundwater during the 2024 (i.e., fourth quarter) site-wide groundwater sampling event, of which four compounds (benzene, ethylbenzene, naphthalene, and 1,2,4-trimethylbenzene) were detected at concentrations that exceeded the SV<sub>GW</sub>(r). In addition to the aforementioned VOCs, 2,2,4-trimethylpentane (a tentatively identified compound) was also reported by the laboratory. Results with a “J” qualifier are estimated concentrations, and results with a “D” qualifier indicate the sample had to undergo dilutions, which results in higher reporting limits for all analytes associated with that sample.

Two compounds commonly associated with unleaded gasoline (MTBE) and its primary breakdown product (TBA) are not suspected to be associated with historical site operations and are monitored and discussed herein due to MTBE-related releases at an upgradient property. The analytes exceeding the residential groundwater MSCs and SV<sub>GW</sub>(r) are summarized below.

#### Shallow Wells

All of the target COCs analyzed for in the shallow groundwater horizon (1,2,3-trichloropropane, 1,2,4-trimethylbenzene, 1,2-dichloroethane, 1,3,5-trimethylbenzene, 2,2,4-trimethylpentane, benzene, ethylbenzene, isopropylbenzene, MTBE, naphthalene, TBA, toluene, total xylenes, 1,2-dibromo-3-chloropropane, and 1,2-dibromomethane) were detected. Concentration ranges for each compound are compared in **Table 4** below to the applicable USEPA RSL, PADEP MSC(r), and PADEP SV<sub>GW</sub>(r).

Table 4 Shallow Well Analytical Results Summary

Analyte	RSL	MSC(r)	1/10 MSC(r)	SV <sub>GW</sub> (r)	1/10 SV <sub>GW</sub> (r)	Detections	Min	Max	Average
1,2,3-Trichloropropane	7.50E-04	40	4	44	4.4	7	0.31	0.65	0.48
1,2,4-Trimethylbenzene	5.6	130	13	510	51	56	1.10	1,000	90.5
1,2-Dichloroethane	0.17	0.05	0.005	34	3.4	1	2.60	2.60	2.60
1,3,5-Trimethylbenzene	6	130	13	360	36	79	0.35	300	45.8
2,2,4-Trimethylpentane	ns	ns	ns	ns	ns	7	1.10	15.0	4.24
Benzene	0.46	5	0.5	23	2.3	95	0.31	29,000	1,868
Ethylbenzene	1.5	700	70	700	70	83	0.47	1200	108
Isopropylbenzene	45	840	84	1900	190	103	0.46	140	37.2

Analyte	RSL	MSC(r)	1/10 MSC(r)	SV <sub>GW</sub> (r)	1/10 SV <sub>GW</sub> (r)	Detections	Min	Max	Average
MTBE	14	20	2	6,300	630	5	0.24	34.0	13.7
<b>Naphthalene</b>	<b>0.12</b>	<b>100</b>	<b>10</b>	100	<b>10</b>	52	1.10	460	71.1
TBA	Ns	ns	ns	ns	ns	38	16.0	3,000	170
<b>Toluene</b>	<b>110</b>	1,000	<b>100</b>	34,000	3,400	93	0.38	1,000	72.7
<b>Total Xylenes</b>	<b>19</b>	10,000	<b>1,000</b>	10,000	<b>1,000</b>	81	0.44	2,500	142
<b>1,2-Dibromo-3-chloropropane</b>	<b>3.30E-04</b>	0.2	<b>0.02</b>	0.57	<b>0.057</b>	37	0.01	0.45	0.044
<b>1,2-Dibromoethane</b>	<b>7.50E-03</b>	0.05	<b>0.005</b>	2.9	<b>0.29</b>	24	0.01	0.30	0.062

**Notes:**

Yellow shaded/bold cell indicates analyte detected above referenced regulatory limit.

All values are in micrograms per liter (µg/L).

ns = no published standard for analyte

RSL = Tap Water (THQ=0.1, TR=1e-06)

Target COCs detected above their respective USEPA RSL were 1,2,3-trichloropropane, 1,2,4-trimethylbenzene, 1,2-dichloroethane, 1,3,5-trimethylbenzene, benzene, ethylbenzene, isopropylbenzene, naphthalene, toluene, total xylenes, 1,2-dibromo-3-chloropropane, and 1,2-dibromoethane. Target COCs detected above the MSC(r) were 1,2,4-trimethylbenzene, 1,2-dichloroethane, 1,3,5-trimethylbenzene, benzene, ethylbenzene, isopropylbenzene, naphthalene, toluene, total xylenes, 1,2-dibromo-3-chloropropane, and 1,2-dibromoethane. Benzene, 1,2,4-trimethylbenzene, 1,3,5-trimethylbenzene, ethylbenzene, isopropylbenzene, naphthalene, toluene, total xylenes, 1,2-dibromo-3-chloropropane, and 1,2-dibromoethane were detected above 1/10<sup>th</sup> the SV<sub>GW</sub>(r). Concentrations for the target COCs are presented in **Table 3A**.

Isoconcentration contours for benzene, ethylbenzene, naphthalene, 1,2,4-trimethylbenzene, and 1,2-dichloroethane in the shallow monitoring wells were prepared for the 2023 site-wide groundwater sampling event (Figures 1 through 5, **Appendix N**) and the 2024 site-wide groundwater sampling event (Figures 11 through 15, **Appendix N**) and were previously submitted in the Quarterly Progress Reports. In addition to the 2023 and 2024 isoconcentration contours, side-by-side comparison isoconcentration contours (2014 and 2024) were prepared for the shallow zone (Figures N-21 through N-24 of **Appendix N**). The 2014 results predate the start-up of the current remediation system. A side-by-side comparison for 1,2-dichloroethane was not prepared due to a limited number of detections. The side-by-side comparisons show that both the magnitude and extent of these compounds have decreased over time as noted below:

- The fourth quarter of 2014 maximum benzene concentration was 27,700 µg/L, with an average concentration of 3,556.7 µg/L and a median concentration of 728.5 µg/L. The fourth quarter of 2024 maximum benzene concentration was 29,000 µg/L; however, the average concentration was 1,867.3 µg/L, with a median concentration of 120 µg/L. In addition to the observed decrease in average and median benzene concentrations, the overall area of the benzene plume with concentrations greater than 1,000 µg/L has been reduced by approximately 28% (Figure N-21, **Appendix N**).
- The fourth quarter of 2014 maximum ethylbenzene concentration was 1,330 µg/L, with an average concentration of 280.9 µg/L and a median concentration of 84.3 µg/L. The fourth quarter of 2024 maximum ethylbenzene concentration was 1,200 µg/L, with an average concentration of 107.9 µg/L and a median concentration of 26 µg/L. In addition to the observed reduction in ethylbenzene concentrations, the area of the ethylbenzene plume with concentrations greater than 100 µg/L has been reduced by approximately 67%, with

the area of ethylbenzene concentrations greater than 100 µg/L becoming more fragmented in 2024 as opposed to a more continuous mass as observed in 2014 (Figure N-22, **Appendix N**).

- The fourth quarter of 2014 maximum naphthalene concentration was 628 µg/L, with an average concentration of 192 µg/L and a median concentration of 152 µg/L. The fourth quarter of 2024 maximum naphthalene concentration was 460 µg/L, with an average concentration of 73.7 µg/L and a median concentration of 25 µg/L. In addition to the observed reduction in overall naphthalene concentrations, the area of the naphthalene plume with concentrations greater than 10 µg/L has been reduced by approximately 54% (Figure N-23, **Appendix N**).
- The fourth quarter of 2014 maximum 1,2,4-trimethylbenzene concentration was 1,170 µg/L, with an average concentration of 302.6 µg/L and a median concentration of 162 µg/L. The fourth quarter of 2024 maximum 1,2,4-trimethylbenzene concentration was 1,000 µg/L, with an average concentration of 93 µg/L and a median concentration of 20 µg/L. In addition to the observed reduction in 1,2,4-trimethylbenzene concentrations, the overall area of the 1,2,4-trimethylbenzene plume with concentrations greater than 100 µg/L has been reduced by approximately 83%, with the area of 1,2,4-trimethylbenzene concentrations greater than 100 µg/L becoming more fragmented in 2024 as opposed to a more continuous mass as observed in 2014 (Figure N-24, **Appendix N**).
- The fourth quarter of 2014 results did not include detections of 1,2-dichloroethane. However, there was a single detection of 1,2-dichloroethane during the fourth quarter of 2024 sampling event (2.6 µg/L). Due to the limited number of detections, comparative contours for 1,2-dichloroethane were not prepared.

**Deep Wells**

Target COCs detected in the deep groundwater horizon were 1,2-dichloroethane, 1,3,5-trimethylbenzene, benzene, ethylbenzene, isopropylbenzene, MTBE, naphthalene, toluene, total xylenes, and 1,2-dibromoethane. There were no reported detections of 1,2,4-trimethylbenzene, 2,2,4-trimethylbenzene, TBA, or 1,2-dibromo-3-chloropropane. Concentration ranges for each compound that was analyzed for are compared below to the applicable USEPA RSL, PADEP MSC(r), and PADEP SV<sup>GW</sup>(r). When screening groundwater for VI, 1/10<sup>th</sup> of the SV<sub>GW</sub> is the screening criterion for sites being considered for the SSS.

Table 5 Deep Well Analytical Results Summary

Analyte	USEPA RSL	MSC(r)	1/10 MSC(r)	SV <sub>GW</sub> (r)	1/10 SV <sub>GW</sub> (r)	Detections	Min	Max	Average
1,2,3-Trichloropropane	7.50E-04	40	4	44	4.4	0	--	--	--
1,2,4-Trimethylbenzene	5.6	130	13	510	51	0	--	--	--
<b>1,2-Dichloroethane</b>	<b>0.17</b>	<b>0.05</b>	<b>0.005</b>	34	3.4	3	0.32	0.67	0.48
1,3,5-Trimethylbenzene	6	130	13	360	36	1	0.33	0.33	0.33
2,2,4-Trimethylpentane	ns	ns	ns	ns	ns	0	--	--	--
<b>Benzene</b>	<b>0.46</b>	<b>5</b>	<b>0.5</b>	23	<b>2.3</b>	6	5.5	1900	722
<b>Ethylbenzene</b>	<b>1.5</b>	700	70	700	70	2	2.6	12	7.3
<b>Isopropylbenzene</b>	<b>45</b>	840	84	1900	190	4	0.6	66	17.5
<b>MTBE</b>	<b>14</b>	<b>20</b>	<b>2</b>	6300	630	15	0.2	160	22.5
<b>Naphthalene</b>	<b>0.12</b>	100	10	100	10	1	1.1	1.1	1.1
TBA	ns	ns	ns	ns	ns	0	--	--	--

Analyte	USEPA RSL	MSC(r)	1/10 MSC(r)	SV <sub>GW</sub> (r)	1/10 SV <sub>GW</sub> (r)	Detections	Min	Max	Average
Toluene	110	1000	100	34000	3400	4	0.35	74	23.4
<b>Total Xylenes</b>	<b>19</b>	10000	1000	10000	1000	1	52	52	52
1,2-Dibromo-3-chloropropane	3.30E-04	0.2	0.02	0.57	0.057	0	--	--	--
<b>1,2-Dibromoethane</b>	<b>7.50E-03</b>	0.05	<b>0.005</b>	2.9	0.29	1	0.014	0.014	0.014

**Notes:**

Yellow shaded/bold cell indicates analyte detected above referenced regulatory limit.

All values are in µg/L.

-- = not applicable

ns = no published standard for analyte

RSL= Tap Water (THQ=0.1, TR=1e-06)

Target COCs detected above their respective USEPA RSL were 1,2-dichloroethane, benzene, ethylbenzene, isopropylbenzene, MTBE, naphthalene, total xylenes, and 1,2-dibromoethane. Target COCs detected above the MSC(r) were benzene, MTBE, and 1,2-dichloroethane. Benzene was the only compound detected above 1/10<sup>th</sup> the SV<sub>GW</sub>(r). Benzene was also the only compound detected above both the MSC(r) and 1/10<sup>th</sup> the SV<sub>GW</sub>(r). Concentrations for the target COCs are presented in **Table 3A**.

Isoconcentration contours for benzene, ethylbenzene, naphthalene, 1,2,4-trimethylbenzene, and 1,2-dichloroethane in the deep monitoring wells were prepared for the 2023 site-wide groundwater sampling event (Figures 6 through 10, **Appendix N**) and the 2024 site-wide groundwater sampling event (Figures 16 through 20, **Appendix N**).

In addition to the 2023 and 2024 isoconcentration contours, side-by-side comparison isoconcentration contours (2014 and 2024) were prepared for benzene and ethylbenzene (Figures N-25 and N-26, **Appendix N**). It should be noted that deep monitoring wells FDR-DW-10 and NOVA-DW-14, along with Steen-DW-07, Steen-DW-08, and Steen-DW-09, were not installed in 2014, thereby limiting the review of the estimated reduction of the areal extent of the overall plume when comparing 2014 and 2024 contoured results for the deeper monitoring wells. However, as noted below, maximum, average, and median concentrations of these compounds have decreased since start-up of the remediation system.

Side-by-side comparisons for benzene and ethylbenzene show that both the magnitude and extent of these compounds have decreased over time as noted below:

- The fourth quarter of 2014 maximum benzene concentration was 5,560 µg/L, with an average concentration of 1,355.4 µg/L and a median concentration of 459 µg/L. The fourth quarter of 2024 maximum benzene concentration was 1,900 µg/L, with an average concentration was 721.7 µg/L and a median concentration of 459 µg/L. A comparison of the 2014 contours to the 2014 contours is presented on Figure N-25, **Appendix N**. The review of maximum, average, and median concentrations indicates that the magnitude of the benzene impacts has decreased over time, which is also reflected in the comparison of the 2014 and 2024 contours.
- The fourth quarter of 2014 maximum ethylbenzene concentration was 21.6 µg/L, with an average concentration of 13.7 µg/L and a median concentration of 18.4 µg/L. The fourth quarter of 2024 maximum ethylbenzene concentration was 12 µg/L, with an average and median concentration of 7.3 µg/L. A comparison of the 2014 contours to the 2024 contours is presented on Figure N-26, **Appendix N**. The review of maximum, average, and median concentrations indicates that the magnitude of the ethylbenzene impacts has decreased over time, which is also reflected by the comparison of the 2014 and 2024 contours.

Although not contoured for a side-by-side comparison, concentrations of naphthalene, 1,2,4-trimethylbenzene, and 1,2-dichloroethane are trending lower as noted below:

- During the fourth quarter of 2014 and fourth quarter of 2024, naphthalene was detected at one location, DSCP-DW-12, at concentrations of 3.6 µg/L and 1.0 µg/L, respectively. Due to the limited number of detections, comparative contours for naphthalene were not prepared.
- During the fourth quarter of 2014, 1,2,4-trimethylbenzene was detected at one location, DSCP-DW-12, at a concentration of 1.1 µg/L; however, the fourth quarter of 2024 results indicate that 1,2,4-trimethylbenzene was not detected in any samples. Due to the limited number of detections, comparative contours for 1,2,4-trimethylbenzene were not prepared.
- During the fourth quarter of 2014, 1,2-dichloroethane was detected at one location, PH-DW-10, at a concentration of 1.2 µg/L. During the fourth quarter of 2024, 1,2-dichloroethane was detected in three monitoring wells, DSCP-DW-1, Steen-DW-07 and Steen-DW-8, at concentrations ranging from 0.32 µg/L to 0.67 µg/L. Due to the limited number of detections and range of concentrations, comparative contours for 1,2-dichloroethane were not prepared.

### **Metals Data**

Groundwater samples collected during the 2024 sampling event were also analyzed for dissolved and/or total metals. All of the sampled groundwater monitoring and groundwater recovery wells were analyzed for both dissolved arsenic and dissolved lead. Select wells (i.e., wells sampled quarterly for the BV-BS pilot study) were also analyzed for both dissolved and total iron and manganese. Analytical data for metals are included in **Table 3B**.

### **Shallow Wells**

Dissolved arsenic was detected in 104 samples at concentrations ranging from 0.73 J µg/L to 120 µg/L, with an average concentration of 13.59 µg/L. The PADEP residential and nonresidential MSC for arsenic, based on total dissolved solids (TDS) <2,500 milligrams per liter (mg/L), is 10 µg/L. A total of 32 of the dissolved arsenic results were equal to or exceeded the MSC. Results with a “J” qualifier are estimated concentrations.

Dissolved lead was detected in 46 of the samples at concentrations ranging from 0.12 µg/L to 47 µg/L, with an average concentration of 1.86 µg/L. The PADEP residential and nonresidential MSC for lead, based on TDS <2,500 mg/L, is 5 µg/L. Lead exceeded the MSC in three samples.

Dissolved iron was analyzed for and detected in seven groundwater samples; concentrations ranged from 400 µg/L to 71,000 µg/L, with an average concentration of 17,480 µg/L. The MSC for iron (a secondary MSC), based on TDS <2,500 mg/L, is 300 µg/L. All seven of the dissolved iron results exceeded the MSC.

Dissolved manganese was analyzed for and detected in seven groundwater samples; concentrations ranged from 22 µg/L to 19,000 µg/L, with an average concentration of 4,516 µg/L. The MSC for manganese, based on TDS <2,500 mg/L, is 300 µg/L. Five of the dissolved manganese results exceeded the MSC.

### **Deep Wells**

Dissolved arsenic was detected in 12 of the 16 wells sampled in the deep horizon at concentrations ranging from 0.81 J µg/L to 7.4 µg/L, with an average concentration of 2.22 µg/L. The PADEP residential and nonresidential MSC for arsenic, based on TDS <2,500 mg/L, is 10 µg/L. None of the dissolved arsenic results exceeded the MSC.

Dissolved lead was detected in two of the 16 deep horizon wells sampled, at concentrations ranging from 0.14 J µg/L to 4.6 µg/L, with an average concentration of 0.16 µg/L. The PADEP residential and nonresidential MSC for lead, based on TDS <2,500 mg/L, is 5 µg/L. None of the dissolved lead results exceeded the MSC.

#### 6.5.2.2.3 Monitored Natural Attenuation Parameters

To investigate the extent of site groundwater biogeochemical conditions indicative of active in-situ petroleum hydrocarbon biodegradation processes, monitored natural attenuation (MNA) analytical data were collected in the third quarter of 2013 and second quarter of 2018. Analytical results are summarized in **Appendix O**, Subsection One, and data packages are provided in **Appendix O**, Subsection Two. Results are interpreted as anaerobic conditions of varying degrees in the central portions of the Site (i.e., within and around the LNAPL body, smear zone, and associated groundwater impacts above the “breach”) that indicate ongoing bio-activity and the mineralization of hydrocarbons to carbon dioxide (CO<sub>2</sub>). Following is a summary of the results:

- In the shallow aquifer zone, nitrate, nitrate, nitrite, and sulfate were generally not detected in the central portion of the Site, where measurable LNAPL is present. Low concentrations of sulfate and nitrate were observed to the north (upgradient) and south (downgradient) of this area. These observations suggest a sulfur- and nitrogen-limited system within the Site’s measurable LNAPL area. Further MNA sampling events are planned to place boundaries on oxidation-reduction zones (nitrate, iron, sulfur reducing, and methanogenic) at the Site and to assess how they vary from upgradient to downgradient and shallow aquifer to deep. Observations include the following: 1) less reducing (less anaerobic) conditions exist at the northernmost (upgradient) and southernmost (downgradient) areas of the Site; 2) the strongest reducing conditions are in the central portion of the Site co-located with the observed LNAPL and highest concentrations of COCs; and 3) in the shallow aquifer zone, relatively high concentrations of CO<sub>2</sub> coincide with the region of measurable LNAPL and areas immediately downgradient.
- In the shallow aquifer zone, relatively low concentrations of methane (CH<sub>4</sub>) were observed upgradient of the measurable LNAPL region, but higher levels were observed in and downgradient of the LNAPL region. The presence of CH<sub>4</sub> is another indicator of a well-developed reducing environment, especially given the evidence of other electron acceptors being depleted.
- In the deep aquifer zone, relatively low concentrations of nitrate and relatively high levels of CH<sub>4</sub> were observed at the southern end of the Site, downgradient of the area of measurable LNAPL. The highest levels of CH<sub>4</sub> were observed at PH-DW-3.
- In the deep aquifer zone, the highest concentrations of sulfate, dissolved iron, and CO<sub>2</sub> were observed at DSCP-MW-20D in the northwestern portion of the Site, upgradient of the area of measurable LNAPL.

#### 6.5.2.3 Hydrocarbon-Impacted Soils

In addition to LNAPL and dissolved-phase impacts, hydrocarbons are also present in the subsurface soil in a zone of varying thickness and depth below the current water table. The nature and extent of the zone are dependent on the pathway through which the LNAPL flowed to its current location, urban infrastructure construction, and emplacement methods, as well as natural and anthropogenic influences on water table levels during modern times. This zone is present as a result of changes in groundwater elevation: as the water table fluctuates, LNAPL atop the water table also fluctuates, but some material adheres to the aquifer matrix in both the vadose and saturated zones. This residue comprises the smear zone.

A series of investigations have taken place at the Site from 1995 to 2024 to investigate these impacts. The focus of the investigations and the resulting list of analytes have evolved over the years to determine the nature and extent of the LNAPL. Initial investigations relied on gasoline range organic, diesel range organic, and total petroleum hydrocarbon analyses. Smear zone characterization samples were analyzed for VOCs and semi-volatile organic compounds as well as metals to assess human health risk. A summary of soil investigations at the Site is included in **Appendix G**. In general, the parameters analyzed in historical soil samples collected at the Site are not consistent with those contained in the current Act 2 TGM (PADEP 2021), Table IV-9 Short List of Petroleum Compounds – Leaded Gasoline, Aviation Gasoline and Jet Fuel (PADEP 2008). Where analyses did include specific compounds for historical data, the detection limits were greater than the current MSC. In 2024, in conjunction with a VI investigation at the Site and to fill any potential data gaps, 28 near-source soil samples were collected from smear zone intervals (approximately 15 ft bgs) that were targeted based on field observations of contamination. Samples were analyzed for the current Act 2 TGM (PADEP 2021), Table IV-9 Short List of Petroleum Compounds (PADEP 2008).

Figures 1 and 2 of **Appendix G** illustrate that the extent of soil impacts are delineated at the Site. Through the historical and 2024 soil investigations, all potential source areas for soil-related impacts on the Site have been identified. Most areas exhibited contaminant levels below current Act 2 MSCs (PADEP 2021), while a few select areas contained residual lead impacts in subsurface soils. Lateral and vertical impacts from former fuel tanks and associated piping were limited in vertical spatial extent, not reaching the water table or the underlying LNAPL. This demonstrates that the operations at the former DSCP likely did not contribute to the LNAPL or to groundwater impacts. The few remaining areas where minor MSC exceedances were observed can effectively be managed by implementing a Soil Management Plan.

#### **6.5.2.4 Hydrocarbon-Impacted Soil Vapor**

Due to the age of the plume and lack of O<sub>2</sub> in the subsurface, hydrocarbons present in the soils biodegrade via methanogenesis into CH<sub>4</sub> gas in the pore spaces of the soil. This occurs at areas of the Site where most free-phase or residual LNAPL exists and also corresponds to areas where relatively low concentrations of nitrate and sulfate nutrients have been observed. The presence of the silt layer at the Site has been shown to limit the vertical migration of petroleum hydrocarbon vapors and CH<sub>4</sub> from the plume (Malcolm Pirnie 2001). However, in places where the silt layer is absent, a potential for the shallow soil gas to contain high concentrations of CH<sub>4</sub> and hydrocarbon vapors has been documented. Previously, soil gas investigations were not a focus because of a lack of remediation standards for soil gas (circa 2004). **Sections 6.5.2.5 through 6.5.2.8** summarize the results of soil gas and VI investigations conducted to date.

#### **6.5.2.5 Previously Conducted Soil Gas and Vapor Intrusion Investigations**

The first soil gas survey was conducted in 1995 as part of the Phase I Remedial Investigation/Feasibility Study (Versar 1995). A total of 81 soil gas samples were collected from approximately 12 ft bgs through the entire DSCP Facility, with the exception of the southwestern corner of the Site. Results from this investigation found the highest VOC concentrations to be centralized in the southern portion of the Site, corresponding with the horizontal limits of the LNAPL plume (see **Appendix P**, Previous Soil Gas Sampling Figures, Figure 7 of the Final Soil Gas Summary Report, Malcolm Pirnie 2001).

PADEP conducted a soil gas survey along the southern border of the Site in 1996, collecting eight soil gas samples at 3 ft bgs. Samples were analyzed for BTEX and MTBE. Two of the eight samples contained BTEX (<50

µg/L) and MTBE (12 to 16 µg/L). The samples were collected near the combined sewer outfall that connects the DSCP sewer system to the Pollock-Packer Avenue sewer (see Figure 8 [Malcolm Pirnie 2001] in **Appendix P**).

In 1998, a soil gas survey was completed above and below the silt layer to characterize the horizontal and vertical distribution of soil vapor, specifically BTEX, at the base of building foundations. Fifteen soil gas samples were collected from 12 ft bgs in the vicinity of Buildings 9 and 13, along the southeastern portion of the Site, to document the concentrations of BTEX at the base of the building foundations as part of the 1999 Draft Health Risk Assessment for Subsurface Hydrocarbon Contamination (Malcolm Pirnie 1999). As shown on Figure 9 in **Appendix P** (Malcolm Pirnie 2001), BTEX soil gas concentrations ranged from 53 µg/L to 1,226 µg/L, and benzene concentrations ranged from 42 µg/L to 1,223 µg/L. In addition to the DSCP soil gas survey, a soil gas survey was conducted at the Former Passyunk Homes Property. A total of 129 soil gas samples were collected from fill overlying the upper silt layer, in the backfill above the Pollock-Packer Avenue sewer, in the upper silt layer, and in the sand and gravel unit above the LNAPL and water table. Samples collected from above the upper silt layer (except those from the Pollock-Packer Avenue sewer) had lower BTEX concentrations than those collected beneath the silt layer. These data support the effectiveness of the silt layer as a barrier to soil gas/vapor migration (i.e., where present/intact) (Malcolm Pirnie 2001).

In the fall of 2000 as part of a soil gas risk assessment, in-situ LEL measurements of soil gas were collected from seven locations south of Building 9. At a depth of approximately 5 ft bgs, the LEL was >100% for all samples (Figure 10 in **Appendix P**). The main combined sewer outfall that connects the sewer system at DSCP to the Pollock-Packer Avenue sewer is located in this area (Malcolm Pirnie 2001). CH<sub>4</sub>, and hence LELs, in soil gas is indirectly related to the presence of LNAPL at the water table. VOCs, CH<sub>4</sub>, and CO<sub>2</sub> (the latter two being byproducts of in-situ biodegradation) can accumulate in the soil gas beneath low-permeability geological or manmade structures, such as concrete floors (Malcolm Pirnie 2001). Results of additional samples collected in 2000 and 2001 indicate locations of in-situ CH<sub>4</sub> of LEL readings of 100% or greater are spatially related to the depth of the silt layer and to areas where the silt layer is absent or thin (Malcolm Pirnie 2001). Areas of the Site where the silt layer is known to be absent coincide with locations of buried infrastructure or former excavations (**Section 6.4; Appendix I**).

Additional soil gas samples were collected by Foster Wheeler in 2000 to further support the risk assessment report (Foster Wheeler 2001). Soil gas samples were collected from 24 locations south of Building 9. At each location, samples were collected from 5 ft bgs, 10 ft bgs, and 15 ft bgs for measurement of VOCs, CH<sub>4</sub>, CO<sub>2</sub>, O<sub>2</sub>, and LEL. A multi-gas meter was used to measure percent CH<sub>4</sub>, CO<sub>2</sub>, O<sub>2</sub>, and LEL. Shallow soil gas samples collected from below the silt layer in an area approximately 280 ft by 120 ft south of Building 9 (Figure 10 in **Appendix P** [Malcolm Pirnie 2001]) had elevated LEL measurements (>100%). The 280-ft by 120-ft area corresponds to the location of a 42-inch-diameter combined sewer outfall that connects to the Pollock-Packer Avenue sewer (Malcolm Pirnie 2001) and is near MW-7, as discussed in **Section 6.4**.

During the 2000 event, Foster Wheeler also collected soil gas samples near MW-3 (between the former Building 28 gas station and the former Building 4 warehouse – southwestern corner of DSCP). These samples confirmed the existence of a silt layer and that the silt layer was serving as a protective barrier, keeping benzene in soil gas below 6 to 8 ft bgs (Foster Wheeler 2001).

In January 2001, DLA's contractor conducted additional focused soil gas sampling to confirm where the upper silt layer was absent or thinning. These areas included the vicinity of the former Building 28 gas station (most likely to correspond to the removal of USTs) between Buildings 12, 13, and 14; the former Bash Street gas station; an area south of Building 9; and areas near RW-6 (south of Building 9) (Figure 12 in **Appendix P**, Malcolm Pirnie

2001). Two additional samples were collected above and below known silt areas to confirm the effectiveness of the silt layer as a natural vapor barrier. Elevated LEL, CH<sub>4</sub>, and benzene concentrations were detected in samples collected south of Building 28 (5 ft bgs), in samples collected at the former Bash Street gas station (5 ft bgs), and in one sample collected south of Building 9 (5 ft bgs, 10 ft south of Building 9 – no silt layer).

Conclusions of the January 2001 investigation indicated that while the potential existed for shallow soil gas to accumulate in all areas of DSCP, shallow soil gas containing CH<sub>4</sub> was identified in specific areas of the Site. These areas appeared to be isolated to locations where the upper silt layer had been disturbed or removed during previous excavations, including excavation areas near the former Building 28 gas station, near the former Bash Street gas station, and in the vicinity of the sewer pipelines along the southern side of Building 9.

**Appendix Q**, Subsection One includes a summary of VI investigations and control actions conducted directly by USACE and Sky Management (the owner of the former government buildings on the Site) in response to reports of odors in Buildings 6 and 30 at the Site.

The results of field screening for VOCs via a photoionization detector (PID) as well as the analytical results of indoor and ambient air samples are provided in the Progress Report; Indoor Air Monitoring – Sky Management Services (USACE 2017; **Appendix Q**, Subsection One). As discussed in this report, the analytical results of samples collected from various locations within Building 6 had detections of site-related COCs in indoor air in exceedance of 1/10<sup>th</sup> of the statewide health standard vapor intrusion indoor air screening value (SV<sub>IA</sub>) for non-residential use. Some of the same COCs detected during the first indoor air sampling event were also present in outdoor ambient air; however, the concentrations were generally higher indoors. Simple temporary control measures, directed by the property manager, were incorporated after the sampling event, which included capping of an open pipe at one location in Building 6 where a VOC concentration of 26.5 parts per million by volume was detected by PID, and regular addition of water to the floor drain traps at another location in Building 6. These controls reduced concentrations in air; however, additional investigation was recommended. Results of indoor air monitoring conducted in Building 30 did not show any exceedances of indoor air screening levels. The results of additional VI investigative activities conducted at Building 6 and Building 30 are discussed in **Section 6.5.2.8.2**.

### 6.5.2.6 Siena Place Vapor Intrusion Investigation

Subsurface investigations were performed upon the request of Judd Builders (developer) by others in December 2016 to address concerns related to odors reported in units at [REDACTED] Roma Drive (Ransom Environmental [Ransom] 2017). On December 1, 2016, Ransom (2017) oversaw the advancement of seven soil borings in the vicinity of the group of four townhomes that includes the [REDACTED] Roma Drive residences. Laboratory analysis of the soil samples identified VOC concentrations that were below the most stringent PADEP MSCs. Benzene was non-detect in the samples.

In addition to the soil investigation activities, on December 1, 2016, Ransom also conducted groundwater investigation activities (Ransom 2017). Ransom installed six temporary well points constructed with a 1-inch-diameter polyvinyl chloride well screen. Laboratory analysis of groundwater samples collected from these temporary borings detected benzene concentration above the PADEP Residential Used Aquifer SHS MSC of 5 µg/L and the PADEP Residential Groundwater SHS Vapor Intrusion Screening Value of 23 µg/L in each of the six groundwater samples. Ethylbenzene was also detected above the PADEP Residential Used Aquifer SHS MSC of 700 µg/L in one groundwater sample.

On December 1, 2016, Ransom (2017) also collected three near-slab soil gas samples and two sub-slab soil gas (SSSG) samples from the vent risers of previously installed sub-slab depressurization systems (SSDs).

Laboratory analysis found that soil gas sample SG-2 (collected from just north of the [REDACTED] Roma Drive residence) exhibited a concentration of benzene above the PADEP Residential Near-Source Soil Gas SHS Screening Value of 620 micrograms per cubic meter. Sub-slab soil gas sample SSDS-2 (collected from the vent riser of the 2205 Roma Drive SSDS) exhibited a concentration of benzene above the PADEP Sub-Slab Soil Gas SHS Vapor Intrusion Screening Value of 120 micrograms per cubic meter.

On December 23, 2016, Ransom returned to the Siena Place Homes and conducted smoke testing along accessible seams, cracks, and penetrations through the concrete slab flooring and poured foundation walls (below surface grade) of the crawl space (Ransom 2017). Smoke testing was conducted with the existing SSDSs for both [REDACTED] Roma Drive operating to generate a subsurface vacuum. Smoke testing was also conducted at pipe joints in the sewer line and conduit for the communication cable where accessible within the crawl spaces. The joints of the piping and the conduit were smoke tested in an effort to determine whether there were any leaks and whether they were under positive or negative pressure. Ransom also conducted smoke testing and vapor screening of accessible exterior sewer line cleanouts, storm and sewer line manhole covers, and roof leader drain lines located in the immediate vicinity of the [REDACTED] Roma Drive units (Ransom 2017). Ransom did not observe any flow indicating either negative or positive pressure influence at any of the utility piping in the crawl spaces, and Ransom did not detect any vapors with the PID around any of the utility piping, including joints and caps (Ransom 2017). Vapors were not detected from screening of the interior of the sewer lines through cleanout caps.

The investigation activities conducted by Ransom appear to confirm that the source of the vapors observed within the [REDACTED] Roma Drive units was attributable to the groundwater contamination beneath the Siena Place development and that the odors observed in the [REDACTED] Roma Drive unit during construction of the concrete patio slab were likely due to trapped vapors volatilizing from the groundwater and not due to a separate soil source (Ransom 2017). Soils did not appear to be a contributing source of vapors, but underground utilities may have acted as a conduit for vapors from remote contamination sources that may have augmented the soil vapor concentrations or facilitated a pathway for higher concentrations volatilizing from nearby groundwater. The vapor barriers at [REDACTED] Roma Drive were subsequently modified to include a coating that extends up the wall of the foundations in the crawl space to address the odor concerns and eliminate the foundation walls as a potential pathway. An investigation was since conducted on the two sewer laterals that connect the Siena Place sewer system to the Pollock-Packer Avenue sewer to determine if pipe bedding material or the sewer conduit present a preferential pathway for vapors from the Pollock-Packer Avenue sewer. The results of this investigation are discussed in **Section 2.5.2.8.6**.

### **6.5.2.7 2018 Vapor Intrusion Assessment**

VI assessment activities were conducted in October and November 2018 at accessible buildings at the Site and surrounding areas within the Act 2 Site as defined in the 2017 NIR (Arcadis 2017). The objectives of the 2018 VI assessment were to investigate and document potential VI exposure pathways in site buildings and develop building-specific VI sampling plans to support future site building-specific VI exposure pathway mitigation and sampling activities. These objectives were pursued in accordance with the procedures established by the SSS of the Land Recycling Program TGM (PADEP 2017). Data collected during the assessment activities were used to update the existing CSM and determine future steps necessary to evaluate and mitigate the VI exposure pathway.

The 2018 VI assessment included reviews of current site building access agreements, available “as-built” and construction drawings, historical site plans, and utility diagrams, followed by observations made during building entry surveys of each building, and recommendations for future site building-specific VI sampling activities to

comply with PADEP VI guidance. Buildings were divided into three groups depending on their proximity to current and/or historical LNAPL extent, as well as dissolved-phase COC concentrations measured in nearby groundwater monitoring wells. Based on the building assessment findings, a method of sampling was recommended for each building and/or group of buildings. The buildings included in the VI investigation are shown on **Figure 13**. Based on the information gathered in the context of the CSM and existing Act 2 regulations (PADEP 2021), collection of up to 157 VI samples were recommended as part of the VI investigation. The methods and findings of the 2018 VI assessment are documented in the Vapor Intrusion Assessment Report (Arcadis 2020b; **Appendix Q**, Subsection Two).

### 6.5.2.8 Vapor Intrusion Investigation

In January 2023, a *Vapor Intrusion Sampling Work Plan for the Commercial/Industrial Buildings, Residential Properties and Sewer – Former Defense Supply Center Philadelphia* (VI Sampling Work Plan) (SERES-Arcadis JV 2023; **Appendix Q**, Subsection Three) was prepared in accordance with the procedures established by the PADEP TGM (PADEP 2021). SERES-Arcadis JV prepared the VI Sampling Work Plan to define the VI investigation activities to be implemented to enable path-to-closure decisions for the Site under Act 2 (PADEP 2021). The VI Sampling Work Plan proposed a phased approach to the collection of samples for laboratory analysis to evaluate the VI pathway at the commercial/industrial buildings and residential properties at Siena Place potentially affected by the site petroleum hydrocarbon plume. The VI Sampling Work Plan outlined a sampling strategy for the subsurface utility corridor of the Pollock-Packer Avenue sewer to assess the potential risk to receptors in Siena Place via an evaluation of soil gas concentrations in pipe bedding along and near connection points to the Pollock-Packer Avenue sewer, as well as conduit vapor concentrations inside of the Pollock-Packer Avenue sewer and lateral sewer connections to Siena Place.

The 2023 VI Sampling Work Plan (SERES-Arcadis JV 2023; **Appendix Q**, Subsection Three) identified the following types of samples to be collected as part of the VI investigation: near-source soil vapor, potential preferential pathway soil vapor (in pipe bedding and sewer or utility conduits), sub-slab soil vapor, SSDS influent vapor, indoor air, sewer conduit vapor (SCV), and ambient air samples. The samples were intended to evaluate the potential for the VI pathway to impact indoor air quality and confirm the effectiveness and necessity of existing engineering controls in place at several commercial/industrial buildings. The VI Sampling Work Plan proposed a phased approach to the collection of samples for laboratory analysis to evaluate the VI pathway at the commercial/industrial buildings and residential properties at Siena Place potentially affected by the site petroleum hydrocarbon plume. The individual properties or buildings included in the commercial/industrial VI investigation were separated into groups as described below:

- Group 1 – Buildings with a vapor barrier and passive SSDS that are either over the current (or historical) extent of LNAPL or have the potential for preferential pathways.
- Group 2 – Buildings that are over the current (or historical) LNAPL plume within a 30-ft distance to the site LNAPL. The VI Sampling Work Plan assumed that no engineering controls are present in these buildings, but that the presences of engineering controls would be investigated as part of the building assessment conducted prior to sampling.
- Group 3 – Buildings falling into three categories: 1) buildings that have adjacent wells with LNAPL present, 2) buildings with limited available groundwater data, or 3) buildings with groundwater VOC concentrations above the  $SV_{GW}$  for protection from VI. The VI Sampling Work Plan assumed that no engineering controls are

present in these buildings, with investigation to be conducted as part of the building assessment prior to sampling.

- Group 4 – Buildings that are outside of the current (or historical) extent of the LNAPL plume and adjacent wells are below the  $SV_{GW}$  for protection from VI, but the potential for preferential pathways exists and, therefore, requires evaluation. Screening preferential pathways at Group 2 and Group 3 buildings were used to screen out Group 4 buildings.
- Group 5 – Buildings that are farthest from the LNAPL plume, that are outside of the current (or historical) extent of the LNAPL plume, and that have adjacent wells that are below the  $SV_{GW}$  for protection from VI but still have the potential for preferential pathways. Due to their distance from the LNAPL plume, the VI Sampling Work Plan determined that VI sampling at these buildings was not necessary if preferential pathways are not confirmed during sampling at buildings in Groups 3 or 4 closer to the source.

Properties consisting of vacant lots with no habitable structures onsite were not to be evaluated as part of the VI Sampling Work Plan given that VI risk will be mitigated by institutional controls. The only residential property for which the VI Sampling Work Plan applied is the Siena Place Homes community. These townhomes are constructed with vapor barriers consisting of a geotextile fabric coated with Liquid Boot® applied to the concrete foundation of the crawl space prior to construction of the townhome unit above. For a typical Siena Place townhome, the VI Sampling Work Plan called for a home assessment followed by indoor air sampling and ambient air sampling at each unit, if deemed to be necessary.

From January to March 2024 and April to June 2024, the VI investigation outlined in the VI Sampling Work Plan (SERES-Arcadis JV 2023) was implemented to collect, analyze, and evaluate vapor samples from buildings at the Site. The 2024 VI investigation built on the VI assessment conducted in 2018 and the 2020 VI Assessment Report, which recommended the VI sampling locations and sample types to be investigated (Arcadis 2020b; **Appendix Q**, Subsection 2). These locations included properties with occupied or habitable structures overlying the LNAPL plume, properties within proximity of the LNAPL plume (per the TGM [PADEP 2017]) or petroleum hydrocarbon constituents in groundwater above PADEP  $SV_{GW}$ , or those having potential preferential pathways that require investigation. PADEP feedback on the 2020 Assessment Report (Arcadis 2020b) led to revisions to the sequence and strategy of the sampling locations and types of samples collected as part of this VI investigation. Properties were separated into groups as described above, with the following sampling types assigned to each group for Phase I of the investigation:

- Group 1 – Indoor air and SSSS vent riser vapor;
- Group 2 – Indoor air, SSSG, preferential pathway (PP), near source (NS), and SCV;
- Group 3 – PP, NS, and SCV;
- Group 4 – PP, NS, and SCV; and
- Group 5 – No samples proposed for Phase I.

The specific basis and protocols for each sampling type and the results of the investigation are comprehensively detailed in the Phase I Vapor Intrusion Investigation Report (VERINA-PARS JV 2025b; **Appendix Q**, Subsection Four). During sampling activities, benzene, ethylbenzene, naphthalene, and 1,2-dibromoethane were the most detected compounds across all building groups and sample types. In general, all of the exceedances observed were only slightly above the respective screening values (i.e., 1/10<sup>th</sup> of the SHS VI screening value), and only a select few exceeded their respective screening values by a factor of 10. The initial round of indoor air samples were collected during the heating season. However, a second sampling event, conducted outside of the heating

season, generally yielded higher concentrations than the initial event. In several instances, results were flagged as exceedances that were non-detect at a detection limit higher than the screening value. This was most common with indoor air and ambient air samples.

The results of the VI investigation are summarized below for each group of buildings, Siena Place sewer lateral sections, and the Pollock-Packer Avenue sewer.

#### 6.5.2.8.1 Group 1 Buildings (BJ's, Home Depot, PHA, and Buildings P, O, N, and J)

Group 1 building samples consisted of indoor air, ambient air, and samples collected from the vent risers of the passive SSDSs installed within these buildings. The SSDS samples were collected as qualitative data to determine if vapors were collecting in the SSDS vent pipes for comparison to the indoor air sample results as a method of gauging effectiveness of the passive SSDSs and vapor barrier systems. These SSDS samples were not compared to a specific screening value. The analytical results are shown on Figures 2 through 5 in the Phase I VI Investigation Report (VERINA-PARS JV 2025; **Appendix Q**, Subsection Four). Several short-list chemicals exceeded their respective  $1/10^{\text{th}}$  of the  $SV_{IA}$  in each of the Group 1 buildings. Benzene, ethylbenzene, naphthalene, and 1,2-dibromoethane most often exceeded  $1/10^{\text{th}}$  of the  $SV_{IA}$ . These same four chemicals were also detected in the SSDS samples, but at higher concentrations than in the indoor air samples, suggesting the existing passive systems are effective. Total xylenes were detected and exceeded  $1/10^{\text{th}}$  of the  $SV_{IA}$  in the Home Depot samples. Naphthalene and 1,2-dibromoethane were the most often detected in the ambient air samples.

#### 6.5.2.8.2 Group 2 Buildings (VES Building; Buildings 6, 8, 9, 11, 12, 13, 14, and 30; Former Steen Property; and PHA Gym)

Group 2 building samples consisted of indoor air samples, SSSG samples, PP samples collected from pipe bedding of conduits, NS samples, and SCV samples based on building access and construction. The analytical results are shown on Figures 6 through 46 of the Phase I VI Investigation Report (VERINA-PARS JV 2025; **Appendix Q**, Subsection Four). Benzene, ethylbenzene, naphthalene, and 1,2-dibromoethane were detected in indoor air and were the same compounds found to be in exceedance  $1/10^{\text{th}}$  of the  $SV_{IA}$  most often. These same compounds were also the most often detected in all sample types. Where sampled, SSSG results contained the same chemicals often at greater concentrations as the corresponding indoor air samples. However,  $1/10^{\text{th}}$  of the statewide health standard vapor intrusion sub-slab soil gas screening values ( $SV_{SS}$ ) for non-residential site use were rarely exceeded.

Building 6 (**Appendix Q**, Subsection Four, Figure 12A), Building 11 (**Appendix Q**, Subsection Four, Figure 24), and Building 30 (**Appendix Q**, Subsection Four, Figure 39) each had one exceedance of  $1/10^{\text{th}}$  of the  $SV_{SS}$  for naphthalene in the SSSG samples. Buildings 12 (**Appendix Q**, Subsection Four, Figure 28) and 14 (**Appendix Q**, Subsection Four, Figure 35) exhibited exceedances of  $1/10^{\text{th}}$  of the  $SV_{SS}$  for naphthalene as well as benzene, ethylbenzene, 1,2-dichloroethane, and 1,2-dibromoethane. Where shown on the figures, some of these results were non-detect values with elevated laboratory detection limits. The other Group 2 buildings were either not sampled for SSSG or did not have exceedances of  $1/10^{\text{th}}$  of the  $SV_{SS}$ .

Results for PP samples from conduit bedding material (if present) were compared to  $1/10^{\text{th}}$  of the  $SV_{SS}$  because PP samples do not have a dedicated screening value. Exceedances of 1,2-dibromoethane at Building 9 (**Appendix Q**, Subsection Four, Figures 20A and 20B) and of naphthalene, 1,2-dichloroethane, and 1,2-dibromoethane at Building 14 (**Appendix Q**, Subsection Four, Figure 36) are non-detect values with elevated laboratory detection limits.

NS sample exceedances of 1/10<sup>th</sup> of the statewide health vapor intrusion near source screening values (SV<sub>NS</sub>) for non-residential were observed at Building 6 (naphthalene, 1,2-dichloroethane, and 1,2-dibromoethane; **Appendix Q**, Subsection Four, Figure 14) and at Building 9, Building 30, and the Steen property (benzene, naphthalene, 1,2-dichloroethane, and 1,2-dibromoethane; **Appendix Q**, Subsection Four, Figures 21A/B, Figure 41, and Figure 44, respectively). These locations lie over the core of the historical LNAPL plume extent or are on the western edge of the Site closest to the former refinery (in the case of the Steen property).

Results of SCV samples from laterals close to these buildings, where identified, were compared to 1/10<sup>th</sup> of the SV<sub>SS</sub> as SCV samples do not have a dedicated screening value. None of the results exceeded 1/10<sup>th</sup> of the SV<sub>SS</sub>.

#### 6.5.2.8.3 Group 3 Buildings (Aldi's, Jim's Ice, Hotel, P. Agnes Buildings, Building 15, Acme, and SEPTA)

Only PP samples from conduit bedding and SCV samples were collected around the Group 3 buildings. As shown on Figures 47 through 58 of the Phase I VI Investigation Report (VERINA-PARS JV 2025; **Appendix Q**, Subsection Four), no samples contained exceedances of the respective screening values.

#### 6.5.2.8.4 Group 4 Buildings (E/Staples, I1, I2, H1, H2, H3, H4, H5, F2, and F3)

PP samples from conduit bedding, SCV samples, and NS samples were collected from the vicinity of the Group 4 buildings. As shown on Figures 58 through 62 of the Phase I VI Investigation Report (VERINA-PARS JV 2025; **Appendix Q**, Subsection Four), benzene concentrations exceeded 1/10<sup>th</sup> of the SV<sub>SS</sub> at two locations near Building E and Building H (Figure 60); however, these results were not consistent across the two sampling events.

#### 6.5.2.8.5 Group 5 Buildings (R, B, C, D, and A)

No samples were proposed to be collected for Phase I of the VI investigation at any Group 5 buildings in accordance with the VI Sampling Work Plan (SERES-Arcadis JV 2023; **Appendix Q**, Subsection Three). The evaluation of the analytical results of the Phase I VI investigation as part of the HHRA (discussed in **Section 8.1**) was used to determine the need to return to these locations to conduct the proposed Phase II sampling at these buildings farther from the historical extent of LNAPL. The evaluation of the results of Phase I of the investigation determined that Phase II sampling including the Group 5 buildings was not necessary.

#### 6.5.2.8.6 Sewer Lateral Sampling – Siena Place Homes

The existence of potential preferential pathways to residential buildings (Siena Place) was evaluated through the collection of SCV and PP samples from the two sewer laterals that connect the Siena Place sewer system to the Pollock-Packer Avenue sewer. The analytical results for these samples were compared to 1/10<sup>th</sup> of the Residential SHS based on the proximity of the sampling locations to the residences. The analytical results are shown on Figures 63 and 64 of the Phase I VI Investigation Report (VERINA-PARS JV 2025; **Appendix Q**, Subsection Four). None of the SCV samples collected contained exceedances of 1/10<sup>th</sup> of the residential SV<sub>SS</sub> values to which they were compared (**Appendix Q**, Subsection Four, Figure 63). Results for PP samples collected adjacent to the sewer laterals indicated that concentrations of 1,2-dibromoethane exceeded 1/10<sup>th</sup> of the residential SV<sub>SS</sub> at three locations, and naphthalene exceeded 1/10<sup>th</sup> of the residential SV<sub>SS</sub> at one location (**Appendix Q**, Subsection Four, Figure 64). Each of these exceedances were from samples collected along the sewer laterals on the northern side of the townhome clusters.

#### 6.5.2.8.7 Subsurface Utility Corridor – Pollock-Packer Avenue Sewer

SCV samples were collected from inside manholes of the combined Pollock-Packer Avenue sewer at the 11 locations shown on Figures 65A, B, and C in the Phase I VI Investigation Report (VERINA-PARS JV 2025; **Appendix Q**, Subsection Four). The analytical results were compared to 1/10<sup>th</sup> of the Residential SHS screening values due to the proximity of the sewer to residences to the east of the Site. None of these SCV samples contained exceedances of 1/10<sup>th</sup> of the residential SV<sub>SS</sub>.

#### 6.5.2.9 Other Known Offsite Sources of Hydrocarbon Impact to the Shallow and Deep Aquifers

Documented subsurface petroleum hydrocarbon impacts from other sources are known to exist within offsite portions of both the shallow and deep aquifer zones, particularly to the west of the Site. The Final Data Gap Analysis Report (Arcadis 2013) presents maps that detail the historical and spatial distribution of COCs in groundwater and associated impacts extending westward toward the former refinery (**Appendix R**, Subsection One, Offsite Sources, Figures 18A through 18D). These figures show the generally contiguous nature of dissolved-phase petroleum hydrocarbon COCs impacts at both the Site and the adjacent former refinery, as well as the similarity of impacts documented at both locations prior to fence-line remedial efforts implemented at the former refinery. Moreover, when MTBE and benzene data were compared to potentiometric data in 2013, a pattern of groundwater flow and COC distribution indicative of COCs co-mingling along the western side of the Site was apparent (Arcadis 2013). This pattern further suggests a flux of COCs from the shallow aquifer beneath both the former refinery and the Site to the deep aquifer via the “breach” in the upper clay unit. As described in **Section 6.3.4**, there is documented evidence of communication between the unconfined aquifer and the lower aquifer within AOI 1 adjacent to the 26<sup>th</sup> Street sewer.

Shallow aquifer impacts to the west are also detailed in the AOI 1 RIR previously referenced (Stantec 2016). A May 2015 potentiometric surface map and a 2014 to 2015 summary of benzene analytical data, both from the AOI 1 RIR, are provided in **Appendix R**, Subsections Two and Three. The potentiometric surface figure, Figure 5-5 from the AOI 1 RIR, uses both AOI 1 data and DSCP data to generate potentiometric surface contours. Only minor differences are observed in the contours compared to those which Arcadis produced at the same time (see Figure 1 [Arcadis 2015] also included in **Appendix R**, Subsection Three). The potentiometric surface map, Figure 5-5 (**Appendix R**), shows that shallow groundwater beneath the Site and AOI 1 is a common aquifer system.

In addition to potentiometric surface data, the AOI 1 RIR also includes analytical data. Figure 10-2 from that report, Unconfined Aquifer Benzene Maximum Concentrations in 2014 and 2015, is included in **Appendix R**, Subsection Two. The figure also shows benzene concentrations in the shallow aquifer as high as 2,430 µg/L in ARCO-3, a well on the eastern boundary of the report’s data grid and just west of the Site. Both the AOI 1 RIR (Stantec 2016) and the Sitewide HHRA Addendum and CP (Sanborn-Head 2025) describe in greater detail the mechanisms by which benzene and MTBE as well as other fuel additives likely migrated onto the AOI 1 portion of the former refinery from the Belmont Terminal facility located just to the north of AOI 1 as shown on Figure 10-2 of the AOI 1 RIR. The Sitewide HHRA CP (Sanborn-Head 2025) discusses in greater detail the remedial efforts at the former refinery and Belmont Terminal that have reduced the offsite migration of COCs from the former refinery from what was shown in the 2014-2015 maximum concentration figure. These remedial efforts included installation of fence-line LNAPL pumping and air sparge curtains to prevent continued migration of former refinery and Belmont Terminal COCs into a break in the 26<sup>th</sup> Street sewer and potentially the deep aquifer where the upper clay unit is missing (as discussed in **Section 6.4.3**).

Deep aquifer impacts to the west of the Site are described in the AOI 11 Site Characterization/Remedial Investigation Report, Sunoco Philadelphia Refinery, Philadelphia, PA (AOI 11 RIR) (Langan Engineering and Environmental Services, Inc. 2011). The AOI 11 RIR includes figures (Figure 5 for VOCs and Figure 6 for metals) with potentiometric and analytical data (Figures 5 and 6 provided in **Appendix R**, Subsection Two). Figure 5 shows benzene impacts in the deep aquifer, including up to 110 µg/L in well S-38D2, which is on the eastern edge of the AOI extent and close to the western boundary of the Site.

Site groundwater impact data as reported in the AOI 1 RIR, the AOI 11 RIR, and the Sitewide HHRA CP indicate the following:

- Distinct LNAPL impacts to the shallow and deep aquifer zone groundwater beneath the former refinery;
- Distinct LNAPL and associated COC impacts to shallow and deep aquifer zone groundwater beneath the Site;
- Comingling of dissolved impacts along the western boundary of the Site, with indications of migration of fuel additives, MTBE and the associated degradation product TBA, from beneath the former refinery to the shallow and deep aquifer zones beneath the Site; and
- Reduced offsite migration since implementation of remedial efforts within AOI 1 and the Belmont Terminal.

## 6.6 Monitoring

### 6.6.1 Light Non-Aqueous Phase Liquid Monitoring

Historical LNAPL data through 2002 were used for site characterization as described in **Section 6.5.2**. Since 2006, additional LNAPL monitoring has been conducted, including depth and thickness (gauging) measurement, transmissivity estimation by interpretation of baildown and skimming test data, as well as analytical LNAPL simulated boiling point data trend analysis.

#### 6.6.1.1 Gauging and Light Non-Aqueous Phase Liquid Extent

Groundwater elevation, LNAPL elevation, and LNAPL thickness are gauged quarterly at each of the Site's 165 monitoring wells (161 onsite and four offsite on the SEPTA property). Measurements are made at each accessible well and recorded to the nearest 0.01 ft. Existing monitoring locations are shown on **Figure 14**. The results of the ongoing program are provided to PADEP in quarterly memos and reports. Wells located to the north, east, south, and west of the central portion of the site have consistently shown no measurable LNAPL, regardless of season or static water level.

**Figure 15** shows the area of LNAPL extent in the fourth quarter of 2024. The figure shows the apparent LNAPL extent; the boundary showing LNAPL presence is inferred from gauging data and does not necessarily indicate consistent in-situ LNAPL saturation, volume, mobility, or recoverability, but is intended to show the general area of measurable LNAPL on the Site. The extent outline from the fourth quarter of 2024 covers significantly less area than the historical LNAPL extent, as shown on **Figure 12**. The LNAPL extent is not increasing over time, instead, the LNAPL extent is decreasing over time and is becoming more stable.

#### 6.6.1.2 Light Fingerprinting

Fuel fingerprinting attempts to identify particular types of petroleum, characterize the effects of weathering on the chemical composition, and provide diagnostic information to determine the source and assess age. LNAPL has

been monitored for compositional changes over time via analytical fingerprinting. In addition to the available historical data through 2006, samples were collected in 2012, 2015, and 2017 and sent to a laboratory for simulated boiling point analysis (Method ASTM International [ASTM] D2887).

#### 6.6.1.2.1 Procedures and Methods

The more recent samples (collected in 2012, 2015, and 2017) were collected by Arcadis and USACE by the following process:

1. Open vault/well.
2. Monitor breathing zone using a PID.
3. Monitor well headspace using a PID. Record on field log.
4. Gauge depths to LNAPL and water and record to hundredths of a foot. Do not measure depth to bottom (to avoid removing LNAPL and/or displacing liquid with the probe).
5. Note sample time in field book. Label sample bottle(s) with format WELL-NAME(MMDDYYYY). Example: PH-RW-A (01312017).
6. Lower bailer to just below the LNAPL-water interface and wait. Slowly raise bailer out of well. Sample LNAPL out of bailer over bucket and absorbent pads.
7. Remove and decontaminate the interface probe.
8. Close and secure well/vault and clean area.
9. Secure sample bottles and observe proper shipping procedure in accordance with Title 49 Code of Federal Regulations (CFR) 172.704(a).

Samples were shipped to an analytical laboratory and analyzed using simulated boiling point analysis. Results are provided below.

#### 6.6.1.2.2 Fingerprinting and Simulated Boiling Point Analysis Results

Sampling dates and locations of samples collected in 2012 (four samples), 2015 (12 samples), and 2017 (six samples) are summarized in **Appendix L**. Sampling locations varied based on the amount of LNAPL present in the well at the time of sampling. The data provided in **Appendix L** are displayed in two ways:

- Figures L-1 to L-4 showing well locations on maps, one map per year, similar to the initial data map described in **Section 6.5.2.1**, with color-coding of sampling results; and
- Charts LC-1 to LC-5, showing data for each well over time, when a well was sampled in more than one event.

The locations of the most recent samples, collected in 2017, were selected because sufficient recoverable LNAPL was present at the time of sampling, and because samples were previously collected at these locations allowing for a temporal comparison to be made. The 2017 and historical simulated boiling point results for samples collected at DSCP-MW-33, DSCP-MW-65, DSCP-RW-2, DSCP-RW-9, and PH-RW-A are provided in **Appendix L**. A sample was also collected at PH-RW-A2, a newer well installed in July 2014, for the first time.

As shown on Figures L-2 to L-4 (**Appendix L**), with well locations marked in blue, the majority of samples collected during all three events showed high percentages of heavier compounds. Over the entire sampling period

of 2012 to 2017, three occurrences of samples with high percentages of lighter compounds were observed, in PH-RW-A (2012), DSCP-MW-3A (2015), and DSCP-MW-33 (2017).

The charts (Charts LC-1 to LC-5) for DSCP-MW-65, DSCP-RW-2, and DSCP-RW-9 either indicate data that are consistent over time (a similar distribution) or indicate heavier compounds (diesel range) in 2017 than in previous years. DSCP-RW-9's plot, showing a progression towards heavier compounds over time, may indicate weathering mineralization or other selective removal/destruction of lighter molecular weight, hydrocarbon-related compounds.

The data graphs for DSCP-MW-33 and PH-RW-A show distributions with more lighter compounds in 2017 than in 2015. However, water table elevations and, therefore, LNAPL elevations measured during sampling were lower in 2017 than in 2015. With a drop in groundwater elevations, LNAPL that is present in deeper intervals may become accessible and drain to the wells. This deeper LNAPL may be a different composition, as it is not as affected by the VES system and may not be as weathered (degraded) as the shallow LNAPL that is exposed to air movement from the VES system.

Overall, the fingerprinting and simulated boiling point analysis data through 2017 show the majority of wells with higher percentages of heavier compounds and localized areas with wells with higher percentages of lighter compounds. The trend of some wells towards heavier compounds over time may indicate that LNAPL near these wells is becoming more stable. However, the presence of wells with lighter compounds indicates that LNAPL composition still varies across the Site and possibly at different depths. Additional discussion of LNAPL stability is provided in **Section 6.6.1.4**.

### 6.6.1.3 Light Non-Aqueous Phase Liquid Transmissivity Testing

LNAPL transmissivity describes the capacity of an aquifer to convey LNAPL to a well, similar to the concept of groundwater or aquifer transmissivity (ITRC 2018). LNAPL transmissivity can be calculated from field measurements during baildown and/or manual skimming tests, in which LNAPL is pumped from a well, and water and LNAPL depths are recorded as LNAPL from the well filter pack and surrounding formation flows into the well. Calculated transmissivity is then compared to a regulatory or site-specific threshold or compared to previous calculated transmissivities to establish a trend over time. Transmissivity at or above 0.8 ft<sup>2</sup>/day is considered indicative of recoverable LNAPL, transmissivity in the range of 0.1 to 0.8 ft<sup>2</sup>/day is indicative of LNAPL that is marginally recoverable depending on the situation, and transmissivity below 0.1 ft<sup>2</sup>/day is indicative of LNAPL that is generally not recoverable (ITRC 2018). Transmissivity values calculated to be below an established threshold, or transmissivity results showing a declining trend over time, are indicative of a stable LNAPL body.

Recoverability of LNAPL based on transmissivity is one metric of LNAPL stability; LNAPL chemical makeup and weathering, as well as trends in partitioned dissolved-phase (groundwater) COC concentrations, are also discussed in the LNAPL stability evaluation in **Section 6.6.1.4**.

#### 6.6.1.3.1 Procedures and Methods

Baildown and manual skimming tests were conducted onsite in 2014 and 2017. Measurements were used to calculate LNAPL transmissivity in support of an LNAPL stability evaluation. Baildown and manual skimming test details are provided in **Appendix S**. Baildown tests were used for wells with greater thicknesses of LNAPL (i.e., >0.5 ft in a 6-inch-diameter well), and manual skimming tests were used for wells with smaller thicknesses (<0.5 ft). The selection process for the baildown testing, as well as the process used to evaluate LNAPL transmissivity, is outlined in the API LNAPL Transmissivity Workbook (API 2016). The workbook uses well construction and LNAPL density details and analyzes baildown test data using three methods: Generalized Bouwer and Rice,

Cooper and Jacob/Jacob and Lohman, and Cooper, Bredehoeft, and Papadopoulos. The API user guide (API 2016), which includes explanations of the three methods, and the location-specific spreadsheets are provided in **Appendix T**. The general approach used for baildown tests is as follows:

- Measure initial depths to LNAPL and water, and calculate volume of LNAPL in well.
- Remove as much LNAPL and as little water as possible from the well, recording volume removed.
- Gauge LNAPL and water levels over time to quantify the recovery rate of LNAPL in the well.

For manual skimming tests, the approach is as follows:

- Measure initial depths to LNAPL water, and calculate volume of LNAPL in well.
- Select a “trigger” LNAPL thickness of 10% to 25% of the original LNAPL thickness.
- Remove as much LNAPL and as little water as possible from the well, recording volume removed.
- Gauge LNAPL and water levels until the LNAPL thickness reaches the “trigger” thickness.
- Remove LNAPL again and repeat test.
- Conduct enough sequential tests to establish a consistent rate, or time required to reach the “trigger” thickness.

Baildown tests were conducted during the first and third quarters of 2017. Baildown and manual skimming tests were conducted in the fourth quarter of 2017.

Results were plotted on graphs of depth to LNAPL and depth to water over time. The rate of LNAPL recovery was estimated in Microsoft® Excel using the slope and automatically generated best fit line, fit to the portion of data after the initial steeply sloped portion of the graph, and corresponding to the portion of recovery controlled by the formation’s LNAPL gradient. The analytical methods used for the analysis and preparation of the spreadsheet are found in the API LNAPL Transmissivity Workbook (API 2016). The spreadsheet uses baildown test data, well construction details, and LNAPL characteristics to estimate transmissivity (in ft<sup>2</sup>/day) using the Generalized Bouwer and Rice Method, the Cooper and Jacob/Jacob and Lohman Method, and the Cooper, Bredehoeft, and Papadopoulos Method (API 2016). Transmissivity at or above 0.8 ft<sup>2</sup>/day is considered recoverable, transmissivity in the range of 0.1 to 0.8 ft<sup>2</sup>/day is marginally recoverable depending on the situation, and transmissivity below 0.1 ft<sup>2</sup>/day is generally not recoverable (ITRC 2018). Spreadsheet calculations and the API user guide are provided in **Appendix T**. Results are summarized below.

#### 6.6.1.3.2 Baildown Testing Results

Baildown tests were conducted as part of system optimization activities in 2014 as well as specifically for determining LNAPL transmissivity in 2017. As part of optimization activities during the fourth quarter of 2014, Arcadis conducted baildown testing of the LNAPL present in DSCP-MW-65. Baildown testing was conducted on November 3 and November 4, 2014, to determine the transmissivity of the LNAPL in this well, and ultimately to determine if LNAPL skimming in MW-65 would yield additional mass recovery. A total of 0.60 gallons were recovered during November 3, 2014 (Test 1) testing, and a total of 1.0 gallon was recovered during November 4, 2014 (Test 2) testing. An average water rebound rate ranging from 0.02 ft/hour (Test 2) to 0.13 ft/hour (Test 1) was observed. An LNAPL rebound rate of 0.03 ft/hour was observed for both tests. The mobility taken from the API model was used to calculate the transmissivity averaged across the screened interval for the well. It should be noted that the inputs for the API model were based on the assumed average lithology across the screened interval at the well. The length-averaged hydraulic conductivities from the three applicable groundwater models

for the Site (Kinkaid, Sloto, and MODFLOW-Pruca models) were used as the inputs in this calculation. However, the hydraulic conductivity inputs obtained from the models vary by as much as to 192 ft/day in any given well. Because of the large variability in the hydraulic conductivity used in the three groundwater models applicable to the Site, a sensitivity analysis was performed, and the API LNAPL model was run for DSCP-MW-65 using the lowest, assumed midpoint and the highest of the screen-averaged hydraulic conductivities from the models for each condition tested. At each of these selected hydraulic conductivities, the API model was run to determine the mobility, transmissivity, and velocity of the LNAPL. Results of the baildown tests are presented in **Appendix T**.

Based on the transmissivity calculations from the baildown tests conducted in 2014, LNAPL at the baseline condition was determined to be recoverable by pneumatic skimming methods. It further appears that immediately after the recovery of the LNAPL in MW-65 for Test 2, the transmissivity of the LNAPL was lowered to the point where it was marginally recoverable (i.e., just above the range that would be considered non-recoverable). The results of the baildown testing suggested that the installation of a pneumatic recovery pump in MW-65 would result in the recovery of additional LNAPL from the subsurface, but that the recovery of LNAPL from MW-65 would trail off quickly.

LNAPL transmissivity was re-evaluated in 2017 utilizing baildown tests and manual skimming tests. Testing was conducted in accordance with the above procedures during the first, third, and fourth quarters of 2017 and at the following locations:

- DSCP-MW-3A;
- DSCP-MW-33;
- DSCP-MW-65;
- DSCP-RW-2;
- DSCP-RW-9;
- PH-PH-18;
- PH-RW-6;
- PH-RW-A;
- PH-RW-C; and
- PH-RW-G.

Test logs are provided in **Appendix T**. Baildown tests were conducted at wells with >0.5 ft of measurable LNAPL at the time of the test. For wells with smaller thicknesses, manual skimming tests were conducted. Data were analyzed using the API LNAPL Transmissivity Workbook (API 2016) to estimate transmissivity and provide one line of evidence for the lateral mobility or lack of mobility of LNAPL in the subsurface. The workbook uses well construction and LNAPL density details and analyzes baildown test data using three methods: Generalized Bouwer and Rice, Cooper and Jacob/Jacob and Lohman, and Cooper, Bredehoeft, and Papadopulos. The API user guide (API 2016), which includes explanations of the three methods, and the location-specific spreadsheets are provided in **Appendix T**.

Results are summarized below in **Table 6**, with a more detailed summary, along with spreadsheet inputs and outputs, provided in **Appendix T**. The arithmetic means of the results from the three methods are provided below.

Table 6 LNAPL Transmissivity Results – 2017 Evaluation

Well ID	Average Calculated Transmissivity (ft <sup>2</sup> /day)	
	Quarter 1 2017	Quarter 3/Quarter 4 2017
DSCP-MW-33	N/A*	N/A*
DSCP-MW-65	0.30	N/A
DSCP-RW-2	0.96	N/A
DSCP-RW-9	3.63	2.78**
PH-RW-A	N/A*	N/A
DSCP-MW-3A	N/A	0.16
DSCP-RW-6	N/A	0.25
PH-PH-18	N/A	0.03
PH-RW-C	N/A	0.48
PH-RW-G	N/A	0.09

**Notes:**

NA = Not applicable. Baildown test not conducted (unless otherwise noted).

N/A\* = Baildown test data were not usable in model due to low LNAPL recharge and negative drawdown.

\*\*High variability observed among the three methods.

As described in the procedures above, baildown tests were not conducted at the same wells during both events due to lack of LNAPL thickness present in each well at the time of testing. Of the original first quarter of 2017 baildown testing well list, only DSCP-RW-9 contained >0.5 ft of LNAPL during the third and fourth quarter 2017 event. Wells in the original list were substituted for the additional third and fourth quarter of 2017 event. The results from both the first quarter of 2017 and third and fourth quarter 2017 tests generally showed low transmissivity (i.e., <0.8 ft<sup>2</sup>/day), except for DSCP-RW-2 in first quarter of 2017 and DSCP-RW-9 during both events. Like the fingerprinting and simulated boiling point analysis data, the results of the 2017 baildown testing indicated LNAPL variability across the Site, and more stable LNAPL at least in some areas.

LNAPL transmissivity testing was conducted again in September 2024. LNAPL manual skimming tests and baildown tests were performed at wells DSCP-RW-9 and DSCP-MW-3A utilizing the ASTM standards discussed above. Only these two wells had enough free LNAPL thickness present to allow testing during this event. The results of the 2024 LNAPL transmissivity evaluation are summarized in **Table 7**.

A baildown transmissivity test was completed at DSCP-MW-3A because in-well LNAPL thickness was >0.5 ft. The LNAPL recharge rate was calculated based on test data, which showed approximately 0.25 gallons of LNAPL recharge over 24 hours of the testing. As shown in the analysis provided in **Appendix T**, the transmissivity was estimated at 0.61 ft<sup>2</sup>/day in this well. This transmissivity result does not exceed the ITRC 0.1 to 0.8 ft<sup>2</sup>/day lower criterion range to produce sufficient LNAPL and indicates that removal activities are no longer practical at this location.

The manual skimming test method was selected over the traditional LNAPL baildown test method for DSCP-RW-9, which had an in-well LNAPL thickness of 0.2 ft. Per the ASTM standard, baildown test methodology is not

recommended for wells with an LNAPL thickness <0.5 ft, whereas manual skimming test methods are not limited by LNAPL thickness. The transmissivity result for DSCP-RW-9 was 0.84 ft<sup>2</sup>/day, which just exceeds the ITRC 0.1 to 0.8 ft<sup>2</sup>/day lower criterion range to produce sufficient LNAPL, indicating that LNAPL removal at RW-9 is still feasible.

Table 7 LNAPL Transmissivity Results – 2024 Evaluation

Well ID	Average Calculated Transmissivity (ft <sup>2</sup> /day)
	Quarter 3 2024
DSCP-MW-3A	0.61
DSCP-RW-9	0.84

In summary, the results of the LNAPL transmissivity testing through 2024 show that the presence of LNAPL is at thicknesses great enough to allow testing, and the transmissivity in LNAPL-bearing wells has decreased over time due to both remedial progress and natural processes. As of the third quarter of 2024, only wells DSCP-MW-3A and DSCP-RW-9 contained LNAPL at a thickness great enough to allow testing. Additionally, only well DSCP-RW-9 exhibited transmissivity above the 0.1 to 0.8 ft<sup>2</sup>/day lower criterion (0.84 ft<sup>2</sup>/day > 0.8 ft<sup>2</sup>/day) range to produce sufficient LNAPL recoverability (ITRC 2018), although significantly reduced from the 2017 results. Additional discussion of LNAPL stability is provided in **Section 6.6.1.4**.

#### 6.6.1.4 LNAPL Stability Evaluation

Future attainment demonstration activities focused on the removal of recoverable site LNAPL and the in-situ stabilization of residual LNAPL mass will be enabled by the following remediation performance-based and site groundwater monitoring-based data evaluation criteria and corresponding methods (see **Section 6.6.1.2**):

1. **LNAPL composition changes through time by simulated boiling point analysis:** The purpose of this activity is to document the in-situ biodegradation of site LNAPL to a weathered and chemically immobile state (i.e., in-situ removal of the volatile, mobile, and lighter molecular weight short-list constituents [PADEP 2008] through weathering) through the collection and analysis of LNAPL samples.
2. **LNAPL recoverability changes through time by LNAPL baildown testing:** The purpose of this activity is to document the continued reduction in transmissivity that accompanies the in-situ degradation of LNAPL.
3. **Statistical trend-based analysis of dissolved-phase COC concentrations through time:** The purpose of this activity is to document the continued reduction in the concentrations of site short-list COCs (PADEP 2008) in shallow and deep zone groundwater in response to ongoing remediation.

### 6.6.2 Groundwater Monitoring

The site well network (**Figure 14**) consists of 165 monitoring points, including 147 shallow or intermediate monitoring wells, 16 deep monitoring wells, and two prepack monitoring points (prepack points are not sampled). As required by the AO, groundwater gauging of accessible monitoring wells was conducted quarterly, and groundwater sampling of statistically determined subsets of wells was also conducted quarterly. Results were provided to PADEP in Progress Reports.

## 6.6.2.1 Procedures and Methods

Gauging and sampling methods are outlined in Standard Operating Procedures distributed to field personnel (**Appendix S**). A summary of gauging and sampling methods, along with the analytical methods employed by an outside laboratory, is provided below.

### 6.6.2.1.1 Gauging Methods

Gauging for groundwater and LNAPL at accessible monitoring wells took place at the start of each quarterly monitoring event, prior to groundwater sampling. Prior to each gauging event, the VES system was shut down to allow groundwater levels to equilibrate prior to measurement. VOCs in well headspaces were measured using PIDs. Water and LNAPL depths were measured using Solinst Model 101 water-oil interface probes (or similar model) and recorded electronically in the field. Total well depths were recorded annually. When practical, wells known to have fewer COC impacts were gauged before wells known to have higher impacts. Decontamination procedures were followed after gauging each well and included washing the interface probe tip and wetted portion of tape with liquid or powder soap (Alconox™, Liquinox®, or similar) and rinsing with clean water.

### 6.6.2.1.2 Sampling Methods

Groundwater samples were collected each quarter from accessible monitoring wells. From the fourth quarter of 2011 through the second quarter of 2014, accessible monitoring wells were sampled quarterly. Beginning with the third quarter of 2014, a statistically determined subset of wells was sampled each quarter, with all wells sampled at least once biannually. A statistical analysis in support of this sampling reduction was presented in Quarterly Progress Reports and is described below.

Wells were sampled using a low-flow technique. Bladder pumps were used to purge water from the wells while water quality meters monitored groundwater parameters during the purging. **Appendix S** details the specific methods of sampling for these processes.

Since 2017, the site well network has been sampled on a biennial or annual basis.

### 6.6.2.1.3 Analytical Methods

Groundwater samples were analyzed using USEPA Method 8260B for VOCs, USEPA Method 8011 for semi-volatile organic compounds, and USEPA Method 6020A for dissolved lead and arsenic. Groundwater samples were analyzed for the PADEP Short List of Petroleum Products for Leaded Gasoline, Aviation Gasoline and Jet Fuel (PADEP Storage Tank Program Guidance, Table IV-9; PADEP 2008). Comparison of COC concentrations in groundwater to specific PADEP standards (further addressed in **Section 6.6.2.3**) was performed for relative comparison only and not to establish quantitative cleanup goals.

Due to the historical detection of arsenic in site soils, groundwater samples were also analyzed for dissolved arsenic. Samples designated for dissolved lead and arsenic analysis were field-filtered. Groundwater samples were also analyzed for MTBE and TBA (a known daughter product of anaerobic degradation of MTBE) to evaluate potential MTBE distribution and degradation and groundwater flow paths in the hydraulically linked aquifer systems.

#### 6.6.2.1.4 Quality Assurance and Quality Control Samples

A project quality assurance plan dictated the following quality assurance and quality control sample frequencies for each sampling site-wide sampling event:

- One duplicate per 20 samples;
- One matrix spike/matrix spike duplicate per 20 samples;
- One field blank per event;
- One equipment blank per 20 samples; and
- One trip blank per cooler during shipment of VOC samples (analyzed for VOCs only).

Documentation of these analyses for each sampling event is provided in the Quarterly Progress Reports.

#### 6.6.2.1.5 Sampling Frequency Reduction Statistical Analysis

After several quarters of sampling accessible wells at the Site, it became clear that the data collected from some of the sampling locations did not appreciably contribute to the ongoing CSM development. This observation led to the idea of optimizing the sampling program via statistical trend analyses of the historical data inclusive of the most recent sampling event to provide an appropriate list of wells to include in the subsequent sampling event. This process was repeated each quarter. The Mann-Kendall Trend Test and the Sen's Slope Estimator trend analysis methods were used to evaluate long-term changes to benzene groundwater concentrations. The statistical analysis utilized eight criteria (described below) to determine the appropriate frequency to sample each well in the network (i.e., quarterly and annually). These analyses effectively optimized the monitoring network while precluding the need to physically add/remove any wells, while at the same time maintaining the value of the data provided by the sampling events. This idea was first presented in the second quarter of 2014 quarterly report and first implemented during the first quarter of 2015 sampling event (February 2015). The methodology is presented in detail in **Appendix U**.

As the analysis of the data proceeds, decisions about changes to the sampling plan will be based on the following guiding principles, which were also presented in each quarterly report since second quarter of 2014:

- **Trends:** Wells with stable downward trends of contaminants will be sampled less often; wells with stable upward trends that are above groundwater standards or unstable trends will generally continue to be sampled regularly. The Mann-Kendall trend detection test will be used to quantify the type of trend (USEPA 2006).
- **Toxicity:** Wells with highly toxic concentrations of contaminants will continue to be sampled often; wells with less toxic concentrations may be sampled at less frequent intervals. The toxicity is estimated by comparing concentrations to PADEP MSCs for Non-Residential Used Aquifers with total dissolved solids <2,500 mg/L. Note that comparisons to MSCs are not meant to be used as cleanup goals, but rather as comparison points for approximating the toxicity of reported concentrations.
- **Sentinel wells:** Wells on the boundary of the site area will continue to be sampled frequently to provide early warning of unexpected movement of contaminants out of the area of interest, or the arrival of contaminants from offsite, which may affect background level designations.
- **Proximity:** Well data will be compared to that from nearby wells to ensure that data quality does not suffer from the reduction in sampling frequency. Nearby wells that provide no unique data may be sampled with less frequency.

- **Fingerprinting:** Relative concentrations of COCs will be compared at nearby wells to determine which provide only duplicated data. Nearby wells with similar fingerprints will be assumed to provide no unique data and may be sampled with less frequency. A variation on the method (USEPA 2004) will be used to compare the data.
- **Clusters:** Wells in multi-level clusters will be sampled frequently and together to provide vertical definition of variations in contaminant concentrations.
- **Depth:** Wells tapping the deep aquifer will continue to be sampled frequently because of the scarcity of data for the deep aquifer.
- **Long-term data:** Because long-term trends can be important in analyses, no wells will be completely removed from the data set as a result of this analysis. Sampling of all wells, at least biennially, will be recommended.
- **Appendix U:** This appendix includes a table of the wells with information about the recommendation for future sampling frequency at each well. The recommendations were made based on data collected through the fourth quarter of 2019.

#### 6.6.2.1.6 Damaged CSX Well Statistical Analysis

In second quarter of 2018, three wells on the CSX property, CSXMW-2, CSXMW-3A, and CSXMW-8, were found to have been incidentally damaged (PARS 2018). The purpose of these wells was to provide sentinel monitoring for potential offsite impacts coming from the west; however, their purpose mainly served to ensure that high concentrations were captured by the monitoring network. Because of this, these wells will be statistically analyzed, and their abandonment will be considered in the future.

#### 6.6.2.2 Gauging Results – Fourth Quarter of 2024

Data from quarterly groundwater gauging events required by the AO are used to identify typical groundwater elevations in the shallow and deep aquifers. The gauging data from the fourth quarter of 2024 are provided in **Table 8**. The potentiometric surface map of the shallow/intermediate water table aquifer during the fourth quarter of 2024 is presented on **Figure 4**. The following observations are noted:

- A groundwater gradient from the north to the south is observed, starting near DSCP-MW-20 at an elevation of 4.27 ft amsl to 1.81 ft amsl at DSCP-MW-15.
- A separate groundwater gradient in the eastern part of the Site, from east to west, is observed. The high point is located at EPH-MWS-10 at 3.79 ft amsl, and elevations decrease to the west towards STEEN-MW-64 (-0.01 ft amsl).
- Localized mounded groundwater areas are observed in the central portions of the Site, where measured groundwater elevations range from approximately 0.79 ft amsl in PH-MW-66 to 7.74 ft amsl in PH-MW-41.

These observations are typical for the shallow aquifer zone over the time period monitored by the contractors since 2012.

**Figure 5** presents the potentiometric surface map of the deep aquifer zone during the fourth quarter of 2024. Observations include the following:

- A deep aquifer groundwater gradient from the north to the south is observed, from 1.84 ft amsl at DSCP-MW-20D to 0.55 ft amsl at PH-DW-3, and continuing down to the deep wells installed in 2017 at -0.30 ft amsl in NOVA-DW-14 and -0.57 ft amsl in FDR-DW-15.
- When the groundwater elevations of nested shallow and deep aquifer pairs are considered, all of the accessible pairs exhibit downward vertical gradients (PARS 2019).

Site groundwater flow generally follows the regional groundwater gradient in a southerly direction. In the southern area of the Site, groundwater flows south from the PHA Building to the southern portion of Siena Place Homes. In the midsection of the Site, the “breach” is oriented approximately east-west in the shallow aquifer potentiometric surface. This consistently observed feature, observed during prior quarterly gauging events, is most pronounced near the BJ’s retail building and in an area extending southwest from the VES system building to the former PHA property. This hypothesis has been validated via site lithologic data, groundwater elevations, and vertical gradients, and is described in **Section 6.3**.

### 6.6.2.3 Sampling Results – Fourth Quarter of 2024

Groundwater analytical results are provided in **Table 3A** (Organics) and **Table 3B** (Inorganics) and are consistent with analytical results from recent quarters. Per the sampling procedures and frequency reduction statistics outlined previously and in **Appendix U**, 160 wells were sampled in the fourth quarter of 2024. Observations include the following:

- The highest concentrations of VOC COCs in the shallow/intermediate aquifer zones are generally observed in wells in the central and western portions of the Site. Results from 17 of the 144 sampled shallow/intermediate wells showed total VOC concentrations >10,000 µg/L, with a maximum of 38,649.6 µg/L at DSCP-MW-65.
- The maximum total VOC concentration in deep wells was 5,524.7 µg/L at PH-DW-3.
- A total of 25 of the 160 sampled wells had MTBE detections, including 11 shallow/intermediate wells and 14 deep wells. Sixteen of these did not have TBA detections.
- Arsenic was detected in 118 shallow and intermediate wells and exceeded the PADEP MSC in 56 of these. The maximum concentration was 132 µg/L in PH-RW-G.
- Lead was detected in 24 shallow and intermediate wells and exceeded the PADEP MSC in four of these. The maximum concentration was 67 µg/L in DSCP-RW-5/MW-25.
- Arsenic was detected in seven deep wells. None of these detections exceeded the PADEP MSC.
- Lead was not detected in any deep wells.

### 6.6.2.4 Sampling Results – Historical and Trend Analysis

Historical groundwater analytical data are provided in **Appendix V**. As described in **Section 6.6.2.1.5**, trends in concentrations over time were analyzed to support an LNAPL stability evaluation (**Section 6.6.1.4**). Trend analysis methods were used to investigate long-term changes to benzene groundwater concentrations. The Mann-Kendall Trend Test and the Sen’s Slope Estimator were used together to fully define the trend of the benzene concentrations. Methodologies for both statistical tests are provided by USEPA (2006). **Appendix U** provides a summary document that describes the application of the tests to the site historical data. At each well, the trend tests were applied to the whole data set, the portion of the data obtained before July 2012, and the data for the period between July 2012 and July 2017.

Historical groundwater data trend analysis results for 32 onsite wells are summarized as follows:

- The majority of wells exhibit stable or decreasing benzene concentrations over time.
  - PH-DW-11 and PH-IW-2 exhibit rising trends in pre-2012 data and falling trends in 2012 to 2017 data, corresponding to optimization of site remediation from 2011 to the present.
- Two wells, STEEN-IW-09 and PH-RW-U, are the exception, showing clearly increasing trends. These wells are located in the central western portion of the Site on the Steen and PHA properties. Other wells on these properties exhibit decreasing benzene concentrations.

Trends for all wells and summary maps are provided in **Appendix U**.

### 6.6.3 Sewer Monitoring and Inspection

As described in **Section 6.4**, sewers are present onsite that are relevant to the CSM and are potential exposure pathways. The Pollock-Packer Avenue sewer and the 26<sup>th</sup> Street sewer are connected to a sewer ventilation system and a biofilter, which are operated by a third party (Stantec 2016). The system was implemented following a PADEP request “to control or abate the accumulation of petroleum hydrocarbon vapors in the sewer and to monitor the sewer to assess the effectiveness of abatement” (PADEP 1997 per Stantec 2016). The system extracts VOCs from the effluent air stream via treatment through a humidifier and biofilter. Arcadis monitors the vacuum effect on the Pollock-Packer Avenue sewer monthly and reports observations to PADEP in the Quarterly Progress Reports. Sewer manholes are monitored with a PID, smoke tube (which is used to determine if air is moving into or out of the sewer manhole covers at the time of the monitoring event), and LEL meter (explosimeter) throughout each calendar year. Vapor detections at sewer monitoring points have diminished over the 2011 to 2024 timeframe, with PID readings regularly exceeding 30 to 40 parts per million (ppm) in the 2011-2012 timeframe and rarely exceeding 1 ppm in the 2023-2024 timeframe. LEL readings over the 2011-2024 timeframe have remained zero or near zero at all monitored locations. Additionally, a sewer entry and inspection by USACE in October 2016 revealed no hydrocarbon or explosive vapors nor leaking LNAPL to the sewer. The sewer walkthrough report (USACE 2016) is included in **Appendix J**.

The manholes monitored along the Pollock-Packer Avenue sewer have included MH-C and MH-G since monitoring began in 2011. At the request of USACE, PID and LEL readings were also collected at the following sanitary sewer manholes starting in February 2012: 19<sup>th</sup> Street and Moyamensing Avenue East, 19<sup>th</sup> Street and Moyamensing Avenue West, Pollock Street and Moyamensing Avenue, and 19<sup>th</sup> Street (near the cut through). Additional manholes MH-A and MH-B were added to the monitoring plan in the second quarter of 2017 following observations of LNAPL in nearby remediation well PH-RW-G. Manholes A-Roma and B-Roma were added to the monitoring plan in February 2018 in response to odor concerns in a residence on Roma Drive. MH-Steen (which is closer to the former refinery and sewer vapor extraction system) was added to the monitoring plan in April 2019 as part of the BV-BS pilot monitoring activities. Sewer manhole locations are shown on **Figure 2**.

As mentioned previously, smoke tubes were used to determine if air was moving into or out of the sewer manhole covers at the time of the monitoring event. For the Pollock Street and Moyamensing Avenue location, air flow indications are not available because of the absence of manhole openings. At all locations, a PID equipped with a 10.6-electron-volt lamp and an LEL/O<sub>2</sub> meter were used to monitor concentrations of VOCs and LELs. In addition to the AO-required monthly monitoring discussed above, an increased monitoring frequency of select manholes of the Pollock-Packer Avenue sewer was initiated in 2019, as part of the BV-BS pilot study. As noted in previously submitted quarterly reports, the data collected can only provide evidence for inferences regarding whether the

sewer VES is operating at the time of measurement. These data do not provide information on efficiency or time periods of operation. Data from all locations from April 2014 to September 2019 are provided in **Appendix J**.

The results of smoke tube testing are inconsistent: each month, a combination of “in,” “out,” and/or “neutral” flows are often observed at the different manholes, and month to month, a particular manhole varies in flow direction without a discernible pattern. PID readings are frequently 0.0 ppm, but a maximum of 51.5 ppm was measured in MH-C in December 2014. No readings above 100 ppm were observed during the monitoring period. Readings above 100 ppm, if observed, would be reported to PADEP, the former refinery, DLA, and the USACE Baltimore and Philadelphia District offices. LEL readings are also frequently 0%, with a maximum of 12% in MH-G in May 2014.

These observations are consistent with the findings of a sewer inspection conducted by USACE, Arcadis, and the Philadelphia Water Department during which no LNAPL was visually observed in the sewer, nor detected by the PID and LEL meter (USACE 2016, included in **Appendix J**).

More recently, monitoring of select manholes of the Pollock-Packer Avenue sewer during the 2019 BV-BS pilot study revealed that VOCs and hydrocarbon odor were detected on a few occasions at manholes located onsite and on the Steen property. However, in all of these cases, the VOC concentrations were highest at manholes closest to the former refinery (on the Steen property), did not appear to correlate with BV-BS operation, and were only detected when the air flow was observed coming out of the manholes. This flow of air out of the manholes most likely takes place during changes in atmospheric pressure or wind, which can affect the air flow in the sewer system. The results of this sewer monitoring are discussed in more detail in the BV-PS Pilot Test Report (PARS 2020) in **Appendix W**.

## 7 Contaminant Fate and Transport Analysis

A fate and transport analysis was performed as required in the Act 2 TGM (PADEP 2021) utilizing the PADEP-developed New Quick Domenico.xls spreadsheet application (Domenico 1987). The one-dimensional analysis is an application of the Domenico (1987) solution to the 3D reactive transport equation. The approach uses a source area concentration with desired distances, dispersivity coefficients, decay coefficients, and other parameters to calculate potential downgradient concentrations. Additional details can be found in the Act 2 TGM (PADEP 2021), which outlines the approach to modeling and PADEP's reporting expectations. The model has many purposes including:

- Modeling length of contaminant plumes;
- Estimation of plume areas for use in environmental covenants;
- Assessment of plume stability and potential for migration; and
- Evaluations of natural attenuation.

The Quick Domenico model simulates impacted shallow groundwater leaking into the deep aquifer zone through the "breach" described in **Section 6** and continues downgradient within the deep aquifer. The purpose of the analysis is to help define the limits of the Site's LNAPL-related dissolved-phase COC impacts to groundwater in the deep aquifer zone, and ultimately provide data and rationale to support creating a non-use aquifer zone to eliminate potential future site groundwater exposure pathway scenarios.

Site groundwater data were used to calibrate and perform a one-dimensional Quick Domenico analysis to model the extent of the site LNAPL constituent benzene in deep aquifer zone groundwater directly beneath and south of the Site. Model output was then calibrated using site data.

Details on the setup/basis, performance, and results of the Quick Domenico analysis in the context of the following inputs are provided in **Appendix X**:

- Site-specific deep aquifer zone groundwater sampling results (used for calibration);
- Site-specific aquifer transmissivity values (from recent slug testing conducted for newly installed and other onsite deep aquifer zone monitoring wells);
- 30-year analysis per regulatory requirements; and
- Three runs conducted with starting concentrations of 14,000 µg/L (most conservative concentration), 8,870 µg/L (average concentration), and 3,550 µg/L (least conservative concentration), with variations in source size. The matrix of model input parameters is provided in Table B of **Appendix X**.

Input parameters and model assumptions were based on site-specific conditions and reported field data acquired during site investigation activities, the details of which are included in **Appendix X** and which are specific to the Site. Model runs for the Site were calibrated using analytical data from quarterly groundwater performance monitoring events at PH-DW-3. Outputs from the aforementioned Quick Domenico model runs are summarized below for benzene, based on a 30-year timeframe and are compared to the various regulatory criteria: the USEPA Tap Water Regional Screening Level for benzene of 0.46 µg/L; the PADEP VI Screening Guideline (23 µg/L); 1/10<sup>th</sup> the PADEP VI Screening Guideline (2.3 µg/L); and the PADEP Act 2 MSC for benzene of 5 µg/L (PADEP 2021). The source concentrations below are based on observed trends at the Site. The extent of the benzene migration over a 30-year period for the varying scenarios is provided in **Table 9** below:

Table 9 Benzene Modeling Outputs

Screening Level (µg/L)		Distance from PH-DW-3: Most Conservative Source Concentration – 14,000 (µg/L)	Distance from PH-DW-3: Average Source Concentration – 8,870 (µg/L)	Distance from PH-DW-3: Least Conservative Concentration – 3,550 (µg/L)
USEPA RSL	0.46	1,840 ft	450 ft	225 ft
PADEP 1/10 <sup>th</sup> VI Screening Level	2.3	1,540 ft	393 ft	173 ft
PADEP Residential MSC	5	1,420 ft	360 ft	160 ft
PADEP VI Screening Level	23	1,160 ft	287 ft	140 ft

As further detailed in **Appendix X**, three predictive modeling runs were simulated using combinations of model inputs (**Appendix X**, Table B) that represented a most conservative, an average, and a least conservative scenario. The most conservative scenario used a set of parameters that promote high groundwater flow velocities, stronger contaminant source, and longer contaminant persistence. The average scenario used parameters more representative of site conditions, supported by site-specific measurements or average values from literature review. The least conservative scenario used a set of parameters that promote lower groundwater velocity, weaker contaminant source, and a short contaminant persistence. While some inputs remained fixed across the three simulations (parameter half-life, organic carbon partitioning coefficient), the remaining inputs (source concentration and width, hydraulic gradient, porosity, etc.) were varied to evaluate a range of potential model domains. The resultant predictions showed parameter transport distances ranging from only a few hundred feet (least conservative) to as far as south of Pattison Avenue (most conservative). The transport distances predicted in the most conservative scenario are inconsistent with recent groundwater sampling results for downgradient deep aquifer wells NOVA-DW-14 and FDR-DW-15 (which are non-detect for Act 2 short-list parameters). These results suggest that the most conservative scenario is not a realistic representation of the deep aquifer behavior, especially when evaluating benzene and 1,2-dichloroethane (Figure 4 and Figure 5, respectively, **Appendix X**); the average and least conservative predictions are more consistent with observed concentrations since the installation of downgradient deep aquifer wells NOVA-DW-14 and FDR-DW-15 in 2017. Both NOVA-DW-14 and FDR-DW-15 were reported as having no detectable concentrations of benzene based on the fourth quarter of 2024 site-wide groundwater sampling event results. To further confirm the extent of site deep aquifer zone impacts, confirmatory groundwater sampling of site deep aquifer zone wells, including deep wells NOVA-DW-14 and FDR-DW-15, will continue as part of a future site post-remediation care plan.

## 8 Human Health Risk Assessment and Site-Specific Ecological Evaluation

A site-specific risk assessment was conducted and is presented in the HHRA Report (submitted under separate cover) and the Site-Specific Ecological Risk Evaluation memorandum (presented in **Appendix B**, Subsection Two). The site-specific risk assessment incorporates results from the VI investigation and was viewed in the context of the current CSM and the proposed path forward under Act 2 (PADEP 2021). The results of the VI investigation were used to conduct a site-specific HHRA, presented in the HHRA Report (**Appendix B**). The ecological risk evaluation was also updated from the version presented in the May 2022 combined RIR and CP, as presented in the Site-Specific Ecological Risk Evaluation memorandum (**Appendix B**).

### 8.1 Human Health Risk Assessment

The purpose of the HHRA was to evaluate potentially complete exposure pathways and characterize potential risks to human health under current and potential future conditions. The properties/buildings comprising the Site were divided into distinct groups based on proximity to known contamination sources, including the current and historical extent of the LNAPL plume, the presence of impacted groundwater, property parcel boundaries, and current land use. These groups are as follows:

- **Group 1:** Within current or historical extent of LNAPL and equipped with VI mitigation systems.
- **Group 2:** Directly over or within 30 ft of the current or historical extent of LNAPL and without VI mitigation systems.
- **Group 3:** Outside current or historical extent of LNAPL but in proximity to monitoring wells with identified LNAPL impacts, limited available groundwater data, or groundwater concentrations of site-related constituents that exceed screening values for VI protection.
- **Group 4:** Outside current and historical extent of LNAPL, adjacent to areas with groundwater concentrations below screening values for VI protection but may have potential preferential pathways.
- **Group 5:** Farthest from current and historical extent of LNAPL plume but may have potential preferential pathways. Given their distance from the LNAPL source area, no environmental sampling data have been collected from these buildings to date. The need for further investigation or sampling at these properties was determined to be unnecessary based on the results of the HHRA for properties/buildings in Groups 3 and 4.

The findings of this assessment indicate that VI does not currently pose a widespread or systematic risk across the Site. For the majority of properties/buildings evaluated, estimated cancer risks and hazard indices for both current and future commercial and construction workers were below applicable PADEP risk thresholds (PADEP 2021). However, several buildings exhibited site-specific conditions, such as elevated indoor air or subsurface concentrations, that introduce some uncertainty or indicate the potential for localized risk. Targeted recommendations are provided below to address these conditions and support long-term protection of human health.

For the Group 1 properties/buildings, short-term construction-related exposures could not be evaluated due to the absence of representative subsurface vapor data. Indoor air samples were collected under post-mitigation conditions and are not indicative of potential exposures during intrusive activities, when mitigation systems such as vapor barriers or passive SSDSs could be disrupted. Sub-slab samples were collected from SSDS piping to

qualitatively assess the effectiveness of the systems, but this method is not considered representative for risk evaluation. If subsurface work is planned in the future, real-time vapor monitoring or collection of targeted subsurface vapor samples, combined with an appropriate health and safety plan, may be warranted to ensure that conditions remain protective of construction workers. Although quantitative evaluation was not possible, potential risks during intrusive activities will be effectively managed through institutional controls, including a land use covenant requiring the existing SSDS to remain in place and implementation of air monitoring and personal protective equipment procedures in a Soil Management Plan.

For Group 2 Building 30 (occupied by U-Haul), indoor air sampling results indicated an elevated noncancer hazard, with naphthalene identified as the primary contributor. However, subsurface vapor data did not show corresponding exceedances, suggesting that the elevated indoor air concentrations may be influenced by conditions within the building rather than VI from the underlying plume. Given the building's current use as a U-Haul truck rental office and storage facility, potential sources such as vehicle exhaust or stored fuel-related equipment may be contributing to indoor concentrations. Although the specific source could not be confirmed, the available evidence does not indicate that the indoor air concentrations are driven by a subsurface source. Accordingly, no additional VI-focused investigation is recommended at this time. If a targeted indoor-source audit does not identify any plausible internal contributors, the need for further VI assessment can be re-evaluated in consultation with PADEP.

At Group 2 Building 9 (mostly occupied by U-Haul), elevated concentrations of 1,1,2-trichloroethane were identified in near-source soil gas. However, indoor air concentrations were within acceptable limits for both cancer and noncancer risk, indicating that current exposures are protective under existing building conditions. Notably, 1,1,2-trichloroethane is not associated with the Site's petroleum-related LNAPL plume, suggesting that the elevated subsurface concentrations may be due to a local or unrelated source. As indoor air represents the most relevant exposure pathway, no additional VI monitoring is recommended at this time. If future changes in land use, building configuration, or subsurface conditions are anticipated, re-evaluation may be warranted to ensure continued protectiveness.

For the former Steen Building (Group 2), risk characterization relied entirely on subsurface data in the absence of indoor air sampling. Although most subsurface media did not show elevated concentrations, near-source soil gas exhibited a significantly elevated hazard index, driven primarily by 1,1,2-trichloroethane. Without indoor air data to confirm whether these subsurface conditions are resulting in actual exposure, potential risk cannot be fully evaluated.

For Group 3 and Group 4 properties/buildings, all evaluated exposure scenarios yielded risk estimates below applicable PADEP thresholds. These properties were located near or outside the known extent of the LNAPL plume and were evaluated using available subsurface vapor data, including utility bedding vapor, and near-source soil gas. At the properties without direct vapor measurements, risk was assessed using data from nearby buildings with similar construction and subsurface conditions. This approach is considered reasonable based on the consistency of available data, although it introduces a minor data limitation. If land use changes or redevelopment are planned at these properties in the future, confirmatory sampling could be considered to verify that site conditions remain consistent and exposures remain within acceptable limits.

## 8.2 Ecological Risk Evaluation

The ecological risk evaluation was updated via memorandum (Site-Specific Ecological Risk Evaluation, presented in **Appendix B**, Subsection Two) to address the requirements for a Site-Specific Ecological Risk Assessment

pursuant to Act 2 (PADEP 2021). The update was developed in accordance with the guidelines set forth in 25 PA Code, Subchapter D (SSS), § 250.402 and 250.404, as they pertain to a release of liability using the SSS. The findings presented in this memorandum supersede the ecological screening presented in the May 2022 combined RIR and CP.

A screening of the Site identified two potential species of concern. After follow-up inquiries with the Pennsylvania Department of Conservation and Natural Resources and the Pennsylvania Fish and Boat Commission, both agencies determined that there is no likely impact to the identified species. Based on a wetlands screening of the Site, a pond was identified in the area east of the PHA Building that was originally constructed as a stormwater retention basin. Because no endangered species were identified within the footprint of the stormwater retention basin, and there are no ongoing or planned remedial actions for this area, the area of the stormwater basin will not be impacted by current and/or future remedial activities at the Site. The ecological risk assessment did not identify any species requiring additional assessment. Therefore, no further ecological evaluation is warranted.

## 9 Summary and Conclusions

As discussed previously, site closure (i.e., release of liability) under Act 2 (PADEP 2021) will demonstrate the elimination of potential human health exposure pathways related to residual LNAPL and associated petroleum hydrocarbon impacts as described in this RIR. Pathway elimination will be achieved through a combination of engineering and institutional controls as allowed via the SSS approach available under 25 PA Code § 250.401. The status of media impacted by petroleum hydrocarbons is detailed below:

As discussed in **Sections 6.5.2** and **6.6.1**, the spatial limits and thickness of the Site's LNAPL have been affected by ongoing product removal, natural attenuation, and water table fluctuations. As a result of these influences, ongoing LNAPL monitoring has demonstrated that LNAPL is becoming less mobile, less recoverable, and more stable (i.e., weathered in situ) with time. Residual LNAPL at the Site will be addressed via pathway elimination and implementation of institutional and engineering controls, which will be discussed in a forthcoming CP.

As discussed in **Sections 6.5.2** and **6.6.2**, groundwater monitoring at the Site has demonstrated that LNAPL-related COCs are present in groundwater and have been fully characterized and delineated. Exceedances of applicable SSSs in groundwater have been identified and will be addressed via pathway elimination and implementation of institutional and engineering controls, which will be discussed in a forthcoming CP.

As discussed in **Section 6.3.2**, soil sampling activities at the Site have demonstrated that LNAPL-related COCs are present in soil and have been fully characterized and delineated. Exceedances of applicable SSSs in soil have been identified and will be addressed via pathway elimination and implementation of institutional and engineering controls, which will be discussed in a forthcoming CP.

As discussed in **Sections 6.5.2.4** and **6.6.3**, VI investigation activities at the Site have demonstrated that LNAPL-related COCs are present in soil vapor and pose a potential risk of VI to site buildings and infrastructure. The potential risk for VI is evaluated in the HHRA Report (submitted under separate cover).

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# Tables

# Figures

# Appendix A

## **Administrative Documents**

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**Subsection Two: 2004 Notice of Intent to Remediate**

**Subsection Three: Quitclaim Deeds**

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# Appendix B

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# Appendix C

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## Groundwater Isoconcentration Contour Maps

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## **Groundwater MNA Analytical Results**

**Subsection One: MNA Data Summaries**

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**Malcolm Pirnie Soil Gas Summary Figures (1995-2001)**

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## Offsite Sources

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**Subsection Three: Groundwater Contour Maps**

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## **Standard Operating Procedures**

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**Subsection Two: LNAPL Baildown Testing**

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# Appendix T

**TPI Guide, Spreadsheets, and Transmissivity Results**

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**Basis of Design (BOD) Report, BV-BS Design Report, BV-BS Work Plan, and BV-BS Pilot Report**

# Appendix X

## Quick Domenico Modeling Results

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