REMEDIAL INVESTIGATION REPORT
AREA OF INTEREST 8

Philadelphia Energy Solutions Refining and Marketing, LLC
Philadelphia Refining Complex
3144 Passyunk Avenue
Philadelphia, Pennsylvania
Sitewide PADEP Facility ID No. 780190
Area of Interest 8 PADEP Facility ID No. 749898

Stantec

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Philadelphia Refinery Operations, a series of Evergreen
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Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACRONYMS

API LDRM	American Petroleum Institute LNAPL Distribution and Recovery Model
ACGIH	American Conference of Governmental Industrial Hygienists
Act 2	Pennsylvania's Land Recycling Program
AF	Attenuation Factor
ANT	Apparent NAPL Thickness
AOI	Area of Interest
Aquaterra	Aquaterra Technologies, Inc.
ARCO	Atlantic Richfield Company
AST	Aboveground Storage Tank
ASTM	American Society for Testing and Materials
BEHP	bis(2-ethylhexyl)phthalate
C	Celsius
CAP	Corrective Action Process
CCR	Current Conditions Report and Comprehensive Remedial Plan
CRP	Community Relations Plan
cm/s	centimeters per second
cm^{3}s/g	cubic centimeters second per gram
CO&A	Consent Order and Agreement
COCs	Constituents of Concern
COMPLEX	PES Philadelphia Refining Complex
DSCP	Defense Supply Center Philadelphia
EDB	1,2-Dibromoethane
EDC	1,2-Dichloroethane
EPA	United States Department of Environmental Protection
ESA	Environmental Site Assessment
Evergreen	Philadelphia Refinery Operations, a series of Evergreen Resource Group, LLC
f_{oc}	fraction of organic carbon
ft bgs	feet below ground surface
ft/d	feet per day
ft^{2}/d	square feet per day
ft/ft	feet per foot
GHD	GHD Services, Inc.
GIS	Geographic Information System
gpm	gallons per minute
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
IST	Integrated Science & Technology, Inc.
k	hydraulic conductivity
k_{v}	vertical permeability
Langan	Langan Engineering & Environmental Services, Inc.
Leidos	Leidos, Inc.
LiDAR	Light Detection and Ranging
LNAPL	Light Non-Aqueous Phase Liquid
LNG	Liquified Natural Gas
LCSM	LNAPL Conceptual Site Model
LTU	Land Treatment Unit
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
µg/l	micrograms per liter
µg/m^{3}	micrograms per cubic meter
MEK	methyl ethyl ketone

MOA	Memorandum of Agreement
MODFLOW	USGS Modular Finite-Difference Flow Model
MSC	Medium Specific Concentration
MTBE	methyl tertiary butyl ether
NAPL	Non-Aqueous Phase Liquid
NAVD 88	North American Vertical Datum of 1988
Newfields	, LLC
NFA	No Further Action
NIOSH	National Institute for Occupational Safety and Health
NIR	Notice of Intent to Remediate
NOC	Notice of Contamination
NOV	Notice of Violation
NRDC	Non-Residential Direct Contact
OSHA	Occupational Safety and Health Administration
PADCNR	Pennsylvania Department of Conservation and Natural Resources
PADEP	Pennsylvania Department of Environmental Protection
PaGWIS	Pennsylvania Groundwater Information System
PBNY	Point Breeze Refinery North Yard
PEL	Permissible Exposure Limit
PES	Philadelphia Energy Solutions Refining & Marketing, LLC
PGW	Philadelphia Gas Works
PID	Photoionization Detector
PNDI	Pennsylvania Natural Diversity Inventory
PNSY	Philadelphia Naval Shipyard
ppm$_{v}$	parts per million by volume
PRCP	Post-Remediation Care Plan
PRM	Potomac-Raritan-Magothy aquifer system
psi	pounds per square inch
PWD	Philadelphia Water Department
RACR	Remedial Action Completion Report
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
REL	Recommended Exposure Limit
RI	Remedial Investigation
RIR	Remedial Investigation Report
RSL	Regional Screening Level
SCR	Site Characterization Report
SHS	Statewide Health Standard
SPT	Standard Penetration Test
SSS	Site-Specific Standard
Sunoco	Sunoco Inc. (R&M)
SPMT	Sunoco Partners Marketing and Terminals, L.P.
Stantec	Stantec Consulting Services, Inc.
SVIA-NR SHS	PADEP Non-Residential Indoor Air Statewide Health Standard Vapor Intrusion Screening
SVIA-NR SSS	PADEP Non-Residential Indoor Air Site Specific Standard Vapor Intrusion Screening Values
SVSS-NR SHS	PADEP Non-Residential Sub-Slab Air Statewide Health Standard Vapor Intrusion Screening Values
SWMU	Solid Waste Management Unit
1,2,4-TMB	1,2,4-Trimethylbenzene
1,3,5-TMB	1,3,5-Trimethylbenzene
TDS	Total Dissolved Solids
TEL	Tetraethyl lead

Tetra Tech	Tetra Tech, Inc.
THQ	Target Hazard Quotient
TR	Target Risk
TLV	Threshold Limit Value
USGS	United States Geological Survey
UST	Underground Storage Tank
Verizon SDWC	South District Work Center of Verizon Pennsylvania, LLC
VI	Vapor Intrusion
VI Guidance	PADEP Land Recycling Program Technical Guidance Manual for Vapor Intrusion into Buildings from Groundwater and Soil
VOC	Volatile Organic Compound
Weston	Weston Solutions, Inc.

1.0 Introduction

This Remedial Investigation Report (RIR) has been prepared by Stantec Consulting Services, LLC (Stantec) for Philadelphia Refinery Operations, a series of Evergreen Resource Group, LLC (Evergreen) for Area of Interest (AOI) 8 (the site), also known as the Point Breeze Refinery North Yard, at the Philadelphia Energy Solutions Refining and Marketing, LLC (PES) Refining Complex (Complex). Sunoco Inc. (R&M) (Sunoco) transferred the Complex to PES on September 8, 2012. Sunoco retained the remediation liability prior to this date. The remediation liability was transferred to Evergreen on December 30, 2013. The remediation program is currently being performed under a Buyer-Seller Agreement signed by Sunoco, PES, and the Pennsylvania Department of Environmental Protection (PADEP) in September 2012.

Site remediation at the PES Complex is ongoing as part of previously-established programs and the 2012 Buyer-Seller Agreement. The PES Complex has operated, and is planned to continue operating, as an oil refinery, marketing terminal, and producer of petrochemicals.

1.1 DESCRIPTION OF THE COMPLEX

The PES Complex is located along the banks of the Schuylkill River in the City of Philadelphia, Philadelphia County, Pennsylvania (**Figure 1-1**). Portions of the PES Complex occupy both the eastern and western Schuylkill River banks. The PES Complex, which is located on industrial property, covers approximately 1,400 acres of land with access restricted by fencing and security measures. The area surrounding the PES Complex is characterized by a mixture of residential, commercial, and industrial properties. Current operations at the PES Complex consist of the production of fuels and basic petrochemicals for industry.

AOI 8 occupies approximately 250 acres of the overall PES Complex (**Figure 1-2**). Surrounding AOI 8 are the following properties/features:

- North: South District Work Center of Verizon Pennsylvania, LLC (Verizon SDWC Property) and other industrial/commercial properties
- East: Vare Avenue, the Schuylkill Expressway, and mostly residential properties
- South: Philadelphia Gas Works (PGW) Passyunk Facility, limited residential properties, and buildings/tankage/terminal associated with AOIs 1 and 2 (Point Breeze Refinery South Yard) and Belmont Terminal
- West: Schuylkill River

1.2 OPERATIONAL HISTORY AND CURRENT USE OF THE COMPLEX

The PES Complex has a long history of petroleum transportation, storage, and processing. The oldest portion of the PES Complex started petroleum related activities in the 1860's, when the Atlantic Refining Company was established as an oil distribution center. In the 1900's, crude oil processing began and full-scale gasoline production was initiated during World War II. In addition to refining crude oil, various chemicals, such as acids and ammonia, were also produced at the PES Complex for a time. The PES Complex has operated continuously as a refining, product distribution, and storage facility. Use of the PES Complex has remained similar following transfer of ownership.

AOI 8 – Point Breeze Refinery North Yard

AOI 8 is located on the northern end of the PES Complex, beyond Passyunk Avenue and the PGW Passyunk Facility. This area of the PES Complex was home to the former Point Breeze Refinery and is still referred to as the Point Breeze Refinery North Yard (PBNY). The former refinery was operated by multiple owners, generally from the late 1800s through the 1990s, except for the No. 22 Boiler House which was operated until 2009. Various industrial processing units were operated in AOI 8 throughout its history in primary association with crude oil refining (**Figure 1-3**). Stantec's understanding of the former process areas/units that were present in AOI 8 is based on review of the historic reports and associated content included in **Appendix A**. Aerial photographs viewed through the Greater Philadelphia GeoHistory Network (The Athenaeum of Philadelphia, 2017) website indicate that the dismantling and decommissioning of the Point Breeze Refinery's processing units began between approximately 1965 and 1970, and was mostly completed by 1985. Additional detail is presented in this section. An active CSX railroad easement bisects AOI 8 into northern and southern portions, and that feature is used for the discussion of former process areas to its north and south.

During operational times, northern AOI 8 contained several aboveground storage tanks (ASTs) of the Point Breeze Refinery No. 3 Tank Farm, and a processing area that contained several units including a gasoline fractionating unit, aviation gasoline and blending plant, alkylation plants/units, cracking units, a unifiner and catformer unit, and a methyl ethyl ketone (MEK) plant. Subsequent to the decommissioning of this processing area which generally commenced in the early 1980s, a Land Treatment Unit (LTU) was established and was operated until 2000. A leaded sludge weathering pad was operated under Resource Conservation and Recovery Act (RCRA) Interim Status near the southeast corner of the LTU until closure circa 1990. The LTU is actively sampled under Resource Conservation and Recovery Act (RCRA) Closure and Post-Closure monitoring activities; groundwater analytical data is presented in this report in **Section 4.0**. There is aerial photographic and subsurface evidence of a historic landfill in northern AOI 8, south of the current Propane Loading Rack. This area of disturbance is apparent in circa 1930 aerial photographs and based on shallow soil data collected and compiled for this RIR, may have been primarily used for the disposal of smelter slag. Currently, only 7 of the No. 3 Tank Farm area's former ASTs remain in-service (**Figure 1-3**). These are tanks 663 (frac bottoms), 668 (wash oil), 672 (gas oil), M-12 (water), RM-39 (butane), RM-40 (butane), and RM-41 (butane). PES maintains tank 666 and possibly other regulated ASTs in AOI 8 as temporarily out of service.

Various plants of the former Point Breeze Refinery were operated in southern AOI 8. These included asphalt, paraffin wax, soap, ammonia, magnesium sulfonate, and acid plants located in the western and southern portion nearer the Schuylkill River. A lube plant, grease plant, and associated nitrobenzene plant were present along the southern property boundary with PGW's Passyunk Facility. According to PES, the asphalt plant was operated up until the 1990s whereas the other plants ceased operation earlier in time. Numerous ancillary structures and ASTs were historically located across most southern AOI 8 in association with the various plants. A Solid Waste Management Unit (SWMU) operated in southern AOI

8 from the 1950s through the 1970s (ENSR, 1992). This SWMU (SWMU 2) was investigated as part of a PES Complex-wide RCRA investigation, and was formally closed in 2016. Details of the investigation, as they relate to SWMU 2, are presented in **Section 3.0**. Currently, there are 4 ASTs remaining in southern AOI 8 with 2 being in-service. The in-service ASTs are RM-79 and RM-80 (both ASTs are used to store butane) (**Figure 1-3**).

Like other AOIs along the Schuylkill River, AOI 8 has a hardened shoreline that consists of a combination of steel and wooden bulkheads (**Figure 1-2**) (Langan, 2008). Stantec and Evergreen have attempted to obtain additional information related to the construction of the AOI 8 bulkheads. However, detailed as-built information has not been located. It is likely that the wooden bulkhead dates to the late 1800s/early 1900s and may have been installed to stabilize the shoreline soon after intertidal and subtidal flats of the Schuylkill River were reclaimed.

Numerous sewers are contained within and bisect AOI 8 for the collection and conveyance of both stormwater and sewage. The City of Philadelphia's Jackson Street Sewer is located in northern AOI 8 and runs from the eastern AOI boundary to its terminus at the Schuylkill River. This combined sewer has a history of environmental investigation and is discussed in detail in later sections of this RIR. According to historical site drawings, a former onsite process sewer for the Point Breeze Refinery (Rambo Creek Sewer) is located in AOI 8 south of the CSX railroad. The Rambo Creek Sewer extends from the eastern AOI 8 boundary and to the west where it drains to the Klondike Separator. A former sump box of this sewer, located to the southeast of the No. 22 Boiler House, was filled-in during redevelopment projects in the area; however, the sewer remains present in the subsurface and continues to collect runoff from the shallow storm sewer network and conveys it through an API-type oil water separator (Klondike Separator) to the stormwater basin on the western perimeter of AOI 8. Some of this storm sewer piping has been capped off where catch basins are no longer present in former AST areas.

Significant re-development has occurred in AOI 8 in recent years in support of AOI 8's current uses. This has included the construction of the Point Breeze North Yard Crude Rail in southern AOI 8 (**Figure 1-3**). A Hazardous Waste Roll-Off Temporary Storage Pad is in northern AOI 8 to the northeast of the former LTU. Currently, main operations in AOI 8 include the offloading of crude oil from the railroad spur, fuel oil storage, refinery butane and propane storage, and terminaling facilities. Several occupied buildings are present within AOI 8, including the Old and New Scale Houses, office trailers, and the Philadelphia Fire Department Building.

1.3 REGULATORY HISTORY/OVERVIEW

Sunoco and the PADEP entered into a Consent Order & Agreement (CO&A) in December 2003 with respect to the former Philadelphia Refinery (now PES Complex). Sunoco's Phase I Remedial Plan (Phase I Plan), dated November 2003, was included as an attachment to the CO&A. In accordance with the CO&A and Phase I Plan, a Current Conditions Report and Comprehensive Remedial Plan (CCR) was prepared by Langan for Sunoco in June 2004. The Phase I Plan and the CCR divided the former Philadelphia Refinery into 11 AOIs, and presented a prioritization of the AOIs based on specific risk factors. The CCR also presented the Phase II remedial approach and schedule to characterize each of the 11 AOIs, and to conduct Phase I and II corrective action activities in accordance with the 2003 CO&A and the Phase I Plan. Since 2003, Sunoco has performed site characterization activities at all 11 AOIs in accordance with the 2003 CO&A. Sunoco has prepared and submitted a corresponding Site Characterization Report (SCR) for each AOI in accordance with the Revised Phase II Corrective Action Activities schedule that was included in the CCR.

In October 2006, Sunoco submitted a notice of intent to remediate (NIR) to the PADEP entering the former Philadelphia Refinery into the Act 2 program. In November 2011, the former Philadelphia Refinery was formally entered into the PA One Cleanup Program with the United States Environmental Protection Agency (EPA) – Region III and PADEP, and Sunoco submitted a Work Plan for Site Wide Approach Under the One Cleanup Program (Work Plan for Site Wide Approach). In November 2014, the NIR was updated and submitted to the PADEP to revise the ownership identity to PES and the remediator identity to Evergreen. The NIR was updated again in December 2016 to change the selected remediation standard for lead in soil to the Residential Statewide Health Standard for the PES North Yard Ball Field in AOI 8. As previously discussed, characterization and remediation work at the PES Complex is currently being performed under the September 2012 Buyer-Seller Agreement signed by Sunoco, PES, and the PADEP.

The following provides a timeline of major events and submissions for the PES Complex and AOI 8:

- 1992
    - ENSR completed a RCRA facility investigation for the Point Breeze Refinery, including the Point Breeze North, South, and West Yards.
- 1993
    - A CO&A was established for the Point Breeze Refinery.
- 1994
    - Sunoco purchased the Girard Point Refinery and Schuylkill River Tank Farm from Chevron. Sunoco generally referred to the Girard Point Refinery as the Girard Point Processing Area and the Point Breeze Refinery as the Point Breeze Processing Area, operating two refineries as the Philadelphia Refinery.
- 2003
    - A revised CO&A, which replaced the 1993 CO&A, was established for the Point Breeze Processing Area, Girard Point Processing Area, the Point Breeze West Yard, and the Schuylkill River Tank Farm.
- 2004
    - The PADEP and EPA signed an agreement entitled “One Cleanup Program Memorandum of Agreement (MOA or One-Cleanup Program),” which clarified how sites remediated under Pennsylvania’s Voluntary Cleanup Program may satisfy RCRA corrective action requirements through characterization and attainment of remediation standards established under the Pennsylvania Land Recycling and Environmental Remediation Standards Act (Act 2).
    - Sunoco prepared a CCR for the Philadelphia Refinery and Belmont Terminal (Langan, 2004).
- 2005

  - PADEP, EPA, and Sunoco agreed that the One Cleanup Program would benefit the project by merging the remediation obligations under the various programs into one streamlined approach which would be conducted under the existing 2003 CO&A.
- 2006
  - Sunoco submitted a NIR to the PADEP for the Philadelphia Refinery thereby entering the refinery into the Act 2 program.
- 2008
  - Sunoco submitted a SCR for AOI 8 on September 30, 2008 (Langan, 2008).
- 2011
  - On November 8, 2011, the EPA provided an acknowledgment letter to Sunoco formally accepting the Sunoco Philadelphia Refinery into the One Cleanup Program.
  - Sunoco submitted the Work Plan for Site Wide Approach to document the site-wide remedial approach extending beyond the requirements of the 2003 CO&A. PADEP and EPA reviewed the plan and provided input. Sunoco submitted a letter of commitment stating the Philadelphia Refinery will be remediated according to the Work Plan for Site Wide Approach.
- 2012
  - Sunoco transferred the Philadelphia Refinery to PES and the facility was renamed the Philadelphia Refining Complex. At the time of transfer PES generally considered the Complex as having two refineries, the Point Breeze and Girard Point Refineries. The Complex also included the Schuylkill River Tank Farm.
  - Sunoco, PES, and PADEP signed the Buyer-Seller Agreement which established the environmental remediation and management obligations of Sunoco and PES following the sale of the PES Complex.
  - Sunoco submitted a Site Characterization/Remedial Investigation Report (SCR/RIR) for AOI 8 on January 31, 2012 (Langan, 2012).
- 2013
  - The legacy remediation liability for environmental impacts existing prior to the conveyance of the Complex to PES was transferred from Sunoco to Evergreen.
- 2014
  - Evergreen submitted an updated NIR to the PADEP for the PES Complex.
  - Evergreen submitted a NIR to PADEP exclusively for the Belmont Terminal which is a separate property owned by Sunoco Partners Marketing and Terminals L.P. (SPMT).
- 2015
  - Langan, on behalf of Evergreen, submitted a Human Health Risk Assessment (HHRA) Report to establish a site-specific standard (SSS) for lead in soil at the PES Complex, the Belmont Terminal, and the SPMT Marcus Hook Industrial Complex (Langan, 2015).
  - The HHRA was approved by the PADEP in a letter dated May 6, 2015 establishing a SSS of 2,240 milligrams per kilogram (mg/kg) for lead in soil.

- 2016
  - Evergreen submitted an updated NIR to the PADEP for the PES North Yard Ball Field in AOI 8.

On May 17, 2016, Evergreen and Stantec met with the PADEP to discuss proposed additional investigation activities at AOI 8. In accordance with the Work Plan for Site Wide Approach, Evergreen is submitting this RIR for AOI 8 to formally satisfy the requirements of Act 2 as specified in 25 PA Code §250.408. This RIR describes site characterization work conducted following the last submittal to PADEP regarding AOI 8 (SCR/RIR; Langan, 2012). Activities that have been performed to complete characterization as required by an RIR under Act 2 include:

- Additional characterization of surface soil (0-2 ft below ground surface [ft bgs] interval) and subsurface soil (2-15 ft bgs) including targeted soil investigations in potential contaminant source areas, such as historic product handling and storage locations, open storage tank incident areas, and known product release areas
- Horizontal and vertical delineation of impacts to soils
- Installation of deep soil borings/monitoring wells and clustered monitoring wells to refine understanding of hydrostratigraphy
- Additional groundwater sampling from monitoring wells not containing light non-aqueous phase liquid (LNAPL)
- Detailed evaluation of onsite and offsite geology and hydrogeology
- Delineation of LNAPL
- Evaluation of LNAPL mobility
- Investigation of the potential vapor intrusion (VI) to indoor air pathway at occupied buildings
- Qualitative-level evaluation of contaminant fate and transport

Evergreen is in the process of developing a MODFLOW model to perform quantitative fate and transport modeling at the PES Complex. Following the approval of this and other RIRs, Evergreen intends to submit a Cleanup Plan, pursuant to 25 PA Code §250.410, which will present remedies chosen for attainment of the selected remediation standards in soil and groundwater.

In accordance with Act 2, the required public and municipal notices for this report have been prepared and issued. **Appendix B** includes a copy of the original NIR, the updated NIRs, report notices, and proof of receipt/publications for the PES Complex.

1.4 ADJACENT PROPERTIES WITH HISTORIC/ONGOING INVESTIGATIONS

1.4.1 PGW Passyunk Facility

The PGW Passyunk Facility is located to the south of AOI 8 and to the north of AOI 2 of the PES Complex and the Belmont Terminal (**Figure 1-2**). The property has been under ownership of PGW (or its predecessor United GAS Improvement Company) since the mid-1800s, and was used to manufacture, process, store and distribute natural gas. Manufacturing and processing activities were reduced at the property by the 1970s, and many of the associated structures were demolished (Weston, 2004). Historical records indicate that six ASTs which stored sodium hydroxide, sulfuric acid, used/recovered motor oil, ink oil, and diesel were present on the property. In addition, five underground storage tanks (USTs) which stored naphtha and diesel were also present on the property. Historical aerial photographs indicate that most these tanks were removed in the mid-2000s, along with other structures.

A narrow strip of land between the Schuylkill River and PGW Passyunk Facility is presently owned by PES. This property was historically owned by the City of Philadelphia but was operated under PGW through the 1980s. In 1982, oil sheening was observed on the Schuylkill River adjacent to this parcel. Oil seepage, coming through steel sheathing at the southern wharf on this parcel, was identified as the source to the river. Subsequently, a remediation program, which included the installation of monitoring wells and three recovery wells, was implemented by PGW within this parcel. A 500-ft containment boom was also installed and maintained in the area of seepage. In 1984, the parcel was sold to the Atlantic Richfield Company (ARCO). In September 1989, ownership of this parcel was conveyed to Atlantic Refining & Marketing Corporation and leased for operation to Sunoco. In 1993, under an administrative order by PADEP, Sunoco and Atlantic Refining & Marketing Corporation became joint participants with PGW for remediation activities in this western parcel (Weston, 2004).

Currently, the property is used for liquefied natural gas (LNG) storage, vaporization, and gas distribution. Laboratory facilities, and maintenance, fueling, and parking of fleet vehicles are also part of operations at the property.

PGW Passyunk Facility remedial investigation activities were conducted by Weston Solutions (Weston) during 2002-2004, in response to the identification of subsurface petroleum hydrocarbon impacts. Quarterly monitoring reports have been submitted to PADEP for remediation activities related to the oil seepage in the western parcel. Progress reports of on-going remediation activities at the property, which document groundwater monitoring and operation of remedial systems, are submitted on a quarterly basis by PGW. Available gauging and analytical data from a portion of those investigations at the PGW Passyunk Facility were used in this report, as discussed in later sections.

1.4.2 Verizon SDWC Property

The Verizon SDWC Property is located to the north of AOI 8 along Maiden Lane and 34th Street (**Figure 1-2**). There is evidence of a historic landfill near the property in the 1940s, prior to which the property was mainly undeveloped land (Leidos, 2015). The parcel was developed to its current layout in 1974. Currently, most of the property is an asphalt parking lot and a single-story building which includes office areas, as well as a garage that is used for vehicle storage and maintenance. Smaller buildings, used for equipment storage, are also present on the property. Historically, three USTs were present on the property. Tanks 001 and 002 were installed in 1976 and 1967, respectively; both tanks were decommissioned and removed in 1991. Closure-related soil investigation indicated the presence of impacted soils at the property; however, the impacts were not attributed to the USTs but likely related to the historic landfill. In August 1995, the PADEP issued a letter of no further action (NFA) related to

Tanks 001 and 002. Tank 003, installed in the same area as former Tank 001, was part of a Phase II Environmental Site Assessment (ESA) in 2010, which included a tank tightness test. Tank 003 was decommissioned and removed in February 2011. Post-closure soil sampling, conducted in 2011, did not indicate impacts to soil from Tank 003 (Leidos, 2015).

As part of an environmental due diligence performed at the property in February 2011, subsurface petroleum hydrocarbon impacts were identified. A Notice of Violation (NOV) was issued by the PADEP in March 2011, owing to presence of historic USTs, previous releases, and soil impacts. Under the Act 32 Storage Tank Program, Leidos Inc. (Leidos) (formerly Science Application International Corporation) completed site characterization and remedial investigations during the 2011-2014 timeframe. Investigations included characterization of soil and groundwater, as well as a vapor intrusion investigation for the main building at the property. Leidos (2015) submitted a Remedial Action Completion Report (RACR) in 2015, which demonstrated incomplete exposure pathways for soil, groundwater, and vapor impacts. A Post-Remediation Care Plan (PRCP) was also presented which placed activity and use limitations on the property. In July 2015, the RACR was approved by the PADEP and liability protection was provided by Chapter 5, Section 501 of Act 2.

A portion of the available well gauging and analytical data from the remedial investigations conducted at the Verizon SDWC Property was used in this report, as discussed in later sections. A copy of the RACR is provided in **Appendix A**.

1.4.3 PES North Yard Ball Field – Moore Street and South 35th Street

The PES North Yard Ball Field, located in northern AOI 8, was previously identified by the EPA to be the former location of a lead smelter known as Metallurgical Products Company. Circa 2009, the EPA notified Sunoco of the ongoing investigation of several properties in Pennsylvania where lead smelters had been identified and recommended that lead concentrations in soil be evaluated. The EPA requested property access from Sunoco to perform the evaluation and in 2009, separate investigations were conducted by TetraTech, Aquaterra Technologies (Aquaterra), and NewFields, LLC to characterize the lead in near-surface soils at the ballfield. Available details of the soil investigations are presented in **Section 3.0**, and the respective reports are provided in **Appendix A**. Liability protection under Act 2 for lead contamination in soil at the PES North Yard Ball Field is a component of this RIR.

1.5 SELECTION OF CONSTITUENTS OF CONCERN

Lists of the constituents of concern (COC) in soil and groundwater for AOI 8 are included as **Tables 1-1 and 1-2**. These tables are updated listings of the COCs identified in the Work Plan for Site Wide Approach for the PES Complex under Pennsylvania One Cleanup Program and will be referred to as the Evergreen Petroleum Short List (**Table 1-1**) and Evergreen Comprehensive List (**Table 1-2**).

1.6 SELECTION OF APPLICABLE STANDARDS AND SCREENING LEVELS

The media of concern for AOI 8 include soil and groundwater. The potential vapor intrusion into indoor air exposure pathway was also evaluated. The approach for attaining Act 2 remediation standards for the media of concern is described in the following sections. As the current and required future use of the PES Complex is industrial, standards for non-residential properties were chosen for comparison (with exceptions for lead described in the following section).

1.6.1 Soil

Most soil results were screened using a multi-step process as described in this section. Soil sample analytical results were first screened against the PADEP non-residential, used aquifer (total dissolved solids [TDS] less than or equal to 2,500 milligrams per liter [mg/l]) Statewide Health Standard (SHS). The following process was used to select the soil SHS for each COC:

- The highest value of either 100 times the groundwater medium specific concentration (MSC) or the generic value MSC was selected to represent the soil to groundwater numeric value.

- The selected used aquifer, non-residential soil to groundwater numeric value was then compared to the non-residential direct contact (NRDC) MSC (0-2 feet or 2-15 feet bgs, as applicable).

- The more stringent of the soil to groundwater numeric value and the direct contact value was selected as the SHS for initial comparison of soil sample results.

The SHS value is usually driven by the soil-to-groundwater MSC, and the soil-to-groundwater pathway will be addressed in the groundwater investigation presented in this RIR (**Section 4**) and through subsequent remedial measures which will be further described in future Act 2 deliverables. To further evaluate the risk posed by the concentrations of COCs which were detected above their respective SHS, the next step in the screening process is to compare all of the soil analytical results to the non-residential direct contact MSCs. Soil sample locations that will require further pathway evaluation or require a remedial measure in order to attain a standard under Act 2 were identified through comparison to the non-residential direct contact MSCs.

Exceptions to this soil screening process exist for lead. On February 24, 2015, Evergreen submitted a HHRA Report to PADEP which presented the development of a risk-based SSS for lead in soil (Langan, 2015). In a letter dated May 6, 2015, PADEP approved the report, and a non-residential direct contact site-specific numerical standard for lead of 2,240 mg/kg was established. This SSS is used in place of the default 0-2 ft bgs direct contact MSC for lead through most of the PES Complex. The second exception to the outlined screening process exists for the PES North Yard Ball Field, where the selected remediation standard for lead in soil was changed to the Residential Statewide Health Standard in December 2016.

1.6.2 Groundwater

Groundwater sample analytical results were screened against the PADEP MSCs for non-residential properties overlying used aquifers with TDS less than or equal to 2,500 mg/l (SHS). Where constituent concentrations are above the selected groundwater SHS, Evergreen has evaluated application of the site-specific remediation standard using the pathway elimination option.

1.6.3 Potential Vapor Intrusion into Indoor Air

Indoor and ambient air sample results collected in AOI 8 were screened against the EPA Region 3 Regional Screening Levels (RSL) for Industrial Air Target Risk (TR)=1E-5, Target Hazard Quotient (THQ)=0.1 (updated June 2017; EPA-RSL, TR=1E-5). The EPA RSLs are used as the threshold values to determine if additional controls will be necessary to address vapor intrusion, and any such controls will be presented in the Cleanup Plan. The non-residential PADEP Indoor Air Site Specific Standard Vapor Intrusion Screening Values (SVIA-NR SSS), the non-residential PADEP Indoor Air Statewide Health Standard Vapor Intrusion Screening (SVIA-NR SHS), the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PEL); the National Institute for Occupational Safety and Health (NIOSH) Recommended Exposure Limits (REL) and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLV) are also provided for reference.

Sub-slab soil gas sample results collected in AOI 8 were screened against the EPA-RSL, TR=1E-5, THQ=0.1, Attenuation Factor (AF) =0.0078 (updated June 2017; EPA-RSL, TR=1E-5, AF = 0.0078) and the non-residential PADEP Sub-Slab Air Statewide Health Standard Vapor Intrusion Screening Values (SVSS-NR SHS).

2.0 ENVIRONMENTAL SETTING

This section summarizes the geologic framework and general hydrogeologic properties of sedimentary deposits and bedrock underlying the south Philadelphia area, with emphasis near the PES Complex. A brief discussion of historical and present-day topography and hydrology is also included. This section provides a regional context from which sedimentary deposits observed beneath AOI 8 (discussed in **Section 5**) can be classified and characterized for the purposes of this RIR. Much of the information presented in this section is being utilized for conceptualization and refinement of a PES Complex-wide geologic model. The geologic model is being used as the basis for a groundwater flow model that utilizes the United States Geological Survey (USGS) modular finite-difference flow (MODFLOW) model. The PES Complex-wide MODFLOW model is under development.

In general, the groundwater resources and stratigraphic framework of the PES Complex area have been well-documented through a variety of data sources, including previous groundwater resource investigations dating back to the early 1900's, state and federal geologic mapping projects, groundwater modeling studies, and consultant characterization and remedial investigation (RI) reports. In large part, available well and test boring logs from previous onsite and local subsurface investigations were the most valuable resource in evaluating the local subsurface stratigraphy. Subsurface information from approximately 750 well and test boring logs was considered in the evaluation of regional conditions for this report. A database of stratigraphic "picks" on interpreted vertical lithologic unit boundaries (and, where possible, geologic formations) was also developed and includes identified records of boreholes completed to bedrock at and near the PES Complex. For the most part, these records include "deep" wells drilled at the PES Complex, the former Defense Supply Center Philadelphia (DSCP) property, and other local properties where investigations have occurred (e.g., CSX, former ARCO, Steen, PGW Passyunk Facility, and Verizon SDWC properties). The purpose of developing and maintaining a "picks" database is to archive geologic interpretations of individual borehole lithologies to bedrock, so that stratigraphic profiles could be developed for use in this and future Act 2 submissions, and so the Schreffler lithologic model (Schreffler, 2001) being used as a basis for MODFLOW modeling could be refined and updated for site-specific use at the PES Complex. It is Evergreen's intention to continue updating the site-specific geologic model as additional subsurface information is collected through remedial investigation activities under Act 2.

Five stratigraphic profiles are presented in this RIR to support evaluation of the lithologic character, geographic extent, and thickness of each geologic unit identified through correlation to published geologic formations. In addition to lithologic and geologic information, the profile content has been updated over what was previously presented by Stantec (2016) and Stantec (2017) to universally include well construction information, groundwater elevations and interpolated surfaces, major sewer locations, and an interpolated top of bedrock surface. The first of the stratigraphic profiles was developed in support of a regional framework discussion through correlation of lithologic units identified in AOI 8 to those previously defined and correlated to published geologic units downdip in AOI 1 (Stantec, 2016). That stratigraphic profile (H-H') is discussed beginning in **Section 2.2.1.1**. The four remaining profiles, developed specifically to support AOI 8 geologic and hydrogeologic interpretations, are introduced in this section to exemplify regional depositional patterns but are discussed in further detail in **Section 5**. The stratigraphic profiles were drawn utilizing the current version of the "picks" database that included new borehole data. Database updates included the addition of subsurface information collected during the installation of new monitoring wells N-147D through N-156, soil boring AOI8-BH-16-001D, and additional interpretations of strata from existing borehole records in the study area (to address data gaps where boreholes completed to bedrock are not available). The bedrock structure contour map previously presented in the AOI 1 RIR (Stantec, 2016) and AOI 4 RIR (Stantec, 2017a) has also been updated and is used to support the discussion presented herein.

2.1 HYDROLOGY AND TOPOGRAPHY

The PES Complex occupies an area of approximately 2.2 square miles adjacent to the Schuylkill River near its confluence with the Delaware River. This region has a long history of human influence and disturbance, dating back to the early 17th Century when European settlers first arrived. The following sections present a brief discussion of the significant land surface morphologic changes that are apparent when comparing modern environments and topography to that shown on historical maps. These changes are important to note in this RIR when considering natural hydrologic conditions, drainage, and the potential for preferential flow paths in the subsurface that may influence the fate and transport of contaminants.

2.1.1 Historical Topography and Natural Depositional Environments

The Philadelphia City Archives (City of Philadelphia, 2017) and several online archival resources, such as the Greater Philadelphia GeoHistory Network (The Athenaeum of Philadelphia, 2017), the USGS National Map Viewer (USGS, 2017), and the Library of Congress (2017) have catalogued and provide free access to copies of historical maps and photographs of Philadelphia. Based on review of many of those maps, it is apparent that much of the land area occupied by the present-day PES Complex was formerly tidal marsh and lowlands that once fringed the Schuylkill River. **Figure 2-1** presents a geo-referenced USGS topographic map from 1898 (20-foot contour interval). The map indicates that several small tributary streams, digitized on-screen and shown as blue lines, formerly dissected that marshland and presumably would have exchanged water with the tidal Schuylkill River on a semi-diurnal basis. Several islands were also present throughout the lowlands, most notably League Island, which are interpreted as erosional remnants of uplands that formed through repetitive cycles of river incision in response to climate changes through the Pleistocene.

The 1898 topographic map shows that relatively higher topography was apparent north and west of the Schuylkill River in the PES Complex area, near Gibson Point. To the south and east, the Schuylkill River coursed through a distinctive meander around Point Breeze, and appeared to have formed an erosive cut bank along present-day AOI 2 and the PGW Passyunk Facility where higher elevations were present (and favoring point bar deposition in AOIs 7 and 8). A southwest-northeast trending ridge of higher elevation was also present south of Point Breeze near AOI 4 (**Figure 2-1**), and between those two areas of higher elevation an unnamed stream was mapped to have been present. That stream appears to have originated in southern AOI 1 and flowed southwest through AOIs 3, 4, and 7, towards its confluence with the Schuylkill River. Another tributary stream, Rambo Creek, bisected AOI 8, coursing to the south and west from a source near the Grays Ferry neighborhood of Philadelphia. Numerous other small streams and ditches draining the lowlands surrounding Hollander Creek were also noted. Additional historic maps indicate that by 1900, an earthen dike had been constructed along the banks of the lower Schuylkill River, and sluices were present at each stream/ditch confluence. Other maps show wooden pilings in places along the Schuylkill River. In general, the construction of containment dikes, sluices, and shoreline hardening would have altered the natural tidal exchange between the Schuylkill River and these historic creeks, thereby limiting the natural accretion of sediment in the marshes that once fringed the river. Moreover, the modifications indicated on these maps would have altered the pre-existing tidal regime and dynamic equilibrium of the Schuylkill River.

2.1.2 Post-Industrialization

Figure 2-1 indicates that by 1898, storage of petroleum near Point Breeze and Gibson Point had already begun. According to City of Philadelphia archives (City of Philadelphia, 2017), much of the remaining tidal marsh and lowland environments nearby were reclaimed and routinely dewatered for farming practices around this same time period (mostly on the west side of the Schuylkill River). Industrialization warranted further land filling activity and shoreline hardening, including bulk-heading and filling of the tributary streams that modified and generally raised the antecedent topography into its present-day configuration. Farms were displaced in favor of industrial and commercial land uses. Although some clusters of residential property and open space have existed or still exist near the PES Complex, most land in south Philadelphia has been used for industrial and commercial purposes for over 100 years (IST, 1998).

2015 Light Detection and Ranging (LiDAR) data obtained from the City of Philadelphia through the Pennsylvania Spatial Data Access (PASDA) (PASDA, 2017) indicates that present-day topography is relatively flat near the PES Complex, and land surface elevations generally range from a few feet below the North American Vertical Datum of 1988 (NAVD 88) near Mingo Creek to approximately 35 feet near the eastern boundary of the PES Complex in AOIs 1, 4, and 8 (**Figure 2-2**). Although subtle, the high-resolution LiDAR model displays topographically low areas that, based on location, likely correlate to the locations of former stream valleys (e.g., Franklin Delano Roosevelt Park). In addition to raising the land surface, much of the filled areas were either paved and/or rendered relatively impervious (**Figure 2-3**), which may have decreased rates of recharge to the water table and necessitated the construction of numerous sewers to convey stormwater runoff (combined with sewage) to the Schuylkill and Delaware Rivers, or deeper intercepting sewers. It is documented that much of the City of Philadelphia's underground wastewater and water supply infrastructure, constructed as early as the late-1800s, is susceptible to leakage either through construction anomalies or degradation through several decades of in-situ weathering (Paulachok and Wood, 1984). These conditions further alter the natural hydrology of the area and become important factors in evaluation of local water-table conditions.

2.2 REGIONAL GEOLOGY AND HYDROGEOLOGIC CONDITIONS

The PES Complex occurs within the up-dip limits of the Atlantic Coastal Plain, generally within two miles of the "Fall Line," where crystalline bedrock of the Appalachian foothills intersects the ground surface (outcrops) (**Figure 2-4**). The Atlantic Coastal Plain is a physiographic province that is defined as having relatively flat topography and as being underlain by a characteristic wedge of unconsolidated sediments that thicken in a southeasterly direction, away from sediment source areas in the Appalachian Mountains. These sediments were deposited atop a sloping bedrock surface in complex fluvial, estuarine, and marginal marine environments along the passive Atlantic margin. Overall, subsidence of the Piedmont land surface in conjunction with cyclical sea-level fluctuations have been the primary controlling mechanisms driving periods of deposition, non-deposition, and erosion in the Atlantic Coastal Plain (Trapp, 1992). In general, the resulting sedimentary record near the PES Complex is complicated, largely incomplete, and under-represented by only Cretaceous and Quaternary deposits, separated by a regional disconformity. Water-bearing sand bodies/units present within the Coastal Plain generally exhibit aquifer properties and where mappable can comprise one or more hydrostratigraphic units. A summary of the PES Complex deposits with correlation to regionally mapped geologic and hydrostratigraphic units is presented in succeeding sections. Conditions specific to AOI 8 are presented in **Section 5**.

2.2.1 Coastal Plain Deposits

2.2.1.1 Anthropogenic Fill

Much of the PES Complex and surrounding area is underlain by historical fill material, which was placed for the purpose of reclaiming lowlands along the banks of the tidal Delaware and Schuylkill Rivers during industrialization. These fill materials are heterogeneous in nature and have been described on borehole logs by others as a mixture of compacted soil and anthropogenic debris, including sand, clay, silt, gravel, cinders, concrete, asphalt, crushed stone, ash, glass, brick fragments, and wood. Apparent fill thickness ranges from a veneer where antecedent topography was highest to greater than 50 feet where it was used as railroad ballast just east of the PES Complex. Within the locations of former stream valleys and marshes (**Figure 2-1**), the historical fill material is generally 20 feet or greater in thickness. Stratigraphic Profile H – H’ (**Figures 2-5 and 2-6**) demonstrates this relationship as it bisects a topographic high that is flanked to the north and south by two former stream valleys filled with approximately 20 feet of materials (axial troughs are approximated along the profile by wells N-82 and S-404).

Fill materials at the PES Complex are observed as both saturated and unsaturated deposits depending primarily on topographic position. Generally, at locations distal to the Schuylkill River, fill occurs above the regional water-table under average hydraulic head conditions. However, fill may contain isolated lenses of groundwater (perched groundwater) in these areas where coarse or granular in nature and separated from the underlying water table by low permeability sediments. In exception, fill is observed to be saturated and/or in hydraulic connection with the water table along the axes of buried stream channels, where the water-table appears to intersect the fill (former gaining stream reaches). Lastly, where fill was placed to reclaim tidal wetlands fringing the area’s river estuaries, it can support a water table and may exhibit “aquifer-like” properties.

2.2.1.2 Quaternary Deposits

Quaternary sedimentary deposits are present beneath the PES Complex and are generally representative of geologically-recent cycles of deposition and erosion that occurred within the last 200,000 years. These cycles of sedimentation were the result of a series of glacial and interglacial periods, namely the Illinoian and Wisconsin glaciations, separated by an intervening interglacial period and followed by the present interglacial period through the Holocene (Sevon et al., 1999). Depositional environments through this period were primarily controlled by sea-level and the successive down-cutting and infilling of ancestral river valleys, primarily that of the Schuylkill and Delaware Rivers (Owens and Minard, 1979). Details of the Quaternary deposits present at the PES Complex are described in the following sections.

2.2.1.2.1 Recent (Holocene) Alluvium

Predominantly gray, muddy deposits with occasional sandy, gravelly, and organic-rich lenses comprise the most recent alluvium present at the PES Complex. These sediments were deposited in dynamic floodplain, channel, and marsh environments through the Holocene. As noted, the upper surface of alluvium, in most places covered by fill, defines the antecedent topography that pre-dated development under a large portion of the area of the PES Complex along the Schuylkill River. This geologic unit is generally restricted to elevations below present-day sea level and up to a few feet above sea level within former tidal wetlands and tributary valleys. The recent alluvium ranges in thickness from a few feet at its landward-most fringe along the Schuylkill River perimeter and up the axial troughs of tributary streams, to as much as approximately 60 feet thick (to elevations as low as approximately -70 feet NAVD 88). Where thickest, these deposits represent a transgressive sequence of backfilling of the Schuylkill River valley as it was drowned by rising sea level through the Holocene. **Figure 2-1** provides some estimation of how extensive the area's tidal marshes once were prior to development, existing generally along the Schuylkill River south of and surrounding Point Breeze. Stratigraphic profiles I – I', J – J', and L – L' exemplify this interpretation and distribution of the most recent alluvial deposits across AOI 8 of the PES Complex (**Figures 2-7, 2-8, and 2-10**).

As a result of its relatively young geologic age and stratigraphic position along the Schuylkill River and tributary creeks, most recent alluvium at the PES Complex is poorly consolidated and saturated with groundwater. However, it generally has limited water-transmitting capabilities due to its predominantly fine-grained texture. The regional water-table surface occurs within the Holocene alluvium in former marsh areas along the Schuylkill and Delaware River estuaries.

2.2.1.2.2 Pleistocene Alluvium

Geologically-recent glacial outwash deposits, commonly referred to informally as the "Trenton gravel," have long been recognized in southeastern Pennsylvania along the Delaware River valley. Sevon and Braun (2000) provide a comprehensive map of glacial deposits in Pennsylvania, including the presence of sand and gravel outwash, interpreted as stratified drift, along the present Delaware River. Owens and Minard (1979) published a comprehensive summary of previous research into these deposits and subdivided the "Trenton gravel" into two distinct deposits (the Spring Lake and Van Sciver Lake beds) based on topographical position and lithology at those type sections. Low et al. (2002) indicate that in most places the "Trenton gravel" rests directly atop Cretaceous sediments and is overlain by younger alluvium of Holocene age near the Schuylkill River. However, these and other interpretations available in literature and the nomenclatures utilized in Pennsylvania have been difficult to apply in a regional context when the geology mapped in neighboring states is considered.

Based on literature review, Stantec supports a more recent interpretation of the Pleistocene deposits in southeastern Pennsylvania presented by Jengo (2006) in which the stratigraphic nomenclature includes the glaciofluvial "Trenton gravel" as being spatially restricted to the lower portion of the Delaware River paleochannel, beneath the Holocene transgressive sequence of deposits. Time equivalent deposits identified as glacial-age tributary alluvium are also defined in that interpretation but are fluvial in origin. Most of the Pleistocene deposits in the area are interpreted by Jengo (2006) to be older, Sangamon-age interglacial deposits belonging to the Cape May Formation Unit 2 mapped across the Delaware River in New Jersey (Stanford, 2006) and south into Delaware (Ramsey, 2005), where the deposits are designated as undifferentiated Delaware Bay Group. Within the PES Complex and proximity where maximum land surface elevations rarely exceed approximately 35 feet NAVD 88, the Pleistocene alluvium within this regional geologic nomenclature is more appropriately assigned to the Cape May Formation terrace. For the purposes of this and other RIRs, it is considered reasonable to more generally describe the Pleistocene deposits as Pleistocene alluvium and distinguish them from the Holocene alluvium. This is primarily based on the lack of detailed stratigraphic data needed to make further distinctions. However, separating the Holocene from the Pleistocene provides enough interpretation to allow for better characterization of the near-surface deposits from a contaminant fate and transport perspective.

At the PES Complex, Pleistocene alluvium is commonly described on boring logs as a brown, reddish-brown or, where stained, black, fine to coarse sand with lenses of gravel. The gravel fraction is often multicolored and comprised of a mixture of sub-angular to sub-rounded, sedimentary and metamorphic rocks derived from the Appalachian Piedmont. Stratification is common and secondary lithologies include silt/clay beds with peat, silty sand, and silty gravel. The Pleistocene alluvium generally ranges in thickness from approximately 10 to 30 feet near the PES Complex. It is commonly capped by fine-grained, muddy deposits that are distinctly different from the Holocene alluvium. It appears to be mostly laterally continuous and its thickness depends on the antecedent Cretaceous topography that it filled and on the degree of erosion from above. Along the present-day Schuylkill River, Stantec has mapped Pleistocene alluvium to be present beneath thick sections of Holocene alluvium to elevations lower than -70 feet NAVD 88 (**Figures 2-7, 2-8, and 2-10**). This is interpreted to represent glacial-age tributary (Schuylkill River) alluvium in the context of Jengo (2006).

The regional water-table at the PES Complex most often occurs within the Pleistocene alluvium. As a result of its stratigraphic position, this geologic unit comprises a significant portion of the water-table aquifer (along with the Potomac-Raritan-Magothy [PRM] aquifer system sand units where they subcrop and localized areas of saturated Holocene alluvium and fill). Published well records indicate that the "Trenton gravel" (Pleistocene alluvium) can be a prolific aquifer (Paulachok, 1991). Nevertheless, due to lateral changes in thickness and to its heterogeneous character, hydraulic properties and groundwater yields can vary widely. Stantec reviewed published data and available onsite aquifer testing data regarding the hydraulic properties of the water-table aquifer and has summarized that data on **Figure 2-11**. It is noted that although most wells tested at the PES Complex and shown on **Figure 2-11** are predominantly screened through Pleistocene deposits, some test results may represent the hydraulic properties of other geologic units that locally comprise a portion of the water-table aquifer, such as the PRM upper sand unit. As discussed in **Section 5** of this RIR, that statement can be expanded to include the middle and/or lower sand unit(s) in the northern reaches of AOI 8 (where the middle clay unit regional aquitard is interpreted to be absent).

Of particular importance to this RIR are water-table aquifer hydraulic property data resulting from a nearly 7-day groundwater extraction test conducted at recovery well RW-2 at the PES Complex (IST, 1998). During testing, RW-2 was pumped at a constant rate of 225 gallons per minute (gpm). Distance-drawdown data analyzed along transects of observation wells suggested that the area of influence extended approximately 1,680 feet from the pumping well under relatively isotropic conditions. Three of the observation well transects were at least partially in AOI 4. The hydraulic conductivity (k) was estimated to be greater than 400 feet per day (ft/d). More recently, a 24-hour pumping test was conducted at the former DSCP property at monitoring well DSCP-MW-65, a well that appears to be screened across the Pleistocene and into underlying sandy Cretaceous deposits (ARCADIS, 2013). Analysis of that data provided in the referenced report supports comparable aquifer properties at the DSCP property. However, it is noted that during the test, the “Trenton gravel” was reportedly dewatered and individual aquifer or geologic unit k values could not be calculated/resolved. Other, in-situ, single well instantaneous displacement tests and short-duration pumping tests for remedial system design suggest a lower k for the Pleistocene, on average, but test results vary widely, from less than 1 ft/d to over 600 ft/d. The observed wide range in k values over relatively short distances is consistent with the water-table aquifer’s lithologic heterogeneity which can be attributed in most part to the nature of the Pleistocene deposits.

2.2.1.3 Cretaceous Deposits

Many studies of the Atlantic Coastal Plain near the PES Complex have identified the presence of Cretaceous-age sediments in the subsurface. **Figure 2-3** depicts the subcrop areas of Cretaceous geologic units across the Delaware River in New Jersey. Extrapolation of the units into Pennsylvania has not been formally completed. These are the oldest sedimentary deposits in the area and are configured in a southeasterly-thickening wedge, overlain by the much younger Quaternary deposits described above and underlain by Piedmont crystalline bedrock. Greenman et al. (1961) detailed the age, character, configuration, and hydraulic properties of these deposits in southeastern Pennsylvania. At the time of that publication, the Cretaceous deposits were assigned primarily to the Raritan Formation and noted to represent three distinct, fining-upward cycles of non-marine sedimentation. Similarities to lithologic sequences identified on borehole logs were correlated to previously-identified strata at their type locality in New Jersey, where the deposits are much thicker and more easily distinguished. Other similar, near time-equivalent geologic formations of Cretaceous age were elsewhere identified in Maryland and Delaware (Jordan, 1962), and geologists began wholly referring to the Cretaceous deposits in south Philadelphia as the PRM aquifer system with focus on hydrostratigraphy.

In south Philadelphia, the PRM aquifer system is subdivided into six geologic units in order of increasing age (Schreffler, 2001):

- upper clay unit
- upper sand unit
- middle clay unit
- middle sand unit
- lower clay unit
- lower sand unit

Sugarman (2017) utilized recent borehole data from offshore drilling to refine understanding of the PRM aquifer system relevant to the study area, which indicate that the lower and middle sand units (aquifers) correlate to the Potomac Formation and the upper sand unit likely correlates to the Magothy Formation. Near the PES Complex, it is generally true that the PRM units are discontinuous, relatively thin, intercalate, and exhibit gradual facies changes that make separation of individual units difficult. Where sand units are present discretely or in continuity with other sandy deposits, they can form a deeper (lower) aquifer at the PES Complex or account for a portion of the water-table aquifer. Total thicknesses of PRM deposits at the PES Complex ranges from 0 feet, where Quaternary deposits are present atop bedrock, to more than 100 feet within paleochannels incised into an irregular bedrock surface. Details of the individual units and bedrock configuration based on boring log records and published descriptions are presented in the following sections.

2.2.1.3.1 Upper Clay Unit

The upper clay unit is a variegated clay/silt that is sometimes discernible from older clay units of the PRM where sandy and gravelly. In general, it is thin when compared to the other PRM clay units in south Philadelphia, and in places distal to the Delaware River, the upper clay may be entirely absent (Greenman et al., 1961). On the basis of geophysical log signature, others have mapped the upper clay to be at least 0.5 feet thick and up to 30 feet thick at the PES Complex, exhibiting its greatest thickness in northern portions of the PES Complex while pinching out to the south (IST, 1998). At the PES Complex, Stantec has assigned the upper clay to first occurrences of light brown, tan, mauve, yellow, gray, and less-commonly, red sandy, silty clay beneath the Quaternary alluvium. However, overall stratigraphic correlation of the PRM across the PES Complex supports the upper clay unit pinching out or being truncated by younger deposits throughout most of the AOIs (**Figures 2-6 through 2-10**).

The upper clay unit by nature acts as a confining or leaky confining bed. Where present, it can create hydraulic separation between the upper sand unit and overlying Quaternary deposits.

2.2.1.3.2 Upper Sand Unit

The upper sand unit is a varicolored but predominantly brown to gray sand with varying amounts of gravel, clay, and silt (Greenman et al., 1961). Nearer the PES Complex, it has been described as mostly silty and/or clayey fine to medium sand (IST, 1998). Where the upper clay is absent, the upper sand occurs directly beneath, and is typically discernable from, the overlying coarser, poorly-sorted, and more heterogeneous Pleistocene alluvium. Stantec used color and lithologic changes, in addition to subtle changes in drilling conditions including Standard Penetration Test (SPT) blow counts, to make “picks” on upper sand occurrences where the upper clay is absent. In general, the upper sand appears most extensive beneath northern portions of the PES Complex (AOIs 1, 2, 3, 4, and 8) where it subcrops Pleistocene alluvium. Beneath the northernmost reaches of the PES Complex, the upper sand may subcrop fill (**Figure 2-9**). The upper sand unit, where present, rarely exceeds 10 to 20 feet in total thickness and is thickest along the axes of troughs cut into the middle clay unit.

The upper sand unit is an excellent aquifer where its thickness and extent are sufficient (Greenman et al., 1961). Aquifer testing of the upper sand unit in New Jersey has indicated that the aquifer has similar hydraulic properties to the middle and lower sand units where discrete (Navoy and Carleton, 1995). At the PES Complex, Stantec did not identify any existing testing data for wells discretely screened within the upper sand unit from which to infer sole hydraulic properties of that unit. The upper sand is fairly continuous along eastern areas of the PES Complex but generally occurs in pockets nearer the Fall Line where bedrock is shallower, and is entirely missing in places along the Schuylkill River. The upper sand unit comprises a portion of the water-table aquifer. Most wells that fully penetrate the water-table aquifer in northern areas of the PES Complex may intersect and be influenced by the hydraulic properties of the upper sand.

2.2.1.3.3 Middle Clay Unit

Whereas other clay units of the PRM are described as being sandy and gravelly in places, the middle clay unit is generally regarded as being a laterally extensive and uniformly massive confining bed of thick, red and white clay with very little sand (Greenman et al., 1961). Near the PES Complex, others have found the middle clay to be nearly continuous in the subsurface (IST, 1998). Based on boring log review and stratigraphic correlation, Stantec would agree with these previous findings and has mapped the middle clay unit of the PRM to be the most persistent of the clay units at the PES Complex. However as discussed in **Section 5** of this RIR, it is missing in places along the perimeter of the Schuylkill River, including an area in AOI 8. Where present, thickness of the middle clay unit generally ranges from less than one foot to more than 20 feet. The middle clay's characteristically muddy texture can vary and become finely-laminated/bedded and intercalated with muddy sand. Downgradient, nearer AOI 9 and the George C. Platt Bridge, some pockets or thin lenses of middle and/or lower clay may be present under a thick section of Quaternary alluvium and upper sand. At other locations beneath the PES Complex, the middle and lower clay units appear to be in direct contact with each other (where the middle sand is absent).

The middle clay unit, in places resting directly on and combining with the lower clay unit, acts as a significant confining bed at the PES Complex. In a regional context, it creates hydraulic separation between the water-table aquifer and deeper, semi-confined aquifer of the middle and/or lower sand units. However, where it appears to be thin and sandy, most notably in the southeastern area of AOI 1, there may be more potential for vertical exchange between groundwater of the deeper aquifer and water-table aquifer, the direction and magnitude of which would depend upon the vertical hydraulic gradients at the time. As noted above, there is also an area in AOI 8 where the middle clay is missing.

2.2.1.3.4 Middle Sand Unit

The middle sand unit is a light-colored, stratified, fine to coarse sand with occasional gravel and clay that was generally deposited in lenticular masses along the axes of troughs carved into the lower clay unit (Greenman et al., 1961). As such, it is by nature discontinuous in the subsurface. Stantec has mapped the presence of middle sand at the PES Complex based on stratigraphic position and where present, is commonly described on boring logs as brown or orange sand and gravel. In some areas where the lower clay was entirely removed by erosion, it may be indistinguishable from and rest unconformably atop the lower sand unit. At those locations, Stantec used subtle changes in sample descriptions, including color, density, and/or texture, of the sequences of sand below the middle clay to infer the contact between those units (in many places the top of the lower sand is fine to medium-grained, white sand with a trace of clay). The middle sand unit, where discernable from the lower sand, has been observed at thicknesses up to approximately 30 feet beneath the PES Complex and is generally thickest in lenticular or tabular bodies.

Much like the other sand units of the PRM, the middle sand unit can be a prolific aquifer where it is laterally continuous and of sufficient thickness. Aquifer testing of the middle sand in New Jersey has indicated that the aquifer has similar hydraulic properties to the lower sand unit (Navoy and Carleton, 1995). At the PES Complex, Stantec did not identify any wells discretely screened within the middle sand unit from which to infer sole hydraulic properties. "Deep" wells at the PES Complex are generally screened in the lower sand, or potentially across the lower and middle sand units, where hydraulically connected.

2.2.1.3.5 Lower Clay Unit

Published descriptions of the lower clay unit indicate that it appears very similar to, and is sometimes inseparable from, the middle clay unit where the middle sand is absent. The lower clay is generally tough, red clay but is known from drilling records to contain softer zones of gray clay stratified with fine sand. The lower clay tends to exhibit its greatest thickness along the lateral margins of paleochannels in underlying bedrock, and can be thin to absent along the axes of paleochannels where eroded prior to deposition of the middle sand unit (Greenman et al., 1961). Of the PRM clay units, Stantec has interpreted the lower clay unit to be the least significant at the PES Complex in terms of both its lateral extent and vertical thickness. This is based on stratigraphic correlation and likely the result of erosion prior to deposition of the middle sand. Generally gray and red, commonly sandy clay and muddy sand zones were assigned to the lower clay if observed below and distinguishable from the middle clay. Where present, the lower clay was observed at thicknesses ranging from less than 1 foot to no greater than 10 feet. The lower clay appears to thicken and become more continuous to the south and east of the PES Complex.

Where physically connected, the lower and middle clay units combine to form a significant confining bed at the PES Complex. In a regional context, they create hydraulic separation between the water-table aquifer and deeper, semi-confined aquifer of the lower/middle sand units. The lower clay can also create localized areas of hydraulic separation between the lower and middle sands, where discretely present.

2.2.1.3.6 Lower Sand Unit

The lower sand unit is a varicolored but predominantly white to yellow sand with gravel, usually fining upward to a cap of fine to medium sand with occasional yellow and gray clay lenses. The lower sand unit is the oldest of the PRM deposits and rests unconformably atop bedrock. The lower sand is generally thickest (up to 87 feet thick) along the axial troughs of paleochannels carved into bedrock by discharge through former positions of the Schuylkill and Delaware Rivers (Greenman et al., 1961). At the PES Complex, Stantec recognizes the lower sand unit to be present as a nearly continuous deposit, with the exception of areas proximal to the Schuylkill River where it appears that the river entirely removed the PRM. Where present, the lower sand unit is observed to range in thickness from approximately 20 feet to a maximum of just over 50 feet, where it fills a bedrock paleochannel beneath a portion of AOI 1. Borehole logs from the PES Complex indicate that the lower sand unit is commonly yellow, white, and pale gray in color and predominantly medium to coarse sand with gravel, or gravel with sand. The lower sand's gravelly texture beneath the PES Complex has been well documented on drilling logs.

Of the PRM aquifer system and Quaternary deposits present, it can be argued that the lower sand unit was historically the most important groundwater resource in south Philadelphia. **Figures 2-12 and 2-13** summarize hydraulic information available for the lower sand unit (considered the lower aquifer at the PES Complex) based on estimates obtained from well testing at the PES Complex (see **Sections 4.5** and **5.2.3**) and published aquifer testing results. Historically, the only identified aquifer test data available for the lower aquifer at the PES Complex was collected from wells near the guard basin in AOI 3 during the early 1990s by ENSR.

At the Philadelphia Naval Shipyard (PNSY), historical pumping test data are available providing estimates of regional hydraulic properties for the lower sand unit that can be reasonably applied to the lower aquifer at the PES Complex. This data indicates an average k value of approximately 134 ft/d (Greenman et al., 1961). Other regional data from Greenman et al. (1961) are also presented on the figures. Adjacent properties investigated by others under Act 2 with available hydraulic property data for the lower aquifer include the PGW Passyunk Facility (WESTON, 2004) and Verizon SDWC Property (lower aquifer subcrop area) (Leidos, 2015).

At the PES Complex, Stantec has recently completed slug and short-duration pumping tests of 7 wells open to the lower aquifer (see **Sections 4 and 5** for a discussion of those tests in AOI 8). Values of k estimated for the lower aquifer from the slug testing range from approximately 66 ft/d to more than 800 ft/d and may include hydraulic properties of the middle sand, lower sand, and/or Pleistocene alluvium (glacial-age tributary alluvium beneath the Schuylkill River) (**Figure 2-12**). Values of k estimated for the same wells from short duration pumping tests (analysis of drawdown and recovery data) tend to be smaller than those from the slug tests, as a larger portion of the undisturbed aquifer is influenced. Across the Delaware River in New Jersey, lower sand unit k values from pumping tests are documented to be slightly higher, on average (**Figure 2-13**).

2.2.2 Bedrock

Bedrock beneath the Coastal Plain near south Philadelphia has been inferred from surface outcroppings above the “Fall Line,” and has been described in the subsurface where penetrated by past drilling activities. Bosbyshell (2008) has mapped schist of the Wissahickon Formation to occur in Philadelphia along the “Fall Line” (**Figure 2-4**). Relatively small bodies of granitic gneiss, resulting from igneous intrusions into the country rock during metamorphism, can also be present. Most boring log records of deep holes drilled at the PES Complex indicate that schist or saprolite with a schistose fabric is present beneath the Coastal Plain, in agreement with published maps.

Available data pertaining to the bedrock surface beneath the PES Complex suggests that the surface generally dips to the southeast but contains local complexity. Greenman et al. (1961) recognized the presence of four paleochannels incised into bedrock and attributed those features to previous positions of the Schuylkill River. Two of those channels, referred to as the Point Breeze Trough and League Island Trough by those authors, occur beneath parts of the PES Complex and influence the total thickness of the Coastal Plain sedimentary sequence above them. **Figure 2-14** was developed from the Greenman et al. (1961) dataset and was refined by Stantec to increase the data density of boreholes to bedrock near the PES Complex. The resultant structure contour map shown in the figure includes identified boreholes to bedrock at the PES Complex, along the Interstate 95 approach to the Girard Point Bridge (PennDOT, 2017), and the former DSCP property. Refinement of the Greenman et al. (1961) dataset has revealed local detail in the bedrock surface underlying the area, including small bedrock paleochannels beneath the eastern portions of AOIs 1 and 4 that appear to be extensions of the League Island Trough, and a few localized bedrock surface highs (pinnacles) particularly within AOI 8 and near the mouth of the present-day Schuylkill River.

In general, bedrock can store and transmit groundwater primarily through secondary porosity structures (e.g., fractures, joints). Bosbyshell (2008) indicates that the Wissahickon Formation can yield up to 20 gpm to wells in the mapped area above the "Fall Line." Balmer and Davis (1996) indicate that in Delaware County, Pennsylvania, the Wissahickon Formation is the most productive of the consolidated rock aquifers present in that county and can yield anywhere from 0 gpm to 300 gpm to wells (data from 127 wells). However, the wells included in their report were generally located above the "Fall Line" and were not screened below significant accumulations of Coastal Plain sediments. In general, when compared to the permeability and thickness of the Coastal Plain deposits, the water-bearing properties of the Wissahickon Formation beneath the PES Complex are considered de-minimis for the purposes of this and other RIRs.

3.0 SOIL INVESTIGATION

The following sections summarize the soil investigation activities performed in AOI 8. Previous investigations are summarized in **Section 3.1**. The remainder of the soil investigation activities described were conducted for this RIR between 2013 and 2016 by Aquaterra and Stantec, on behalf of Evergreen. The goal of the investigation was to characterize soil in potential contaminant source areas, including historic product handling and storage locations, open storage tank incident areas, and known product releases. A secondary goal of the soil characterization was to delineate Coastal Plain strata and correlate those observed to published geologic units in areas of data gaps, where additional wells were deemed not necessary. In addition to collecting soil samples from borings advanced for the source-targeted soil investigations, soil samples were collected during monitoring well installation activities regardless of whether the area was expected to contain a source of petroleum compounds in soil, except for AOI8-BH-16-001D which was installed to characterize stratigraphy. Soil sample data collected as a part of PES investigations were evaluated and results included for investigations performed up to the time of this RIR.

All characterization fieldwork was performed in accordance with Evergreen's *Quality Assurance/Quality Control Plan and Field Procedures Manual* (**Appendix C**). Soil borings were advanced using a variety of methods including hand auger, backhoe, split spoons sampling. The general strategy for the RI was to characterize soil in the 0-2 ft bgs and greater than 2 ft bgs intervals (unsaturated soil). Generally, subsurface soil samples were collected at the depth exhibiting the highest photoionization detector (PID) response and/or above the water table. Delineation was performed to the highest of the SHS, the NRDC MSCs, and the numeric SSS (for lead) as defined in **Section 1.6**. **Table 3-1** summarizes the soil boring rationale for the 2016 investigation activities, and soil boring logs are included in **Appendix D**. All soil analytical results are summarized on **Table 3-2**, which compares the results to the non-residential SHS (as defined in this report, the more stringent of the soil to groundwater numeric value and the direct contact value), and **Table 3-3**, which compares the results to the NRDC MSC and the lead SSS. Samples were analyzed for the Evergreen Comprehensive List (**Table 1-2**) or a shorter list of analytes, if deemed appropriate in a specific situation (i.e. delineation of individual compound exceedances). MEK was added for soil borings collected near the former MEK plant, as noted on **Table 3-1**. Analysis of soil samples was conducted by Pennsylvania-accredited Laboratories. All laboratory analytical reports for investigation work conducted between 2013 and 2016 are included in **Appendix E**.

3.1 SUMMARY OF PREVIOUS SOIL ANALYTICAL RESULTS

As part of the site investigation program conducted in 2008, several soil borings and monitoring wells were completed under the supervision of Aquaterra (Langan, 2005). Associated soil sampling results are provided in **Tables 3-2** and **3-3**. These samples were collected from the 0-2 ft bgs interval, and analyzed for the Evergreen Petroleum Short List. One soil boring and several monitoring wells were completed under site characterization activities in 2013 by Stantec. Shallow (0-2 ft bgs) and deep (2-15 ft bgs) soil samples collected from these locations, were analyzed for the Evergreen Comprehensive List, and the analytical results are presented on **Tables 3-2** and **3-3**. NRDC MSC exceedances were noted in several samples, and are discussed in **Section 3.5** below.

Most ASTs in AOI 8 were removed prior to The Storage Tank and Spill Prevention Act 32 of 1989; however, some soil samples have been collected for tank closures and tank related incidents regulated under 25 PA Code Chapter 245, in addition to characterization soil sampling that has been performed as part of the Act 2/One Cleanup program. Although the rationale and results of these soil sampling projects are not discussed in detail in this RIR, as they have been submitted to PADEP under 25 PA Code Chapter 245 reporting, they are relevant to the characterization of AOI 8 under Act 2. The analytical results for these tank-related assessments are included on **Tables 3-2** and **3-3**, and the soil sample locations are shown on **Figure 3-1**. The investigation of open storage tank incidents was performed as part of the field effort for this RIR, and those results are discussed in the following sections.

3.2 HISTORIC PRODUCT HANDLING/STORAGE AREAS

Until circa 1970, refined petroleum products were distilled, blended, transferred, and stored in the Point Breeze Refinery North Yard. Historic refinery plans indicated that many former ASTs associated with this refinery unit were closed prior to the effective dates of requirements of The Storage Tank and Spill Prevention Act 32 of 1989. As such, records of historic incidents associated with these ASTs and units do not exist or are not readily available. However, based on the previous site usage, additional soil sampling was completed to investigate potential petroleum source areas in soil where existing soil data is unavailable over large areas of AOI 8. These characterization and subsequent delineation soil boring locations (AOI8-BH-16-001D through AOI8-BH-16-063, and AOI8-BH-079 through AOI8-BH-16-083) are shown on **Figure 3-1**. Soil samples were also collected during monitoring well installations in addition to the soil boring locations. Soil sample NRDC MSC or lead SSS exceedances are discussed in the following sections.

A Land Treatment Unit is present in AOI 8 and is actively sampled under RCRA Closure and Post-Closure monitoring activities. No further sampling was completed in this area. Additionally, no sampling was conducted within the active Point Breeze North Yard Crude Rail and siding areas due to safety and existing impervious cover providing pathway elimination.

According to historic records, a release occurred at a sump along the Rambo Creek Sewer located southeast of the No. 22 Boiler House (**Figure 1-3**). On July 3, 2010, oil was discovered in and around the sump, which occurred because of discharge backup at the Klondike Separator. According to historic correspondence, the release was cleaned up and limited soil sampling was conducted in the area of the spill in 2013. However, results from the sampling are not available and no soil disposal documentation was located. The area was redeveloped during the construction of the Point Breeze North Yard Crude Rail project. Significant cut-and-fill activities occurred and the sump was filled in to grade. No additional remedial investigation activities were completed related to this incident, since the area is an active railroad.

PES North Yard Ball Field – Moore Street and South 35th Street

The PES North Yard Ball Field, located in the northern portion of AOI 8, was identified as the location of a former lead smelter known as Metallurgical Products. In 2009, separate investigations were conducted by TetraTech and NewFields, LLC to characterize the lead in soils at the PES North Yard Ball Field under the supervision of the USEPA. NewFields, LLC used a portable x-ray fluorescent spectrometer (XRF) to obtain surface concentrations of lead in 27 soil samples across the area. A second investigation was performed by Tetra Tech and included XRF lead readings at 29 locations. In addition, four soil samples (MP-01 through MP-04) were collected for laboratory lead analysis. Copies of these investigation reports are included in **Appendix A**. The location and results of the four laboratory soil samples are shown on **Figure 3-1**. Due to the current use of the PES North Yard Ball Field, the soil sample results were compared to the residential SHS.

Sludge Weathering Pads

Two sludge weathering pads existed during the refinery's history in the PBNY. One of the pads, SWMU 2, consisted of the former leaded tank bottom treatment area, also referred to as the sludge weathering pad (ENSR, 1992). According to PES, a second, leaded sludge weathering pad was historically operated in the southeast corner of the PBNY LTU under RCRA Interim Status until it was closed circa 1990. No additional information discussing this pad has been identified. Operations at SWMU 2 date back to the 1940s, when lead sludges were deposited into a pit at the location of the SWMU concrete pad. Between 1959 and 1975, the concrete pad served as a foundation for a building. After the building was demolished in 1975, the concrete pad was used for sludge weathering until 1980 (ENSR, 1992). Test trenching and soil sampling around the concrete pad were completed by ENSR as part of a refinery-wide RCRA Investigation. Additional characterization was completed in 2008 by Langan (Langan, 2012), which included six characterization borings and one soil sample for total lead and Toxicity Characteristics Leaching Procedure (TCLP) lead. Furthermore, soil borings AOI8-BH-16-015, AOI8-BH-16-028, and AOI8-BH-16-029 were completed during the 2016 RI activities in the vicinity of SWMU 2. Shallow and deep soil samples were collected and analyzed for the Evergreen Comprehensive List of COCs. Concentrations of COCs did not exceed the SHS or NRDC MSCs for any soil samples.

In a letter to the EPA Region III dated February 16, 2016, GHD Services, Inc. (GHD) requested formal SMWU 2 closure. This request was granted by the EPA in a letter dated November 29, 2016.

3.3 CLOSED STORAGE TANK INCIDENTS

This section provides descriptions of soil investigations related to recently closed storage tank incidents. Evergreen has addressed historic AOI 8 storage tank incidents for which it is responsible through the 25 PA Code Chapter 245 CAP Program (PADEP, 2001) under separate cover. Review of past activities indicated that one incident (31920) did not require any additional characterization work; however, four incidents (46786, 5912, 5914, and 45965) required further characterization and delineation. All storage tank incidents are summarized on **Table 3-4**. Soil characterization activities were conducted to further investigate several storage tank incidents within AOI 8. For borings associated with storage tank incidents that involved releases within tank berms, soil analytical results are presented in this RIR for informational purposes only as they relate to overall AOI 8 soil characterization.

A Site Characterization Report/Remedial Action Completion Report (SCR/RACR) was submitted for incident nos. 31920, 5912, 5914, and 45965 (Stantec, 2017b). This SCR/RACR was approved by PADEP in a letter dated August 14, 2017. The open incident, no. 46786 for PB 663, requires additional remedial action as discussed further in this section.

PB 552 (Incident 31920)

Tank PB 552, historically used to store gas oil, was permanently closed-in-place and removed in 2003. As part of tank closure activities, eleven soil borings (AOI8-GP-1 through AOI8-GP-11) were completed along the perimeter of the tank. This tank was noted to be situated about 10% underground; as such, the soil sampling was conducted in accordance with a site assessment protocol specified by the PADEP Southeast Regional Office to roughly follow the Technical Guidance Document for Closure Requirements for Underground Storage Tanks (USTs). One soil sample was collected above the water table (8-14 ft bgs) from each soil boring and analyzed for benzene, toluene, ethylbenzene, total xylenes, isopropylbenzene, flourene, naphthalene, and phenanthrene. Four of the eleven soil samples exceeded the SHS for naphthalene; therefore, a Notice of Reportable Release (NORR) was submitted to the PADEP on July 8, 2003. Soil samples did not exceed corresponding NRDC MSCs for any COCs.

PB 663 (Incidents 34422 and 46786)

On April 25, 2004, approximately 158 gallons of gas oil was released into the tank PB 663 containment area, from a leak in the 8-inch header at the tank field manifold. Subsequently, an NORR was submitted to the PADEP on May 7, 2004, and incident No. 34422 was assigned to this release. As part of interim remedial activities, the released material was recovered using vacuum trucks and absorbent pads with approximately 42.7 tons of impacted soils disposed of off-site, and the excavated area was covered with crushed stone. Post-excavation soil sampling was completed in June 2004, with collection of four shallow (0.5 ft bgs) samples, and analyzed for the PADEP short list of parameters for fuel oil nos. 4, 5, and 6. Exceedances to the SHS and NRDC MSCs were found; however, a stone cap was established in the area of these exceedances. A Site Assessment Report dated November 24, 2004 was approved by PADEP as a SCR/RACR, with a contingency to provide a post-remedial care plan (PRCP).

During an out-of-service tank inspection in May 2011, 23 holes were found in the tank floor. No visual evidence of leaks was found during the inspection process; therefore, characterization soil sampling was not performed at the time. Incident No. 46786 was assigned to this suspected release. During the AOI 8 remedial investigation activities in 2016, three soil borings (AOI8-BH-16-059 through AOI8-BH-16-061) were completed around the perimeter of tank PB 663. Two samples (shallow and deep) were collected and analyzed for the Evergreen Comprehensive List of COCs. A NRDC MSC exceedance of benzo(a)pyrene in one boring and SSS exceedances of lead were detected in two soil borings. Therefore, additional delineation borings, AOI8-BH-16-079, AOI8-BH-16-080, and AOI8-BH-16-083 were completed, as discussed further in section 3.5 below. Due to the observed NRDC MSC and lead SSS exceedances at this tank and required PRCP for previously closed incident No. 34422, the open incident related with PB 663 was detailed in a separate Site Characterization Report (SCR), submitted to the PADEP on July 5th, 2017 (Stantec, 2017c). The SCR was approved by the PADEP in a letter dated September 21, 2017.

PB 669 (Incident 5912)

On September 16, 2000, a leak from the steam coil caused the release of approximately 200 gallons of gas oil within the tank containment area of PB 669. As part of interim remedial measures, the free product was recovered via vacuum trucks, and contaminated soils were proposed to be excavated. No evidence of characterization soil sampling is available; therefore, two soil borings (AOI8-BH-16-062 and AOI8-BH-16-073) were completed in the area of the former tank containment berm as part of the AOI 8 RI activities. Two soil samples were collected from each soil boring and analyzed for the Evergreen Comprehensive List of COCs. In addition, shallow and deep soil samples were collected in 2013, at monitoring well N-146 to the southwest of tank PB 669, and analyzed for the Evergreen Comprehensive List of COCs. One sample exceeded the SHS for lead; however, the concentration did not exceed the lead SSS. No COCs exceeded the NRDC MSCs.

PB 1937 (Incidents 5912 and 45965)

According to internal and PADEP records, two open incidents are listed for tank PB 1937. No documentation or information is available for Incident No. 5914 (dated 8/5/1989); however, a record of phone notification to PADEP regarding a 840-gallon gas oil release was noted on 2/7/1995. No evidence of characterization soil sampling is available for either incident; therefore, four perimeter soil borings (AOI8-BH-16-074 through AOI8-BH-16-077) were completed within the tank containment area of former tank PB 1937. Two soil samples were collected from each soil boring and analyzed for the Evergreen Comprehensive List of COCs. Samples did not exceed the NRDC MSCs for any COCs.

3.4 HISTORIC RELEASES

As part of the remedial investigation under Act 2, historic releases that could have created sources for hydrocarbons in soil were identified as reasonably practicable. In order to identify areas that would require further investigation, a review of internal PES Complex files was performed in September 2014. No record of historic releases in AOI 8 were discovered during this process, as such additional soil investigations were not required in AOI 8.

3.5 DELINEATION OF DIRECT CONTACT MSC/SSS EXCEEDANCES

To characterize the horizontal and vertical extent of identified contamination in AOI 8 soil (up to the time of this RIR), areas exhibiting exceedances of the non-residential direct contact MSC and the SSS for lead were delineated. These areas and associated investigations are described below.

- Two surface soil samples collected north of Tank PB 663 (0.0-0.5 feet bgs) exhibited exceedances of the NRDC MSCs. These samples were collected from an area now covered by a surficial stone layer providing pathway elimination. The stone cap continues to provide pathway elimination, and as such, additional soil sampling was not conducted. This is the area associated with Incident 34422, which requires a PRCP as discussed in Section 3.3 above.

- The surface soil sample collected from monitoring well N-99 required vertical and horizontal delineation for a benzo(a)pyrene NRDC MSC exceedance. Three additional soil borings (AOI8-BH-16-070, AOI8-BH-16-071, and AOI8-BH-16-072) were completed around the perimeter of N-99, within approximately 10 feet from the N-99 well pad. Shallow soil samples were collected from each boring and analyzed for benzo(a)pyrene. All sample results were below the NRDC MSC for benzo(a)pyrene.

- The surface soil sample collected from soil boring BH-08-34 (adjacent to N-2) required delineation for benzo(a)pyrene NRDC MSC exceedance. Three additional soil borings (AOI8-BH-16-067, AOI8-BH-16-068, and AOI8-BH-16-069) were completed, within about 10 feet of BH-08-34. Shallow soil samples were collected from each boring and analyzed for benzo(a)pyrene. All sample results were below the NRDC MSC for benzo(a)pyrene.

- The surface soil sample collected from monitoring well N-123 required delineation for benzo(a)pyrene NRDC MSC exceedance. Three additional soil borings (AOI8-BH-16-064, AOI8-BH-16-065, and AOI8-BH-16-066) were completed, within approximately 10 feet of the N-123 well pad. Shallow soil samples were collected from each boring and analyzed for benzo(a)pyrene. All sample results were below the NRDC MSC for benzo(a)pyrene.

- The surface sample at AOI8-BH-16-059 required delineation to the south and west for lead SSS exceedance. Two additional borings (AOI8-BH-16-079 and AOI8-BH-16-080) were completed, and shallow samples were collected from each boring for lead analysis. All samples were below the lead SSS.

- The surface sample at N-154 required delineation to the northwest for lead SSS exceedance. AOI8-BH-16-078 was completed to the northwest of N-154; however, the shallow sample from that location also exceeded the lead SSS. One additional boring (AOI8-BH-16-082) was completed further to the northwest, and a shallow sample was collected for lead analysis. Sample results were below the lead SSS.

- The surface sample at AOI8-BH-16-006 required delineation to the northwest for benzo(a)pyrene NRDC MSC exceedance. One additional boring (AOI8-BH-16-081) was completed, and a shallow sample was collected for benzo(a)pyrene analysis. Sample results were below the NRDC MSC for benzo(a)pyrene.

- The surface sample at AOI8-BH-16-061 required delineation to the northwest for benzo(a)pyrene NRDC MSC exceedance. One additional boring (AOI8-BH-16-083) was completed, and a shallow sample was collected for benzo(a)pyrene analysis. Sample results were below the NRDC MSC for benzo(a)pyrene.

- Lead SSS exceedance was observed in surface sample at AOI8-BH-16-033. Lead concentration in subsurface sample from this location is below the lead SSS. This exceedance is broadly delineated by samples in nearby borings (BH-08-11, BH-08-12, BH-08-17, N-122)), where lead in samples are below the lead SSS.

4.0 GROUNDWATER INVESTIGATION

4.1 HISTORIC GROUNDWATER INVESTIGATIONS

Many groundwater investigations have been conducted within AOI 8 and the surrounding offsite area evaluated in this RIR. From those investigations identified through historical document review, the oldest well logs indicate that the installation of monitoring wells occurred at the PES Complex as early as 1982. Most of the investigations that span multiple properties appear to have been performed in response to suspected releases of petroleum substances to the subsurface based on the identification of petroleum odors in area sewers, observations of LNAPL in excavations, or operational losses. Previous consulting reports describe the purpose, methodologies, and present the results of historic groundwater sampling events performed in conjunction with the investigations. On behalf of Evergreen, Stantec identified, collected, and included as much of the historical subsurface information as was feasible in this RIR. That data includes well construction details and well logs, summarized on **Table 4-1** and included in **Appendix D,** and available analytical data collected from historic reports for wells located in AOI 8, which includes results dating back to 1985. **Table 4-2** presents groundwater analytical results for water-table aquifer wells, and **Table 4-3** presents groundwater analytical results for lower aquifer wells. In addition to onsite data, relevant offsite analytical data for the Verizon SDWC Property and PGW Passyunk Facility has been included in this RIR for the fate and transport assessment presented in **Section 9**.

4.2 WELL INSTALLATION ACTIVITIES

This section describes well installation activities that were performed as part of the AOI 8 remedial investigation. Activities are discussed by purpose to clarify characterization goals. All fieldwork was performed in accordance with the *Evergreen Field Procedures Manual* (**Appendix C**). Monitoring well locations are shown on **Figure 1-2**. Well logs, including both lithologic and well construction details, are included in **Appendix D**. Well construction details are also summarized on **Table 4-1**. The following sections discuss the well installation strategy/rationale, which is also summarized on **Table 3-1**.

4.2.1 Water-Table Monitoring Well Installations

To aid in refinement of hydraulic gradients near the points of compliance, replace key wells previously destroyed, and to complete the horizontal delineation of dissolved-phase COC and LNAPL impacts in the water-table aquifer, six monitoring wells (N-150, N-151, N-152, N-153, N-154, and N-156) were installed within AOI 8 as part of RI activities. Evergreen installed two additional wells, N-155 and N-157, within the timeframe of the RI as potential remediation wells for total fluids recovery near the AOI 8 northern property boundary (**Section 9.2.6**). Wells N-153 and N-154 serve as LNAPL delineation wells near the AOI 8 boundary with the Verizon SDWC Property, and well N-151 was installed in southern AOI 8 to delineate and characterize LNAPL previously identified by former monitoring well N-125 (destroyed). Well N-152 serves as a characterization well downgradient of the former MEK Plant and aided in the understanding of groundwater flow patterns in that area. Monitoring wells N-150 and N-156 were installed in a cluster along with lower aquifer well N-149D to provide delineation of LNAPL and dissolved-phase groundwater impacts near the former mouth of the historic buried Rambo Creek valley. It is noted that in addition to the monitoring well installations, two potential recovery wells (N-155 and N-157) were installed by Evergreen near the northern AOI 8 boundary with the Verizon SDWC Property to evaluate the feasibility of total fluids recovery in that area.

4.2.2 Lower Aquifer Monitoring Well Installations

Three monitoring wells (N-147D, N-148D, and N-149D) were installed in the lower aquifer in AOI 8 to aid in vertical delineation of dissolved impacts in groundwater by replacing wells previously destroyed, to address data gaps identified in the existing lower aquifer well network, and to refine the existing hydrogeologic model for the PES Complex presently under development. Pilot soil borings performed prior to the well installations were advanced to bedrock to evaluate Coastal Plain hydrostratigraphy and identify appropriate well screen intervals, except for N-148D which was solely drilled to replace/replicate the historic destroyed well N-46D construction. Monitoring well N-147D was located to generally replace historic destroyed well N-44D. Screen intervals were subsequently selected in the lower aquifer and well screens were installed from 56 to 66 ft bgs for N-147D, from 55 to 65 ft bgs for N-148D, and from 72 to 77 ft bgs for N-149D.

4.2.3 Well Installation Field Procedures

Prior to the commencement of exploratory drilling, each location was cleared for subsurface utilities to a depth of 8 ft bgs using a backhoe. Utility clearing was performed by H.T. Sweeney & Son, Inc., of Brookhaven, Pennsylvania, with oversight by Aquaterra. Advancement of soil borings and monitoring well installations were performed in July and August of 2016 by Parratt-Wolff, Inc. (Parratt-Wolff) of Lewisburg, Pennsylvania. Drilling oversight was performed by a combination of Stantec and Aquaterra staff. A combination of hollow stem auger and mud rotary drilling methods was utilized during borehole advancement for each monitoring well installed. Pilot boreholes utilized for subsurface characterization were reamed with larger drilling tools to the selected well screen depths to allow for the 4-inch PVC wells to be installed, except for wells N-155 and N-157 which are 6-inch PVC wells. The wells were developed by Parratt-Wolff or Total Quality Drilling for approximately 2 to 4 hours utilizing several cycles of air lifting and surging. The wells were developed until groundwater produced was relatively free of turbidity. Groundwater and sediment generated during well development was contained in plastic totes. The totes were emptied by Total Quality Drilling using a vacuum truck and the water was treated at the PES Complex's wastewater treatment plant.

During drilling, surface and subsurface soil samples were collected from the locations for laboratory analysis of the Evergreen Petroleum Comprehensive List. Split-spoon soil sampling for geologic characterization was performed on regular intervals, supplemented by continuous sampling in places at the discretion of the field geologist (sampling was not performed during pilot borehole advancement for well N-157). Soils were field screened with a PID, and lithologies were logged by a Stantec geologist or Aquaterra technician. In addition, one Shelby tube was collected within a muddy stratum of the apparent PRM aquifer system (apparent middle clay unit). The Shelby tube sample and selected spoon samples were sent to GeoStructures in King of Prussia, Pennsylvania, for analysis of particle size, fraction of organic carbon (f_{oc}), porosity, density, and permeability. Results of the laboratory testing are discussed in **Section 5** and the laboratory report is included in **Appendix F**.

4.3 GROUNDWATER SAMPLING EVENTS AND RESULTS

Two comprehensive rounds of characterization groundwater sampling were conducted in 2016 to characterize current conditions. All fieldwork was performed in accordance with the *Evergreen Field Procedures Manual* (**Appendix C**). Monitoring well locations are shown on **Figure 1-2**. The 2016 characterization groundwater samples were analyzed for the Evergreen Comprehensive List, although pre-2016 groundwater data may have included analysis of additional and/or a reduced number of parameters. Groundwater samples collected for characterization of groundwater conditions near well N-152 were also analyzed for MEK. Groundwater sampling analytical results, including available historical results, are summarized on **Table 4-2** (water-table aquifer) and **Table 4-3** (lower aquifer). Along with conventional/low-flow sampling methodologies, the following wells were also chosen to be characterized using passive (no purge) sampling methodology: N-105, N-147D, N-148D, and PZ-505. These sample results are identified with “HS” in the sample ID. Sub-LNAPL groundwater samples were collected from several wells to characterize COC concentrations beneath potential source areas (N-25, N-34, N-56, N-59, N-61, N-68, N-82, N-83, N-102, N-112, N-116, N-130, N-137, N-138, N-139, N-146, N-151, PGW-MW-7, PGW-MW-9, PZ-501, RW-205, RW-206, RW-306, RW-502, V-MW-5). These sample results are identified in the tables by an “SL” qualifier.

In summary, nearly all COCs on the Evergreen Comprehensive List were detected in AOI 8 groundwater during the 2016 sampling events. Concentrations of the following twenty-four compounds were detected in groundwater above the SHS during the 2016 sampling events: 1,2,4-TMB, 1,3,5-TMB, 2-methylnaphthalene, anthracene, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, cobalt, dibenz(a,h)anthracene, ethylbenzene, fluoranthene, indeno(1,2,3-c,d)pyrene, lead, naphthalene, nickel, pyrene, toluene, vanadium, and zinc. AOI 8 hydrostratigraphic units and groundwater sampling results are discussed further in **Sections 5** and **9**, respectively.

4.4 WELL GAUGING ACTIVITIES

Stantec presently conducts annual groundwater and LNAPL gauging of existing and accessible wells at the PES Complex. The PES Complex-wide annual well gauging event, which is typically conducted during the second quarter of each year, is used to identify the presence of LNAPL and determine groundwater flow patterns. Liquid level measurements, groundwater contour figures, and product thickness figures are submitted to PADEP with the Philadelphia Refinery Remediation Program Groundwater Remediation Status Reports for the first half of each year. **Table 4-4** presents liquid level measurements collected from AOI 8 and the surrounding area during the 2008 and 2017 annual gauging events. The table also includes gauging events from June and October of 2016 performed specifically for this RIR. Groundwater elevation contours from these well gauging events are discussed further in **Section 5**. In addition to the annual events, select wells in AOI 8 are gauged quarterly. These data are submitted to PADEP semi-annually in the Groundwater Remediation Status Reports. Although not included in **Table 4-4**, available gauging data from the adjacent Verizon SDWC and PGW Passyunk Facility properties has been included in the assessment of local groundwater conditions.

4.5 AQUIFER TESTING AND GROUNDWATER MONITORING

During August 2016, a Stantec geologist and Parratt-Wolff conducted short-duration constant rate pumping tests on wells N-147D, N-148D, and N-149D. The purpose of the testing was to acquire recovery data that could be used as an additional line of evidence to estimate lower aquifer hydraulic properties in AOI 8. The tests were performed using a three-inch submersible pump set just above each well's screen on a one-inch discharge line. Pumped groundwater was discharged directly to plastic totes for subsequent disposal as described in **Section 4.2.3**. Two check valves were installed above the pump in the discharge line to prevent backflow and allow for the collection of recovery data. During the tests, the pumping rate was maintained at approximately 20 to 25 gpm. Pumping was continued for approximately 10 to 15 minutes at a near-constant rate until the rate of drawdown in each well approached stabilization. Three successive tests were performed on each well, and water-level data was collected using a vented data logger.

Shortly after the well recovery tests, Stantec returned to AOI 8 to perform slug tests on wells N-147D, N-148D, and N-149D. The purpose of the slug testing was to establish lower aquifer k estimates to compare to those estimated from the recovery tests. A pneumatic slug assembly was used to pressurize the well casings and initiate instantaneous water-level displacements from which the recovery data could be evaluated (rising-head tests). Both the pumping and slug tests were performed in general accordance with the *Evergreen Field Procedures Manual* (**Appendix C**). AQTESOLV Version 4.5 Professional was used to fit solutions to the normalized slug test and pumping test recovery data. Well N-148D exhibited an overdamped/non-oscillatory response to the slug tests. Wells N-147D and N-149D exhibited underdamped/oscillatory responses to the slug tests. Stantec applied a combination of slug test solution methods to fit the data and estimate hydraulic conductivity, including the Hvorslev (1951) or KGS Model (Hyder et al., 1994) for overdamped tests (N-148D), and Butler and Zhan (2004) or McElwee and Zenner (1998) for underdamped tests (N-147D and N-149D). In addition, short periods of water-level monitoring data were collected between the pumping tests in wells N-148D and N-149D to evaluate the effect of river tides on the lower aquifer.

For the pumping tests, it became apparent that the discharge line check valves were not completely preventing backflow into the wells during recovery and the resultant data were deemed not representative of a true aquifer response. The constant rate pumping test results have not been included in this RIR. In addition, some of the slug tests initiated by the pneumatic method were influenced by small air leaks which affected the repeatability of test results. The solution methods applied to the underdamped tests suggest that those wells are influenced by a significant vertical flow component and that wellbore skin may be affecting the test results, as suggested by the low estimates of specific storage. Results of the slug testing and water-level monitoring are discussed in **Section 5**, and the slug test data analyses are presented in **Appendix G**.

5.0 SITE-SPECIFIC HYDROGEOLOGIC CONDITIONS

In **Section 2**, details regarding Stantec's interpretation of regional geologic conditions were presented. The purpose of this section's discussion of site-specific conditions is to refine the regional hydrogeologic framework to summarize conditions observed beneath AOI 8, with an emphasis on groundwater occurrence, groundwater flow, and hydraulic head potentials. It is understood that although this RIR is designed to address subsurface conditions beneath AOI 8, the PADEP has previously requested that investigations of individual AOIs at the PES Complex look beyond the boundary of the AOI being investigated.

For the purpose of adding context to this remedial investigation and to more comprehensively evaluate AOI 8 points of compliance, Evergreen and Stantec have invested considerable effort in the review and incorporation of subsurface data from neighboring AOIs and offsite properties into this RIR. Specifically, Stantec has utilized well log, well gauging, and groundwater analytical data from perimeter wells in PES Complex AOI 1, AOI 2, and Belmont Terminal in this investigation of AOI 8. Available environmental reports, gauging, and analytical data for the PGW Passyunk Facility and Verizon SDWC property have been utilized herein for the years presented through collaborative data exchanges with the property owners. Stantec also has performed informal file reviews of PADEP Southeast Regional Office Land Recycling Program (Act 2) files to obtain additional information and reports for the PGW Passyunk Facility and Verizon SDWC properties. Boring/well logs reviewed for the characterization of AOI 8 are included in **Appendix D**. A well summary table, including construction details for AOI 8 wells where available, and well gauging data utilized in groundwater contouring and evaluation of recent hydraulic head conditions for portions of AOIs 1, 2, 8 and Belmont Terminal are included in **Tables 4-1** and **4-4**, respectively.

5.1 GEOLOGIC FORMATIONS AND UNITS OBSERVED

On the basis of available lithologic data from boring logs, the principle of stratigraphic position, results of past investigations, review of historical maps, review of archived sediment core samples from select monitoring wells, test drilling in support of this investigation, and attempted correlation of observed lithologies across the study area to a published geologic framework (e.g., Quaternary deposits and the PRM aquifer system), Stantec has interpreted the following stratigraphy in the subsurface beneath AOI 8. A generalized stratigraphic column adopted from Schreffler (2001) is included as **Table 5-1** and discussed further in **Section 5.2** in the context of interpreted hydrostratigraphy.

5.1.1 Anthropogenic Fill

Anthropogenic fill is present beneath the existing land surface at most locations in AOI 8 and has been identified to range in thickness from a thin veneer to a maximum of approximately 20 feet. Fill has generally been placed in most significance along the perimeter of the Schuylkill River and is thickest along the axis of a former stream valley (Rambo Creek) that once bisected AOI 8, as mentioned in **Section 2.1.1** and depicted in **Figure 2-1**. Stratigraphic Profiles H – H' and J – J' (**Figures 2-6** and **2-8**) cut across that former valley and indicate that it widened from approximately 500 to 1,000 feet as it progressed towards its confluence with the Schuylkill River (thalweg approximated by AOI 8 wells N-82 and N-126 on the referenced profiles). Historic contoured topography (**Figure 2-1**) suggests that the stream valley was sourced offsite to the north and east of AOI 8, in the vicinity of the Grays Ferry neighborhood. Borehole logs for wells and soil borings that intersect the fill in this valley and elsewhere in AOI 8 indicate that the fill is heterogeneous in nature, as previously described, and is composed of an admixture of sand and gravel, mud, and anthropogenic debris including bricks, construction debris, ash, cinders, and slag. In AOI 8, fill is commonly saturated and can either support a perched water table above fine-grained Holocene and Pleistocene alluvium (separated from regional saturation), or can contain the water-table surface. Precipitation percolating through and groundwater discharging into the fill in the former Rambo Creek channel can also lead to localized groundwater mounding, most persistent where the water-table equilibrium surface intersects the fill. For this reason, it is important to evaluate the former stream as a preferential flow path for separate and dissolved-phase contaminant transport (**Section 9**).

5.1.2 Recent (Holocene) Alluvium

Recent alluvial deposits are present in AOI 8 in significant thickness. These sediments represent Holocene fluvial/estuarine depositional environments of the Schuylkill River and tidal portions of its tributaries. Recent alluvium is thickest in AOI 8 along its western perimeter where up to 60 feet of mostly muddy, organic-rich sediments accreted in a point bar along the inside of a prominent meander in the Schuylkill River. Eastward of that area, the recent alluvium pinches out to an elevation just above present sea level against a terrace underlain by a sequence of Pleistocene and/or Cretaceous alluvium. Stratigraphic profiles I – I’, J – J’, and L – L’ (**Figures 2-7, 2-8, and 2-10**) characterize the landward extent of these deposits. Because of its relatively young age, the recent alluvium is poorly consolidated and easily distinguishable in boreholes from Pleistocene muds by its soft consistency, dark gray to black color, and commonality of layers/laminae of decomposing organic material (e.g., leaf mats) and fine, micaceous sand. Near the confluence of former buried Rambo Creek valley and the Schuylkill River, a significant thickness (up to approximately 25 feet) of mostly fine sand was identified in the alluvium through split spoon sampling of well N-149D. This sand body may represent alluvium deposited near the mouth of Rambo Creek and may extend upstream to the north and east where it pinches out near the location of well N-126 (**Figure 2-8**). Monitoring well N-156 was constructed to intersect this sand body so that groundwater quality could be evaluated in this potential flow path at the point of compliance (discussed further in **Section 9**).

5.1.3 Pleistocene Alluvium

Pleistocene alluvium is present throughout most of eastern AOI 8 and ranges in thickness from approximately 10 to 15 feet. The spatial pattern generally defines a river terrace that is positioned above the Schuylkill River and former buried Rambo Creek floodplains at elevations between approximately 10 and 30 feet NAVD 88. Its upper surface partially constituted the antecedent topography that preceded industrialization at the PES Complex. In large part, Pleistocene alluvium within the PES Complex is capped by a fine-grained, brown to brownish gray silt/clay with occasional lenses of sand and gravel that commonly grades with depth to sand and gravel. This fine-grained facies is commonly mottled from the slow percolation of recharge from ground surface and generally is present above the seasonal high water table (i.e., does not support local artesian water-table conditions). As demonstrated by the stratigraphic profiles, the upper muddy facies of Pleistocene alluvium is less often present in AOI 8 and is reflective of denudation of the terrace to the north and east.

In AOI 8, the Pleistocene alluvium is chiefly reddish brown, poorly-sorted sand and sand with gravel, but includes secondary lithologies of silty, sandy gravel and clay/silt in lenses. As described PES Complex-wide, the Pleistocene alluvium is a heterogeneous unit that is reflective of its textural immaturity and depositional environments. In AOI 8, the water table typically occurs near the lower contact of the Pleistocene alluvium with the underlying PRM upper sand unit, leaving the upper sand to comprise the bulk of the water-table aquifer. Within axial portions of the Rambo Creek incision, it appears that stream erosion during the latest Pleistocene completely removed the older Pleistocene deposits and most of the PRM upper sand unit, dissecting the terrace and exposing the top of the PRM middle clay unit (e.g., monitoring wells N-147D and N-126 on **Figure 2-8**). Pleistocene alluvium is also present deep beneath the Schuylkill River, underneath the Holocene alluvium. Following the depositional model of Jengo (2006), this alluvium would be geologically younger than the Pleistocene alluvium discussed above (i.e., Cape May Formation, Unit 2) and would represent glacial-age tributary alluvium transported down the Schuylkill River at about the same time that the “Trenton gravel” was being deposited in the Delaware River valley.

5.1.4 Upper Clay Unit

The PRM upper clay unit is interpreted to be patchy beneath most of AOI 8 and was mapped as the first occurrence of reddish yellow, brown, and brownish yellow clay/silt (commonly sandy and laminated) beneath the Pleistocene alluvium. The upper clay was distinguished from the underlying middle and/or lower clay units where possible by stratigraphic position, color, consistency, and overall lithologic character. Where interpreted to be present, the upper clay generally ranges in thickness from less than one foot to approximately 5 feet. **Figure 2-6** was drawn to carry the upper clay north or up-dip from where it was mapped by Stantec (2016) in AOI 1. The figure demonstrates that the upper clay is thin but fairly continuous through the southeastern corner of AOI 8. Beyond that area, the remaining stratigraphic profiles indicate that only patches of upper clay are interpreted to exist elsewhere. In the context of AOI 8 hydrostratigraphy, the upper clay unit is interpreted to be a part of the water-table aquifer and where present, function as an aquitard limiting groundwater exchange between the Pleistocene alluvium and upper sand unit.

5.1.5 Upper Sand Unit

The PRM upper sand unit is interpreted to be present beneath most of AOI 8 and ranges in thickness from approximately 5 to 15 feet. The upper sand unit appears to be thickest along the axes of troughs cut into the middle clay unit. The upper sand unit is generally light gray to pale yellow, fine to medium-grained quartz sand with a trace to little silt, distinctly different from the heterogeneous Pleistocene alluvium. Muddy lenses are common to the upper sand unit where it is well-sorted, very-fine to fine sand. Gravelly sand and gravel beds are less common in AOI 8 than in areas down-dip. Under average head conditions, the water table generally occurs near the top of the upper sand unit in AOI 8 and as such the upper sand unit is interpreted to be part of the water-table aquifer. Stratigraphic profiles support that the upper sand unit is absent in western AOI 8 and along the downstream portion of former Rambo Creek where it was removed by stream incision. The upper sand unit is also missing where the lower sand unit caps a local bedrock pinnacle (**Figure 2-7**).

5.1.6 Middle Clay Unit

The PRM middle clay unit is mapped in this RIR as a near-continuous deposit of predominantly medium to high plasticity, gray and red clay/silt beneath AOI 8. Where interpreted from boring logs, the middle clay may be up to 20 feet thick and is thickest in eastern and southern areas of AOI 8. Like AOI 1 (Stantec, 2016), the lithology of the interpreted middle clay is noted to vary beneath AOI 8, from red gray 'fat' clays to sandy gray clay and silt with fine sand laminations. Variability in middle clay lithology is plausible in this subcrop area near the "Fall Line," where the PRM aquifer system's "defined" lithologic units experience thinning and facies changes that can alter the primary lithologies from that of their down-dip type section, and make separation of each geologic unit difficult and interpretive. Lignite, noted by Greenman et al. (1961) to be oftentimes present at the base of the middle clay unit, has been observed in select borings and was used in this RIR as a potential stratigraphic marker to help guide identification and correlation of the middle clay beneath AOI 8 (e.g., soil boring AOI8-BH-16-001D and monitoring well N-147D). The middle clay unit generally represents an aquitard that separates the two mappable hydrostratigraphic units (i.e., the water-table and lower aquifers) beneath most of the PES Complex, but where thin and sandy, could support limited recharge to the underlying lower aquifer through vertical leakage (leaky confining bed), depending on head potentials between those aquifers (discussed further in **Section 5.4**). In northwestern AOI 8, the middle clay unit is missing and the lower aquifer subcrops patches of younger geologic units and areas of fill.

5.1.7 Middle Sand Unit

The PRM middle sand unit has been mapped in this RIR to be present beneath AOI 8 as lenticular to tabular sand bodies cut into the lower sand, primarily based on lithologic changes and stratigraphic position. The middle sand is generally mapped where brown and reddish yellow, occasionally muddy, gravelly, and stratified sand is present between the interpreted middle clay and lower sand units (the lower clay appears to be absent or patchy). Where enough borehole log detail exists to distinguish it from the lower sand, the middle sand may be up to approximately 10 feet thick. Like the other PRM units under western AOI 8, the middle sand would have been eroded by Schuylkill River incision. The middle sand unit is interpreted to form a portion of the lower aquifer hydrostratigraphic unit.

5.1.8 Lower Clay Unit

The interpretations presented in this RIR suggest that the PRM lower clay unit is absent from beneath AOI 8. If present locally, the lower clay unit is considered to be of minimal importance from a hydrostratigraphic perspective because it is not considered mappable at scales relevant to AOI 8 fate and transport.

5.1.9 Lower Sand Unit

Of the six published PRM geologic units, the lower sand unit appears to be the thickest and most laterally continuous beneath and near AOI 8. In general, the lower sand typically coarsens with depth, from a dense fine to medium pale gray, pale yellow, and white (commonly muddy) quartz sand to white and varicolored sandy gravel and gravelly sand. Scattered lenses of clayey sand and gravel within the overall sequence are common. Thickness of the lower sand (in places possibly combined with the middle sand) generally ranges from approximately 10 feet to over 40 feet beneath AOI 8 and the surrounding area evaluated. Maximum thickness is observed beneath southcentral AOI 8, where the lower sand unit fills a bedrock trough. Because of its predominantly sandy and gravelly lithology and spatial continuity, the lower sand is interpreted to form the great majority of the lower aquifer hydrostratigraphic unit.

5.1.10 Crystalline Bedrock

Bedrock has been observed beneath AOI 8 and, where encountered, has been described as moderately to highly-weathered mica schist. Where highly-weathered, the saprolite is generally a sandy, micaceous clay/silt that contains a visible rock fabric. As shown on **Figure 2-14**, the top of bedrock beneath AOI 8 spans a significant elevation range and has been identified from as shallow as a few feet below NAVD 88 (e.g., **Figure 2-7**) to approximately -70 feet NAVD 88. The magnitude of relief on the bedrock surface is due to the proximity of northwestern AOI 8 to the “Fall Line” and the continuation of a shallow bedrock pinnacle under the Schuylkill River and into AOI 8. There are older maps available through the online resources referenced in **Section 2** that indicate rock outcroppings were historically present along the banks of the Schuylkill River in this area. The bedrock surface (including saprolite) is interpreted by Stantec to function as an aquitard representing the base of the lower aquifer, and locally the base of the water-table aquifer.

5.2 AQUIFER HYDRAULIC PROPERTIES

Two aquifers have been established as mappable water-bearing units beneath AOI 8 of the PES Complex. In general, these are the water-table (unconfined) and lower (semi-confined) aquifers (**Table 5-1**). These are the same aquifers previously defined by Stantec (2016) and Stantec (2017) for AOIs 1 and 4 to the south of AOI 8. However as discussed in this section, an important distinction exists in AOI 8 whereby the lower aquifer subcrops (prior to human influence it was an outcrop area) fill in an area of AOI 8 where the middle clay and younger units are absent atop shallower bedrock. Where the middle clay unit regional aquitard is missing, hydraulic heads in the lower aquifer sediments are able to equilibrate with atmospheric pressure and form the water-table surface. As discussed, the northern and western portion of AOI 8 is a recharge area for the lower aquifer where it reaches its up-dip limit near the Fall Line.

For the purposes of this RIR, Stantec identified and has evaluated properties of the two aquifers through review of approximately 250 well logs and soil boring records. The goal of the records review was to identify relatively distinct hydrostratigraphic units from well gauging data and where available, lithologic logs, soil physical properties, and well/aquifer testing data. Hydrostratigraphic units were assigned to wells where possible using the stratigraphic profiles developed for this RIR and nearby, deep boreholes as control points (**Table 4-1**). Overall, approximately 95% of existing monitoring wells used in AOI 8 are screened above the level of regional saturation (perched water) or across the water-table aquifer and were constructed to intersect the first occurrence of groundwater. This includes the area where the lower aquifer comprises the water table. The remaining 5% are screened in the semi-confined lower aquifer, which may include portions of screened intervals that intersect lithologies correlated to the middle sand, lower clay, and/or lower sand units.

It is noted that where identified based on lithology and stratigraphic position, the PRM upper sand and middle sand geologic units appear to be hydraulically connected to portions of the two mappable aquifers. Because of apparent discontinuities in the upper and lower clay units, they do not appear to represent discrete hydrostratigraphic units at a mappable scale in this area. It is also noted that hydraulic head potentials between the water-table and lower aquifers vary laterally across AOI 8, and where the middle clay and younger deposits are missing, the lower aquifer is unconfined. These hydrogeologic conditions are discussed further in subsequent sections and are supported by **Figures 5-1** through **5-9**, which show groundwater elevation contours for both aquifers for calendar years 2008, 2016, and 2017.

5.2.1 Methodology for Evaluation of Hydraulic Data

For the purposes of evaluating present-day hydraulic head, groundwater flow patterns, magnitudes of groundwater flow (groundwater velocities), and any potential variability in those conditions through time for the aquifers identified in this RIR, Stantec reviewed and interpreted 2008, 2016, and 2017 water-levels from well gauging events performed in AOI 8 and synoptically at adjacent offsite properties (as described in **Section 4.4**). The analysis included gauging data, where available, from wells at the PGW Passyunk Facility and Verizon SDWC property. For wells gauged by Stantec, depth-to-water measurements were collected with an optical oil/water interface probe and reported to the nearest hundredth of a foot. Water-table elevations were calculated using surveyed well top-of-casing elevations and, where necessary due to LNAPL accumulations, corrected using appropriate LNAPL density data (see **Table 4-4** for well gauging data).

The results presented herein are interpreted to represent near-static hydraulic head conditions for the years presented. During the 2016 and 2017 well gauging events, there were no known, actively operating groundwater recovery systems in AOI 8 or at the referenced adjacent properties (excluding total fluids recovery by PGW's consultant at recovery well RW-2, operation of mobile skimmer systems collecting LNAPL at PGW, and potential operation of a soil vapor extraction/air sparging system at the PGW Passyunk Facility). The total fluids recovery systems at the PGW Border Remediation System (PGW Border System), Jackson Street Sewer Remediation System (Jackson Street System), and the North Yard Bulkhead and No. 3 Tank Farm Separator System (North Yard Bulkhead System) were not operational during the June 2008 gauging presented in this RIR. It is noted that the integrity of offsite well gauging data utilized but not collected by Stantec personnel was assumed to have been evaluated by others. However, Stantec did spot check selected offsite well gauging data and may have removed some wells from contouring where deemed appropriate.

After well data evaluation, Golden Software's Surfer® 12 was used to interpolate the well data using block and/or point Kriging. Grid residuals were evaluated and the interpolated surfaces were subsequently contoured and imported into a geographic information system (GIS) for display and evaluation. Due to the high well density in areas of AOI 8 and the commonality of apparent groundwater anomalies in the shallow subsurface, October 2016 water-table elevation and lower aquifer potentiometric surface datasets were then refined through several iterations of gridding and borehole log review to remove anomalous data, where appropriate (the October 2016 dataset was considered most comprehensive for AOI 8 as it included gauging of the Verizon SDWC Property wells). For the water-table aquifer, an evaluation to identify anomalous data points was warranted for those wells screened within areas of apparent groundwater mounding where it was unclear whether those water-level elevations represent true water-table mounds under unconfined conditions, or areas of perched groundwater in fill or alluvium not at equilibrium with atmospheric pressure and positioned above the level of regional saturation. Well identifiers representing the filtered October 2016 dataset were then used to select consistent May/June 2008, June 2016, and May 2017 datasets, based on data availability. Those wells were added to the queries for consistency between the datasets presented to the extent possible to allow for reasonable evaluation of the persistence of groundwater flow patterns in the aquifers. For comparative purposes, both “unprocessed” and “processed” surfaces are presented and discussed in this RIR for the May 2017 water-table aquifer data (unfiltered and filtered data).

5.2.2 Unconfined (Water-Table) Aquifer

Beneath the study area, the water-table aquifer is primarily composed of saturated and permeable portions of fill, Holocene alluvium, Pleistocene alluvium, and the PRM upper sand unit. Where present in mappable thickness, the water-table aquifer also includes the intervening PRM upper clay unit. On average, the saturated thickness of the water-table aquifer beneath AOI 8 is approximately 5 to 15 feet. In exception, the water-table aquifer saturated thickness can be up to 30 feet where the middle clay is missing and the lower aquifer sediments constitute all or a portion of the aquifer. As a part of this RIR, Stantec mined existing data and has identified estimations of k in the water-table aquifer for the AOI 8 area (including the Verizon SDWC and PGW Passyunk Facility) from 23 in-situ aquifer (slug) tests (see **Figures 2-11 and 2-13**). From those tests and as previously discussed in **Section 2.2.1.2.2**, estimated values of water-table aquifer k vary from less than 1 ft/d to more than 250 ft/d. The wide range of estimated values of k is likely reflective of several factors true to AOI 8, including heterogeneity in the Pleistocene deposits, heterogeneities in the fill, insufficient well development, separate-phase residual hydrocarbons near the water table, and the occurrence of a lower aquifer subcrop area. Low values of k may be the result of poor well-aquifer hydraulic communication related to inadequate well development, fouling of the well screen post-installation, residual hydrocarbons, and low permeability sediments enveloping the well screen. In contrast, relatively high values of k appear to be associated with the lower aquifer subcrop area (e.g., well N-37, Verizon SDWC wells). It is noted herein that Stantec is presently evaluating reasonable values of reported water-table aquifer k for AOI 8 and elsewhere as a part of PES Complex-wide numerical model calibration and sensitivity analysis.

In addition to estimates of k, other estimates of water-table aquifer properties were evaluated. Limited estimates of vertical permeability (k_v) are available for the water-table aquifer near AOI 8. Weston (2004) collected Shelby tubes in fine-grained Pleistocene alluvium and laboratory testing provided k_v estimates of approximately 10^{-7} to 10^{-8} centimeters per second (cm/sec). Laboratory testing data collected for AOI 8 (**Appendix F**) indicates that the effective porosity of granular lithologies in the water-table aquifer may range from approximately 15 to 30 % (wells N-148D and N-149D) in mostly poorly-graded to silty sands with up to 40% gravel.

5.2.2.1 Hydraulic Heads and Groundwater Flow

For the purpose of demonstrating an understanding of water-table aquifer groundwater flow patterns in AOI 8 and vicinity, four well gauging datasets spanning a 9-year period were evaluated. PGW Passyunk Facility and Verizon SDWC data was included, where available, to aid in understanding of the hydraulic gradients and flow directions at the points of compliance. As noted above and shown in **Figure 5-1**, water-table mounds and other anomalies are apparent in this area and where present can obscure the pattern of overall regional flow within the water-table aquifer. The most significant, apparent groundwater mound in the study area is located in northwestern AOI 8, near the propane terminal and existing ASTs south of the ballfield. Boring logs indicate that mounding in this area is the result of persistent (dating back to the time of well installation in the 1980s) groundwater perching within significant fill deposits present atop a low permeability stratum mapped as the upper clay unit (**Figure 2-10**).

Other areas of localized groundwater perching are apparent near the Jackson Street Sewer and CSX Property easement in central AOI 8. Groundwater mounding may in places be the result of leaking infrastructure (such as fire suppression lines or sewers) that creates localized anomalies, defined by only one well in areas of less complete data coverage. Wells constructed with long but shallow screen intervals have the potential to intersect more than one water-bearing zone and can contain unreliable water levels. These factors are noted because identification of true groundwater mounds and groundwater depressions in the water-table aquifer is imperative to estimating reasonable values of horizontal hydraulic gradients, vertical flow potential, and groundwater velocities for predicting accurate scenarios of contaminant fate and transport.

Figures 5-2, **5-3**, **5-4**, and **5-5** display 2008, 2016, and 2017 water-table elevation contours after analysis and filtering of existing well gauging datasets, as interpreted by Stantec. With localized areas of perched groundwater and/or anomalous data from suspect wells removed, contours for all three years indicate that water-table aquifer groundwater flows in a pattern that generally mirrors the historical topography shown on **Figure 2-1**. An east-west trending groundwater divide is present beneath a topographic high centered near the PGW Passyunk Facility and AOI 8 border, and groundwater flows in a radial pattern away from the highest topographic elevations. This divide extends to the northeast along the perimeter of AOI 8 and separates westward flow components to former Rambo Creek from those to the southeast where available data is sparse (monitoring well N-152 was recently installed to help bridge this data gap).

An additional groundwater divide is present in northcentral AOI 8 that appears to result in part from subtly higher natural topography in that area, extending out of residential areas to the northeast. Groundwater converges between the aforementioned divides along lowlands associated with former Rambo Creek where it is indicated to have been a receiving stream based on the data presented. The former creek valley extends and turns to the north in close proximity to the AOI 8 eastern boundary, extending the pattern of flow convergence. An erosional remnant of the Pleistocene alluvial terrace extends north from the PGW border near Schuylkill Avenue, and radial groundwater flow to the north and west is apparent around that feature. Groundwater mounding is apparent within the filled Rambo Creek valley and former floodplain of the Schuylkill River, suggesting that the river bulkhead is limiting groundwater to surface water discharges from this aquifer near the mouth of the former creek. Hydraulic gradients in the water-table aquifer are variable but generally fall within the range of approximately 0.0006 ft/ft (e.g., filled tidal flats along the Schuylkill River) to 0.02 ft/ft (e.g., along the Schuylkill River cut bank).

Manmade features appear to disrupt natural patterns of groundwater flow in AOI 8. Two areas of apparent groundwater infiltration into the Jackson Street Sewer are supported by the contours: one small area just west of the Land Treatment Unit (monitoring well N-83) and a broad area in central AOI 8 (generally between wells N-89 east to RW-304). A broadly defined area of groundwater convergence is present near the AOI 8 and Verizon SDWC border. The exact causal mechanism for this feature is not completely understood but is likely a result of groundwater discharge to one of several submerged sewers in the area, including the Mifflin Street Sewer, drop sewers in 34th Street, an intercepting chamber below the Mifflin Street Sewer (located on the west side of the 34th Street crossing), a drop sewer that connects the Mifflin Street Sewer to the Lower Schuylkill East Side Intercepting Sewer (previously referred to as the 26th Street Intercepting Sewer [Stantec, 2016]), and an onsite sanitary sewer lifting station in the vicinity of Schuylkill Avenue. The Rambo Creek process sewer is located in an area of natural groundwater discharge and although as-built information as to its depth is not available, is likely submerged and could influence hydraulic heads in the water-table aquifer.

5.2.3 Semi-Confined (Lower) Aquifer

Beneath AOI 8, the lower aquifer is mapped in this RIR to be composed of the PRM middle and lower sand units as the lower clay unit appears to be absent in this area. The lower aquifer is also interpreted to include a less significant portion of Pleistocene alluvium (glacial-age tributary alluvium) beneath and fringing the Schuylkill River, where these deposits are semi-confined by Holocene alluvium and hydraulically connected to the PRM deposits (e.g., **Figure 2-8**). On average, the saturated thickness of the lower aquifer beneath AOI 8 ranges from 10 to 50 feet. The thickness is largely dependent on the configuration of the underlying bedrock surface and as such, the lower aquifer is thickest along the southern AOI 8 boundary where a bedrock trough exists (e.g., N-147D).

As noted in **Section 4.5** and on **Figure 2-12**, Stantec performed slug tests on lower aquifer deposits in AOI 8 using wells N-147D, N-148D, and N-149D to estimate the aquifer's hydraulic properties. Well testing indicates that a representative k range for lower aquifer strata in AOI 8 may be approximately 169 to more than 850 ft/d (**Appendix G**). This encompasses lithologies that include well-graded sand with a trace of silt/clay and gravel, to sandy gravel with cobbles (see sieve analyses in **Appendix F**; N-149D split-spoon recoveries were poor through the screen interval and sample volumes were insufficient for laboratory testing). For comparative purposes, empirical methods of estimating k from sediment grain-size distribution and textural maturity can be used following the methods of Hazen (1911) and Shepherd (1989) outlined in Fetter (1994). Stantec performed these calculations using the laboratory testing data for screen interval samples collected from N-147D and N-148D. When compared to slug test values displayed on **Figure 2-12**, these calculations estimate comparable k values of approximately 58 to 344 ft/d for N-147D, and 34 to 194 ft/d for N-148D. GES (1993) estimated a k for well N-37 of approximately 3 ft/d for apparent lower aquifer deposits in the recharge area identified in this report. The driller's log for N-37 indicates that the screen intersects dark gray fine sand and gravel, and as such the reported k value seems anomalously low for this aquifer.

Lower aquifer k data can also be reasonably estimated from historical offsite testing (**Figure 2-13**). From those tests at the Verizon SDWC Property (tested wells are interpreted to be screened in/near the lower aquifer subcrop area) and PGW Passyunk Facility, values of lower aquifer k are estimated to vary from approximately 1 to 256 ft/d. Stantec is presently evaluating a reasonable range of values of AOI 8 aquifer k as a part of PES Complex-wide numerical model calibration and sensitivity analysis. No direct estimates of k_v are available for lithologies correlated to the lower aquifer beneath AOI 8. However, a component of vertical flow (anisotropy) is apparent in Stantec's slug testing analysis results for the partially penetrating wells. When compared to empirical methods, the relatively higher k values estimated from the slug tests is likely attributable to components of both horizontal and vertical groundwater flow in the aquifer.

5.2.3.1 Hydraulic Heads and Groundwater Flow

Groundwater flow within the lower aquifer beneath AOI 8 and proximity has been evaluated and contoured utilizing data from up to 30 wells, and the resultant groundwater surfaces are shown on **Figures 5-6** through **5-8** for near-synchronous well gauging events conducted in May/June of 2008, October 2016, and May 2017 (not enough lower aquifer well coverage is available for the June 2016 event to warrant contouring of that data presented for the water-table aquifer). At the locations evaluated, the well gauging data indicates that the lower aquifer has artesian conditions or is at least semi-confined beneath the majority of AOI 8. In exception, there is a comparatively small area in northwestern AOI 8 where the middle clay surpasses its up-dip limit in the Coastal Plain and the lower aquifer subcrops (prior to human influence this was an outcrop area) fill and is unconfined. This area is broadly defined to the south by well N-114, the west by wells N-37, N-70, and N-69, to the north by wells at the Verizon SDWC Property, and to the east by Schuylkill Avenue. Wells in this general area can be used to contour both the water-table and lower aquifer surfaces as the heads are assumed to be equal where the middle clay is not present nor continuous (**Section 5.4.1**).

Lower aquifer groundwater flow directions and the persistence of observed patterns can be inferred from the hydraulic head datasets presented in this RIR. The highest hydraulic heads in the lower aquifer at the PES Complex are located in the noted subcrop area near the northwestern AOI 8 boundary where it is unconfined. Lower aquifer groundwater flows from that area to the south across AOI 8 in a radial pattern under a gradient of approximately 0.002 to 0.006 ft/ft. There are also indicated components of groundwater flow to the west towards the Schuylkill River, and east towards the Schuylkill Expressway near the AOI 8 boundary. Beginning near the AOI 8 southern boundary with the PGW Passyunk Facility, lower aquifer hydraulic gradients decrease to approximately 0.0004 to 0.0008 ft/ft. This is likely a reflection of the continuity of the middle clay unit in that area as groundwater continues to flow south under areas distal to the Schuylkill River. Immediately adjacent to the Schuylkill River, contours indicate that lower aquifer groundwater flows toward the river under hydraulic gradients that are influenced by river tides (**Section 5.4.2**). The Jackson Street sewer appears to be infiltrating groundwater from the lower aquifer sediments near well N-83 and creates slight convergence of contours near that well. At the

Schuylkill River, lower aquifer groundwater can either flow under, discharge into, or receive surface water from the river depending on the permeability of the riverbed sediments along the AOI 8 shoreline, and on the dynamic head differential between the tidal river and the aquifer.

It is noted that based on existing well data, it is not discernable whether a lower, semi-confined aquifer exists beneath the PES North Yard Ball Field and to areas north of AOI 8 (the complete extent of the subcrop area is unclear). The soil boring drilled as a pilot hole for well N-100 (**Figure 2-9**) suggests that the PRM middle clay unit is present in minimal thickness in the area. Well PH-55 on **Figure 2-10** indicates that the middle clay is present in significant thickness to the north and east of AOI 8 and the Verizon SDWC Property. As evidenced by other areas of the PES Complex where the middle clay unit is present in significant thickness and extent, hydraulic heads in the deeper, PRM sands beneath the PES North Yard Ball Field and areas north of AOI 8 may be lower than the water-table heads indicated for wells N-1, N-99, and N-100. As such, there is the potential for components of groundwater flow to the north in the lower aquifer. This pattern would primarily depend on the relative continuity of the PRM deposits beneath that area to support the presence of more than one discrete water-bearing stratum.

5.3 CLAY UNIT PROPERTIES

5.3.1 Upper Clay Unit

The PRM upper clay unit appears to be of limited thickness and lateral extent beneath AOI 8 and proximity. As such, the upper sand unit is interpreted as being hydraulically continuous with the overlying Pleistocene alluvium. However, where locally present in measurable thickness, the upper clay unit aquitard could maintain hydraulic separation between the two water-bearing units and lead to localized areas of artesian pressure in the upper sand. Stantec did not collect any Shelby tubes in the apparent upper clay unit in AOI 8 due to its limited thickness and spatial extent. However, based on its comparable lithology to the middle clay, it can be reasonably assumed that where present the upper clay unit k_v may be similar to that of the middle clay and range from approximately 10^{-7} to 10^{-9} cm/s (Stantec, 2017a).

5.3.2 Middle Clay Unit

The PRM middle clay unit is generally regarded as the regional confining unit beneath most of the PES Complex that locally separates the mappable water-bearing strata. Understanding the character and extent of the middle clay is of importance to this and other RIRs at the PES Complex because where present it can mitigate or prevent the downward migration of shallow groundwater contamination into the lower aquifer. The middle clay unit appears to be laterally continuous beneath only southern and eastern areas OF AOI 8 and creates hydraulic separation between the water-table and lower aquifers in those areas (as demonstrated by the head potentials discussed in **Section 5.4.1**). Along the Schuylkill River, the middle clay is missing and has been replaced by a thick sequence of mostly fine-grained alluvium. In exception, adjacent to northwestern AOI 8, shallow bedrock occurs and historically outcropped along the Schuylkill River. Relatively shallow bedrock extends to the south and east into AOI 8 from this area and as mapped in this RIR, the middle clay is missing and patchy (**Figures 2-7, 2-9, and 2-10**).

Where the middle clay is present, there exists the potential for vertical groundwater exchange (leakage) to occur through the middle clay that is dependent on the permeability of the middle clay among other factors. Stantec collected one Shelby tube in the apparent middle clay unit beneath AOI 8 from the pilot boring for monitoring well N-148D (40.5 to 42.5 ft bgs). A permeability test was performed by Geostructures on a sample extruded from the tube (ASTM Method D5084) and has provided an estimated middle clay unit k_v of approximately 4.8×10^{-7} cm/s (see **Appendix F**). This result supports that the middle clay is relatively impervious where present and is comparable to other recent results presented by Stantec (2017) for the middle clay.

To add local context to the discussion of middle clay continuity beyond the perimeter of AOI 8, Stantec reviewed the lithologic logs for 4 deep wells installed under the oversight of Weston (2004) at the PGW Passyunk Facility and reviewed other publicly available records/reports for local subsurface information. A brief Pennsylvania Groundwater Information System (PaGWIS) search was also conducted. Identified well logs were interpreted and stratigraphic “picks” were made on the apparent formations/units based primarily on lithologies recorded. The logs were used in conjunction with well data from the PES Complex to bridge data gaps in the stratigraphic profiles presented in this report. Correlation and interpretation between the well logs reviewed indicates that the middle clay is present beneath the PGW Passyunk Facility (**Figure 2-6**) where deep exploration has occurred. To the north and east of AOI 8, only a few sparse well records were identified in Greenman et al. (1961) and where logs are available (e.g., PH-55), the middle clay is interpreted to be present (**Figure 2-10**). Stantec did not identify any well logs to the north beyond well N-100 where the presence or absence of the middle clay could be interpreted (**Figure 2-7**).

5.4 AQUIFER CONDITIONS

5.4.1 Head Potentials Between Aquifers

Stantec evaluated the magnitude of vertical hydraulic head potentials for October 2016 between the water-table and lower aquifers (where discrete hydrostratigraphic units are present) throughout the study area by identifying locations of appropriately-located well pairs in AOI 8, and by utilizing offsite well pair locations previously identified by Weston (2004) for the PGW Passyunk Facility. **Figure 5-9** displays the results of that evaluation. The figure indicates that in areas of AOI 8 where the middle clay unit aquitard is present, the hydraulic head potential between observed aquifers was positive (downward) in October 2016. The positive potentials in AOI 8 ranged from approximately 3 feet to 11 feet. Near-equal hydraulic heads are assumed to be present in the lower aquifer subcrop area, as exemplified by wells N-137 and N-4; however, separation of geologic units in the area is difficult using existing lithologic logs. Smaller hydraulic head potentials exist to the south of AOI 8 and the PGW Passyunk Facility where the middle clay unit is missing in an area east of 26th Street (Stantec, 2016). In general, the pattern of vertical hydraulic head potentials mirrors topography and proximal to the Schuylkill River, is influenced dynamically by river tides.

5.4.2 Influence of River Tides on Aquifer Heads

The Schuylkill River forms the western and parts of the southern boundary of AOI 8 and is a tidal estuary that experiences astronomical tides on a semi-diurnal scale. The head of the tide is located just north of the PES Complex at Fairmount Water Works Dam near Fairmount Park in the City of Philadelphia. According to data obtained from the USGS tide gauge near 30th Street (USGS Station 01474501), the tidal amplitude in the river ranges up to approximately 7 feet per semidiurnal cycle (generally from -3 feet to 4 feet NAVD 88). Cyclical fluctuations of the surface water level in the Schuylkill River may directly or indirectly propagate landward and affect water levels in the aquifers beneath AOI 8. This could influence gradients and hydraulic heads to an extent and magnitude that is related to the degree of river and aquifer communication.

Greenman et al. (1961) concluded that Delaware River tides propagate landward through the water table no more than a few hundred feet from the river. Those authors also noted a harmonic, sinusoidal pressure wave in the artesian aquifers near the Delaware River that decreased in amplitude with distance from the river. Weston (2004) monitored water levels in wells at the PGW Passyunk Facility for the purpose of evaluating river tide effects on the aquifers. Interestingly, those data show that the lower aquifer adjacent to the river (PGW-MW-1D) contained a much more significant tidal signal (amplitude greater than 4 feet) than the water-table aquifer at similar locations (which comparatively displayed almost no tidal influence).

To evaluate the presence or absence of a river tide signal in the lower aquifer beneath AOI 8, Stantec collected water-level data from wells N-148D and N-149D. The well data has been plotted with synoptic data from additional lower aquifer wells at the PES Complex and the USGS river gauge data to compare the timing and amplitude of the signals (**Figure 5-10**). The data plot demonstrates that a semidiurnal tide signal is present and that the lower aquifer near both AOI 8 wells N-148D and N-149D fluctuated by up to approximately 1 foot in response to river tides. Comparatively AOI 1 wells (S-42I and S-264D) and AOI 4 well S-218D near 26th Street exhibited an approximately 0.1 to 0.2-foot tidal response. The timing of tidal cycles during the monitoring period was nearly synchronous at well N-149D (located approximately 50 feet from the river), whereas there was a lag of approximately 15 to 45 minutes between the arrival of high tide at the gauge and at the location of well N-148D (approximately 1,500 feet from the river). The close timing of the tides in the AOI 8 wells supports that the signal is in response to water-level changes in the Schuylkill River and not the tidal Delaware River to the south (or earth tides).

When compared to observed variability in AOI 8 lower aquifer water levels due to climatological and potential anthropogenic influences, **Figure 5-10** well monitoring data indicates that river tides significantly influence water levels in that aquifer beneath the PES Complex. An additional line-of-evidence supporting this conclusion is the asymmetrical shape of the tide signal in the AOI 8 wells, which mirrors that of the flood tide-dominated Schuylkill River (tides are asymmetrical in favor of the flooding tide). These observations support the interpretation that local to AOI 8, there may be a near direct connection between the lower aquifer and the Schuylkill River. Stantec suspects the degree of connection may be greatest where shallow bedrock is present beneath the Schuylkill River and/or where the river is deeply scoured and/or maintenance dredged (e.g., scour between the Passyunk Avenue bridge pilings). Although no monitoring data is presented for the water-table aquifer in this report, Stantec has collected additional water-level data at the PES Complex that indicates the river tide signal is almost always greater in the lower aquifer. River bulkheads, low permeability sediments/fill, and/or the elevation of the bottom of the water-table aquifer may explain that phenomenon (i.e., places where the majority of the water-table aquifer saturated thickness occurs above the Schuylkill River).

6.0 LNAPL INVESTIGATION

To investigate LNAPL in AOI 8, a comprehensive LNAPL Conceptual Site Model (LCSM) was prepared and is included as **Appendix H** of this RIR. In general, the LCSM utilizes a technical approach to evaluate the potential mobility of LNAPL present at the site incorporating multiple lines of evidence, including observations of LNAPL distribution over time, an analysis of apparent NAPL thickness (ANT), physical and chemical laboratory analysis of LNAPL samples, and theoretical estimates of LNAPL mobility supported by field and laboratory measurements to understand whether AOI 8 LNAPL areas are residual (immobile), mobile (recoverable), and/or migrating. As defined in the LCSM, residual LNAPL represents LNAPL that is trapped in soil pores, mobile LNAPL is LNAPL that exceeds residual saturation, and migrating LNAPL is LNAPL that is observed to spread or expand. It is noted that although mobile LNAPL includes migrating LNAPL, not all LNAPL indicated to be mobile is migrating.

The following summarizes findings and conclusions of key elements of the LCSM utilizing data gathered from literature review, historical and recent field investigations, laboratory analyses, and remediation efforts.

- Gauging and hydraulic data from the adjacent Verizon SDWC Property and PGW Passyunk Facility were utilized, when available, to achieve a site model which is representative of cross-boundary conditions. LNAPL modeling was conducted based on 2016 data, which represents the most recent complete data from the PES Complex and the two properties adjacent to AOI 8.

- Numerous LNAPL characterization samples collected from the area by Stantec and others through time have identified the presence of several variably-weathered products and product mixtures in the subsurface at AOI 8 (**Figure 6-1**). The variation in LNAPL characteristics is indicative of multiple product releases at different times with subsequent co-mingling of some plumes. For the purposes of this and other RIRs for the PES Complex, laboratory-characterized LNAPL samples (i.e., qualitative analysis using chemical data of hydrocarbon distributions [gas chromatographic patterns] and comparison to reference product sample data) have been generalized by Stantec into the product groups (see LCSM for a description of the categories) listed below:

    - Light Distillate
    - Middle Distillate
    - Heavy Distillate
    - Mixtures of Light/Middle/Heavy Distillates

- Most LNAPL plumes in AOI 8 are characterized as heavy distillate or heavy distillate mixtures. With the exception of a likely contiguous plume near the PGW Border System, the LNAPL plumes are considered to be relatively small, isolated occurrences in discrete areas of AOI 8 (**Figure 6-1**).

- A review of apparent non-aqueous phase liquid (NAPL) thickness (ANT) data through time suggests that in general, LNAPL plumes at AOI 8 are not migrating. This is mainly because the vertical thickness of LNAPL as observed in most AOI 8 monitoring wells has not been increasing over the period of record. However, increasing ANT trends have recently been observed in a portion of the wells in the following generalized areas: PGW Border System area, North Yard Bulkhead System area, an area south of the Verizon SDWC Property, and an area north of the Jackson Street Sewer System.

- A conservative value for the site-specific mobility term was calculated to be $2.31\text{x}10^{-4}$ cubic centimeters per second per gram (cm^3s/g) which is above the practical limit of mobility.

- The critical pore entry pressure was estimated for wells that had greater than 0.1 feet of apparent LNAPL thickness in 2016. The estimated critical pore entry pressure thickness ranged from 0.10 to 44.59 feet with an average of 2.73 feet. For 16 of the 45 wells evaluated, the observed LNAPL thickness was greater than the critical pore entry pressure indicating that the LNAPL observed at these wells is potentially mobile.

- ASTM suggests that LNAPL seepage velocities less than $1\text{x}10^{-6}$ cm/s are indicative of functionally immobile LNAPL. As a part of this LNAPL CSM, plume velocity calculations were calculated for wells with greater than 0.1 feet of ANT in 2016. The estimated velocity for 25 of the 45 wells evaluated was greater than the limit of functional mobility; whereas 20 of the 45 wells evaluated did not have sufficient mass for mobility calculations. Model calculated plume velocities ranged from $3.4\text{x}10^{-6}$ cm/s to $1.7\text{x}10^{-3}$ cm/s with an average velocity of $6.2\text{x}10^{-4}$ cm/s, indicating that LNAPL is functionally mobile in some areas of AOI 8.

- The API LDRM model was applied to wells with greater than 0.1 feet of ANT in 2016. The LDRM model indicates that LNAPL in 10 of the 45 wells evaluated was within the range of practicable recoverability, five wells are in the transitional range, and remaining 30 wells have estimated LNAPL transmissivity values below the limit of practicable recoverability.

Pore entry pressure, mobility modeling, and LDRM evaluations indicate that areas of potentially mobile and practicably recoverable LNAPL are present within AOI 8. In general, based upon the multiple lines of evidence presented, LNAPL observed at AOI 8 appears to be stable or decreasing (not migrating) as a whole and not practically recoverable. However, LNAPL present in a few areas of AOI 8 may be mobile, able to migrate, and/or recoverable. These areas include:

- The PGW Border Remediation System area: N-127, N-130, N-151, N-31, N-47, N-48, N-49, N-51, N-76, N-82, PZ-202, PZ-204, RW-201, RW-204, RW-205, RW-206, PGW-MW-30, and PGW-MW-31 have exhibited at least one line of evidence indicating mobility
- Northern AOI 8, adjacent to the Verizon Property: N-138, N-139, and N-146 (note that nearby well N-142 did not exhibit lines of evidence indicating potential LNAPL mobility)
- Discrete locations in AOI 8: N-102, N-112, N-116, and RW-300

The results of this LNAPL mobility assessment may be used to focus additional testing and to facilitate recovery system optimization. As additional site-specific LNAPL data becomes available it may be used to update the LNAPL mobility evaluations presented herein.

7.0 VAPOR INTRUSION

The vapor intrusion pathway in AOI 8 was evaluated for potential receptors of vapors originating from petroleum hydrocarbon source material, in accordance with the PADEP Land Recycling Program Technical Guidance Manual for Vapor Intrusion into Buildings from Groundwater and Soil under Act 2 (VI Guidance) (PADEP, 2017a). In accordance with the VI Guidance, an evaluation of the potential for a complete vapor intrusion pathway was conducted for each building based on size, construction, and use. Within AOI 8, five buildings were identified as occupied buildings requiring further evaluation of the vapor intrusion pathway. The Propane Terminal building, located north of the PES North Yard Ball Field, was identified as being occupied. However, the building is not within proximity distance to soil and groundwater impacts, nor within proximity distance to any known preferential pathways. Therefore, it was not included in the indoor air evaluation during the RI.

The adjacent Verizon SDWC Property was identified as potential receptor from LNAPL and dissolved-phase groundwater impacts. An indoor air evaluation was selected as the method to investigate whether a complete pathway for hydrocarbon vapors exists within these buildings. In addition to indoor air sampling, data collected from other investigations which include sub-slab air, soil vapor, and sewer air samples are also presented in this section. **Table 7-1** presents the building information available for indoor air evaluation for the Verizon Property Building and AOI 8 buildings. A summary of available sample field parameters is provided in **Table 7-2**, and available field summary sheets are included in **Appendix I**.

7.1 SUMMARY OF FIELD INVESTIGATIONS

The following sections summarize all vapor intrusion investigations within and around AOI 8, including those completed as part of AOI 8 RI, which was conducted in general accordance with the VI Guidance. The evaluation of indoor air was selected as the preferred investigation approach because indoor air data represent conditions that are as close to the receptor as possible; therefore, provide the most accurate representation of concentrations at the point of exposure. In general, the AOI 8 VI sampling events were conducted during the heating season when levels of volatile organic compounds (VOCs) inside buildings are expected to be higher than during warmer months.

7.1.1 Philadelphia Fire Department Building

Based on the presence on LNAPL in well PGW-MW-7, the Philadelphia Fire Department building, which is located approximately 200 feet from PGW-MW-7 in southern AOI 8 along the Schuylkill River, was identified as a potential receptor of volatiles from LNAPL. Vapor intrusion assessments were completed in AOI 8 by Aquaterra in 2009, as detailed in the SCR/RIR by Langan (2012). One indoor air and one ambient air sample (FIREHOUSE AMB #420 and FIREHOUSE INDR #413), and four soil gas samples (AOI8_SG-1 through AOI8_SG-4) from sample ports near the exterior walls, were collected. The sample locations are shown on **Figure 7-1**, and the results of the indoor air and soil gas samples are presented in **Tables 7-3 and 7-4,** respectively.

7.1.2 Onsite RI Activities

As part of a current conditions investigation, Stantec conducted a vapor investigation for various occupied buildings in 2012. On October 24, 2012, one ambient air sample (AOI8 Sample 23) and one indoor air sample (AOI 8 Sample 22) were collected to evaluate the vapor intrusion pathway for the Old Scale House and outdoor air located within AOI 8. All samples were collected from the breathing zone (3-6 feet above floor/ground level) using Summa© canisters with laboratory-provided regulators set to collect air over one continuous 4-hour period, which was determined to represent VOC concentrations during normal operating conditions at the PES Complex. The samples were packaged by Stantec field personnel and transported by FedEx Ground to Columbia Analytical Services, Inc. under chain-of-custody documentation for analysis of VOCs on the Evergreen Petroleum Short List by EPA method TO-15.

In March 2016, four indoor air and one ambient air samples were collected by GHD as part of remedial investigation activities at the PES Complex. One indoor sample was collected from each occupied building identified in AOI 8 during the survey as follows: Building 6642 (AOI8-AI-16-001), Building 6641 (AOI8-AI-16-002), New Scale House (AOI8-AI-16-003), and Old Scale House (AOI8-AI-16-004). One ambient air sample (AOI8-AA-16-001) was collected in an open area to the northeast of Buildings 6641/6642. The samples were analyzed for VOCs by EPA method TO-15.

Four additional samples were designated as trip blanks for the overall site-wide investigations from the two sampling events. All sample locations are shown on **Figure 7-1**, and the results of these samples are provided in **Table 7-3**.

7.1.3 Verizon SDWC Property

Between 2011 and 2013, Leidos conducted a vapor intrusion investigation at the adjacent Verizon SDWC Property, which included soil gas, sub-slab, indoor, and ambient air sampling. Five sub-slab sample points (V-SGSP-1 through V-SGSP-5) were installed within the building footprint. Ambient air samples were collected from two locations located to the north and south of the building. Indoor air samples were collected from the Main Office, Lunch Room, and the Southwest Office. Four soil gas sample points (V-SG-1, V-SG-2, V-SG-3, and V-SGSP-6) were installed in the parking lot. Locations of all samples are shown on **Figure 7-2**.

A vapor intrusion investigation was conducted by Stantec in March 2017, complementary to the investigation conducted by Leidos, and included ambient air, indoor air, and sub-slab air sampling. Two ambient air samples, North and South, were collected from the parking lot areas to the north and south of the building, respectively (**Table 7-5**). The ambient air locations coincide with the ambient air sample locations collected by Leidos during the 2011-2013 sampling events. Indoor air samples were collected from the three occupied spaces identified by Leidos: Main Office, Lunch Room, and Southwest Office. In addition, Stantec collected an indoor air sample from the South office, and one indoor air sample from the Northwest office, which were identified as additional occupied spaces during Stantec's building survey in November 2016. Four sub-slab samples were collected from sample points installed during the Leidos investigation (V-SGSP-1, V-SGSP-2, V-SGSP-4, and V-SGSP-5). Sub-slab sampling was conducted in accordance with *Evergreen Field Procedures Manual* and the VI Guidance. Stantec's attempt to access sample port, V-SGSP-3, was unsuccessful.

Stantec and Leidos vapor intrusion investigation sample locations were coincident therefore all sample locations are shown on **Figure 7-2**. The results of samples collected from vapor intrusion investigations at the property are provided in **Tables 7-4, 7-5, and 7-6**. The samples were analyzed for VOCs by EPA method TO-15.

7.1.4 Jackson Street Sewer Investigation

PADEP previously identified the Jackson Street Sewer as a potential VI offsite migration pathway towards residential neighborhoods. The Jackson Street Water Curtain, installed in 2003, is located near the eastern AOI 8 boundary (**Figure 7-1**). In 2009, Aquaterra collected one ambient air sample (JACKSON AMB #062) near the Jackson Street Sewer, and three air samples within the manholes (Nos. 1, 3, and 6) of the Jackson Street Sewer. The manholes were located on both sides of the water curtain, near the eastern AOI 8 boundary. The sample results are presented in **Table 7-7**.

The Mifflin Street Sewer, located north of AOI 8, was identified as a potential preferential pathway for vapor intrusion. The groundwater results from monitoring wells near the sewer were compared to the Groundwater to Indoor Air Statewide Health Standard, Residential Screening Levels (**Table 7-8**). The results show exceedances of several compounds in monitoring wells at the AOI 8 boundary near the Verizon SDWC Property, however these exceedances are limited to certain wells and in general correlate to LNAPL plumes in the area.

No other potential receptors were identified within the specified proximity distances that warranted further vapor intrusion evaluation within AOI 8.

7.2 SAMPLE RESULTS

The analytical results of air sampling activities are presented in the following sections. Analytical results are presented on **Tables 7-3 through 7-7,** and the available laboratory analytical reports are included in **Appendix E**.

Indoor air and ambient air sample results were compared to six sets of screening values:

- EPA RSL, TR=1E-5, THQ=0.1
- SVIA-NR SHS
- SVIA-NR SSS
- OSHA PEL
- NIOSH REL
- ACGIH TLV

The VI Guidance establishes the EPA RSL, TR=1E-5, THQ=0.1 as appropriate screening values when it can be demonstrated that vapor intrusion is the only complete exposure pathway for a receptor. Upon the completion of remediation activities, volatilization to the breathing zone will be the only potentially complete pathway for petroleum impacts in AOI 8. A calculated site-specific standard is not being used, except for lead in soil, which is not a potential vapor intrusion concern.

Sub-slab air sample results were compared to two sets of screening values:

- EPA RSL, TR=1E-5, THQ=0.1, Attenuation Factor =0.0078
- SVSS-NR SHS

The VI Guidance establishes 0.0078 as the attenuation factor applicable to the EPA RSLs for sub-slab soil gas samples.

Soil Gas air samples results were compared to the following screening values:

- SVNS-NR SHS
- SVSS-NR SHS

Samples from the Jackson Street Sewer investigation were compared to the following standards for residential (R) air:

- EPA RSL, TR=1E-5, THQ=0.1
- SVIA-R SHS
- SVIA-R SSS

7.2.1 Ambient and Indoor Air Results

Ambient and indoor air samples were collected from within AOI 8 and from the Verizon SDWC Property (**Tables 7-3 and 7-5**). While historic data shows exceedances to the EPA RSLs for various site COCs, no exceedances were observed in samples collected during 2016-2017. It should be noted that the reporting limits for 1,2-dibromoethane (EDB) exceeded the screening criteria in the historic onsite samples.

7.2.2 Sub-Slab Air Results

Sub-slab air samples were collected within AOI 8 and at the Verizon SDWC Property (**Tables 7-4 and 7-6**). In pre-RI samples, various COCs were detected and one sample exceeded the EPA RSL for benzene. At least one COC was detected in all 2017 sub-slab samples, however none of the samples exceeded the corresponding EPA RSLs. It should be noted that the reporting limits for EDB, naphthalene, and 1,2-dichloroethane (EDC) exceeded the screening criteria in several historic samples.

7.2.3 Soil Gas Sample Results

Soil gas sample results from onsite and Verizon Property locations are presented **Table 7-4**. With the exception of benzene in one sample (AOI8-SG-1), none of the COCs exceeded the screening criteria in the soil gas samples. It should be noted that the reporting limits for EDB, EDC, and naphthalene exceeded the screening criteria in the onsite samples.

7.2.4 Jackson Street Sewer Sample Results

All samples collected as part of the Jackson Street Sewer potential migration pathway evaluation were compared to residential EPA RSLs and residential SHS (**Table 7-7**). Most of the constituents were not detected, and none of the constituents exceeded the EPA RSLs or the residential SHS. It should be noted that the reporting limits for EDB and EDC exceeded the screening criteria in the four sewer air samples.

7.3 SUMMARY

The evaluation of indoor air was selected as the preferred investigation approach because indoor air data represent conditions that are as close to the receptor as possible; therefore, provide the most accurate representation of concentrations at the point of exposure. The VI Guidance establishes the EPA RSL, TR=1E-5, THQ=0.1 as appropriate screening values when it can be demonstrated that vapor intrusion is the only complete exposure pathway for a receptor. Upon the completion of remediation activities, volatilization to the breathing zone will be the only potentially complete pathway for petroleum impacts in AOI 8.

- Ambient and indoor air samples collected within AOI 8 and at the adjacent Verizon SDWC Property during 2016-2017 did not exceed the EPA RSLs for any site COCs.
- Sub-slab air samples collected at the Verizon SDWC Property in 2017 did not exceed any EPA RSLs (using attenuation factor for sub-slab soil gas).
- One soil gas sample, collected at the Philadelphia Fire Department building in 2009, exceeded the EPA RSL for benzene. Evergreen plans to conduct additional indoor air and/or soil gas sampling at the Philadelphia Fire Department building to assess current site conditions.

Data from the required second round of indoor air sampling will be presented in a future Act 2 deliverable. As no concentrations of COCs were detected above the EPA RSLs in indoor air samples during the remedial investigation, no specific controls will be necessary to manage the vapor intrusion pathway. It is noted that this conclusion is dependent upon the remainder of the exposure pathways being eliminated through other remedial activities and controls.

8.0 QUALITY ASSURANCE/ QUALITY CONTROL

Methods established by Evergreen to examine data quality are outlined in **Appendix C**, *Quality Assurance/Quality Control Plan and Field Procedures Manual*. All fieldwork conducted as part of the site characterization activities was performed in accordance with the procedures outlined in the *Evergreen Field Procedures Manual*, **Appendix C**. An assessment of analytical data collected as part of this investigation under the *Quality Assurance/Quality Control Plan* is included in **Appendix J**. The following sections describe specific aspects of quality assurance/quality control procedures that pertain to the activities outlined in this report.

8.1 EQUIPMENT DECONTAMINATION

Sampling equipment was either dedicated or decontaminated in accordance with the field sampling procedures to prevent cross-contamination. Prior to sampling, the equipment was decontaminated with successive rinses of detergent, potable water, and distilled water.

8.2 EQUIPMENT CALIBRATION

Air quality monitors used for both air monitoring and soil screening were calibrated prior to use. Both a zero calibration and a span calibration using gases of known concentration as recommended by the manufacturer (i.e. 100 parts per million by volume (ppm_v) isobutylene for the photoionization sensor) were performed.

8.3 SAMPLE PRESERVATION

Samples were placed directly into chemically preserved and/or non-preserved glassware provided by the analytical laboratory, as appropriate. Soil and groundwater samples were preserved and shipped at a temperature of approximately 4° Celsius (C) or less by application of ice prior to shipment to the analytical laboratory. This temperature was maintained during shipment by placing ice in zip-top bags above, around, and below the sample containers.

8.4 DOCUMENTATION

Chain-of-custody forms were maintained throughout the RI sampling program to document sample acquisition, possession, and analysis. Chain-of-custody documentation accompanied samples from the field to the laboratory. Each sample was assigned a unique identifier that was recorded in the field notes as well as on the chain-of-custody document.

9.0 FATE AND TRANSPORT ASSESSMENT

This section of the RIR presents a fate and transport assessment that aims to broadly delineate subsurface impacts related to the former production and storage of petroleum hydrocarbons at AOI 8, and provide context for the evaluation of pathways that could influence the fate and transport of related contaminants. The assessment was designed in accordance with a September 30, 2015, meeting during which Evergreen's team of consultants and the PADEP collaboratively decided that individual AOI RIR submissions for the PES Complex would include qualitative-level assessments of contaminant fate and transport. These assessments were to include an evaluation of plume stability, COC trends, and potential impacts to receptors, including surface water. It is understood that the findings and conclusions of the AOI-specific, qualitative assessments will ultimately be used in a site-wide MODFLOW and transport model (e.g., MT3DMS model) to quantitatively predict contaminant fate and transport at the PES Complex, including comprehensive simulations that will address the future extent of contamination and cumulative mass loading to potential receptors. Model predictions will be used to support informed decision making during Cleanup Plan activities.

9.1 NATURAL TRANSPORT PATHWAYS

Detailed discussions that demonstrate characterization of the geologic and hydrogeologic conditions beneath AOI 8 are presented in **Section 5** of this RIR and are summarized in the conceptual site model presented in **Section 10**. In the context of contaminant fate and transport, the purpose of this subsection is to discuss natural flow paths in the subsurface and to identify the presence of any areas of preferential flow due to geologic conditions inherent to AOI 8. The following conditions have been characterized:

- The LiDAR-based elevation model shown on **Figure 2-2** and the water-table elevation maps presented in **Section 5** indicate that groundwater flow patterns in the water-table aquifer beneath AOI 8 and its perimeter generally mirror surface topography. There is convergent flow along the axis of former Rambo Creek and westerly flow towards lower elevations along the Schuylkill River. Dissolved-phase COCs and LNAPL, where present and mobile, are anticipated to follow these pathways.

- The lower aquifer reaches its up-dip limit in northwestern AOI 8 in an area of shallow bedrock. In this area, the PRM middle clay unit is not present and the lower aquifer is unconfined. Lower aquifer groundwater surface contours presented in **Section 5** indicate radial flow from this recharge area. This is an area where the lower aquifer may be vulnerable to the downward migration of contamination from shallow sources.

- The stratigraphic profiles presented in **Section 2** support that alluvial deposits along the axis of former Rambo Creek may continuously thicken to the west and southwest near the Schuylkill River. Based on stratigraphic position and inferred permeability, this channel-like deposit could transport contaminants preferentially towards the river.

- The stratigraphic profiles presented in **Section 2** indicate that a thick sequence of Holocene muds is present along the AOI 8 Schuylkill River boundary. Granular alluvium is present beneath the muddy sequence. This fine-grained depositional feature (point bar deposit) may limit the natural discharge of groundwater to the river. Conversely, groundwater discharge to the Schuylkill River may occur through the deeper (Pleistocene) alluvium in areas of non-deposition or scour, particularly during low tide.

9.2 ANTHROPOGENIC FEATURES AND PATHWAYS

9.2.1 Historic Fill

Anthropogenic fill is present beneath the existing land surface at most locations in AOI 8 and has been identified to range in thickness from a thin veneer to a maximum of approximately 20 feet. Fill has generally been placed in most significance along the perimeter of the Schuylkill River and along the axis of former Rambo Creek that once bisected AOI 8. Significant fill deposits have also been observed along the northern AOI 8 border near South 34th Street and the Verizon SDWC Property. Most fill is generally heterogeneous in nature, poorly consolidated, and is sufficiently permeable to allow for the percolation of surface water or water leaked from utilities, and is subject to contamination from surface or subsurface petroleum releases. Where the base of the fill layer intersects the water table, groundwater discharge to fill may be occurring. As indicated by data presented in this RIR including the stratigraphic profiles and water-table contour maps, preferential groundwater flow through fill deposits in former Rambo Creek valley is supported. Along the Schuylkill River, the filled floodplain supports a water table and a subtle groundwater mound. A feature somewhat unique to AOI 8 when compared to other PES Complex areas is the general lack of a fine-grained alluvial cap on the Cape Map Formation (**Figure 2-6**). Where that stratum is missing, fill is generally in direct communication with more granular Pleistocene and Cretaceous deposits and the aquifer is therefore more vulnerable to contamination from fill sources.

9.2.2 Onsite Storm Sewer System

A shallow storm sewer system exists beneath AOI 8 and was reviewed by Stantec utilizing a 1972 Atlantic Richfield Company drawing titled North Yard Storm Water System. The primary function of the storm sewer system is to collect and convey surface runoff derived from precipitation. Stormwater runoff is collected from within tank berm areas, roadways, and is conveyed via gravity flow to the Rambo Creek Sewer. The Rambo Creek Sewer picks up additional flow along its course across AOI 8 and discharges to an API-type stormwater separator near the Schuylkill River referred to as the Klondike Separator. No information pertaining to the depth or invert elevations of the storm sewers has been identified, however the Rambo Creek Sewer is indicated to be 36 inches in diameter and is present in an area of relatively shallow groundwater. It is reasonable to assume that in addition to transport of COCs from surface water sources in AOI 8, groundwater and LNAPL may also infiltrate the Rambo Creek Sewer from sources in the valley fill and the sewer could function as a preferential pathway for contaminant transport. Rambo Creek Sewer was digitized on screen by Stantec using the above-referenced drawing; it is shown on **Figure 1-2** and most other figures included in this RIR.

9.2.3 Philadelphia Water Department Sewers

Several City of Philadelphia combined sewers either bisect or are adjacent to AOI 8. Because these sewers are large, relatively deep, and generally intersect or are submerged beneath the water table, they are evaluated as potential contaminant migration pathways in this report. Pertinent construction information is presented below and drawings obtained for the assessment are included in **Appendix K**. Regional maps were obtained from the PWD Water Transport Records in 2017 and apply to all sewers discussed below. These are as follows:

- Map 14, Philadelphia Water Department Water Pollution Control Division, PWD 214603 (Current as of 1/20/2013)
- Map 15, Philadelphia Water Department Water Pollution Control Division, PWD 214604 (Current as of 1/20/2013)
- Map 19, Philadelphia Water Department Water Pollution Control Division, PWD 214608 (Current as of 1/20/2013)
- Map 20, Philadelphia Water Department Water Pollution Control Division, PWD 214609 (Current as of 1/20/2013)

The regional maps were registered in a GIS and sewers pertinent to this assessment were digitized on screen by Stantec. The sewers are shown on **Figure 1-2** as well as on most of the figures throughout this RIR.

9.2.3.1 Mifflin Street Sewer

Stantec obtained the following additional drawings from the PWD through a Pennsylvania One Call in 2017:

- Plan of Main Sewer Built in Mifflin Street from 83.26ft W. of W.H.L. 36th St. to E.H.L. of 32nd St., 48th Ward, Philadelphia, Department of Public Works, Bureau of Surveys, PWD 308154 (Date of Completion 12/23/1925)
- Sanitary Sewer, Intercepting Chamber, Intercepting Manhole and Appurtenant Work in Mifflin Street Between 36th Street and Vare Avenue, Lower Schuylkill East Side Intercepting System, City of Philadelphia Water Department, PWD 191930 (Date of Completion 7/6/1959)

Stantec has concluded the following regarding the Mifflin Street Sewer based on review of the referenced as-built drawings:

- The portion of the sewer adjacent to AOI 8 and intersecting the Verizon SDWC Property was constructed circa 1925 in an open excavation.
- From approximately 32nd Street west to the Schuylkill River where it discharges, the sewer is constructed of an 8-foot by 5-foot reinforced concrete culvert.
- The combined sewer was designed to flow west along a grade of approximately 0.34 feet per 100 feet of pipe.
- Inverts indicate that sewer bottom elevations range from approximately 0.38 feet near 34th Street to -6.29 feet at the Schuylkill River (undisclosed elevation datum). These elevations generally correspond to present depths below ground surface of approximately 20 feet to 22 feet.

- In the late 1950s, the sewer was connected to the Lower Schuylkill East Side Intercepting Sewer (interceptor) through construction/excavation of an Intercepting Chamber on the west side of where it crosses 34th Street, and tunneling of a 21-inch vitrified pipe sewer to convey the combined flow east to the interceptor. The chamber contains a tide dam with a top elevation of 1.25 feet. The invert elevation of the Intercepting Chamber is -0.73 feet, and the invert of the junction manhole in 34th Street accessing the drop pipe is noted as -4.88 feet. The drop pipe connects to the interceptor at elevation -16.86 feet beneath the east side of Vare Avenue.

9.2.3.2 Jackson Street Sewer

- The portion of the sewer bisecting AOI 8 was constructed in the early 1900s, between approximately 1903 and 1917 (GES, 1993).
- From approximately Vare Avenue west to the Schuylkill River where it discharges, the as-built indicates a 6.5-foot to 7.5-foot diameter brick and mortar sewer.
- The combined sewer was designed to flow west along a grade of approximately 0.28 feet per 100 feet of pipe.
- Inverts indicate that sewer bottom elevations range from approximately 3.93 feet near Vare Avenue to -7.5 feet at the Schuylkill River (undisclosed elevation datum). These elevations generally correspond to present depths below ground surface greater than approximately 20 feet.
- The sewer is connected to the Lower Schuylkill East Side Intercepting Sewer by means of an Intercepting Chamber located near the eastern AOI 8 boundary (construction data and as-built details for this chamber were not obtained). The invert elevation of the Intercepting Chamber is 3.93 feet, and the invert of the junction manhole accessing the drop pipe to the interceptor is noted as -15.57 feet.

9.2.3.3 Lower Schuylkill East Side Intercepting Sewer

Stantec (2016) and Stantec (2017a) discussed drawings of the 26th Street Intercepting Sewer to the south of AOI 8. This intercepting sewer is also called the Lower Schuylkill East Side Intercepting Sewer (sewer). Stantec obtained the following additional drawings from the PWD through a Pennsylvania One Call in 2017:

- Intercepting Sewer in Vare Ave., Delaware River Port Authority R/W, Private Property, and 26th St. Between Mifflin St and D/R/W (former Shunk St.) South of Passyunk Ave., Sheet 1 of 2, City of Philadelphia Water Department, PWD 192045 (Dated 3/25/1963)
- Intercepting Sewer in 34th Street and Vare Ave. Between South of Morris St. (Sta. 35+40.08) and Mifflin St. (Sta. 45+46.92), Sheet No. 4 of 4 Sheets, City of Philadelphia Water Department, PWD 1070332 (Last Dated 10/2/1957)

The following conclusions are primarily based on review of the drawings included in **Appendix K**:

- The sewer portion adjacent to AOI 8 is indicated to have been constructed by 1963.

- The sewer is located along the western side of 26th Street near the AOI 8 boundary from approximately 28th Street up to Maiden Lane, where it crosses to the eastern side of Vare Avenue and the Schuylkill Expressway.
- The sewer is constructed of vacuum-processed (a process by which excess water and air is removed from the surface of wet concrete by vacuum for the purpose of compacting the concrete, increasing its strength, lowering its permeability, and increasing resistance to high-velocity liquid flow), reinforced concrete pipe that is 5.25 feet in diameter.
- The sewer flows to the northwest along a grade of 0.07 to 0.09 feet per 100 feet of pipe along the AOI 8 area. The sewer was designed to capture gravity flow from large, combined PWD sewers via intercepting chambers and drop pipes.
- Along the AOI 8 corridor, the sewer appears to have been constructed in a tunneled excavation that was approximately 8 feet high by 9.5 feet wide.
- Inverts indicate that sewer elevations range from -17.43 feet near the intersection of 28th Street and Vare Avenue to -20.24 feet near the intersection of 34th and Moore Streets (the drawings do not disclose the elevation datum).
- It is assumed that the pipe joints consist of bell ends that were slipped together in the tunnel. The annular space surrounding the sewer pipe was then backfilled with concrete (plan indicates Class 25-1).

9.2.3.4 Passyunk Main Relief Sewer and Shunk Street Sewer

Although separated from AOI 8 in most places by the PGW Passyunk Facility, these two large-diameter sewers are briefly discussed in the context of this RIR because the hydraulic gradients presented support the conclusion that one or both sewers (and associated structures) is subject to groundwater infiltration and as such, may exhibit hydraulic influence on local water table conditions.

Stantec's review of the referenced PWD drawings indicates the following is true of these sewers:

- The Passyunk Main Relief Sewer is a 10.5-foot diameter concrete sewer that runs along the northern perimeter of Passyunk Avenue from 28th Street southwest to the Schuylkill River where it discharges. The sewer begins near Rittner and 24th Streets where it was tunneled to the west and southwest and passes under Vare Avenue and the Schuylkill Expressway. The sewer then runs south along 28th Street over an Intercepting Chamber to Passyunk Avenue where it turns southwest. An 18-inch drop pipe connects the Intercepting Chamber to a 30-inch pipe that runs northeast along Passyunk Avenue, from the Shunk Street Sewer Intercepting Chamber to the 26th Street Interceptor. The sewer's grade is generally 0.10 feet per 100 feet and invert elevations drop from approximately -5 feet near 28th Street to -9 feet at the Schuylkill River.
- The Shunk Street Sewer is a 13-foot diameter (beginning at 26th Street) brick and mortar sewer that runs along Passyunk Avenue to the south of the Passyunk Main Relief Sewer from 28th Street southwest to the Schuylkill River where both sewers discharge. The sewer originates along Shunk Street to the east and traverses under the CSX Railroad Property, 26th Street, and the Belmont Terminal before reaching Passyunk Avenue and turning southwest. An intercepting chamber is present near the intersection of Dover Street and Passyunk Avenue. The 30-inch drop pipe referenced above collects flow from this sewer and conveys it northeast to the 26th Street Interceptor.

From 26th Street to the Schuylkill River, invert elevations are approximately -3 feet to -9 feet along a grade of 0.001 to 0.1 feet per 100 feet.

9.2.4 Schuylkill River Bulkhead

Presently, the Schuylkill River bank is at least in part separated from AOI 8 by a bulkhead. Knowledge of the location, construction, and condition of the bulkhead(s) is critical to the understanding of any risks that AOI 8 contamination could pose to the river and its ecosystems. From a fate-and-transport perspective, the bulkheads could have a significant influence on minimizing the migration of groundwater, soil, and LNAPL contamination from AOI 8 to the river. **Figure 1-2** displays Evergreen and Stantec's current understanding of the location of AOI 8 bulkheads, which includes both wooden and steel portions. An effort to obtain construction information related to both types of bulkheads in AOI 8 was performed as part of this RIR, however no reports or drawings were located. It is likely that the wooden bulkhead along most of the AOI 8 shoreline was constructed by the early 1900s as the timing would be consistent with the hardening of river shorelines in the region. The steel bulkheads were likely constructed along with other PBNY structures by the mid-1900s.

Where available in places along the Schuylkill River in the Point Breeze Refinery South Yard and Girard Point Refinery, geotechnical information on steel bulkhead construction indicates that the structures are anchored into bedrock. For this assessment, it is assumed that both groundwater and LNAPL could migrate through the wooden bulkhead based on its age and unknown construction. Where steel bulkheads are present, it is assumed that they are of limited permeability and are supported by bedrock. Evergreen and Stantec will continue to seek information pertinent to bulkhead construction and will use that information in the MODFLOW model to assist in Cleanup Plan remediation decisions.

9.2.5 Remediation Systems

Within AOI 8, several remediation systems are present and were historically installed for the primary purpose of recovering LNAPL by means of total fluids recovery. Most systems are not currently operating. The water curtain component of the Jackson Street System, referred to as the Jackson Street Water Curtain, is the only active remedial feature at the time of this RIR (**Figure 1-2**). In general, the water curtain was installed on the east end of the Jackson Street Sewer to minimize the potential for offsite migration of vapors through the sewer pathway. Vapors would be derived from the volatilization of petroleum hydrocarbons in AOI 8 near the sewer. There are 2 inactive remediation systems and inactive components of one additional system in AOI 8: the PGW Border System, the North Yard Bulkhead System, and the Jackson Street System's total fluids recovery wells. **Appendix L** provides a detailed discussion of the remediation systems. System design, purpose, operational history, and where appropriate, records of totalized fluid recovery, are summarized in the appendix.

9.2.6 Future Remediation Plans

At the time of this RIR, Evergreen is evaluating the performance history of existing remediation systems in AOI 8 and throughout the PES Complex. It is generally understood that remedial performance and options near the AOI 8 property boundary with the Verizon SDWC Property and PGW Passyunk Facility need to be reviewed. A test well (N-157) was recently installed and a well performance test recently conducted to evaluate the feasibility of total fluids recovery as a remedial option near the Verizon SDWC Property. Those data are being assessed and may be included in the Cleanup Plan, or submitted to the PADEP prior to submittal of the plan to provide an update on status of remediation in that area of groundwater contamination.

9.3 GROUNDWATER CONSTITUENTS OF CONCERN

9.3.1 Water-Table Aquifer (unconfined)

Concentrations of the following Evergreen Comprehensive List COCs were detected above the MSC in water-table aquifer groundwater during the 2016 characterization sampling events (see **Table 4-2**): 1,2,4-TMB, 1,3,5-TMB, 2-methylnaphthalene, anthracene, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2-ethylhexyl)phthalate (BEHP), chrysene, cobalt, ethylbenzene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, lead, naphthalene, nickel, pyrene, toluene, vanadium, and zinc.

Available historical analytical data from previous groundwater sampling events were reviewed by Stantec. Historical data indicates that no additional COCs were identified at concentrations in excess of the current SHS during past AOI 8 water-table aquifer groundwater sampling. It should be noted that exceedances of arsenic, barium, chromium, and selenium, which are not part of the Evergreen Comprehensive List, have been observed over the period of record.

9.3.2 Lower Aquifer (semi-confined)

Concentrations of the following COCs were detected above the SHS in lower aquifer groundwater during 2016 characterization sampling events (see **Table 4-3**): benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, BEHP, dibenz (a,h)anthracene, and naphthalene.

Available historical analytical data from previous groundwater sampling events was reviewed by Stantec. Additional Evergreen Comprehensive List COCs were identified at concentrations in excess of the current SHS during past AOI 8 lower aquifer groundwater sampling, which include phenanthrene, pyrene, and cobalt. It should be noted that exceedances of arsenic, manganese, and chromium were also noted in the lower aquifer over the period of record; however, these constituents are not part of the Evergreen Comprehensive List.

9.4 DISTRIBUTION OF GROUNDWATER PLUMES

For purposes of this qualitative-level assessment of AOI 8 contaminant fate and transport, Stantec evaluated available analytical data from Evergreen's electronic database for the two most comprehensive groundwater analytical data sets, assembled from events conducted in 2008 (supplemented by 2002-2004 offsite data at the PGW Passyunk Facility, and compared to 2011 data at the Verizon SDWC Property) and 2014 through 2016 (supplemented by near time-equivalent offsite data where available). The goal of the assessment is to broadly identify the areas where elevated COC concentrations (plumes) are present in one or both defined aquifers (where discrete). Data from offsite wells at the PGW Passyunk Facility and Verizon SDWC Property were incorporated to aid in delineation and provide context regarding potential dissolved COC plumes across AOI 8 boundaries. Offsite data were incorporated using the most relevant available datasets, which included analytical data from Weston (2004) and from Leidos (2011 and 2016a, 2016b, 2016c, and 2017). PES Complex wells along the northern perimeter of AOIs 1, 2, and the Belmont Terminal were also included in the assessment.

Stantec utilized interpolation methods to search for trends in the datasets and to identify potential groundwater plume areas. When viewing these data as presented, it should be noted that several factors can influence contaminant concentrations measured in groundwater samples obtained from wells, including but not limited to well construction, well condition, sampler procedures, laboratory procedures, seasonal variability, residual LNAPL in the formation, additional source through recurrent or new releases of petroleum, source removal through LNAPL remediation, and degradation by natural attenuation through the temporal ranges of data utilized in each figure. Nonetheless from a qualitative perspective, these data provide a line-of-evidence to support broad conclusions about contaminant source and fate resulting from groundwater transport.

9.4.1 Water-Table Aquifer

9.4.1.1 Benzene

Of the Evergreen Comprehensive List COCs identified to be present in groundwater in both aquifers beneath AOI 8, benzene was chosen as the primary COC for this discussion. Benzene was chosen as a qualitative-level proxy for other contaminants evaluated because of its higher water solubility and potential to be mobile or migrating in the aquifers, due to its general persistence in groundwater at and near the PES Complex, and because benzene contamination is anticipated to be one of the primary COCs (along with methyl tertiary butyl ether [MTBE] present in other AOIs) driving regulatory closure for groundwater under Act 2. Other COCs identified in groundwater are discussed in **Section 9.6** in the context of benzene and to some extent, where appropriate, lead distribution.

Figures 9-1 and **9-2** present benzene concentration plots for the referenced sampling events in the water-table aquifer. The maximum observed benzene concentration (where data for more than one groundwater sampling event were available per stated time period) was interpolated using the point Kriging gridding method. Contours are displayed using a logarithmic scale, and both colorized grids and contours were cropped to the data extents. Grid classifications were normalized for both plots (see color scales) based on a lower concentration limit represented by the MSC (i.e., 5 µg/L for benzene) and an upper concentration limit representative of the highest observed benzene concentration.

Based on available data, the following dissolved plumes were identified in recent years (2014-2016):

- Three general areas of dissolved plume cores have been characterized for benzene:
    - PGW Border System area
    - Northern AOI 8/Verizon SDWC Property area
    - Schuylkill River Bulkhead area

- Additionally, isolated areas of benzene exceedances are also observed in two generalized areas:
    - Northern AOI 8, along and to the north of the Jackson Street Sewer
    - Southern AOI 8, along the western reach of Rambo Creek Sewer

9.4.1.2 Lead

Among metals, lead has the highest number of observed exceedances in data from the 2016 characterization sampling events. **Figure 9-3** shows lead concentrations and relative level of exceedances above the lead SHS (5 µg/L) in water-table aquifer wells in 2016. For a majority of the wells within AOI 8, lead was not detected above the laboratory detection limit. With few exceptions, lead exceedances are generally concentrated in northern AOI 8, south of the Propane Terminal. These exceedances are likely attributable to the historic disposal of lead smelter slag **(Section 1.4.3**) observed in fill historically placed in the area. Alternatively, some lead identified at lower concentrations may be attributable to releases of crude oil or refined petroleum products containing lead.

9.4.2 Lower Aquifer

Along with benzene, several SVOCs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, BEHP, phenanthrene, pyrene, and naphthalene), and metals (lead, manganese, arsenic, chromium, and cobalt) were detected above the respective SHS in certain lower aquifer wells (**Table 4-3**). **Figure 9-4** displays groundwater exceedances for the lower aquifer wells; interpolation of potential plumes was not warranted due to limited spatial data availability for the lower aquifer. Although historical exceedances of these compounds are identified, the majority of wells do not exhibit exceedances in recent sampling events (2014-2016). It should be noted that arsenic, manganese, and chromium are not part of the Evergreen Comprehensive List of COCs.

In exception, two areas of benzene exceedances are identified to originate in the lower aquifer subcrop area (see **Figure 2-7**). In southern AOI 8, the data support that benzene present in the lower aquifer subcrop area, identified by well N-112, may be migrating downgradient from an LNAPL source southwest towards the Schuylkill River, a pathway identified by wells N-44D and N-75. The plume area is delineated by wells to the north (N-37 and N-94), well N-147D to the east (replacement for N-44D), well N-149D to the south/southeast, and wells N-73 and N-38D to the west.

The second area is present along the AOI 8 boundary near the Verizon SDWC Property and is supported by interpretations of well N-155 data (**Figure 2-9**). Well N-157 was recently drilled to replace N-155 but groundwater has not yet been sampled (it is indicated on the cross section because the driller's log supports the interpretation of bedrock occurrence). The benzene exceedances at well N-155 are delineated up gradient to the northwest (well N-4), to the southeast (well N-9), and to the south (well N-13). Well N-21 has indicated benzene exceedances in the lower aquifer since 2012 in a somewhat isolated area that could possibly relate to down gradient migration from a N-155 source area. Lack of stratigraphic control indicating the presence or absence of a lower aquifer offsite, to the north of AOI 8, limits the ability to demonstrate side-gradient to up-gradient delineation in that direction. In this area, a dissolved benzene plume is present in the water-table aquifer which may not be discretely separated from the lower aquifer, depending on the presence or absence of the middle clay unit aquitard. If the benzene concentrations in the water table are interpreted to represent a lower aquifer condition in this area, then the plume could be broadly delineated to V-MW-4 and V-MW-16.

9.5 GROUNDWATER PLUME STABILITY ASSESSMENT

To qualitatively assess the stability of the identified groundwater plumes, Stantec utilized the referenced concentration plots to evaluate overall plume size and COC concentration trends. In addition, COC concentration trend plots were created for selected wells with historical data that are located near plumes (to evaluate trends), and/or at locations downgradient of the plume cores (to evaluate potential mobility of dissolved-phase plumes with emphasis near the property boundary) (see **Figures 9-5a, 9-5b, and 9-5c**). The following conclusions can be made based on this qualitative assessment of benzene.

Schuylkill River Bulkhead Area

Benzene concentrations along the bulkhead area (PZ-504, PZ-505, N-61, N-57, N-58, and N-59) have been decreasing or non-detect over the period of record (**Figure 9-5a**). Based on present-day groundwater flow patterns, the apparent trend may be attributable to source depletion in fill deposits along the river where LNAPL and/or dissolved-phase benzene had migrated.

Northern AOI 8/Verizon SDWC Property Area

The monitoring well network in this area was expanded post-2010, and a fairly discernable decreasing trend can be observed in wells within the plume core (N-137, N-138, N-139, as well as offsite wells V-MW-2, V-MW-6, V-MW-7, and V-MW-8) (**Figure 9-5b**). These trends are suggestive of a depleting source from past historic releases in this area. LNAPL characterization data suggests that most free-phase source in this area is highly to severely weathered.

PGW Border Remediation System Area

Very limited groundwater analytical data is available for wells located in the southeastern portion of AOI 8, within or near the PGW Border System. Available data for monitoring well N-82 is shown on **Figure 9-5c**. Additionally, available data from offsite wells PGW-MW-42R and PGW-MW-10S, which are presumed to be located side gradient and up gradient of well N-82, are also included on **Figure 9-5c**. These data although sparse indicate that within AOI 8, the benzene plume may be expanding down-gradient towards the northwest.

Lower Aquifer Exceedances

Trends indicated on **Figure 9-4** for the benzene exceedances in southern AOI 8 support a plume that has likely reached a steady-state condition, based on data from destroyed well N-44D and well N-75 near the point of compliance at the Schuylkill River. In northern AOI 8 and offsite at the Verizon SDWC Property, benzene data is temporally limited to 2016 where confidence in the hydrostratigraphy is highest on PES Complex property. However, if the water-table plume is decaying in the offsite area, it may be reasonable to assume that a lower aquifer plume would be approaching a steady-state condition.

9.6 OTHER GROUNDWATER CONSTITUENTS OF CONCERN

Additional Evergreen COCs (co-contaminants) present above the MSCs in AOI 8 groundwater were generally found to be distributed in patterns that mirror or are localized to the benzene plumes, or have no discernable pattern based on the monitoring well network available (a few scattered well exceedances). As summarized in **Section 9.4** of this report, the following can be qualitatively stated regarding groundwater COCs in AOI 8:

- With the exception of benzene the COCs that have demonstrated the highest number of exceedances in water-table aquifer groundwater during the 2014-2016 timeframe are benzo(a)anthracene, benzo(a)pyrene, benzo(b)flouranthene, benzo(g,h,i)perylene, chrysene, and naphthalene. The distribution of these substances in groundwater also suggests that they were released in the same areas as benzene and were likely components of the same petroleum hydrocarbon products. Therefore, benzene is used as a qualitative-level proxy for the fate and transport assessment of these substances in this report. Where these substances are present as co-contaminants along the AOI 8 property boundary and may pose potential risk to offsite receptors, they will be further evaluated during quantitative fate and transport model simulations and documented in a future Act 2 submission.

- The remaining COCs identified at concentrations above the MSC in water-table aquifer groundwater during 2014-2016 sampling were generally only observed in a few AOI 8 well samples. Within AOI 8, no significant spatial distribution of these constituents was observed. Most of these compounds are generally less soluble in groundwater than benzene. Where these substances are present as co-contaminants along the AOI 8 property boundary and may pose potential risk to offsite receptors, they will be further evaluated during quantitative fate and transport model simulations and documented in a future Act 2 submission.

- Additional COCs present in the lower aquifer, such as SVOCs and metals, appear to have no pattern of spatial distribution in AOI 8 that could relate to significant groundwater transport. Most of these compounds are generally less soluble in groundwater than benzene. Where these substances are present as co-contaminants along the AOI 8 property boundary and may pose potential risk to offsite receptors, they will be further evaluated during quantitative fate and transport model simulations and documented in a future Act 2 submission.

9.7 POTENTIAL ONSITE AND OFFSITE RECEPTORS

Based on the identified impacts to groundwater at AOI 8, Stantec has evaluated the following as potential receptors.

- Vapor intrusion affecting potential occupants of buildings in AOI 8 located above groundwater plumes and/or areas of LNAPL was evaluated. Occupied buildings in AOI 8 and the adjacent Verizon SDWC Property were sampled as a part of site characterization activities. Sampling included indoor air, ambient air, sub-slab gas, and soil gas. Results from the ambient air, indoor air, and sub-slab air samples did not exceed the EPA RSLs. The EPA RSL for benzene was exceeded in one historic soil gas sample collected at the Philadelphia Fire Department building.

- Infiltration of groundwater into underground utilities has the potential to generate vapors along subsurface corridors, or direct vapor migration into the vadose zone. The Jackson Street and Mifflin Street Sewers were identified as potential vapor migration (external preferential) pathways for petroleum hydrocarbon sources identified in AOI 8 because they either do not meet the 30-foot horizontal proximity distance from AOI 8 identified groundwater impacts, or are submerged beneath the water table in areas of potential groundwater impacts (do not meet the vertical separation distance). A vapor mitigation system (Jackson Street Water Curtain) is currently in operation to prevent potential vapors migrating from the Jackson Street Sewer onto neighboring properties. The groundwater analytical data from wells near the Mifflin Street Sewer were compared to the Groundwater to Indoor Air RSLs. The exceedances were limited to certain wells and in general correlate to LNAPL plumes in the area.
- Other potential vapor receptors were not identified within the proximity distances specified in the PADEP Technical Guidance Manual (PADEP, 2017) that warranted further vapor intrusion evaluation.
- The Schuylkill River could receive AOI 8 impacted groundwater either directly via groundwater seepage/discharge from either of the defined aquifers, or by way of infiltration into sewers that cross AOI 8 (e.g., the Jackson Street Sewer). Rambo Creek Sewer collects stormwater runoff in AOI 8, and drains into the Klondike Separator for eventual treatment at the Point Breeze process sewer. During extreme precipitation events, the Klondike Separator may temporarily discharge to the adjacent stormwater retention basins which drain to the Schuylkill River.
- A well search of PaGWIS records for the PES Complex and a one-mile buffer area was performed by Stantec in 2017 (**Appendix M**). Most identified well records are for monitoring or recovery wells at the PES Complex, or monitoring and dewatering wells installed by others for nearby facilities (some with record of previous abandonment). Stantec reviewed the PaGWIS results and used the PADEP eMapPA tool as a secondary resource to identify three potential water supply wells that Evergreen intends to further evaluate as human health receptors and report on in future Act 2 deliverables.
- The PRM aquifer system is utilized for water supply in New Jersey. The aquifers of that system, chiefly the lower sand unit, can receive recharge via vertical leakage through confining units and direct recharge from younger deposits along their subcrop area in south Philadelphia, which includes a portion of AOI 8. Groundwater COCs, such as benzene, present in the lower aquifer beneath AOI 8 have the potential to migrate offsite.

9.8 PLANS FOR COMPREHENSIVE FATE AND TRANSPORT ANALYSIS

It is understood that the findings and conclusions of this and other AOI-specific, qualitative assessments at the PES Complex will ultimately be used in a site-wide MODFLOW and transport model (e.g., MT3DMS model) to quantitatively predict contaminant fate and transport, including comprehensive simulations that will address the future extent of contamination and cumulative mass loading to potential receptors. Under Act 2 and in consideration of the One Cleanup Program, this level of analysis is warranted, in general, to assess risk posed by PES Complex COCs to potential receptors, to assess plume stability, to assist in selection of remedial alternatives to assist in the process of attaining remediation standards, and to estimate time to project closure. Model predictions will be used to support informed decision making during Cleanup Plan activities.

The model will focus on groundwater movement within the Coastal Plain of south Philadelphia, Pennsylvania, near the PES Complex. The model domain was adopted from an earlier USGS model developed by Schreffler (2001), later updated by Sloto (2012), and has been updated by Stantec to better represent site-specific groundwater flow conditions beneath the PES Complex. Updates to the Schreffler (2001) and Sloto (2012) models have included layer refinement, grid discretization, model layer hydraulic property refinement using site-specific testing data, recent topography, recent Schuylkill River bathymetry, and the inclusion of drains and pumping wells to simulate water withdrawals near the PES Complex. At the time of this RIR, updates to the model are nearly completed and a presentation to the PADEP is planned for early 2018. Evergreen anticipates that a comprehensive fate and transport assessment based on the numerical modeling results will be submitted to PADEP in a separate Act 2 submission.

10.0 CONCEPTUAL SITE MODEL

Through comprehensive file review and characterization activities performed as a part of this RIR, Stantec's conceptual understanding of the present conditions identified at AOI 8 and nearby proximity is summarized as follows.

10.1 DESCRIPTION AND SITE USE

- The PES Complex is located along the banks of the Schuylkill River in the City of Philadelphia, Philadelphia County, Pennsylvania (**Figure 1-1**). The PES Complex, which is located on industrial property, covers approximately 1,400 acres of land with access restricted by fencing and security measures. Current operations at the PES Complex consist of the production of fuels and basic industrial petrochemicals.

- The area surrounding the PES Complex is characterized by a mixture of residential, commercial, and industrial properties, including the PGW Passyunk Facility and the Verizon SDWC Property.

- AOI 8 occupies approximately 250 acres of the PES Complex in the northern portion, and is commonly referred to as the Point Breeze Refinery North Yard (**Figure 1-2**).

- Historically, various plants including asphalt, paraffin wax, soap, ammonia, magnesium sulfonate, acid plants, lube plant, grease plant, and associated nitrobenzene plant were operational within AOI 8. Numerous ancillary structures and ASTs were historically located across much of AOI 8 in association with the various plants.

- Currently, main operations in AOI 8 include the offloading of crude oil from the Point Breeze North Yard Crude Rail, fuel oil storage, propane and butane storage, and terminaling facilities. Several occupied buildings are present within AOI 8, including the Old and New Scale Houses, office trailers, and the Philadelphia Fire Department Building.

10.2 GEOLOGY AND HYDROGEOLOGY

10.2.1 Geologic Framework

- The PES Complex occurs within the up-dip limits of the Atlantic Coastal Plain, generally within two miles of the "Fall Line" (**Figure 2-2**). Historical maps indicate that AOI 8 topography was generally low-lying prior to industrialization and defined by the following notable features: a broad floodplain along the perimeter of the Schuylkill River, an incised tributary stream valley (former Rambo Creek) bisecting AOI 8, and higher elevations to the north and south of the stream. Present-day topography has been significantly altered by humans and is generally capped by paved or otherwise low permeability surface materials (**Figure 2-3**).

- Published geologic information indicates that the Coastal Plain sedimentary record beneath, and in the vicinity of, AOI 8 is complex, largely incomplete, and under-represented by only Cretaceous and Quaternary deposits, separated by a regional disconformity. Total Coastal Plain thickness above bedrock (predominantly variably weathered mica schist) ranges from approximately 20 to 70 feet in this area (**Figure 2-14**).

- Beneath AOI 8 and the area evaluated, the following Coastal Plain deposits may be present, in order of increasing depth/age: anthropogenic fill, Quaternary alluvium (including Holocene and Pleistocene components), and the Cretaceous PRM aquifer system, including the upper clay, upper sand, middle clay, middle sand, lower clay, and lower sand units. These deposits are identified and described in this RIR based on correlation to published geologic formations/units mapped in the region (**Figure 2-4**) using lithology and stratigraphic principles (**Figures 2-5** through **2-10**).

- Within the Coastal Plain, thicknesses of fill and each individual geologic formation/unit vary across the PES Complex. Near-surface fill deposits are generally thickest atop former Schuylkill River lowlands and along the axis of former Rambo Creek but thin where historic topography was highest. Holocene-age alluvium is present in AOI 8 in significant thickness along the Schuylkill River perimeter and pinches out at an elevation just above present sea level. Pleistocene-age alluvium is present in places beneath the Holocene sequence and beneath a river terrace that defines AOI 8's higher elevations. Cretaceous-age deposits of the PRM aquifer system are present beneath the Quaternary deposits generally throughout the eastern area of AOI 8, but are discontinuous elsewhere as a result of downcutting by the Schuylkill River. In northwestern AOI 8, a natural outcrop area of Cretaceous-age deposits was present due to shallow bedrock (the deposits have since been capped by fill).

- Hydrostratigraphic units (aquifers and aquitards/confining beds) were defined from the geologic units to identify water-bearing strata on a mappable scale applicable to AOI 8 (**Table 5-1**).

10.2.2 Water-Table Aquifer (unconfined)

- Beneath AOI 8, the water-table aquifer is primarily composed of saturated portions of fill, Quaternary alluvium, and the underlying PRM upper sand unit. The intervening PRM upper clay unit aquitard, where present, is also included in this aquifer. Localized perched conditions have been observed, particularly in places where fill saturates overlying lower permeability strata of the Pleistocene or Cretaceous.

- Where shallow bedrock is present in northwestern AOI 8, the water-table aquifer appears to be composed mostly of Cretaceous deposits (where the lower aquifer outcrops).

- On average, the saturated thickness of the water-table aquifer beneath AOI 8 is approximately 5 to 30 feet.

- Estimated values of water-table aquifer k vary from less than 1 ft/d to more than 250 ft/d in AOI 8 (**Figures 2-11** and **2-13**). Permeability (k_v) of muddy strata found within the water-table aquifer may range from approximately 10^{-7} to 10^{-8} cm/sec (fine-grained Pleistocene alluvium), the f_{oc} may range from approximately 0.8% to more than 4%; and effective porosity may range from approximately 15% to 30%.

- Two prominent areas of groundwater perching are apparent beneath AOI 8 that appear to result from fill saturation above lower permeability deposits (**Figure 5-1**).

- Recent (2016-2017) patterns of AOI 8 water-table aquifer groundwater flow appear relatively consistent through time (**Figures 5-2** through **5-5**). Flow patterns and gradients in this aquifer do not appear to be significantly influenced by river tides (unpublished monitoring data collected during a recent well performance test).

- Hydraulic gradients in the water-table aquifer are variable but generally fall within the range of approximately 0.0006 ft/ft to 0.02 ft/ft and are primarily the result of topographically driven flow. Groundwater flows in a pattern that generally mirrors the historical topography shown on **Figure 2-1** and includes an east-west trending groundwater divide beneath the PGW Passyunk Facility/AOI 8 border, an additional groundwater divide in northcentral AOI 8, groundwater convergence along former Rambo Creek, and groundwater mounding within the filled Rambo Creek valley and former floodplain of the Schuylkill River.

- Groundwater infiltration into the Jackson Street and Mifflin Street Sewers is supported by the data presented in this RIR. The Rambo Creek Sewer may also be susceptible to groundwater infiltration.

- Offsite to the south of AOI 8 and the PGW Passyunk Facility, water-table aquifer groundwater flow appears to be influenced by infiltration into the large, deep sewers present beneath Passyunk Avenue.

10.2.3 Lower Aquifer (semi-confined)

- Beneath AOI 8, the lower aquifer is primarily composed of saturated portions of the PRM lower and middle sand units. Pleistocene alluvium supports the lower aquifer along the Schuylkill River beneath the Holocene sequence. The lower clay unit aquitard appears to be absent. The middle clay unit aquitard and Holocene alluvium create semi-confined (artesian) conditions in this aquifer where present.

- The lower aquifer is unconfined where shallow bedrock is present in northwestern AOI 8, and the water-table aquifer appears to be composed mostly of Cretaceous deposits in this subcrop area.

- On average, the saturated thickness of the lower aquifer beneath AOI 8 is approximately 10 to 50 feet.

- Lower aquifer k is estimated to vary from approximately 34 ft/d to more than 850 ft/d (**Figure 2-12**, calculations presented in **Section 5.2.3,** and **Appendix G**). The f_{oc} is estimated at approximately 0.6%.

- Recent (2016-2017) patterns of AOI 8 lower aquifer groundwater flow appear relatively consistent through time (**Figures 5-6** through **5-8**). Data presented in this report identifies a semidiurnal tide signal in the lower aquifer of up to approximately 1 foot as far as 1,500 feet landward from the Schuylkill River (**Figure 5-10**).

- The highest hydraulic heads in the lower aquifer at the PES Complex are located in the subcrop area near the northwestern AOI 8 boundary where it is unconfined. Lower aquifer groundwater flows from that area to the south across AOI 8 in a radial pattern under a gradient of approximately 0.002 to 0.006 ft/ft with components of flow to the west and east. The Jackson Street sewer appears to locally infiltrate groundwater from lower aquifer sediments. At the Schuylkill River, lower aquifer groundwater may flow under, discharge into, or receive surface water from the river depending on dynamic hydraulic conditions.

10.2.4 Vertical Head Potentials

- Vertical hydraulic head potentials were evaluated for October 2016 between the water-table and lower aquifers (where discrete hydrostratigraphic units are present) (**Figure 5-9**). All co-located well pairs indicated a positive (downward) head potential that ranged from approximately 3 feet to 11.4 feet. Hydraulic heads in both aquifers are considered equal in the area of the lower aquifer subcrop. **Figures 2-6** through **2-10** show aquifer surfaces for the contoured October 2016 and May 2017 datasets presented in this report and display in profile view the relationship between heads in the water-table and lower aquifers.

10.3 COMPOUNDS OF CONCERN

10.3.1 Soil

- AOI 8 soil delineations were performed to the highest concentration in soil of the SHS, the non-residential direct contact MSC, and the numeric SSS (for lead) for the Evergreen Comprehensive List, unless a shorter list of analytes was appropriate for a specific situation (**Figure 3-1**).

- Benzo(a)pyrene and lead were identified in AOI 8 surface soil samples at concentrations in excess of the SSS for lead and the non-residential, direct-contact MSC for benzo(a)pyrene (**Table 3-3**).

- Where identified in surface soil to exceed the referenced standards, both lead and benzo(a)pyrene have been delineated both horizontally and vertically through characterization activities and review of existing soil sample analytical data.

- No exceedances of the non-residential direct contact MSCs for compounds listed on the Evergreen Comprehensive List were identified in subsurface soil in AOI 8.

10.3.2 Groundwater

- Two comprehensive rounds of characterization groundwater sampling were completed in 2016 as a part of this RIR and groundwater samples were analyzed for the Evergreen Comprehensive List COCs.

- Concentrations of the following compounds were detected above the SHS in water-table aquifer groundwater during the 2016 sampling events: 1,2,4-TMB, 1,3,5-TMB, 2-methylnaphthalene, anthracene, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, BEHP, chrysene, cobalt, ethylbenzene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, lead, naphthalene, nickel, pyrene, toluene, vanadium, and zinc (**Table 4-2**).

- Available historical groundwater sample data for the lower aquifer indicates that concentrations of the following Evergreen Comprehensive List COCs have been detected above the SHS during 2016 characterization sampling events: benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, BEHP, dibenz(a,h)anthracene, and naphthalene (**Table 4-3**).

10.3.3 Indoor/Ambient Air, Sub-Slab Air, and Soil Gas

- Vapor intrusion data is available for all occupied buildings within AOI 8, as well as the adjacent Verizon SDWC Property and the Philadelphia Fire Department Building. A combination of ambient air, indoor air, sub-slab air, and soil gas sampling was conducted at the occupied buildings, as discussed in **Section 7.0**.

- There were no exceedances of the EPA RSLs in ambient air and indoor air samples collected during the 2016-2017 sampling events.

- At least one COC was detected in the 2017 sub-slab samples collected at the adjacent Verizon SDWC Property; however, none of the samples exceeded the corresponding EPA RSLs.

- One soil gas sample, collected at the Philadelphia Fire Department Building, exceeded the EPA RSL for benzene.

10.4 LNAPL DISTRIBUTION AND MOBILITY

- A comprehensive LCSM was prepared and is included as **Appendix H** of this RIR.

- LNAPL samples collected from site monitoring wells through time have identified the presence of several variably-weathered products and mixtures of products refined from crude oil in the subsurface at AOI 8 (**Figure 6-1**).

- Variability in LNAPL characteristics observed at AOI 8 is indicative of multiple product releases at different times with subsequent co-mingling of plumes. A majority of the LNAPL plumes in AOI 8 are characterized as heavy distillate or heavy distillate mixtures. With the exception of a likely contiguous plume near the PGW Border System, the LNAPL plumes are considered to be relatively small, isolated occurrences in discrete areas of AOI 8.

- A review of apparent LNAPL thickness data through time suggests that overall, LNAPL plumes at the site are not migrating, in general, because the vertical thickness of LNAPL as observed in AOI 8 monitoring wells has not been increasing.

- Based on mobility calculations through the LDRM, some LNAPL appears to be potentially mobile in the following general areas: PGW Border System area, North Yard Bulkhead System area, an area south of the Verizon SDWC Property, and an area north of the Jackson Street Sewer System. LNAPL areas are routinely monitored through well gauging.

- Based on multiple lines of evidence, LNAPL observed at AOI 8 appears to be stable or decreasing (not migrating) as a whole and immobile at most locations along the plume fronts presented.

10.5 QUALITATIVE FATE AND TRANSPORT OF SELECTED COMPOUNDS

- A soil to groundwater model to evaluate the soil to groundwater pathway was not developed for the qualitative fate and transport assessment presented in this RIR. Rather, a qualitative-level assessment of groundwater data has been completed (**Section 9**).

- Of the COCs identified to be present in groundwater beneath AOI 8, benzene was chosen for the qualitative assessment of fate and transport presented in this RIR because of its higher water solubility and potential mobility when compared to other Evergreen Petroleum Short List COCs, and/or due to its general persistence in groundwater at the PES Complex. Benzene is also likely to be a primary COC driving regulatory closure under Act 2 for these reasons. Other COCs identified in groundwater are discussed in the context of benzene distributions.

- Recent (2014 through 2016) benzene concentrations in water-table aquifer groundwater beneath AOI 8 suggest that three general areas of benzene concentrations above the SHS are present: the PGW Border System area, northern AOI 8 near the Verizon SDWC Property and Mifflin Street, and the Schuylkill River Bulkhead area (**Figure 9-2**). **Figure 9-1** comparatively shows the same general plume areas existed historically both onsite and offsite. Concentration trends generally support that dissolved-phase benzene groundwater plumes have stabilized both onsite and offsite near the Verizon SDWC Property. This is supported by up to 30 years of groundwater analytical data where available. In exception, the plume in the PGW Border System area may be expanding into AOI 8 from areas to the south (up gradient).

- Recent (2014 through 2016) distributions of dissolved-phase benzene in water-table aquifer groundwater appear to in-part reflect groundwater movement along current hydraulic head gradients identified at AOI 8 and proximity. Additional distribution of benzene and other co-located COCs may have been influenced by the historic operation of recovery wells (e.g., PGW Border System), or have resulted from gradients induced by other historical pumping on or near the site.

- The most elevated concentration of benzene in water-table aquifer groundwater in AOI 8 is located near well N-82 in the southeastern corner. Groundwater flow patterns and contaminant trends support that this benzene migrated from an offsite source. The elevated benzene in this area generally does not correlate to the location of the largest LNAPL plume along the PGW Border System area but rather to a smaller plume. Stantec is aware that PGW is operating an air sparging and soil vapor extraction system in the apparent source area for this plume, which appears to be located near well PGW-MW-10S.

- Dissolved lead was identified at concentrations above the SHS in water-table aquifer groundwater during 2016 comprehensive sampling (**Figure 9-3**). With few exceptions, lead exceedances are generally concentrated in northern AOI 8, in an area south of the PES North Yard Ball Field. These exceedances are likely attributable to the historic disposal of lead smelter slag **(Section 1.4.3**) observed in the area fill, or possibly historic product releases from the ASTs located in this area. Inorganic lead is generally regarded to be a relatively immobile contaminant as it readily adsorbs to aquifer solids (e.g., hydrous ferric oxide) however inorganic lead can, in the presence of anaerobic conditions (e.g., low dissolved oxygen conditions created by the microbial degradation of petroleum hydrocarbons), be released into groundwater. Lead alkyls used as antiknock agents in gasoline (most significantly through the years 1925 to 1975), chiefly tetraethyl lead (TEL) and its water-soluble degradation products triethyl and diethyl lead, are indicated to be generally unstable in most subsurface soil and groundwater environments and degrade into inorganic lead (Mansell et al., 1995). As such, it is likely that lead present in groundwater will attach to aquifer sediments within the approximate extent of the dissolved-phase COC plumes.

- Two areas of benzene exceedances are identified to originate in the lower aquifer subcrop area (**Figure 9-4**). In southern AOI 8, benzene may be migrating downgradient from the subcrop area southwest towards the Schuylkill River. The second area is present along the AOI 8 boundary near the Verizon SDWC Property. This area is delineated to the south in AOI 8. North of AOI 8, the presence of a discrete lower aquifer hydrostratigraphic unit is unclear. Data from Verizon SDWC Property wells was used to demonstrate delineation of benzene in the water-table aquifer where concentration trends support that source decay may be occurring. This condition may be true of the lower aquifer if the middle clay unit aquitard continues to be locally absent. Wells at the Verizon SDWC Property were generally not constructed to discretely evaluate more than one water-bearing stratum, if present.

- Testing data included in **Appendix F** indicate that AOI 8 water-table aquifer deposits may contain approximately 0.8 to 4.7% organic carbon, and the lower aquifer deposits may contain approximately 0.6% organic carbon.

- The PRM lower sand unit was historically developed and heavily pumped for water supply in southeastern Philadelphia. There are records of historic production wells in Greenman et al. (1961) for the PBNY area. Although detailed pumping records are not available, groundwater withdrawals from these wells and associated drawdown of the lower aquifer may have influenced contaminant distributions.

- Quantitative fate and transport analysis of selected dissolved-phase COCs through AOI 8 aquifers, including benzene and possibly lead, will be performed utilizing a site-wide MODFLOW model.

10.6 POTENTIAL MIGRATION PATHWAYS AND SITE RECEPTORS

- AOI 8 occupies approximately 250 acres in the northern portion of the PES Complex, and is also referred to as the Point Breeze Refinery North Yard. Access is restricted by fencing and security measures.

- PES is responsible for overall PES Complex security and oversight of contractor safety, and PES implements PPE and work plan/permitting protocols that mitigate the potential for worker exposure to impacted soil, groundwater, and/or LNAPL through the direct contact pathway.

- AOI 8 areas with identified surface soil exceedances of the SSS and direct-contact MSC for lead and benzo(a)pyrene, respectively, have been delineated and remedies will be addressed in a future Act 2 Cleanup Plan.

- No exceedances of the EPA RSLs were observed in ambient air, indoor air, and sub-slab air samples collected during the 2016-2017 sampling events.

- The Jackson Street and Mifflin Street sewers were identified as potential vapor migration (external preferential) pathways for petroleum hydrocarbon sources identified in AOI 8. A vapor mitigation system (Jackson Street Water Curtain) is currently in operation to prevent potential vapors migrating from the Jackson Street Sewer onto neighboring properties. The groundwater analytical data from wells in the vicinity of the Mifflin Street Sewer were compared to the Groundwater to Indoor Air RSLs. The exceedances were limited to certain wells and in general correlate to LNAPL plumes in the area. The Rambo Creek Sewer is also identified as a potential preferential pathway within AOI 8 for vapor migration as well as dissolved groundwater impacts. However, the Rambo Creek Sewer extends from eastern AOI 8 and drains into the Klondike Separator for eventual treatment at the Point Breeze process sewer; therefore, offsite migration via the onsite sewer pathway is unlikely. In exception, during heavy precipitation events, the Klondike Separator may discharge into the adjacent stormwater retention basins which drain into the Schuylkill River.

- The Jackson Street and Mifflin Street sewers are identified as potential receptors of AOI 8 and offsite groundwater based on flow patterns (convergence and irregularities) identified in this RIR.

- LNAPL observed at AOI 8 appears to be stable or decreasing (not migrating) as a whole and immobile at most locations along the plume fronts presented. Based on multiple lines of evidence discussed in the LCSM, LNAPL mobility appears to be limited to the following general areas: PGW Border System, northern AOI 8 adjacent to the Verizon SDWC Property, and isolated locations including the lower aquifer subcrop area (e.g., N-102, N-112, N-116, and RW-300). LNAPL areas are continually monitored through well gauging.

- Dissolved-phase Evergreen Comprehensive List COCs, including benzene, are present in water-table aquifer groundwater at concentrations above their respective SHS within, and in places directly adjacent to, AOI 8. AOI 8 appears to be a receptor of offsite, dissolved-phase COC impacts related to the PGW Passyunk Facility. Although some uncertainty exists due to subsurface complexity, AOI 8 may be or may have been a contributor to offsite groundwater contamination at the Verizon SDWC Property.

- Natural pathways for groundwater flow exist in the Coastal Plain deposits beneath AOI 8. In the water-table aquifer, they are primarily topographically driven. There is convergent flow along the axis of former Rambo Creek and westerly flow towards lower elevations along the Schuylkill River. The lower aquifer reaches its up-dip limit in northwestern AOI 8 in an area of shallow bedrock, where it subcrops fill and/or Pleistocene deposits (the middle clay unit aquitard is missing). Dissolved-phase COCs and LNAPL, where present and mobile, are anticipated to follow these pathways.

- Fill deposits are common to AOI 8 and are generally of sufficiently permeability to allow for the percolation of surface water or water leaked from utilities, and is subject to contamination from surface or subsurface petroleum releases. Preferential groundwater flow through fill deposits in former Rambo Creek valley and across the former floodplain of the Schuylkill River is supported by data presented in this RIR.

- The stratigraphic profiles presented in **Section 2** support that alluvial deposits along the axis of former Rambo Creek may continuously thicken to the west and southwest near the Schuylkill River. Based on stratigraphic position and inferred permeability, this channel-like deposit could transport contaminants preferentially towards the river. Well N-156 was installed to characterize this deposit at the Schuylkill River point of compliance.

- The stratigraphic profiles presented in **Section 2** indicate that a thick sequence of Holocene muds is present along the AOI 8 Schuylkill River boundary. Granular alluvium is present beneath the muddy sequence. This fine-grained depositional feature (point bar deposit) may limit the natural discharge of groundwater to the river. Conversely, groundwater discharge to the Schuylkill River may occur through the deeper (Pleistocene) alluvium in areas of non-deposition or scour, particularly during low tide.

- The Schuylkill River is the only surface water body located adjacent to AOI 8. LNAPL impacts are not anticipated to be migrating into the Schuylkill River; however, the Schuylkill River could receive AOI 8 impacted groundwater either directly via groundwater seepage/discharge from either of the defined aquifers, or by way of infiltration into sewers that cross AOI 8 (e.g., the Jackson Street Sewer). Rambo Creek Sewer collects stormwater runoff in AOI 8, and drains into the Klondike Separator. During heavy precipitation events, the Klondike Separator may discharge into the adjacent stormwater retention basins which drain into the Schuylkill River.

- The water-table aquifer is not utilized for municipal or nearby communal, potable water supply in south Philadelphia.

- The PRM aquifer system is utilized for water supply in New Jersey. The aquifers of that system, chiefly the lower sand unit, can receive recharge via vertical leakage through confining units and direct recharge from younger deposits along their subcrop area in south Philadelphia, which includes a portion of AOI 8. Groundwater COCs, such as benzene present in the lower aquifer beneath AOI 8 have the potential to migrate offsite. The potential for migration of dissolved-phase Evergreen Comprehensive List COCs from AOI 8 into, and along, the lower aquifer will be evaluated through use of a site-wide MODFLOW model and will be presented in a separate Act 2 submission to PADEP.

11.0 ECOLOGICAL ASSESSMENT

The majority of AOI 8 is covered with soil, gravel, and impervious surfaces. The soil and gravel-covered portions of AOI 8 are not likely to serve as a breeding area, migratory stopover, or primary habitat for wildlife. On October 31, 2016, a survey of endangered, threatened, and special concern wildlife and habitat was conducted by submitting a search request through the Pennsylvania Natural Diversity Inventory (PNDI) Environmental Review Tool. The results of the PNDI search identified no known impacts by the Pennsylvania Game Commission and the U.S. Fish and Wildlife Service.

The PNDI search identified potential endangered species impacts that required further review by the Pennsylvania Department of Conservation and Natural Resources (PA DCNR) and the Pennsylvania Fish and Boat Commission (PA FBC). No effect letter requests were submitted to PA DCNR and PA FBC on October 31, 2016. A response was received from the PA DCNR on November 4, 2016, indicating that no impact is anticipated to the species of special concern. In a letter dated November 28, 2016, the PA FBC noted that certain areas of AOI 8 might serve as a potential habitat for the Eastern Redbelly Turtle (Pseudemys rubriventres), which is a threatened species. A wildlife salvage effort for the turtles was conducted in 2013 in the stormwater basin adjacent to the Schuylkill River as part of the construction of the PES North Yard Crude Rail (**Appendix A**). As the remedial investigation at AOI 8 did not include disturbance within 300 feet of the potential habitat at the Schuylkill River, no immediate action is warranted with regard to the species of concern. This threatened species will be further evaluated as an ecological receptor for impacts related to Evergreen's environmental liability in the Act 2/ One Cleanup Program. Additional ecological risk assessment will be conducted in a future Act 2 deliverable to determine whether COC impacts from AOI 8 constitute an unacceptable risk to ecological receptors.

All ecological assessment documentation is included in **Appendix N**.

12.0 COMMUNITY RELATIONS ACTIVITIES

A Community Relation Plan (CRP) that includes public involvement with local residents to inform them of the anticipated investigations and remediation activities was completed as part of the original NIR submittal in 2006. Updated NIRs were submitted in 2014 and 2016. The purpose of the CRP is to provide a mechanism for the community, government officials, and other interested or affected citizens to be informed of onsite activities related to the investigation activities at the PES Complex. This plan incorporates aspects of public involvement under both PADEP's Act 2 program and EPA's RCRA Corrective Action program. This report and future Act 2 reports will include the appropriate municipal and public notices in accordance with the provisions of Act 2. Notices will be published in the Pennsylvania Bulletin and a summary of the notice will appear in a local newspaper. As part of the CRP, Sunoco held an initial public meeting in the City of Philadelphia to present the strategy and give status updates of the project at the CRP meeting on an as requested basis. A copy of the original NIR, the 2014 and 2016 NIR updates, and the Act 2 report notifications for this RIR are included in **Appendix B**.

13.0 CONCLUSIONS AND RECOMMENDATIONS

Stantec has prepared this RIR for AOI 8 of the PES Complex to satisfy the requirements under Act 2, as specified under 25 PA Code §250.408 (Remedial Investigation Report). The documented investigation activities were performed in general accordance with a 2011 revised Work Plan for Site Wide Approach, and were conducted in support of Evergreen's commitment to remediate legacy environmental impacts that existed at the PES Complex prior to its conveyance to PES in 2012 (Buyer-Seller Agreement). In support of those stated objectives, this RIR has described a comprehensive evaluation of available historical data pertaining to AOI 8, and has documented a remedial investigation strategy that included the collection of a significant amount of additional subsurface information in the time since previous AOI 8 Act 2 deliverables were submitted to the PADEP. Investigations performed as a part of this report also considered and where relevant, sought to address PADEP comments directed towards previous RIR submissions for the overall PES Complex.

The following summarizes Stantec's conclusions and recommendations regarding AOI 8.

13.1 SOIL

Lead and benzo(a)pyrene were identified in AOI 8 surface soil samples at concentrations in excess of the SSS and non-residential, direct contact MSC, respectively. Where identified in surface soil to exceed the referenced standards, both lead and benzo(a)pyrene have been delineated horizontally and vertically. Concentrations of COCs in all other collected soil samples (including subsurface soil) were below the highest of the SHS, the non-residential direct contact MSC, or the numeric SSS (for lead).

Soil from "hotspot" locations (N-99, BH-08-34, N-123, AOI8-BH-16-059, N-154, AOI8-BH-16-078, AOI8-BH-16-006, AOI8-BH-16-061, AOI8-BH-16-033) will require further pathway evaluation or a remedial measure in order to attain a standard under Act 2. With few exceptions, AOI 8 lead exceedances are likely attributable to the historic disposal of lead smelter slag (**Section 1.4.3**) from a former industrial property (Metallurgical Products) or possibly from historic releases of crude oil or refined petroleum products containing lead. Elsewhere in AOI 8 and other PES Complex areas, it is noted that Stantec has observed some correlation between the locations of lead exceedances in soil and the occurrence of (presumably smelter) slag and cinders in areas of anthropogenic fill. Metals contained within those fill materials are commonly encountered in the Philadelphia area and are generally presumed to be chemically inert under most geochemical conditions.

13.2 GROUNDWATER

13.2.1 Water-Table Aquifer (unconfined)

1,2,4-TMB, 1,3,5-TMB, 2-methylnaphthalene, anthracene, benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, BEHP, chrysene, cobalt, ethylbenzene, dibenz(a,h)anthracene, fluoranthene, indeno(1,2,3-c,d)pyrene, lead, naphthalene, nickel, pyrene, toluene, vanadium, and zinc were identified in AOI 8 water-table aquifer groundwater at concentrations in excess of the SHS during 2016.

Beneath AOI 8, the water-table aquifer is primarily composed of saturated portions of fill, Quaternary alluvium, and the underlying PRM upper sand unit. The intervening PRM upper clay unit aquitard, where present, is also included in this aquifer. Localized perched conditions have been observed, particularly in places where fill saturates overlying lower permeability strata of the Pleistocene or Cretaceous. Where shallow bedrock is present in northwestern AOI 8, the water-table aquifer appears to be composed mostly of Cretaceous deposits (where the lower aquifer outcrops). Hydraulic gradients in the water-table aquifer generally fall within the range of approximately 0.0006 ft/ft to 0.02 ft/ft and are primarily the result of topographically driven flow in a pattern that mirrors the historical topography. Notably this includes an east-west trending groundwater divide beneath the PGW Passyunk Facility/AOI 8 border, an additional groundwater divide in northcentral AOI 8, groundwater convergence along former Rambo Creek, and groundwater mounding within the filled Rambo Creek valley and former floodplain of the Schuylkill River. Groundwater infiltration into the Jackson Street and Mifflin Street Sewers is supported by the data presented in this RIR. The Rambo Creek Sewer may also be susceptible to groundwater infiltration.

A qualitative assessment of the fate and transport of benzene in AOI 8 water-table aquifer groundwater was performed as a proxy for future quantitative analyses of benzene and potentially other compounds. The qualitative assessment has indicated the following.

- Recent (2014 through 2016) benzene concentrations in water-table aquifer groundwater beneath AOI 8 suggest that three general areas of benzene concentrations above the SHS are present: the PGW Border System, northern AOI 8 near the Verizon SDWC Property, and the Schuylkill River Bulkhead. These delineated plumes appear to have existed since at least the early 21st Century and appear to be relatively stable, except for the plume in the area of the PGW Border System, where northern (down gradient) expansion into AOI 8 is apparent.

- The most elevated concentration of benzene in water-table aquifer groundwater in AOI 8 is located near well N-82 in the southeastern corner. Groundwater flow patterns and contaminant trends support that this benzene migrated from an offsite source. The elevated benzene in this area generally does not correlate to the location of the largest LNAPL plume along the PGW Border System but rather to a smaller plume. Stantec is aware that PGW is operating an air sparging and soil vapor extraction system in the apparent source area for this plume, which appears to be located near well PGW-MW-10S.

Other, generally less-mobile COCs such as SVOCs and metals were evaluated in the water-table aquifer. The distribution of other VOCs and SVOCs detected in AOI 8 groundwater suggests that they were released in the same areas as benzene and were likely components of the same petroleum hydrocarbon products. Metals such as lead are generally associated with areas of fill containing slag and cinders, most notably in northern AOI 8 south of the Propane Terminal where a historic lead smelter once existed. Metals and most SVOCs are generally regarded as relatively immobile as they readily adsorb to aquifer solids.

Offsite water-table aquifer groundwater along the northern AOI 8 boundary should continue to be monitored closely for potential plume expansion and to further establish trends to be used in fate and transport modeling. Monitoring of onsite water-table aquifer groundwater along the southern AOI 8 boundary should also continue for similar reasons regarding plume expansion from the south. It is generally noted that existing, offsite groundwater contamination along the perimeter of AOI 8 in the water-table aquifer may be the result of other, nearby sites with documented or undocumented releases of petroleum hydrocarbons.

The findings and conclusions of this and other AOI-specific, qualitative assessments at the PES Complex will ultimately be used in a site-wide MODFLOW and transport model to quantitatively predict contaminant fate and transport, including comprehensive simulations that will address the future extent of contamination and cumulative mass loading to potential receptors. Under Act 2 and in consideration of the One Cleanup Program, this level of analysis is warranted, in general, to assess risk posed by PES Complex COCs to potential receptors, to assess plume stability, to assist in selection of remedial alternatives, to assist in the process of attaining remediation standards, and to estimate time to project closure. Model predictions will be used to support informed decision making during Cleanup Plan activities.

13.2.2 Lower Aquifer (semi-confined)

Concentrations of the following COCs were detected above the SHS in lower aquifer groundwater during 2016 characterization sampling events: benzene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, BEHP, dibenz (a,h)anthracene, and naphthalene.

Beneath AOI 8, the lower aquifer is primarily composed of saturated portions of the PRM lower and middle sand units. Pleistocene alluvium supports the lower aquifer along the Schuylkill River beneath a Holocene sequence of mostly muddy sediments. The lower clay unit aquitard appears to be absent. The middle clay unit aquitard and Holocene alluvium create semi-confined (artesian) conditions in this aquifer where present. The lower aquifer is unconfined where shallow bedrock is present in northwestern AOI 8, and the water-table aquifer appears to be composed mostly of Cretaceous deposits. The highest hydraulic heads in the lower aquifer at the PES Complex are in this subcrop area, and groundwater flows to the south across AOI 8 in a radial pattern under a gradient of approximately 0.002 to 0.006 ft/ft, with components of flow to the west and east. Presently, it is not discernable whether a lower aquifer exists beneath the PES North Yard Ball Field and areas north of AOI 8 (the true extent of the subcrop area is unclear). There is the potential for components of groundwater flow to the north. The Jackson Street sewer appears to locally infiltrate groundwater from lower aquifer sediments, and infiltration of groundwater into the Mifflin Street Sewer may create upward gradients and flow convergence near 34th Street and Maiden Lane. At the Schuylkill River, lower aquifer groundwater may flow under, discharge into, or receive surface water from the river depending on dynamic hydraulic conditions.

A qualitative assessment of the fate and transport of benzene in AOI 8 lower aquifer groundwater was performed as a proxy for future quantitative analyses. Two areas of benzene exceedances are identified to originate in the lower aquifer subcrop area. In southern AOI 8, benzene may be migrating downgradient from this area southwest towards the Schuylkill River. Along the AOI 8 boundary near the Verizon SDWC Property, benzene is delineated in AOI 8, but lack of offsite stratigraphic control on the presence or absence of a discrete lower aquifer limits the ability to demonstrate side gradient to up gradient delineation in the offsite direction. As noted in **Section 13.2.1**, MODFLOW modeling should be utilized to evaluate fate and transport along these lower aquifer pathways during Cleanup Plan activities.

The PRM aquifer system is utilized for water supply in New Jersey. The aquifers of that system, chiefly the lower sand unit, can receive recharge via vertical leakage through confining units and direct recharge from younger deposits along their subcrop in the south Philadelphia area. Groundwater COCs, such as benzene present in the lower aquifer beneath AOI 8 have the potential to migrate offsite. As indicated for the water-table aquifer, a MODFLOW model will be utilized during quantitative fate and transport analyses to evaluate that potential based on the COC source areas identified in this RIR. It is anticipated that Stantec will present the model results in a separate Act 2 submission to PADEP in 2018.

13.3 VAPOR INTRUSION

A vapor intrusion evaluation was completed in and near all occupied buildings in AOI 8, as well as the adjacent Verizon SDWC Property. Observed COC concentrations in indoor air, ambient air, and sub-slab air did not exceed the corresponding EPA RSLs. One historic soil gas sample, collected at the Fire Department Building, exceeded the EPA RSL for benzene. Upon completion of remediation activities, it is assumed that volatilization to the breathing zone will be the only potentially complete pathway for legacy petroleum impacts in AOI 8; therefore, EPA RSLs are applicable. It is noted that this conclusion is dependent upon the remainder of the exposure pathways being eliminated through other remedial activities and controls.

Evergreen will continue to operate the Jackson Street Water Curtain and report performance information in semi-annual Philadelphia Refinery Groundwater Remediation Status Reports. Details regarding plans to maintain this vapor mitigation system will be included in a future Act 2 deliverable. A required second round of air sampling will be completed and presented in a future Act 2 deliverable. No other vapor intrusion assessment activities are recommended for AOI 8.

13.4 LNAPL

LNAPL present in the subsurface at and directly adjacent to AOI 8 has been delineated. Based on multiple lines of evidence presented in this report, LNAPL observed at AOI 8 appears to be stable or decreasing (not migrating) as a whole, immobile at most locations, and highly to severely weathered along the plume fronts identified. Most LNAPL sampled though time has been characterized as heavy distillate or mixtures of heavy distillates, and is indicative of multiple product releases at different times with subsequent co-mingling of some of the plumes in the subsurface. Based on the type of LNAPL identified in the water-table aquifer and former PBNY site usage, most petroleum hydrocarbon products released in AOI 8 were presumably light distillates such as gasoline and/or leaded gasoline, heavy distillates such as lubricating and fuel oils, and residuum such as asphalts and waxes.

Although recovery wells operating within the AOI 8 remediation systems have been out of operation for several years, it is recommended that the PGW Border System be further evaluated for startup, optimization, and efficiency to address LNAPL (and possibly other dissolved-phase contaminants in the area) as a part of Cleanup Plan activities.

14.0 SIGNATURES

The following parties are participating in the remediation at this time and are seeking relief of liability under Act 2 of 1995.

Tiffani L. Doerr, P.G.
Project Manager
Evergreen Resources Management Operations

This RIR has been prepared in accordance with the final provisions of Act 2 and the June 8, 2002 Land Recycling Program Technical Guidance Manual.

15.0 REFERENCES

NOTE: ELECTRONIC COPIES OF REFERENCED REPORTS ARE INCLUDED IN **APPENDIX I** AS A COMPACT DISK ATTACHMENT.

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TABLES

Remedial Investigation Report
Area of Interest 8
Philadelphia Refining Complex
Philadelphia, Pennsylvania
Philadelphia Refinery Operations,
a series of Evergreen Resources Group, LLC
3144 Passyunk Avenue, Philadelphia, Pennsylvania

FIGURES

Remedial Investigation Report
Area of Interest 8
Philadelphia Refining Complex
Philadelphia, Pennsylvania
Philadelphia Refinery Operations,
a series of Evergreen Resources Group, LLC
3144 Passyunk Avenue, Philadelphia, Pennsylvania

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APPENDIX A
COPIES OF REFERENCED CONSULTANT REPORTS (CD-ROM)

Remedial Investigation Report
Area of Interest 8
Philadelphia Refining Complex
Philadelphia, Pennsylvania
Philadelphia Refinery Operations,
a series of Evergreen Resources Group, LLC
3144 Passyunk Avenue, Philadelphia, Pennsylvania

APPENDIX B
NOTICE OF INTENT TO REMEDIATE, REPORT NOTIFICATIONS, AND PROOFS

Remedial Investigation Report
Area of Interest 8
Philadelphia Refining Complex
Philadelphia, Pennsylvania
Philadelphia Refinery Operations,
a series of Evergreen Resources Group, LLC
3144 Passyunk Avenue, Philadelphia, Pennsylvania

APPENDIX C
QUALITY ASSURANCE/QUALITY CONTROL PLAN AND FIELD PROCEDURES MANUAL (CD-ROM)

Remedial Investigation Report
Area of Interest 8
Philadelphia Refining Complex
Philadelphia, Pennsylvania
Philadelphia Refinery Operations,
a series of Evergreen Resources Group, LLC
3144 Passyunk Avenue, Philadelphia, Pennsylvania

APPENDIX D
SOIL BORING AND MONITORING WELL LOGS

Remedial Investigation Report
Area of Interest 8
Philadelphia Refining Complex
Philadelphia, Pennsylvania
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APPENDIX E
LABORATORY ANALYTICAL REPORTS (CD-ROM)

Remedial Investigation Report
Area of Interest 8
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APPENDIX F
GEOTECHNICAL LABORATORY TESTING REPORT

Remedial Investigation Report
Area of Interest 8
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APPENDIX G
AQUIFER TESTING DATA AND ANALYSIS

Remedial Investigation Report
Area of Interest 8
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Philadelphia, Pennsylvania
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APPENDIX H
LNAPL CONCEPTUAL SITE MODEL

Remedial Investigation Report
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APPENDIX I
SAMPLE FIELD SHEETS – VAPOR INTRUSION SAMPLING

Remedial Investigation Report
Area of Interest 8
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APPENDIX J
DATA USABILITY ASSESSMENT

Remedial Investigation Report
Area of Interest 8
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APPENDIX K
PWD SEWER AS-BUILT DRAWINGS (CD-ROM)

Remedial Investigation Report
Area of Interest 8
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APPENDIX L
REMEDIATION SYSTEMS SUMMARY

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APPENDIX M
PAGWIS WELL SEARCH

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APPENDIX N
ECOLOGICAL ASSESSMENT DOCUMENTATION

Remedial Investigation Report
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