FOURTH QUARTER OF 2016 AND CALENDAR YEAR 2016 SUMMARY PROGRESS REPORT FOR THE FORMER DEFENSE SUPPLY CENTER PHILADELPHIA FACILITY

Philadelphia, PA

February 15, 2017

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Philadelphia, PA

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Fourth Quarter of 2016 and Calendar Year 2016 Summary Progress Report for the Former DSCP Facility, Philadelphia, PA

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ACRONYMS AND ABBREVIATIONS

AMSL – Above Mean Sea Level

Arcadis – Arcadis U.S., Inc.

AST – Aboveground Storage Tank

BRAC – Base Realignment and Closure

CH_4 – Methane

^{14}C – Carbon-14

CO_2 – Carbon Dioxide

COC – Constituents of Concern

CSM – Conceptual Site Model

CY – Calendar Year

DESC – Defense Energy Support Center (also known as DLA Energy)

DLA – Defense Logistics Agency

DSCP – Defense Supply Center Philadelphia

EPA – Environmental Protection Agency

Ft – Feet

IDW – Investigation Derived Waste

LEL – Lower Explosive Limit

LNAPL – Light Non-Aqueous Phase Liquid

LOD- Limit of Detection

mg/L – Milligrams per Liter

MSC – Medium Specific Concentration

MTBE – Methyl Tert-Butyl Ether

NUAD – Non-Use Aquifer Determination

O_2 - Oxygen

O&M – Operation and Maintenance

PADEP – Pennsylvania Department of Environmental Protection

PAID – Philadelphia Authority for Industrial Development

PARS- PARS Environmental, Inc.

PES – Philadelphia Energy Solutions

PGW – Philadelphia Gas Works

PHA – Philadelphia Housing Authority

PID – Photo-ionization Detector

pMC – Percent Modern Carbon

PWD – Philadelphia Water Department

QA/QC – Quality Assurance and Quality Control

RIR- Remedial Investigation Report

SSS – Site Specific Standard

Sunoco – Sun Oil Company

SVOC – Semi-Volatile Organic Compounds

TBA – Tert-Butyl Alcohol

TDS – Total Dissolved Solids

TtEC – Tetra Tech, Inc.

µg/L – Microgram per Liter

USACE – United States Army Corps of Engineers

VES – Vacuum Enhanced Skimming

VOC – Volatile Organic Compounds

WMP – Waste Management Plan

1 EXECUTIVE SUMMARY

This Fourth Quarter of 2016 and Calendar Year (CY) 2016 Summary Progress Report (Progress Report) for the Former Defense Supply Center Philadelphia (DSCP) Site presents an update regarding remediation system operations and maintenance (O&M) data, Site-wide liquid level and groundwater elevation gauging data, Site-wide groundwater sampling data, and a description of potential activities for the First Quarter of CY 2017. The activities described herein were conducted as required by the Administrative Order (Order), dated December 10, 1999 between the Commonwealth of Pennsylvania, Department of Environmental Protection (PADEP) and the Department of the Army and DSCP (collectively the Defense Logistics Agency, or DLA) by Arcadis U.S., Inc. (Arcadis) and PARS Environmental, Inc. (PARS).

This report includes a summary of Order-required remediation activities completed during CY 2016. As approved by the PADEP via electronic mail (e-mail) on January 4, 2017, this summary is hereby provided in lieu of a stand-alone annual report for the Former DSCP Site. Additionally, the PADEP has approved an annually-recurring regulatory due date for the annual summary Progress Report of February 15, or the first following business day, of the next calendar year (e-mail approval dated January 12, 2017).

The Order requires that remediation be conducted as needed to remove as much petroleum Light Non-Aqueous Phase Liquid (LNAPL) as is practicable from beneath the Former DSCP property, which includes Quartermaster Plaza, the CSX railroad right of way, the Steen property, and the Former Passyunk Homes property (currently the Philadelphia Housing Authority [PHA] property and the Siena Place property). Collectively, these properties are defined in the Order as the “Affected Area”, and the Affected Area is the “Site” as defined under the Pennsylvania Land Recycling and Environmental Remediation Standards Act (Land Recycling Act or Act 2).

This Progress Report documents the state of the Site remediation optimization and Act 2 path-to-closure work conducted during the Fourth Quarter of 2016. The Order-required LNAPL remediation work described herein was implemented with the goal of improving the rate of LNAPL remediation via existing Site remediation equipment. This goal is being achieved despite naturally occurring constraints such as elevated groundwater levels and the resulting submerged LNAPL present in the water table aquifer in portions of the Site.

During CY 2016, vapor phase petroleum hydrocarbon mass and LNAPL recovery continued via vacuum enhanced skimming (VES). O&M data have been used to continuously optimize the VES system performance, specifically to enhance the rate of vapor and liquid phase petroleum hydrocarbon recovery. To track the removal of petroleum hydrocarbon mass via the VES system, analytical results of influent summa canister Environmental Protection Agency (EPA) Toxic Organic Chemical method TO-15 samples were evaluated. Supplemental optimization testing in the form of additional Radius of Influence (ROI) and Respirometry testing were also conducted during the Third Quarter of 2016. These tests were conducted for both optimization of the VES system extraction wells and for evaluation of a future biovent/biosparge strategy.

Additional activities designed to enhance the conceptual Site model (CSM) and/or to evaluate the operation and control of the Site's remediation systems were also conducted. These included one liquid level gauging event and one groundwater sampling event per quarter in CY 2016.

As discussed in previous reports, LNAPL recovery at the Former DSCP Site was initially very robust. However, recovery rates diminished from 1999 to 2005 as groundwater elevations began to rise beneath the Site and the availability of easily recoverable LNAPL decreased. The 2005 addition of a VES system, which combined petroleum hydrocarbon vapor recovery with LNAPL recovery, temporarily halted this trend. By the end of 2006, the rate of LNAPL recovery again began to define a generally decreasing trend which continued until the Fourth Quarter 2011, when VES optimization efforts began (for a complete history, see Appendix E).

Optimization efforts initiated in 2011 marked the beginning of significant increases in mass recovery. These efforts included focusing the available vacuum towards fewer recovery wells, on an ongoing rotational basis, resulting in increased radius of influence and access to previously unrecoverable mass. As a result of these efforts, the mass of petroleum hydrocarbons recovered as vapor since the Fourth Quarter of 2011 is now approximately seven times greater than the amount recovered since the start-up of the VES system in 2005 (e.g., 73,086 gallons from the Fourth Quarter 2011 to date versus 10,038 gallons from 2005 through the Third Quarter 2011). During the Fourth Quarter of 2016, 1,013 gallons of LNAPL were recovered by the Former DSCP fixed-skimming system (a tenfold increase from last quarter), 37 gallons of LNAPL were recovered by the Former Passyunk Homes fixed-skimming system, 21 gallons of LNAPL were recovered by modular LNAPL recovery systems, and an additional 2,062 gallons of LNAPL (as vapor) were recovered by the VES system, for a total recovery of 3,133 gallons for the quarter.

During CY 2016, 1,215 gallons of LNAPL were recovered by the Former DSCP fixed-skimming system, 93 gallons of LNAPL were recovered by the Former Passyunk Homes fixed-skimming system, 52 gallons of LNAPL were recovered by modular LNAPL recovery systems, and an additional 8,620 gallons of LNAPL (as vapor) were recovered by the VES system. The total recovery for CY 2016 is 9,980 gallons, and the new cumulative recovery of LNAPL as of December 31, 2016 is 1,053,987 gallons.

While still higher than the pre-2011 vapor phase LNAPL recovery rates, the rate of recovery by VES has been decreasing since the peak rate observed during the Fourth Quarter of 2014. The recovery rate decrease suggests that despite continued LNAPL recovery, the removal of volatile organic compounds (VOCs) by the VES wells is slowly abating as focused vacuum extraction is applied. The technical team continues to seek out and leverage new ways to optimize or enhance the system within the constraints of the existing remediation system setup as well as the existing federal financial and contracting limitations.

The isotopic analysis of carbon dioxide (CO_2) collected from the VES system's influent vapor during the Fourth Quarter of 2016 demonstrates that approximately 81.1% of the CO_2 in Site soil gas may be directly attributed to natural and VES system-driven biodegradation of the Site LNAPL. If the result of this isotopic sample of CO_2 from the VES system influent in the Fourth Quarter of 2016 were applied to the entire quarter, the CO_2 concentration extrapolates to approximately 99,380 pounds (lbs) of petroleum hydrocarbon compounds degraded in-situ on a quarterly basis. This equates to another 16,734 gallons of LNAPL remediated in the Fourth Quarter of 2016 by in-situ biodegradation. The CY 2016 total is approximately 361,362 lbs, or 60,870 gallons.

Limited available Site characterization and remediation data from the adjacent former Sun Oil Company (Sunoco) refinery, currently Philadelphia Energy Solutions (PES), were reviewed, but additional data needs remain, specifically on the current nature of remediation activities, groundwater flow, and petroleum hydrocarbon contaminant transport within the aquifer systems beneath and downgradient of the refinery. Synchronization of aquifer sampling and monitoring activities, and the sharing and evaluation of data may be essential to the establishment of Site aquifer- specific cleanup goals under the Act 2 program. These include a Site Specific Standard (SSS) pathway elimination approach for LNAPL and specific petroleum hydrocarbon Constituents of Concern (COC) in the shallow aquifer zone. Regarding the deep aquifer, pursuit of a background standard approach as defined under Act 2 or attainment of a Site-specific Non-Use Aquifer Determination (NUAD) are both potentially viable options. Data reported in this and prior reports since October 2011 continue to support pursuit of these potential Act 2 endpoints.

In addition to the summary of Fourth Quarter of 2016 and CY 2016 work completed, this report also presents activities tentatively planned for the First Quarter of CY 2017. These activities will support continued refinement of the DLA's remediation strategy under the Order and provide a foundation for continued voluntary Site path-to-closure activities under Act 2.

2 INTRODUCTION

The Former Defense Supply Center Philadelphia (DSCP) property was closed under the 1993 Base Realignment and Closure (BRAC) program. In 2001, the US Army transferred the air and surface rights to the Philadelphia Authority for Industrial Development (PAID) for commercial development. A shopping center, known as Quartermaster Plaza, was constructed in 2004 on the northwestern portion of the Former DSCP property. It currently contains approximately 18 retail stores and 4 restaurants.

Between 2002 and 2008, residences at the former Passyunk Homes complex were razed, and a new Philadelphia Housing Authority (PHA) office and maintenance building was constructed in the central portion of the Site (south of Interstate 76 [I-76], the Schuylkill Expressway) and on the northern portion of the Former Passyunk Homes property. The Former Passyunk Homes property was purchased by Penrose Park Associates and is being redeveloped for residential housing. This growing housing development and neighborhood is called Siena Place. The former Sun Oil Company (Sunoco) refinery boundary is located approximately 100 feet (ft) from the upgradient western edge of the Site, across a section of I-76 and west of the CSX Railroad, (as shown on Figures 1 through 3). The refinery is now owned by Philadelphia Energy Solutions (PES), a subsidiary of Energy Transfer Partners L.P.

Petroleum hydrocarbon constituents and Light Non-Aqueous Phase Liquid (LNAPL) are present in the shallow (i.e., water table) aquifer at the Site. The area impacted by LNAPL has been investigated by teams from the former Sunoco refinery, the Former DSCP, and the Defense Energy Support Center (DESC). Remediation began in 1996 using skimmer pumps installed to remove the petroleum LNAPL from the shallow aquifer, and a full-scale vacuum enhanced skimming (VES) System has been in operation since 2005.

This Progress Report is submitted in accordance with the terms of the Order dated December 10, 1999 and summarizes Site remedial progress and environmental monitoring results from the Fourth Quarter (October, November, and December) of 2016 and calendar year (CY) 2016. The following items are included in this Progress Report:

- Monthly photo-ionization detector (PID), smoke tube, and lower explosive limit (LEL) meter monitoring data for two sanitary sewer manholes on the Packer Avenue Sewer (MH-C and MH-G, as shown in Figures 1-3), and three additional sanitary sewer locations selected by the Defense Logistics Agency (DLA) and the United States Army Corps of Engineers (USACE) (19th and Moyamensing East, 19th and Moyamensing West, Pollock and Moyamensing, and 19th Street [near the cut through]).
- Site-wide groundwater elevation and LNAPL thickness gauging data collected from a liquid level measurement event beginning on November 29, 2016.
- Analytical data generated from a groundwater sampling event conducted November 30 through December 6, 2016.
- Data from continued collection and isotopic analysis of carbon dioxide (CO_2) and methane (CH_4) samples from VES system influent.
- A presentation of statistical analysis of well field data and recommendations for future sampling frequency reduction at specific locations for eventual Act 2 attainment demonstration and performance monitoring purposes.

- A discussion of remediation operation and maintenance (O&M) data from the Site's fixed and modular LNAPL skimming units and VES System.
- Evaluation of data from Site remediation system optimization testing activities conducted during the quarter.
- Annual summary of CSM and O&M activities from CY 2016.

3 VAPOR MEASUREMENTS FROM THE PACKER AVENUE SEWER

Two Packer Avenue sewer manholes (MH-C and MH-G), as shown on Figures 1 through 3, were monitored with a PID, smoke tubes, and LEL meter. As previously reported, the intent of the monitoring is to evaluate the vacuum effect on the Packer Avenue sewer system imparted by the Sewer Vapor Extraction system located on the former Sunoco refinery. The Sewer Vapor Extraction System is managed and maintained by the operators of the former Sunoco refinery. The purpose of the Sewer Vapor Extraction system is to prevent a buildup of gases (e.g., CH_4 and petroleum hydrocarbon vapors) in the sewer system. The purpose of the reporting of readings in this report is to provide feedback to the Pennsylvania Department of Environmental Protection (PADEP) on sewer monitoring data obtained from the aforementioned manholes. The data collected can only provide evidence for inferences regarding whether the Sewer Vapor Extraction System is operating at the time of measurement. These data do not provide information on efficiency or time periods of operation. Only through a direct line of communication with the current owners and a real-time reporting system for operation data can verification of the system's efficacy be ascertained. Continued coordination with the new ownership (PES) is recommended as the system is part of the existing set of engineering controls intended to eliminate a vapor exposure pathway. Vapor measurements were collected on October 26, 2016, November 18, 2016, and December 14, 2016, and are shown in Table 1.

Smoke tubes were used to determine if air was moving into or out of the sewer manhole covers at the time of the monitoring event. The results of smoke tube testing indicated that air was flowing out of MH-C and into MH-G during the October 2016, November 2016, and December 2016 monitoring events. At the 19^{th} and Moyamensing East location, airflow was out of the manhole cover during the October 2016, November 2016, and December 2016 events. Airflow at the 19^{th} and Moyamensing West location was into the manhole cover during the October 2016 and December 2016 events and out of the manhole cover during the November 2016 event. At the 19^{th} Street (near cut through) location, airflow was out of the manhole cover during the October 2016 event and neutral during the November 2016 and December 2016 events. Following smoke tube testing, a PID equipped with a 10.6 electron-volt (eV) lamp, and a MSA Passport LEL/Oxygen (O_2) meter was used to monitor and gather measurements from ports in the two sewer manhole covers. PID readings ranged from 0.0 parts per million (ppm) to 0.3 ppm. LEL readings were 0% during all monitoring events at all locations except for 1% at MH-G, 19^{th} and Moyamensing East and West locations in October 2016; no readings above 100 ppm were recorded. Readings above 100 ppm are reported to the PADEP, former Sunoco refinery, the DLA, and the USACE Baltimore and Philadelphia District offices. These observations are consistent with the findings of a sewer inspection conducted by USACE, Arcadis, and the Philadelphia Water Department (PWD) during which no LNAPL was visually observed in the sewer, nor detected by the PID and LEL meter (*Summary of Work: Packer Avenue Sewer Inspection*, USACE 2016).

At the request of the USACE, PID and LEL readings were also collected at the following sanitary sewer manholes, each of which measured 0.0% LEL and readings of no higher than 0.1 ppm (via PID measurement): 19th and Moyamensing East, 19th and Moyamensing West, Pollock and Moyamensing, and 19th Street (near the cut through).

At the Pollock and Moyamensing location, airflow indications were not available because of the absence of manhole openings.

These observations are consistent with previously reported sanitary sewer readings since October 2011.

4 LIQUID LEVEL GAUGING AND GROUNDWATER SAMPLING

Site-wide liquid level gauging and groundwater sampling events were conducted during the Fourth Quarter of 2016. Similar to previous gauging events, and as required by the Order, all accessible wells within the Site's monitoring and recovery well network were included for gauging. In the Third Quarter of 2016 progress report, a subset of 80 wells out of 163 was recommended for sampling during the Fourth Quarter of 2016 event, based on the results of statistical analyses conducted to support well network reduction scenarios (Appendix D, Arcadis 2016). However, access to the SEPTA property was not available during the event, and two wells on that property were not sampled, lowering the number of sampled wells from 80 to 78. Comprehensive groundwater sampling events were previously conducted during 2012, 2013, and the first 3 quarters of 2014, and included the entire Site monitoring and recovery well network, except for those wells not accessible at the times of the events. Optimized well sampling events have been conducted since the Fourth Quarter of 2014, including another comprehensive event in the Fourth Quarter of 2015. The next comprehensive groundwater sampling event is anticipated to take place during the Fourth Quarter of 2017, and optimized events consisting of subsets of wells are expected for each quarter until then.

Data from the most recent event (Fourth Quarter of 2016), along with that from previous sampling events, has provided the clearest view to date of the distribution of dissolved-phase petroleum hydrocarbon impacts in the shallow/intermediate and deep aquifer systems beneath the Site. Additionally, this information has been added to the Site's database, which includes laboratory analytical results from five partial groundwater sampling events conducted from 2010 to 2011. These events included only about one third (approximately 40 wells) of the Site's monitoring well network. The intent of continued data collection and integration with past groundwater gauging and sampling event data is ultimately to provide remediation performance feedback on the ongoing remediation of LNAPL, as defined under the Order, and to support eventual remediation standard attainment demonstration under the Act 2 program.

4.1 Liquid Level Gauging – Fourth Quarter of 2016

The VES system and pneumatic skimming system recovery wells were deactivated on November 22, 2016, and liquid level gauging data from the Site's monitoring and recovery well network were collected on November 29, 2016. Table 2 contains the gauging event data.

4.1.1 Site Hydrographs

Hydrographs for Site monitoring wells selected previously for long term groundwater elevation trend monitoring have been updated. These hydrographs are included as Appendix A (for MW-29, MW-32, MW-35, MW-36, PH-14, PH-15, PH-18, and PH-20). Except for abandoned wells PH-15 and MW-35, the hydrographs show groundwater elevations during the Fourth Quarter of 2016 gauging event to have been within the upper range of the elevations recorded since 2001. Over time, these oscillating groundwater elevations show amplitudes of approximately two feet, and are generally concomitant as indicated by similar trends on the hydrographs for MW-29, MW-32, MW-36, PH-14, PH-18 and PH-20. These hydrograph patterns therefore may represent variables affecting the entire Site, such as seasonal changes, precipitation, and leaking sewers.

The groundwater levels measured during the Fourth Quarter of 2016 continue to be well above (i.e., by approximately two to five feet) the drought-indicative groundwater elevations reported from late 2001 to the beginning of 2003. A chart showing recorded precipitation in Philadelphia per month since 2011 is presented in Appendix A. Broadly, the data continue to support the underlying Site-wide trend towards higher groundwater elevations since the start of Site LNAPL remediation activities in the late 1990s.

4.1.2 Site Hydrographs and the Packer Avenue Sewer

During the Fourth Quarter of 2016 and consistent with previous observations, groundwater elevations in the wells in close proximity to the Packer Avenue sewer were higher than the bottom of the sewer, and measurable LNAPL was not observed in the monitoring wells located south of the Packer Avenue sewer. In addition to quarterly hydrographs, Appendix A also contains figures depicting the elevation of the LNAPL, the groundwater table, and the bottom of the sewer.

4.1.3 Potentiometric Surfaces and Groundwater Gradients

The gauging event included the monitoring and recovery wells on the Former DSCP property, the Former Passyunk Homes property (i.e., around the PHA building and Siena Place Homes property), the CSX property, the Steen property, and the P. Agnes property. Access to the Southeastern Pennsylvania Transportation Authority (SEPTA) property was not available during the gauging event, and the 4 wells on this property were therefore excluded from gauging. In addition, access to the hotel property on Penrose Avenue was also not available during gauging, and the 3 wells on this property were excluded from the event.

Groundwater elevations used to prepare the hydrographs (Appendix A) and the potentiometric surface maps shown in Figures 1 and 2 were determined by subtracting the depth to water from the elevation of the surveyed measuring point (the top of the inner well casing). In cases where LNAPL was measured in a well, the groundwater elevations were corrected by multiplying the apparent LNAPL thickness by a specific gravity of 0.77, and adding this value to the groundwater elevation. This value, used in previous calculations, is an average of the range of specific gravity values provided in the *Fourth Quarter of 1999 Progress Report* by IT Corp (specifically Appendix D of that report).

Corrected groundwater elevation data was used to create a potentiometric surface map for the shallow/water table aquifer zone beneath the Site (Figure 1). A few Site wells are screened in areas where the presence of near-surface silty clay units and/or the presence of extensive paved areas of the

Site appear to impede infiltration of precipitation, creating isolated perched zones. Additionally, based on the continued observance of isolated potentiometric high points at discrete well locations, some wells appear to be influenced by other infiltration sources, such as leakage from the numerous sanitary and storm sewer laterals that underlie the Site. As has been the case during prior gauging events, anomalous elevation heads were measured in the wells listed below (i.e., with respect to levels measured in the majority of surrounding shallow aquifer zone wells). The monitoring wells excluded from the shallow aquifer zone potentiometric map include CSX-MW-1, DSCP-MW-1, DSCP-MW-20, DSCP-MW-23A, PH-RW-A, PH-RW-B, PH-RW-I, PH-RW-W, PH-RW-W2, PH-MW-13, PH-MW-37, PH-MW-57, PH-RW-V, PH-PH-6, PH-PH-2, and PH-PZ-4.

Based on water level measurements and well construction details, several well screens were submerged at the time of the gauging event. Groundwater elevations for wells with submerged screens have been excluded from the shallow aquifer/water table potentiometric surface map (Figure 1). These wells include DSCP-MW-5, DSCP-MW-11, DSCP-MW-14, DSCP-MW-33, DSCP-MW-59, DSCP-MW-1A, DSCP-RW-5/MW-25, EPH-MWS-5, PH-MWS-4, and PH-RW-N. Exclusion of these wells, and the anomalous wells described above, does not materially affect the interpretation of the potentiometric surface for the gauging event.

The Figure 1 potentiometric surface map of the shallow/water table aquifer indicates that groundwater in the northern part of the Site flows down gradient from the northwest to the south starting near DSCP-MW-45A at an elevation of 3.88 ft above mean sea level (AMSL) to around 0.92 ft AMSL at DSCP-MW-3A. In the central and central southern portions of the Site, measured groundwater elevations ranged from approximately 1.0 to 3.0 ft AMSL, with localized mounded areas up to approximately 4.0 ft. In the southeastern part of the Site a separate and distinct potentiometric high is observed with a flow gradient from southeast to northwest. The high point is located at EPH-PH-7 at 3.06 ft AMSL, and elevations decrease to the northwest towards EPH-MW-39 (0.63 ft AMSL).

Groundwater level measurements from Steen property monitoring wells revealed groundwater elevations lower than those measured from monitoring wells at the DSCP site (i.e., -0.69 ft AMSL at STEEN-PH-11 and -0.73 ft AMSL at STEEN-MW-61). This finding is generally in line with past groundwater elevation data obtained prior to loss of access to the Steen property in 2013. The resulting shallow aquifer zone potentiometric map suggests a localized, southwest oriented groundwater gradient. This observation will be further vetted through evaluation of future Site gauging data.

Site groundwater flow generally follows the regional groundwater gradient in a southerly direction. In the southern area of the Site, groundwater flows south from the PHA building to the southern portion of Siena Place Homes. In the midsection of the Site, a trough-like depression is oriented approximately east-west in the shallow aquifer potentiometric surface. This consistently observed feature, observed during prior quarterly gauging events, is most pronounced near the BJ’s retail building and in an area extending southwest from the VES system building to the former PHA property. The source of this feature is hypothesized to be a paleochannel not unlike others that have been identified within the Atlantic Coastal Plain (e.g., the Reybold Paleochannel in New Castle County Delaware, “a relatively narrow sand-filled trough defined by deep incision at the base of the Columbia Formation…interpreted to be the result of scour by the sudden release of powerful floodwaters from the north associated with one or more

Pleistocene deglaciations")[1]. Like the referenced paleochannel, the On-Site feature cuts across the Cretaceous confining bed that otherwise separates the Site's shallow and deep aquifer zones. This hypothesis has been validated via Site lithologic data, groundwater elevations, and vertical gradients, as discussed in later sections of this report.

Gauging data from the Site's 14 deep aquifer zone wells, including 3 deep wells on the Steen property, were used to create a deep aquifer zone potentiometric surface map, shown on Figure 2. Previous deep aquifer zone potentiometric maps indicated a gradient oriented south to southeast, a direction generally concordant with the dip azimuth of the deep aquifer zone's hydrostratigraphic units. Figure 2 remains consistent, showing a southern groundwater flow direction, with a high point of 3.69 ft AMSL at DSCP-MW-20D and a low point of -0.49 ft AMSL at PH-DW-2.

Vertical gradients (i.e., head potentials) between the shallow and deep aquifer zone for the Fourth Quarter of 2016 well gauging event are shown on Table 3. Gradients were calculated using measured groundwater elevations for wells within nested shallow and deep aquifer zone pairs. Well pairs included:

- CSX-DW-4 and CSX-MW-7
- DSCP-DW-1 and DSCP-MW-23A
- DSCP-DW-13 and DSCP-MW-11
- DSCP-DW-6 and DSCP-MW-2B
- PH-DW-10 and PH-MWS-1
- PH-DW-11 and PH-PH-22
- PH-DW-2 and PH-MWS-15
- DSCP-MW-20D and DSCP-MW-20
- PH-DW-3 and EPH-PH-5

Three of the nine pairs above displayed downward vertical gradients during the Fourth Quarter of 2016 well gauging event. PH-DW-10 and PH-MWS-1, PH-DW-11 and PH-PH-22, and PH-DW-3 and EPH-PH-5 showed upward gradients of 0.02 ft, 0.73 ft, and 0.11 ft, respectively, during the event. The reasons for the appearance of upward gradients are unclear, but localized confined (artesian) conditions may be present due to groundwater being "pinned" against the bottom of low-permeability zones as a result of rising groundwater elevations. Overall, however, the data indicate a broad downward groundwater flow potential throughout the midsection of the Site. The locations of these well pairs showing downward vertical gradients are generally coincident with the approximate reported extent of the aforementioned

[1] Subsurface Geology of the Area Between Wrangle Hill and Delaware City, Delaware. Delaware Geological Survey Report of Investigations No. 78, Jengo, J.W., McLaughlin Jr., P.P, and Ramsey, K.W. 2013

"breach" in the base of the Site's shallow aquifer zone[2]. Additional discussion on Constituents of Concern (COC) and the results of direct push work conducted to help further evaluate aquifer features such as the previously reported "breach" are discussed in subsequent sections of this report.

Measured LNAPL and groundwater depth data were used to prepare an apparent LNAPL thickness map (Figure 3). The apparent LNAPL thickness contours are approximate and do not necessarily indicate consistent in-situ LNAPL saturation, volume, mobility or recoverability. However, the measurements are useful as a metric, to be used in context with other metrics such as constituent concentrations, to evaluate the progress of Site remediation through time. Measured LNAPL thickness is influenced spatially by various factors including: 1) the heterogeneous nature of the LNAPL (i.e., both type and degree of weathering – a range of light, middle, and heavy end distillates were identified via historic LNAPL forensic data), 2) hydrogeologic characteristics (aquifer heterogeneity- units of varying grain size intersected by the screened interval of a given well), 3) well construction (screen type and interval, sand pack design), and 4) temporal changes (e.g., seasonal groundwater level fluctuations).

Compared to previous quarterly report data, the general trends of the LNAPL distribution remain the same, suggesting that the LNAPL body at the Site is stable and, barring no unusual perturbations (i.e. hydraulic stresses imparted from new supply wells or contributions from new LNAPL sources), not laterally mobile. As shown on Figure 3, the distribution of LNAPL appears to be constrained within an elongated area, following an east-west trend. This distribution has been seen in previous gauging events and appears to roughly coincide with the recurring east-west "trough" in the shallow potentiometric surface (Figure 1). No LNAPL was observed in the Steen property wells gauged during the Fourth Quarter 2016 event. However, as the Steen wells will be included in pending Site gauging events, additional data will be collected in support of any future changes to the conceptual site model.

While small LNAPL thickness increases and decreases in individual wells are observed, these superficial changes in thickness may be related to the focused vacuum and skimming approach that has been applied to date, and seasonal fluctuations in groundwater elevation.

Data from recent groundwater/LNAPL gauging events conducted at the former Sunoco (currently PES) refinery and adjacent Philadelphia Gas Works (PGW) property have been received and are currently being reviewed.

4.2 Site Wide Groundwater Sampling Event – Fourth Quarter of 2016

A groundwater sampling event was conducted at the Site between November 30 and December 6, 2016. The event was the fourth groundwater sampling event of CY 2016. The event included 78 out of 165 wells within the Site's monitoring and recovery well network on the Former DSCP property, the Former Passyunk Homes property (the new PHA building and the Siena Place Homes), the CSX property, the P. Agnes property, and the Steen property. As mentioned above, access to the SEPTA and Penrose Avenue hotel properties were not available during gauging and sampling. Two wells on the SEPTA property were recommended for sampling during the quarter, but were not sampled due to the access

[2] As defined by Ron Sloto, USGS, in meetings on September 17, 2010 and January 19, 2012.

issue noted above. The selection of wells was based on the statistical analysis originally presented in the Fourth Quarter of 2014 progress report and updated in the Third Quarter of 2016 progress report.

Like the previous groundwater sampling events, the Fourth Quarter of 2016 event included collection of samples for laboratory analysis of previously defined Short List COC[3] from all accessible monitoring and recovery wells included on a statistically-determined list developed during the previous quarter. Laboratory analytical data from the Fourth Quarter of 2016 sampling event will be combined with historic sampling data and future Site-wide sampling data to: 1) evaluate remedial performance, 2) support determination of LNAPL stability, and 3) present data in support of an Act 2 Site Specific Standard (SSS) pathway elimination approach for LNAPL.

The recovery wells connected to the VES System and the pneumatic system on the Former DSCP property and the Former Passyunk Homes property were deactivated on November 22, 2016. Site recovery wells were reactivated on December 9, 2016, following completion of groundwater gauging and sampling activities.

After liquid level data were collected, and prior to sampling the well, pH, conductivity, temperature, dissolved oxygen, and turbidity readings were measured every five minutes for up to one hour as the well purged, to ensure that water quality parameters had stabilized prior to sampling. Groundwater samples were then collected from the middle of the saturated screened interval of each groundwater monitoring well via low flow sampling techniques using QED bladder pumps. Groundwater sampling logs are included in Appendix B. For LNAPL-bearing wells, sample collection was accomplished using procedures designed to obtain representative groundwater samples free of LNAPL. These procedures are outlined in previous quarterly progress reports.

COCs were selected from the PADEP *Short List of Petroleum Products for Leaded Gasoline, Aviation Gasoline and Jet Fuel.* Selection was based on the reported approximate composition of LNAPL at the Site, and not on any reported releases of these petroleum products. The Short List of Petroleum Products includes:

- Benzene
- Toluene
- Ethyl Benzene
- Xylenes (Total)
- Cumene (Isopropyl benzene)
- Naphthalene
- Trimethyl benzene, 1,2,4- (Trimethyl benzene, 1,3,4-)
- Trimethyl benzene, 1,3,5-
- Dichloroethane, 1,2-

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[3] PADEP Short List for Petroleum Products- Leaded Gasoline, Aviation Gasoline, and Jet Fuel

- Dibromoethane, 1,2-
- Lead (dissolved)

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

Samples from the 78 wells were analyzed using EPA 8260B for Volatile Organic Compounds (VOCs), EPA 8011 for Semi-Volatile Organic Compounds (SVOCs) and EPA 6020 A for dissolved lead and arsenic. Analytical data packages are located in Appendix C. Tabulated analytical results for VOCs and Metals are presented in Tables 4a and 4b. Results were compared to the PADEP Groundwater Medium Specific Concentrations (MSCs) for Non-Residential Use Aquifers with Total Dissolved Solids (TDS) less than or equal to (≤) 2,500 milligrams per liter (mg/L). Analytical results that exceed the Non-Residential Used Aquifer (TDS <2,500 mg/L) Groundwater MSCs are bolded and highlighted in yellow. If the detection limit for a reported result exceeds the MSC, and the sample result is non-detect, the result is highlighted in gray. These standards have been selected for comparison purposes only and are not intended to be the target cleanup goals for Site groundwater. A SSS pathway elimination and LNAPL stability approach to Site groundwater cleanup may be pursued for the shallow aquifer zone, as previously discussed with PADEP (e.g. meetings held on October 27, 2011, January 19, 2012, March 13, 2012, March 6, 2013, and March 16, 2016). Specific criteria for the determination of Site LNAPL stability will be provided in a forthcoming report. For the deep aquifer zone, as discussed during the March 6, 2013 and March 16, 2016 PADEP meetings, either a background standard approach or Non-Use Aquifer Determination (NUAD) approach will be pursued.

Table 4a shows analytical results of the Site VOC COC, including MTBE and TBA, compared to the MSCs. Table 4a also shows the sum of all VOC COC. These results are shown on Figure 4 through Figure 13. The figures are organized to summarize differing concentration ranges for both the shallow and deep aquifers, as follows:

- Figure 4 shows total VOC results for COC in the shallow aquifer that are greater than 10,000 micrograms per liter (ug/L).
- Figure 5 shows total VOC results for COC for the shallow aquifer that are between 3,000 ug/L and 10,000 ug/L.
- Figure 6 shows total VOC results for COC for the shallow aquifer that are between 1,000 ug/L and 3,000 ug/L.
- Figure 7 shows total VOC results for COC for the shallow aquifer that are between 100 ug/L and 1,000 ug/L.
- Figure 8 shows total VOC results for COC for the shallow aquifer that are between 1 ug/L and 100 ug/L.
- Figure 9 shows total VOC results for COC for the shallow aquifer that are less than 1 ug/L.
- Figure 10 shows total VOC results for COC in the deep aquifer that are greater than 1,000 ug/L.

- Figure 11 shows total VOC results for COC in the deep aquifer that are less than 1,000 ug/L.
- Figure 12 shows MTBE and TBA results for the shallow/intermediate aquifer.
- Figure 13 shows MTBE and TBA results for the deep aquifer.

Site metals concentration in the groundwater for the shallow and intermediate aquifer zones are shown in Figures 14 and 15, and Site metals concentrations in the deep aquifer are shown in Figure 16. Each of these figures show the data compared to the Non-Residential Used Aquifer (TDS <2,500 mg/L) Groundwater MSC. Arsenic and lead are the two diagnostic metals detected in groundwater at the Site. The observed lead and arsenic may have an association with the Order-defined petroleum hydrocarbon impacts. However, given the presence of reducing conditions within the groundwater impact area, both metals may have been mobilized from aquifer material. Tabulated metals values are given in Table 4b.

4.2.1 Site-Wide Groundwater Sampling Event Data- Quality Assurance and Quality Control Review

Following receipt of the Fourth Quarter of 2016 groundwater sampling laboratory data, the USACE performed a quality assurance and quality control (QA/QC) review. A complete summary of the review is provided in Appendix C.

The following QA/QC issue was noted in the Fourth Quarter of 2016 data review:

- All samples were prepared and analyzed within the required holding times, with the exception of the reported analyses for TBA in samples PH-DW-2, PH-MWS-13 and its field duplicate, EPH-MW-39, and CSXMW-9, which were performed one to two days outside of the 14-day holding for volatile organic compounds. These holding time exceedances have no significant impact on the usability of the data for TBA.
- An unusually low response was observed for the internal standard TBA-d9 and the undiluted VOC analysis of sample DSCP-DW-12. This low response is attributed to a matrix interference with the VOC analysis of this sample, and the positive result for TBA, the only target compound associated with this internal standard, was qualified “J” in the database to indicate that the reported value is estimated and may be higher than what is presented.

The limited review of the data did not identify any major problems with the laboratory analysis associated with this sampling event. All outliers that were observed for this event were minor exceedances and have no significant impact on the data, and all results from this this sampling event are considered usable with the qualifications described above.

4.2.2 Site-Wide Groundwater Sampling Event Observations – Shallow and Deep Aquifer Zone

<u>Volatile Organic Compound Constituents of Concern</u>

A total of 6 of the 64 sampled shallow and intermediate wells yielded results where total VOC COC exceeded 10,000 ug/L (shown in blue on Figures 4-11, detail Figure 4), including one well on the Steen property. These wells are generally clustered within the central and western portions of the Site, including the VES well network on the PHA property and the general vicinity of the VES building. One well, STEEN-PH-10 (total VOCs 25,023 ug/L), is located on the western boundary of the Site. One of the sampled wells on the Former DSCP property and four of the sampled wells on the PHA property showed total VOC COC greater than 10,000 ug/L. The northernmost of these wells is DSCP-MW-3A (total VOCs 11,659 ug/L), and the southernmost well is PH-RW-U (12,653 ug/L). The maximum total VOC concentration detected during the quarter was 29,664 ug/L in PH-IW-10. Within the wells with high total VOCs, benzene is consistently the COC with the highest concentration. Benzene concentrations in this set of wells range from 11,659 ug/L in DSCP-MW-3A to 29,664 ug/L in PH-IW-10.

Overall, the highest reported groundwater VOC COC concentration data points generally cluster in the center of the Site and occupy an area with an elongated east to west axis, with points of lower VOC COC concentration surrounding the area. This spatial distribution of the high VOC wells coincides with the trough-like feature in the shallow aquifer zone potentiometric surface and measured LNAPL distribution.

While locations of high VOC COC and locations of greatest measured LNAPL thickness both lie in the trough feature in the center of the Site, a complete correlation between LNAPL thickness and groundwater VOC COC concentration was not observed. For example, only 3 of the 6 sampled wells with total VOC COC concentrations >10,000 ug/L showed any measurable LNAPL during the Fourth Quarter gauging event. This may be an indication of the spatially variable composition of the Site's LNAPL, as previously reported, and specifically may indicate the presence of heavier or more weathered LNAPL in the vicinity of wells with measurable LNAPL but relatively low dissolved phase VOC concentrations. At the site, it has been demonstrated that LNAPL is selectively weathered of lighter weight COCs through volatilization and in-situ biodegradation as well as the work of the Site's VES system, resulting in lower concentrations of VOC COC components. Therefore, barring any new source addition, declining COC concentration trends and the continued observation of discordant LNAPL and VOC COC distributions are to be expected.

Surrounding the area of total VOC COC results greater than 10,000 ug/L are the greater than 1,000 to less than 10,000 ug/L wells, shown in yellow on Figures 4-11. Figures 5 and 6 show results between 1,000 ug/L and 10,000 ug/L. A total of 12 of the 64 sampled shallow and intermediate wells yielded total VOC COC results in this category. For these wells, benzene was typically the COC with the highest concentration.

Predominantly toward the edges of the Site are a total of 28 of the sampled shallow and intermediate wells with concentrations less than 1,000 ug/L in the Fourth Quarter of 2016, shown in green on Figures 4-11. In 2 of these locations, benzene still exceeds the Non-Residential Used Aquifer (TDS ≤2,500 mg/L) Groundwater MSC of 5 ug/L. As indicated above, this standard is for comparison purposes only, and is not intended as a target cleanup goal.

Of the 14 sampled deep wells, one deep well, PH-DW-3, yielded total VOC COC concentrations above 1,000 ug/L during the Fourth Quarter of 2016 as shown in Figure 10. PH-DW-3, located in the southern portion of the Site, showed a total VOC result of 12,267 ug/L, including a benzene result of 11,400 ug/L. Of the remaining deep wells where total VOC COC were below 1,000 ug/L, 7 wells, including 2 wells on the Steen property, exceeded the Non-Residential Used Aquifer (TDS ≤2,500 mg/L) Groundwater MSC for at least one compound.

MTBE and TBA

Figures 12 and 13 show MTBE and TBA results in the shallow/intermediate and deep aquifer zones. During the Fourth Quarter of 2016, MTBE was detected in 17 of the 78 sampled wells, including 7 detections which were above the Non-Residential Used Aquifer (TDS ≤2,500 mg/L) Groundwater MSC. Observations regarding MTBE results include:

- 7 of the sampled shallow/intermediate wells are shown with MTBE detections, including a maximum of 24.6 ug/L measured at DSCP-IW-13. These locations are spread across the Site.
- 10 of the sampled deep wells are shown with MTBE detections, including a maximum of 121 ug/L measured at STEEN-DW-09.

Since the Third Quarter of 2013 groundwater sampling event, samples have also been analyzed for TBA, a daughter product derived from the biodegradation of MTBE, or a precursor chemical compound in the manufacturing of MTBE. While TBA is not a PADEP regulated compound, it was sampled for to aid in understanding of the flux of groundwater and COC within the Site's aquifer systems. TBA was not tested for in sampling events prior to the Third Quarter of 2013. In the Fourth Quarter of 2016, 31 of the 78 sampled wells showed TBA detections.

Figures 12-13 show the following observations:

- 26 shallow/intermediate wells showed TBA detections, including a maximum of 593 ug/L measured at PH-RW-U, located in the central portion of the Site.
- Five deep wells showed TBA detections, including a maximum of 629 ug/L measured at PH-DW-3 in the southern portion of the Site.
- The regions of highest TBA detections in the shallow/intermediate zones are located within the central portion of the Site, as well as along the western side of the Site.
- Four wells in the shallow/intermediate zones with MTBE detections did not show TBA detections during the Fourth Quarter of 2016.
- Six wells in the deep zone showed MTBE detections but not TBA detections.

Dissolved Metals

Table 4b and Figures 14, 15, and 16 show dissolved metals results for arsenic and lead in the shallow and deep aquifers. Dissolved lead concentrations are represented by larger circles, while dissolved arsenic is represented by small circles. Detections that exceed the Non-Residential Used Aquifer (TDS≤2500 mg/L) Groundwater MSCs are highlighted in blue. The metals result for arsenic and lead in the shallow aquifer showed detections exceeding MSCs in the same areas of high VOC COC concentrations and anaerobic and reducing conditions, where measurable LNAPL is located. In addition, results from several shallow wells on the CSX property to the west of the Site showed levels of arsenic and lead that exceeded the MSCs.

As mentioned in Section 4.2.1, an apparent increase in detections of both arsenic and lead was observed in this quarter's results as compared to previous quarters. However, recently revised laboratory protocol dictated that all detections above the laboratory detection limit be reported as positive results, instead of only reporting detections above the laboratory limit of detection (LOD) as positive. Results therefore may not indicate an increase in lead or arsenic as compared to other quarters. As indicated above, laboratory management is currently investigating the option of using the previous protocol for future analyses for the Site.

Specific observations of the arsenic and lead analytical data include:

- 43 of the 64 sampled shallow/intermediate wells are shown with arsenic detections, including a maximum of 288 ug/L measured at DSCP-RW-5/MW-25. 22 of these detections exceed the PADEP MSC.
- Arsenic is detected in the shallow/intermediate groundwater throughout the Site, with some of the most elevated detections centered on the area of measurable LNAPL. However, several shallow/intermediate wells along the western boundary of the Site, including 5 on the CSX property and 5 on the Steen property, yielded arsenic detections above the PADEP MSC.
- 7 of the sampled deep wells are shown with arsenic detections, including a maximum of 8.1 ug/L measured at DSCP-DW-12. These detections are below the PADEP MSC.
- 5 of the sampled shallow/intermediate wells are shown with lead detections, including a maximum of 88.3 ug/L measured at DSCP-RW-5/MW-25. DSCP-RW-5/MW-25 is located in the central portion of the Site. 4 of the lead detections in samples from the shallow/intermediate aquifer zone exceed the PADEP MSC.
- 2 of the sampled deep wells are shown with lead detections including a maximum of 2.7 (estimated) ug/L measured at DSCP-MW-20D. These detections are below the PADEP MSC.

4.2.3 Historical Site-Wide Groundwater Sampling Event Data Observations

Historical VOC COC data tables were compiled from Site-wide groundwater sampling events dating as far back as 1994. These tables are provided in Appendix D, and may be read in conjunction with Figures 4-13, which show the most recent groundwater sampling data. The color-coding used in these figures (blue for total VOCs >10,000 ug/L, green for 1,000-10,000, and yellow for <1,000) has been applied to the well names in the historic data table for reference.

During the Fourth Quarter of 2016, the historical data shown in Appendix D was used for continued sample reduction statistical analyses as described below in Section 4.2.4. Future groundwater sampling event data will also be evaluated by these procedures. This information will be used along with O&M data to evaluate Site LNAPL stability trends and to focus future Site remedial efforts in pursuit of Order defined cleanup goals. Further details will be provided in a pending Act 2 report (e.g., a Remedial Investigation Report [RIR]).

4.2.4 Sample Reduction Statistical Analysis

After several quarters of sampling all accessible wells at the Site, analytical data and statistical analyses led to the idea that some of the sampling locations could either be reduced in sampling frequency or removed entirely from the sampling scheme. The efforts to identify the sample locations that must be analyzed each quarter, and to identify those that can be sampled less often, are presented in each quarterly report. The effort is performed with the intent to avoid adversely affecting the fate and transport analyses of Site COCs, and to support LNAPL stability. The trend analysis concept and process was originally presented in the Second Quarter of 2014 progress report and described in detail in the Third Quarter of 2014 report. A recommended reduction in sampling frequency for the Fourth Quarter of 2016 was presented in the Third Quarter of 2016 report. During the Fourth Quarter of 2016, the data have continued to be closely analyzed to identify trends and allow for the eventual definition of a point of compliance monitoring well network for the Site. The methodology is presented in detail in Appendix D.

As the analysis of the data proceeds, decisions about changes to the sampling plan will be proposed based on the following guiding principles, which were also presented in the previous quarterly reports during CY 2014, 2015, and 2016:

- Trends: Wells with stable downward trends of petroleum hydrocarbon constituents will be sampled less often; wells with stable upward trends with concentrations that are above groundwater standards, or wells with unstable trends will generally continue to be sampled regularly. The Mann-Kendall trend detection test will be used to quantify the type of trend (see EPA QA/G-9S, Data Quality Assessment: Statistical Methods for Practitioners, February 2006).
- Toxicity: The toxicity of a given constituent for the purposes of this analysis is estimated by comparing concentrations observed in a monitoring well to PADEP Medium Specific Concentrations (MSCs) for Non-Residential Used Aquifers with TDS ≤ 2500 mg/L. Wells with concentrations of constituents that exceed MSCs will continue to be sampled often; wells with lower concentrations may be sampled at less frequent intervals. Note that comparisons to MSCs are not meant to be used as clean-up goals, but rather as comparison points for approximating the toxicity of reported concentrations.
- Sentinel wells: Wells on the boundary of the Site area will continue to be sampled frequently to provide early warning of unexpected movement of constituents out of the area of interest, or the arrival of constituents from off-site, which may affect background level designations.
- Proximity: Well data will be compared to that from nearby wells to ensure that data quality does not suffer from the reduction in sampling frequency. Nearby wells that provide no unique data may be sampled less frequently.
- Fingerprinting: Relative concentrations of COCs will be compared at nearby wells to determine which provide duplicated data. Nearby wells with similar fingerprints will be assumed to provide no unique data and may be sampled less frequently. A variation on the method described in EPA/600/5-04/054 Fingerprint Analysis of Contaminant Data: A Forensic Tool for Evaluating Environmental Contamination will be used to compare the data.
- Clusters: Wells in multi-level clusters will be sampled frequently and together to provide vertical definition of variations in constituent concentrations.
- Depth: Wells installed in the deep aquifer will continue to be sampled frequently because of the scarcity of data in the deep aquifer.
- Long-term Data: Since long-term trends can be important in analysis, no wells will be completely removed from the dataset as a result of this analysis. Sampling of all wells at least biennially will be recommended.

Appendix D contains a table of Site wells together with specific information to support future sampling frequencies at each well. During the First Quarter of 2017, sampling of 124 wells is recommended.

5 VES SYSTEM OPERATION AND MAINTENANCE

Remediation began at the Site in 1996 utilizing in-well skimmer pumps for removal of LNAPL. In March 1999, operation of an expanded LNAPL skimming system commenced. The expanded system included two separate fixed pneumatic LNAPL skimming systems at the Former DSCP property and the Former Passyunk Homes property (the PHA property). The current VES System, which began operation in March 2005, was installed to enhance LNAPL recovery rates by inducing a pressure (i.e., vacuum) gradient that can help draw additional LNAPL to the recovery wells without depressing the groundwater table. The VES system also removes hydrocarbon mass via vapor phase recovery which can be expressed as LNAPL using a vapor mass to LNAPL volume conversion factor. For a complete history of Site remedial operations, please see Appendix E. This history reveals how the more recently adopted dynamic approach to O&M has allowed remediation efforts to evolve based on the physical operating parameters of the system and changing subsurface conditions, so that recovery is more effective. Below is a description of the performance of the mobile and VES systems and related remediation O&M observations during the Fourth Quarter of 2016.

5.1 Fixed Skimming System – Fourth Quarter of 2016

The fixed LNAPL skimmer pumps are connected to a totalizer installed in each recovery well vault. Recovery well totalizers are used only to estimate the LNAPL recovered from each well during skimmer pump operation. This is because some air passes through the totalizers along with the LNAPL, and/or totalizers can occasionally become stuck as a function of regular operation, resulting in inaccurate estimation of the quantity of LNAPL recovered at each well. For this reason, the recovery well totalizers are only used to confirm if LNAPL is being recovered by the wells during system optimization, and do not represent a quantitative measurement of the LNAPL recovered. The more accurate measurement of the volume of LNAPL recovered by skimming is obtained from tank charts which correlate storage tank volume and the depth of LNAPL measured in a given Site LNAPL storage tank (where the total volume of LNAPL recovered is monitored continuously and recorded weekly, at a minimum). This tank chart data is obtained via a volume-measuring probe installed in each of the Site's two LNAPL above ground storage tanks (ASTs).

The fixed system LNAPL skimmer pumps located on the Former Passyunk Homes property (the current PHA property) are connected to a 5,200-gallon AST and the fixed system LNAPL skimmer pumps located on the Former DSCP property are connected to a 10,000-gallon AST. Tables 5 and 6 detail the totalizer-estimated quantity of LNAPL recovered from each of the fixed system recovery wells, in addition to the total and cumulative LNAPL recovered by each fixed system based on the tank charts mentioned above. Table 5 contains the LNAPL recovered for the Former DSCP system and Table 6 contains the LNAPL recovered for the Former Passyunk Homes system.

During the Fourth Quarter of 2016, an increased amount of LNAPL was recovered via the Former DSCP area fixed skimming system. The LNAPL totalizers in the recovery well vaults did not register any LNAPL recovery (as shown in Table 5). However, tank chart readings indicated the AST on the Former DSCP property received approximately 1,013 gallons of LNAPL during the quarter. This increase in liquid recovery may have occurred because of changes in water table elevations, as well as system repairs and adjustments to the levels of the skimming pumps. This results in a total approximate volume of LNAPL recovered by the Former DSCP area fixed system of 510,006 gallons, from system start-up in the Third Quarter 2005 through the end of the Fourth Quarter of 2016.

During the Fourth Quarter of 2016, and according to the totalizers in each recovery well vault (as shown on Table 6), the Former Passyunk Homes property fixed skimming system did not register any LNAPL recovered. However, based on the volume-measuring probe data and resultant tank chart readings, the AST on the Former PHA property received approximately 37 gallons of LNAPL during the quarter. This brings the total amount of LNAPL recovered by the Former Passyunk Homes fixed skimming system to approximately 167,977 gallons since it was started in March 1999.

The DSCP skimming system was shut down on October 18, 2016 for repairs to the compressor, and was restarted on October 21, 2016. The DSCP skimming system was also off briefly on November 21, 2016 due to a tank level indicator adjustment. The DSCP and PHA fixed skimming systems were shut down from November 22, 2016 through December 9, 2016 in preparation for and during the quarterly groundwater gauging and sampling event. Except for this time interval, the PHA skimmer system operated continuously during the quarter. Neither AST used for storing LNAPL was pumped out during this quarter. System O&M, pump cycling frequency and pump intakes were adjusted as necessary. Adjustments were made to optimize LNAPL recovery while maintaining enough LNAPL thickness in the wells to prevent pumping groundwater along with the recovered LNAPL.

Despite the short-term increase in recovery to over 1,000 gallons this quarter, and as discussed in previous quarterly reports, the LNAPL recovery by skimmer pump from approximately 2006 to date continues to be lower than what was witnessed during the first 6 years of skimmer system operation, when several thousands of gallons were recovered each quarter. This general decrease in LNAPL recovered by skimmer is most likely the result of the following factors:

- The majority of the LNAPL that was recoverable by skimmer pump has been removed.
- A reduction in the regional pumping rates in the shallow aquifer over the years in the vicinity of the Site has resulted in higher groundwater elevations. As a result, much of the remaining LNAPL/petroleum hydrocarbon mass at the Site is now most likely trapped below the water table. This change in the regional aquifer effectively reduced the amount of mobile LNAPL available for recovery by skimmer pump. The resulting increase in the groundwater level has also submerged the screened interval in some recovery wells thereby cutting off the recovery well from any mobile LNAPL and or hydrocarbon vapor that may be present adjacent to the well.
- Fouling due to biomass and/or mineral buildup in well screens, sand packs, and formation materials adjacent to the Site's wells. Fouling can occur due to biological activity (biofouling) or from extended periods of vapor recovery. In the case of vapor recovery, the lighter fraction of the LNAPL is volatilized, leaving behind the less volatile, heavier, and more viscous petroleum fraction. In addition, residual LNAPL in the formation surrounding recovery wells is weathered by ongoing remediation, which may reduce soil porosity, resulting in a reduction in LNAPL transmissivity and the rate of recovery over time.

Because of the generally lower ability to recover LNAPL by skimmer pump, Arcadis has been conducting ongoing optimization testing activities on the vapor recovery portion of the VES system as discussed in Section 5.3 below. Additionally, Arcadis has been conducting ongoing optimization of the operational strategy of the fixed skimmer systems including:

- Keeping skimmer pumps off in recovery wells that exhibit less than 0.3 ft of free LNAPL to prevent water from being pumped into the ASTs, and to reduce the amount of labor expended on tasks that do not yield significant LNAPL recovery. These recovery wells are checked periodically and the skimmers are turned on only when supervised to pump out accumulated LNAPL but not to pump water into the ASTs.
- Removing skimmer pumps from recovery wells that do not exhibit recoverable LNAPL to reduce costs associated with maintaining pumps in wells where no LNAPL is being recovered. These pumps are kept onsite and will be re-deployed when recoverable LNAPL is measured in these recovery wells.
- Operating sets of fixed skimming (recovery) wells at higher vacuum levels (i.e. between 20 and 45 inches of water [iw]) for extended periods of time, then periodically stopping the vacuum and using the skimmer pumps to pump out the LNAPL that has accumulated. This strategy, often referred to as "pulsing" the smear zone, is a dynamic approach to LNAPL recovery which can help mobilize LNAPL in the smear zone not otherwise effected by a more static VES strategy. Periodically stopping the vacuum in this strategy is necessary in some of the wells as the effectiveness of the skimmer pumps may be decreased by these higher vacuums. This pulsing of the aquifer is done by focusing LNAPL skimming at the VES wells being utilized in rotating groups, discussed in more detail in Section 5.3 below.
- Continued skimming using the RW-A and PH-20 skimmers on the Former Passyunk Homes Skimming System with a pump controller removed from one of the mobile systems. This strategy began as part of an optimization test in the Third Quarter of 2011, and has been used as part of routine operation since. The approach involves operating the skimmer on a timed schedule (three events per day, five minutes per event) in place of continuous operation if LNAPL is present, allowing LNAPL to recover in the well between periods of pump operation. This prevents the surrounding LNAPL in the formation from being cut off, and the resulting surface tension allows more LNAPL to be drawn to the well. Adjusting the pump controller frequency to pump only during short durations throughout the day ensures that the pump is only active when LNAPL is present. This results in reduction in the overall amount of water being handled, and reduces energy usage while maximizing LNAPL recovery. Additional optimization testing began in the Third Quarter of 2013, and is ongoing whenever enough LNAPL is present in these wells to warrant skimming. The results of this ongoing optimization test will continue to be provided in future quarterly reports. Results to date indicate that this strategy appears to have contributed to an increase in the amount of LNAPL recovered by the fixed skimming system.

LNAPL recovery tables are provided in Appendix F.

5.2 Modular Skimming Systems – Fourth Quarter of 2016

In addition to the fixed skimming systems, modular skimming systems are deployed on as as-needed basis to target specific wells that exhibit optimal conditions for LNAPL recovery. The feasibility of deploying modular units at other locations of the Site is evaluated each quarter. Modular skimming systems are currently in place at two well locations on the Site: DSCP-MW-3A (installed October 2004) and DSCP-MW-65 (installed January 2013). During portions of the Fourth Quarter of 2016, LNAPL was observed in PH-RW-A2 in thicknesses that indicate potential for skimming recovery at this location. Modular and fixed skimming options for PH-RW-A2 will be evaluated in the First Quarter of 2017.

5.2.1 Modular Skimming at DSCP-MW-3A

A modular LNAPL recovery system was installed on the Former DSCP property at well DSCP-MW-3A on October 25, 2004. The system was not operated from the Third Quarter of 2013 to the Third Quarter of 2015 due to lack of recoverable LNAPL in this well and concerns with damaged pump tubing. During the First and Second Quarters of 2015, LNAPL thicknesses in DSCP-MW-3A were great enough to indicate that LNAPL recovery was practicable at this location. New LNAPL collection tubing and double containment piping was installed in the Third Quarter of 2015, and recovery resumed on August 18, 2015. During the Fourth Quarter of 2016, 18 gallons of LNAPL were recovered at DSCP-MW-3A. The LNAPL recovery data for this modular system is included in Table 7. A graph showing the total LNAPL recovery per quarter over time by the modular systems is included in Appendix F.

As discussed above, the ongoing optimization efforts involve testing the Site's LNAPL skimming methodology. The operational methodology being applied to the fixed skimming systems is also being applied to the modular skimming unit currently installed at DSCP-MW-3A. The modular skimmer has a pump controller that allows the unit to pump LNAPL on a timed frequency of twice per day for 5 minutes if LNAPL is present.

5.2.2 Modular Skimming at DSCP-MW-65

In January 2013, monitoring well DSCP-MW-65 was installed for the purposes of conducting an aquifer pumping test to measure hydraulic parameters of the underlying aquifer system (Arcadis, 2013), and a pilot test was conducted at DSCP-MW-65 using an existing spare mobile skimming system during the Third Quarter of 2015.

During start-up testing, it was determined that the amount of recoverable LNAPL in DSCP-MW-65 was enough to continue longer term recovery.

A pump controller is programmed to skim LNAPL from the well at set frequencies. This control allows the pump schedule to be adjusted to match the rate of LNAPL recharge, so that LNAPL is skimmed from the well with minimal water. During the course of the testing, the skimmer pump frequency in DSCP-MW-65 was increased in steps from twice per day to six times per day, while maintaining equilibrium with the LNAPL recharge rate. During the Fourth Quarter of 2016, 3 gallons of LNAPL were recovered, for a total of 132 gallons of LNAPL recovered from DSCP-MW-65 by the modular skimming pilot test (2015 to present). This number has been included Table 7, Appendix F (LNAPL Recovery) and in the recovery totals in the executive summary above and in Section 7.2 below. Modular skimmer testing is ongoing at DSCP-MW-65 into the Fourth Quarter of 2016, and the pump frequency and LNAPL recovery rate will continue to be evaluated and optimized.

LNAPL recovery will continue at DSCP-MW-65 via a modular skimming system as part of routine operation, provided that this well continues to exhibit LNAPL in excess of 0.3 ft or if LNAPL recovery remains consistent.

5.3 VES System Operation and Optimization- Fourth Quarter of 2016

As part of system improvement activities in 2004, the VES system was installed to enhance the recovery rate of the existing LNAPL skimming systems. As originally designed, the VES system allows the placement of vacuum on selected recovery wells to create a pressure (vacuum) gradient. Ideally, this gradient helps draw additional LNAPL to the recovery well. However, the applied vacuum also removes hydrocarbon mass via vapor phase recovery which can be expressed as gallons of LNAPL using a conversion factor. Additional details on the calculations were provided in previous quarterly reports and are discussed in Appendix E – Site History.

The well field optimization testing that commenced in the Fourth Quarter of 2011 determined that the application of focused VES system-generated vacuum on a selected subset of recovery wells increased the overall rate and quantity of petroleum hydrocarbon mass recovery from the VES system. This focused vacuum strategy, as opposed to the equal application of VES vacuum to all Site recovery wells, has been continued through the Fourth Quarter of 2016 with subsets of wells being used for continuous VES operation. Appendix G shows which VES system wells were operated during this quarter.

The VES system wells, shown in Appendix G, have been grouped into primary, secondary and tertiary subsets of wells. In the current remedial strategy, wells from the primary group are utilized for continuous focused vacuum extraction due to consistent mass recovery yielded by these wells. These wells are only shut off briefly when necessary to periodically pump out the LNAPL that accumulates by skimmer pump if necessary, or to address high water level issues. This strategy is utilized to maximize mass recovery in the vapor and liquid phases. The secondary group of recovery wells do not yield enough vapor or liquid mass for continuous vacuum extraction, but may be utilized for vapor extraction when vapor headspace readings collected during normal O&M, indicate that they have the potential to yield substantial vapor mass for some period of time. The added benefit to this occasional rotation of secondary group wells is that it can be used to generate a pulsing effect in portions of the plume, which can help draw additional LNAPL and vapor mass towards the recovery wells, expediting remediation.

The remaining recovery wells (tertiary group) are not currently used due to low vapor mass or submerged screens. These tertiary wells are checked less frequently (i.e. quarterly or less), due to historically low vapor mass recovery, but may be brought online if conditions change. The VES system was operated during the Fourth Quarter of 2016 with the wells listed in Appendix G at an applied vacuum of between 36 and 46 iw.

During the Fourth Quarter of 2016, the VES system operated continuously using the primary thermal oxidizer TOX-100, with the following exceptions:

- October 17, 2016 through October 18, 2016 due to a power outage.
- November 22, 2016 through December 9, 2016 when the VES and skimming system were shut down for the quarterly liquid level gauging and groundwater sampling event.

Only one thermal oxidizer (TOX-100) was necessary for treatment of extracted vapors from the VES system during the Fourth Quarter of 2016. The secondary, backup thermal oxidizer, TOX-200, was not operable during the Fourth Quarter of 2016; however, troubleshooting work and repairs were conducted so that it can be returned to service as the backup air pollution control device. Work done on TOX-200 during the Fourth Quarter of 2016 included:

- Replacement of wires and conduit between the combustion blower motor and the start control cabinet for proper continuity and shorts to ground.

A high temperature fault was also identified. The cause of this fault is expected to be investigated and remedied during the First Quarter of 2017. After completion of the work, TOX-200 will remain off but in a ready to operate state as a backup air pollution control device, should a problem arise with TOX-100.

Monitoring of CH_4 (with and without carbon filter), LEL, CO_2, and O_2 were recorded periodically during the quarter. Mass recovery was calculated using PID data collected at the VES system manifold. However, high CH_4 results tend to negatively skew the PID data collected at the VES system manifold, therefore PID data was calibrated using TO-15 summa canister air sample data. The petroleum hydrocarbon mass recovery calculations for the focused VES system are based on a weighted average of the compounds detected in the TO-15 manifold combined influent vapor samples. These samples are collected twice-monthly, when possible, to allow better accuracy of the mass recovery calculations. During the Fourth Quarter of 2016, four of these samples were collected. The average molecular weights from the results of the TO-15 samples of the combined influent were calculated in grams per mole (g/mol) as follows:

- October 11, 2016 – 90.76 g/mol
- October 25, 2016 – 90.23 g/mol
- November 16, 2016 – 90.58 g/mol
- December 19, 2016 – 89.88 g/mol

The TO-15 summa canister vapor sample results can be found in Appendix H. Mass recovery calculations are presented in Appendix I.

During the Fourth Quarter of 2016, the VES system operated in optimized/focused-vacuum mode yielding a weighted average mass recovery of 6.90 pounds/hour (lbs/hr). Mass recovery remains higher utilizing the focused vacuum remedial strategy than it was prior to optimization in 2011.

During the Fourth Quarter of 2016, the average CH_4 (with carbon filter), as measured at the combined influent, was 1.54%, slightly lower than the previous quarter (1.6%). The CH_4 with carbon filter values are used to quantify the contributions of in situ bioremediation. The average CO_2 was 6.79%, up from 5.8 in the previous quarter, and the average O_2 was 10.5%, down from the 11.4% in the previous quarter.

During operational periods, one thermal oxidizer was adequate to treat the vapor from the VES system. The VES system was operated using TOX-100 during the Fourth Quarter of 2016. The second oxidizer, TOX-200, is undergoing repairs into the Fourth Quarter of 2016. Upon completion of repairs, TOX-200 will be maintained on standby in the event of a problem with TOX-100.

The overall VOC recovery for the VES system from October 1, 2016 through December 31, 2016 was 12,249 pounds, which correlates to approximately 2,062 gallons of LNAPL. This is calculated using the mean density of the compounds detected in the laboratory analytical results of the summa canister samples collected from the influent vapor stream at the VES system manifold. This mean density is calculated based on a weighted average of the molecular weights of the compounds detected. This conversion factor was calculated as follows during the Fourth Quarter of 2016:

- 5.97 lbs/gallon on October 11, 2016
- 5.94 lbs/gallon on October 25, 2016
- 5.89 lbs/gallon on November 16, 2016
- 5.95 lbs/gallon on December 19, 2016

A graph showing the cumulative mass recovery of the VES system per quarter is included in Appendix F. As shown on this graph, the mass recovered by the optimized VES system since the Fourth Quarter of 2011 is now approximately seven times greater than the total mass recovered by the VES system from its start-up in 2005 through the Fourth Quarter of 2011. In the Fourth Quarter of 2016, VES mass recovery was lower than the previous quarter, although overall recovery was higher due to increased liquid recovery from the DSCP system.

While still higher than the LNAPL recovery rate in the vapor phase observed prior to the Fourth Quarter of 2011, the rate of recovery by VES has been decreasing since the peak rate observed during the Fourth Quarter of 2014. The decrease in rate of recovery suggests that despite the continued LNAPL recovery, VOCs being recovered from the VES wells is slowly abating due to preferential weathering of the VOC fraction of the LNAPL as focused vacuum extraction is applied. Continued LNAPL recovery could be best enabled by a supplemental in-situ air-injection bioremediation strategy.

5.4 Methane and Carbon Dioxide Forensic Techniques

In addition to petroleum hydrocarbon mass recovered as VOCs, the VES system also contributes to the in-situ degradation of hydrocarbon mass by way of aerobic microbial degradation (biodegradation). The effect of aerobic and anaerobic microbial degradation can be estimated using the concentration of CO_2 and CH_4 entering the VES system. To determine a “weighting” factor to convert CO_2 and CH_4 to pounds of hydrocarbon mass degraded in situ, carbon isotopic analysis of the CO_2 and CH_4 from the headspace of recovery wells, as well as the VES-extracted soil vapor, commenced in the Third Quarter of 2013 and is ongoing into the Fourth Quarter of 2016. The analysis of the carbon isotopes present in these samples can be used to determine the portion of CO_2 and CH_4 attributed to biodegradation of a fossil fuel compared to the portion derived from more modern sources (such as the presence of trash and debris in fill soils, the decay of naturally occurring organic matter such as peat in soils, and/or leaky sanitary sewers).

In the Fourth Quarter of 2016, a sample was collected on October 11, 2016 at the combined VES influent sampling port for isotopic analysis of CO_2 soil vapor. In previous quarters, isotopic samples were collected monthly. Due to the consistency of sample results from month to month, this sampling frequency was reduced to quarterly, as indicated in the Third Quarter of 2016 Progress Report, and isotopic samples will be collected once per quarter in future quarters.

Analytical results as well as calculated results of the percent contribution from petroleum hydrocarbon degradation are provided below and in Table J-2 of Appendix J.

The amount of the carbon-14 (^{14}C) isotope, expressed as percent modern carbon (pMC), in the CH_4 and CO_2 is used to determine the "age" of the CH_4, and CO_2, similar to the age dating of organic material from archeological sites (i.e. CH_4 or CO_2 derived from degradation of petroleum hydrocarbons will have zero ^{14}C, while CH_4 or CO_2 derived from anthropogenic sources such as landfills may be up to 100 pMC). The analytical results of the CO_2 in the October 11 sample indicate that the carbon present in the CO_2 had a ^{14}C value of 14.0 pMC. This low value of ^{14}C indicates that the CO_2 is primarily derived from biodegradation of petroleum hydrocarbons (i.e. aerobic and anaerobic degradation of the LNAPL plume).

These analytical results suggest that the relatively high levels of CH_4 present in the formation and extracted by the VES system are in large part the result of years of anaerobic biodegradation of LNAPL or dissolved components of LNAPL, due to the quiescent hydrodynamics of the groundwater system at the site. This has allowed for the removal/consumption of alternative electron acceptors at a rate that is greater than the rate at which the transport of alternate electron acceptors into the core of the contamination plume is occurring, thus creating a methanogenic core within the LNAPL body. This process is occurring naturally, and is independent of the VES system operation and is represented by the following equation:

$$\mathbf{2C_{organic} + 2H_2O = CO_2 + CH_4}$$

This process is occurring naturally, and is independent of the VES system operation. However, the CO_2 present in the formation and extracted soil vapor is increasingly being derived from aerobic in-situ biodegradation, which can be directly attributed to:

- The operation of the VES system (i.e., as the VES system withdraws CO2, CH_4, and VOC laden soil gas, the concurrent infiltration of atmospheric air supplies oxygen to the subsurface).
- The flux of more oxygen enriched groundwater flowing from up-gradient to down-gradient through the more anoxic portions of the Site.

The available isotopic analytical results of CO_2 in the soil vapor of the VES system combined influent conducted during the Fourth Quarter of 2016 yielded a value of 14.0 pMC. This demonstrates that an average of approximately 14% of the CO_2 recovered by the VES system during the Fourth Quarter of 2016 is derived from modern or anthropogenic sources (i.e. not related to in-situ degradation of the petroleum hydrocarbons). To determine how much of the remaining 86% of the CO_2 is then directly attributed to in-situ biodegradation of the VOCs, the percent derived from degradation of peat and organics in soil must be considered. As described in the Technical Memorandum included in Appendix J, the amount of ^{14}C in CO_2 derived from the degradation of peat is approximately 74 pMC. The percent contribution from petroleum hydrocarbon biodegradation is then expressed as:

$100 - \frac{100 \text{ x } 14 \text{ pMC (sample result)}}{74 \text{ pMC (contribution from peat)}}$ = 81.1% (from petroleum hydrocarbons)

The results of this analysis therefore demonstrate that the percent of the CO_2 recovered that may be directly attributed to in-situ biodegradation is approximately 81.1%. As discussed above, this in-situ biodegradation is attributed to both the aeration of the aquifer by the venting action of the VES system, as well as naturally occurring anaerobic biodegradation processes. Regardless of the source, the rate of this biodegradation may be tracked in the zones affected by the VES system by applying this conversion factor to the total amount of CO_2 recovered in the influent soil vapor stream.

Updated mass degraded in-situ by biodegradation results based on updated isotopic data are provided in Table 4 of Appendix I. However, if the results of these isotopic samples of CO_2 from the VES system influent in the Fourth Quarter of 2016 were applied to the entire quarter, a total of 99,380 lbs of VOCs were degraded in-situ as measured by CO_2 recovered. This yields another 16,734 gallons of LNAPL remediated in the Fourth Quarter of 2016 by in-situ degradation calculated using the same LNAPL densities discussed in Section 5.3 above. This total is not added to the total mass recovery by the VES system, but is presented separately in Appendix I.

6 INVESTIGATION DERIVED WASTE

The approach to management of investigation derived waste (IDW) is outlined in the Site Waste Management Plan (WMP; PARS, April 2015) submitted to USACE. The WMP was developed to be a "living" document, such that IDW from each phase of work would be addressed in an addendum to the WMP.

The following IDW was removed from the Site during the Fourth Quarter of 2016:

- One roll-off bin containing approximately 400 lbs of sampling event IDW, including tubing and PPE, from the Fourth Quarter of 2016 sampling event (removed September 9, 2016).
- Approximately 1,070 gallons of liquid waste, including purge water from quarterly groundwater sampling events (removed December 23, 2016).

Waste manifests are provided in Appendix K.

7 FOURTH QUARTER OF 2016 SUMMARY

7.1 Conceptual Site Model

The following bullets summarize the observations made during the Fourth Quarter of 2016 in the context of the current Conceptual Site Model (CSM):

- Figures 1 and 2 present the potentiometric surface data for the shallow/intermediate and deep aquifer zones during the Fourth Quarter of 2016 gauging event. The surfaces do not differ greatly from those published in previous quarterly progress reports. Regionally, horizontal gradients within each aquifer zone are oriented south to southeast. However, each shallow/intermediate aquifer map has revealed an elongated east-west oriented "trough" feature in the potentiometric surface beneath the midsection of the Site. This feature appears to be a persistent, localized zone of depressed groundwater elevations that differs from the regional pattern of groundwater flow.

- Vertical gradients, as measured by well pairs within and proximal to the "trough" are predominantly indicative of downward groundwater flow. This has been a constant observation using data generated from past quarterly gauging events.

- The "trough" approximately coincides spatially with the limits of the interpreted "breach" described as a geologic feature that allows hydraulic connection between the shallow/intermediate aquifer units and the underlying Cretaceous aquifer units.

- Figure 3 indicates the extent of measurable LNAPL in Site wells during the Fourth Quarter of 2016 gauging event. Viewed in context with previously published Site LNAPL thickness maps, Figure 3 reveals that the horizontal extent of Site LNAPL is generally constant through time, and is generally confined to the area of the "trough" above the "breach" mentioned above. A consistently observed downward gradient in that area, along with buoyant forces, have trapped LNAPL in the "trough" above the "breach."

- As shown on Figures 4-9, the highest concentrations of PADEP Short List COC in the shallow/intermediate aquifer zones are generally observed in the center of the Site, coinciding with the location of the "trough/breach" and region of greatest measurable LNAPL thickness.

- MTBE and TBA Observations

    - As shown on Figures 12-13, TBA detections were reported in the shallow, intermediate, and deep aquifer zones more frequently than were MTBE detections, indicating a predominantly anaerobic and reducing environment is present at the site, and thus MTBE is degrading via TBA anaerobically. The spatial distribution of these detections is generally confined to the "trough/breach," but some notable differences are observed.

    - The locations of highest TBA detections are situated within the central and western portions of the Site. While these areas are still within the approximate limits of the "trough/breach," they do not always coincide with areas of measurable LNAPL thickness, as shown on Figure 3.

    - MTBE detections were reported predominantly in the central and western portions of the Site, as shown in Figures 12-13. Some of these detections do not coincide with TBA detections.

- As shown on Figures 14-15, the majority of shallow/intermediate arsenic detections and MSC exceedances are generally located within the approximate limits of the "trough/breach," in the area of measurable LNAPL where anaerobic conditions predominate. However, some of the shallow/intermediate lead detections and MSC exceedances occur outside of the "trough/breach," and are found within the northwestern and western portions of the Site.

- On Figure 16, data reveal limited arsenic and lead impacts in the deep aquifer zone.

- Based on fingerprinting data presented in the Third Quarter of 2015 progress report (Arcadis 2015) from the May 2015 LNAPL sampling, LNAPL in specific areas of the site (i.e. near DSCP-RW-9 and PH-RW-A) is shown to contain higher percentages of heavier hydrocarbons than in previous sampling events. This trend towards heavier hydrocarbons suggests ongoing degradation of the LNAPL as a result of both natural processes and remediation activities. Additional LNAPL fingerprint sampling events are planned to further document the LNAPL degradation trend.

7.2 VES System Operation and Maintenance

The total LNAPL recovered from the start of LNAPL recovery operations in 1996 through the Third Quarter of 2016 was 1,050,854 gallons. During the Fourth Quarter of 2016, an additional 2,062 gallons of LNAPL was recovered by the VES system, 1,013 gallons were recovered by the Former DSCP fixed skimming system, 37 gallons were recovered by the Former Passyunk Homes fixed skimming system, and 21 gallons of LNAPL were recovered by modular LNAPL recovery systems, yielding a total of 3,133 gallons of LNAPL for the quarter. This brings the cumulative recovery of LNAPL since the start of LNAPL recovery operations in 1996 through the end of the Fourth Quarter 2016 to 1,053,987 gallons. The following table illustrates the LNAPL recovered in gallons during the Fourth Quarter of 2016 as compared to recovery during the Third Quarter of 2016.

Recovery System	Current Quarter LNAPL Recovered (Gallons)	Previous Quarter LNAPL Recovered (Gallons)	Change in LNAPL Recovered (Gallons)
Former DSCP Fixed System	1,013	145	+868
Modular Units	21	14	+7
Passyunk Homes System	37	16	+21
VES System	2,062	2,268	-206
Total	**3,133**	**2,443**	**+690**

The above total mass recovered during the Fourth Quarter of 2016 does not include the mass degraded by in-situ biodegradation as measured by CO_2 recovered by the VES system and calculated based on isotopic sampling of the VES system influent. As discussed in Section 5.4, the mass degraded in-situ during the quarter equates to an estimated 16,734 additional gallons of LNAPL remediated by the VES system via in-situ biodegradation.

The total cumulative LNAPL recovery through the end of the Fourth Quarter of 2016 is shown in the table below. Total cumulative data shown is the sum of the recovery from the Fourth Quarter of 2011 through the Fourth Quarter of 2016, added to the total cumulative LNAPL recovered as previously reported by Tetra Tech, Inc. (TtEC) in the Third Quarter of 2011 Progress Report.

System	System Description	Dates	Gallons
Army Corps of Engineers	This value has been reported by the United States Army Corps of Engineers as the total removed during their initial recovery efforts at the Former DSCP.	1996 – 1999	153,350
Former Internal Combustion Engine	An internal combustion engine was used to perform a pilot test of vacuum enhanced skimming. This number represents the calculated volume of LNAPL removed as vapors from this event.	2002 – 2003	2,840
Former DSCP System	This value represents the volume of LNAPL removed utilizing the recovery system on the Former DSCP Property. See Section 5.1 for system details.	1999 - Current	510,006
Former Passyunk Homes System	This value represents the volume of product removed utilizing the recovery system on the Former Passyunk Homes Property. See Section 5.1 for system details.	1999 – Current	167,977
Mobile Units	This value represents the total volume of product removed utilizing the mobile recovery systems. See Section 5.2 for system details.	1999 – Current	136,580
VES System	The calculated volume of LNAPL removed as vapors from the existing VES system. See Section 5.3.	2005 – Current	83,124
Vacuum Truck Extraction (VTE) Testing	Estimated amount of liquid LNAPL Recovered during VTE testing.	June 2012	110
TOTAL		**1,053,987 Gallons**	

Observations during remediation O&M and optimization testing conducted to date are summarized as follows:

- The majority of the mobile LNAPL (or LNAPL available for recovery) has been removed from the Site. However, petroleum mass is still available for recovery in the vapor phase and treatment via biodegradation in-situ. Recovery via skimming varies with water table fluctuations, and also was improved in the Fourth Quarter of 2016, in part due to skimming system optimization activities such as adjustment of pump depths.

- By increasing the vacuum on the VES system recovery wells, an increase in mass recovery has been observed in some wells.

- Seasonal water table fluctuations affect the rate of recovery during a given quarter, as shown in Appendix A (Site hydrographs) and Appendix I (mass tracking). In areas where well screens have a significant proportion submerged beneath the water table, liquid, and vapor recovery is significantly decreased.

- An optimization test using a pump controller similar to those employed on the mobile units is being tested on recovery well PH-RW-A and PH-PH-20, has yielded promising results. The controller allows the skimmer to pump more LNAPL over time by not pumping all of the LNAPL out of the well (and thereby not cutting off the well from the LNAPL in the formation). This strategy also decreases the amount of water the skimmers pump into the storage tanks as the pump frequency can be set such that the pump only operates when its intake is fully immersed in LNAPL. Due to the success of this optimization test, operation of recovery wells PH-RW-A and PH-PH-20 utilizing pump controllers is now part of the routine operation of the PHA skimming system.

    - This optimized operational strategy for the fixed skimming systems appears to have contributed to increases in the amount of LNAPL recovered by skimming from the Third Quarter of 2012 through the Fourth Quarter of 2016. However, even with these improved LNAPL recovery results, more mass can be recovered as vapor or destroyed in situ through biosparging/bioventing and natural attenuation than by skimming alone given the current hydrogeologic conditions at DSCP.

- The VES optimization efforts applied to the VES system have been successful. The mass recovered by the optimized VES system since the Fourth Quarter of 2011 is approximately seven times the total mass recovered by the VES system since its start-up in 2005 through the end of the Fourth Quarter of 2011.

- In general, the high levels of CO_2 in the vapor stream of the VES system during the optimization testing, as well as declining mass recovery by VES, indicate that in-situ degradation of petroleum hydrocarbon is actively occurring in the shallow aquifer. However, the presence of CH_4 and lack of O_2 in the vapor stream indicate that this process is largely anaerobic and that aerobic degradation (the faster of the two processes) is O_2 limited. As a result, the Former DSCP Site is amenable to a technology that would provide O_2 to the subsurface to accelerate the process of in-situ degradation.

- Site O&M data and past experience lead to the conclusion that if O_2 were added to the subsurface at the Site, the area that would show the most degradation of hydrocarbons would be in the fringes of the impacted area, where measured LNAPL is not as thick, in areas where the LNAPL is less degraded, and where VES is limited due to the high water table. The results of previous LNAPL fingerprinting analyses and maps provided in prior correspondence with the PADEP suggest that the areas of the Site near PH-RW-A, DSCP RW-2, and DSCP-MW-65 are potential locations where O_2 injection technologies may be effective. The testing of vapor headspace and radius of influence (ROI) of the new VES wells installed in the vicinity of PH-RW-A, PH-RW-B2, and PH-RW-W2 further supports the idea that the Northeast corner of the PHA property is an area that is amenable to an air/O_2 injection strategy.

- An evaluation of previously completed bail-down testing at DSCP-MW-65 revealed that LNAPL recovery is attainable from this well for some period of time if a skimmer pump were to be deployed in this well. In the Third Quarter of 2015, a mobile skimming system pilot test at this location commenced, and a total of 132 gallons of LNAPL have been recovered since the Third Quarter of 2015. Operation of the mobile skimming system at DSCP-MW-65 will continue through future quarters as part of routine system operations provided that well DSCP-MW-65 continues to provide LNAPL recovery, or exhibits LNAPL in excess of 0.3 ft.

- The result of the isotopic analysis of CO_2 from the VES system influent vapor conducted during the Fourth Quarter of 2016 demonstrates that 81.1% of the CO_2 may be attributed to the VES system operation and contributions from natural biodegradation. If the results of this isotopic sample of CO_2 from the VES system influent in the Fourth Quarter of 2016 were applied to the entire quarter, a total of 99,380 lbs of VOCs would have been degraded in-situ as calculated from measured CO_2. This yields another 16,734 gallons of LNAPL remediated in the Fourth Quarter of 2016 by in-situ degradation. The results of upcoming isotopic samples will be provided in subsequent quarterly reports.

The evaluation of these optimization testing activities is ongoing into the First Quarter of 2017; the results of the testing will be provided to PADEP in the quarterly reports.

8 ANNUAL SUMMARY REPORT FOR THE CALENDAR YEAR 2016

This section of the Fourth Quarter of 2016 Progress Report is a summary of the activities conducted during CY 2015, as required by the terms in the PADEP Administrative Order dated December 10, 1999. Like the combined Fourth Quarter of 2015 Progress and 2015 Annual Summary Report, the summary of CY 2016 activities has been appended to the Fourth Quarter of 2016 Progress Report in place of a separate submittal, as approved in emails from PADEP dated January 4, 2017 and January 12, 2017. For more detailed information regarding activities from previous quarters, please refer to the individual quarterly progress reports that have been prepared for CY 2016. This section summarizes the progress of petroleum hydrocarbon LNAPL remediation at the Site for CY 2016, which encompasses the LNAPL skimming and hydrocarbon vapor extraction being conducted on the Site.

8.1 First Quarter of 2016 PADEP Progress Meeting

On March 16, 2016, a progress meeting with PADEP was conducted by DLA, USACE, ARCADIS, and PARS. LNAPL recovery progress, remediation optimization efforts, system upgrades, ongoing quarterly remediation performance gauging and sampling data and potential Act 2 endpoints were discussed. Meeting minutes were published by PADEP, dated March 28, 2016, and are including in Appendix M of the Second Quarter of 2016 Progress Report.

8.2 Vapor Measurements from the Packer Avenue Sewer – CY 2016

Two Packer Avenue sewer manholes (MH-C and MH-G), as seen in Figures 1-3, were monitored monthly with a PID, smoke tubes, and an explosimeter throughout CY 2016. No readings in excess of 100 ppm were observed during CY 2016.

Below is a summary of readings collected during CY 2016:

January 22, 2016	MH-C	MH-G	July 19, 2016	MH-C	MH-G
LEL (%)	0.0	0.0	LEL (%)	0.0	0.0
PID (ppm)	3.6	2.4	PID (ppm)	0.8	0.3
Air Flow	OUT	IN	Air Flow	OUT	OUT
February 15, 2016			August 8, 2016		
LEL (%)	1	0	LEL (%)	0.0	0.0
PID (ppm)	0.0	0.0	PID (ppm)	0.0	0.3
Air Flow	OUT	IN	Air Flow	IN	IN
March 21, 2016			September 27, 2016		
LEL (%)	0	0	LEL (%)	0.0	0.0
PID (ppm)	0.0	0.1	PID (ppm)	7.9	17.2
Air Flow	OUT	IN	Air Flow	OUT	IN
April 20, 2016			October 26, 2016		
LEL (%)	0.0	0.0	LEL (%)	0	1
PID (ppm)	8.7	5.8	PID (ppm)	0.1	0.1
Air Flow	OUT	OUT	Air Flow	OUT	IN
May 23, 2016			November 18, 2016		
LEL (%)	0.0	0.0	LEL (%)	0.0	0.0
PID (ppm)	2.1	3.2	PID (ppm)	0.0	0.0
Air Flow	OUT	OUT	Air Flow	OUT	IN
June 22, 2016			December 14, 2016		
LEL (%)	0.0	0.0	LEL (%)	0.0	0.0
PID (ppm)	1.1	2.8	PID (ppm)	0.3	0.0
Air Flow	OUT	OUT	Air Flow	OUT	IN

At the request of the USACE, readings were also collected on a periodic basis during CY 2016 at the following additional manholes: 19th and Moyamensing East, 19th and Moyamensing West, Pollock and Moyamensing, and 19th Street (near the cut through). The maximum LEL reading was 1% and the maximum PID reading was 17.2 ppm during the checks of these manholes, and no odors other than normal sewer gas odors were observed. These observations are in line with previously reported observations since October 2011.

8.3 Quarterly Liquid Level Gauging

Quarterly measurements of the depth to groundwater and LNAPL, if present, were obtained from the Site recovery and monitoring wells during the CY 2016. These gauging events were conducted to evaluate groundwater flow directions as well as apparent LNAPL thickness in wells. The Fourth Quarter of 2016 measurements are discussed in Section 4.1 of this report. Results of the remaining measurements can be found in the previously submitted quarterly progress reports.

During CY 2016, upward gradients between shallow-deep well pairs were observed in one well during the First Quarter, and three wells each during the Second, Third, and Fourth Quarters. In previous years, fewer upward gradients were observed, including quarters with no upward gradients (i.e. First and Second Quarters of 2015, Second Quarter of 2014). The technical team will continue to monitor these gradients to identify any trends regarding the frequency, magnitude, and location of these upward gradients.

8.4 Quarterly Site-Wide Groundwater Sampling

Site-wide groundwater sampling events were conducted during each quarter of 2016. Analytical data from these events were collected to evaluate the concentrations and distribution of COC across the Site. Samples were analyzed for the aforementioned PADEP Short List COC, along with TBA and arsenic. Sampling results for the Fourth Quarter of 2016 are discussed in Section 4.2 of this report. Results of the previous quarterly events are provided in their associated quarterly progress reports.

Beginning in the Third Quarter of 2013, a historical data table was developed to compare recent analytical results to those from sampling events dating as far back as 1994. The most recent table, including results from the Fourth Quarter of 2016, is provided in Appendix D. Results from future sampling events will be added to this data table, to establish increasing or decreasing trends in COC concentrations for the purpose of evaluating LNAPL stability under the cleanup goal defined in the Order.

Additionally, beginning in the Third Quarter of 2014, historical groundwater quality data were used in quarterly statistical analyses to optimize the Site's monitoring well network, and to eventually support definition of the Site's Point of Compliance (POC) wells. Details regarding the motive and methodology of the analysis are found in the Second Quarter and Third Quarter of 2014 progress reports, and results of the most recent analysis are found in Section 4.2.4 and Appendix D of this progress report.

8.5 VES System Operation and Maintenance

A summary of the quarterly LNAPL recovery operations of the various systems in CY 2016 is included in Appendix F. Table 1 of Appendix F contains a list of LNAPL recovery throughout CY 2016 and the following sections summarize this period of recovery. Figures 1 through 4 of Appendix F present the quarterly totals of LNAPL removed along with a running total of the LNAPL removed from the Former DSCP system, the Former Passyunk Homes system, the mobile systems, and LNAPL recovered as vapor from the VES system, respectively.

8.5.1 Fixed Skimming System

As discussed in greater detail in Section 5, recovery well totalizers onsite provide inaccurate estimates of the LNAPL recovered from each well for skimmer pump optimization. A more accurate reading of the total LNAPL recovered is obtained via readings from a volume-measuring probe installed in each of the Site's two recovered LNAPL ASTs.

Appendix F, Figures 1 and 2 illustrate the Former Passyunk Homes and Former DSCP system LNAPL recovery by quarter.

8.5.1.1 Fixed Skimming System Quarterly Results CY 2016

During CY 2016, a total of 1,215 gallons of LNAPL was recovered by the Former DSCP area fixed skimming system. The LNAPL recovered per quarter is broken down as follows:

- First Quarter of 2016: 12 gallons LNAPL recovered
- Second Quarter of 2016: 45 gallons LNAPL recovered
- Third Quarter of 2016: 145 gallons LNAPL recovered
- Fourth Quarter of 2016: 1,013 gallons LNAPL recovered

During CY 2016, a total of 93 gallons of LNAPL was recovered by the Former Passyunk Homes area fixed skimming system. The LNAPL recovered per quarter is broken down as follows:

- First Quarter of 2016: 14 gallons LNAPL recovered
- Second Quarter of 2016: 26 gallons LNAPL recovered
- Third Quarter of 2016: 16 gallons LNAPL recovered
- Fourth Quarter of 2016: 37 gallons LNAPL recovered

8.5.2 Modular Skimming System – Quarterly Results CY 2016

During CY 2016, mobile skimming systems were operated at DSCP-MW-3A and DSCP-MW-65, and recovered a total of 52 gallons. The LNAPL recovery is as follows:

- DSCP-MW-3A Total: 20 gal
  - First Quarter of 2016: 0 gal
  - Second Quarter of 2016: 0 gal
  - Third Quarter of 2016: 2 gal
  - Fourth Quarter of 2016: 18 gal
- DSCP-MW-65 Total: 32 gal
  - First Quarter of 2016: 8 gal
  - Second Quarter of 2016: 9 gal
  - Third Quarter of 2016: 12 gal
  - Fourth Quarter of 2016: 3 gal

Mobile skimming system locations will continue to be evaluated, and recovery at locations with suitable LNAPL thickness, such as DSCP-MW-65, will continue as part of routine system operation provided that LNAPL recovery at this location continues or LNAPL exists in this well at a thickness greater than 0.3 ft.

8.5.3 Summary of VES System Operation and Optimization Results CY 2016

Monitoring of CH_4 (with and without carbon filter), LEL, CO_2, and O_2 were recorded periodically during the year. Mass recovery was calculated using PID data collected at the VES system manifold. However, high CH_4 results tends to negatively skew the PID data collected at the VES system manifold, therefore PID data was calibrated using TO-15 summa canister air sample data. The petroleum hydrocarbon mass recovery calculations for the focused VES system are based on a weighted average of the compounds detected in the TO-15 manifold combined influent vapor samples discussed in greater detail in Section 5.3. The TO-15 summa canister vapor sample results for CY 2016 can be found in appendices for each quarterly report previously submitted as well as Appendix H for this report for the Fourth Quarter 2016. Mass tracking calculations for CY 2016 are presented in Appendix I.

The May 31, 2016 thermal oxidizer effluent air sample originally yielded lab results with detections of three compounds not typically associated with Site COC, including cis-1,2-dichloroethene, 1,1,1-trichloroethane, and trichlorethene. Upon request by Arcadis and PARS, the lab reviewed the data, and determined that contamination occurred from an unrelated sample via a dilution syringe. A revised lab report and a Corrective Action Report (CAR) were issued by the lab, and were included in Appendix I of the Second Quarter of 2016 Progress Report (Arcadis 2016). Results did not affect mass tracking calculations.

During CY 2016, the VES system operated in optimized/focused-vacuum mode yielding an average mass recovery of 6.55 lbs/hour. This rate is slightly higher than the average recovery rate seen in CY 2015, and remains higher than the mass recovery rate prior to optimization testing. For comparison, the VES system averaged approximately 4.17 lbs/hour in the Third Quarter 2011 (prior to optimization testing). During CY 2016, the average combined influent CH_4 (with carbon filter) was 1.6%, the average CO_2 was 5.7%, and the average O_2 was 11.6%.

The overall mass recovered via the VES system for CY 2016 was 51,186 lbs, which correlates to approximately 8,620 gallons of LNAPL. This number is calculated using the mean density of the compounds detected in the laboratory analytical results of the summa canister samples collected from the influent vapor stream at the VES system manifold. The analytical results as well as the calculations supporting the conversion factor are presented in the individual quarterly reports for CY 2016; however, the conversion factor ranged from 5.89 to 5.99 lbs VOCs per gallon of LNAPL.

The mass recovery per quarter by the VES system as VOC vapor for CY 2016 is broken down as follows:

- First Quarter of 2016: 2,445 gallons of LNAPL
- Second Quarter of 2016: 1,845 gallons of LNAPL
- Third Quarter of 2016: 2,268 gallons of LNAPL
- Fourth Quarter of 2016: 2,062 gallons of LNAPL

The new cumulative total LNAPL recovered as vapor by the VES system since system start up in 2005 through the end of the CY 2016 is now 83,124 gallons.

The evaluation of recovery and optimization testing activities is ongoing into the First Quarter of 2016; the results of the testing will be provided to PADEP in CY 2017.

8.5.4 Second Quarter of 2016 Vapor Point Installation and Optimization Testing

During the Second Quarter of 2016, four vapor monitoring points were installed on the PHA property in the western central portion of the Site to enhance understanding of the CSM, and to provide points for vacuum-influence radius of influence testing, as well as respirometry testing in support of system optimization and a potential future bioremediation approach. Direct-push borings were advanced at each location, and 1” (outer diameter) PVC screens and risers were installed to depths of approximately 20’-25’. Construction details and direct-push logs were provided in Appendix K of the Second Quarter of 2016 Progress Report (Arcadis 2016).

Radius of influence (ROI) testing and respirometry testing were conducted. The results of ROI and respirometry testing are reported below.

8.5.4.1 ROI Testing Results

ROI testing was conducted on May 2, May 3, and May 5, 2016. Testing activities included focused vacuum step tests on individual wells for the purpose of evaluating related changes in vacuum ROI and vapor phase mass recovery at the new vapor monitoring points.

Results of ROI testing indicated the following:

- With vacuum applied to PH-RW-B2 at 60 iw, induced vacuums of 1-2 iw were observed in vapor monitoring points VP-2, VP-4, and VP-5.
- With vacuum applied to PH-RW-U at 60 iw, no induced vacuums were detected at vapor monitoring point VP-5.
- With vacuum applied to PH-RW-W2 at 40 iw, induced vacuums of 1-2 iw were observed in vapor monitoring points VP-1 and VP-2.

The results of the testing discussed above are still being evaluated, however the initial review of the data finds that an applied vacuum of 40 to 60 iw at PH-RW-B2 and PH-RW-W2 are successful in generating induced vacuums in vapor monitoring points. For the purposes of this evaluation, the ROI is defined as point at which the induced vacuum is at least 1% of the applied vacuum (Kuo, 2014). Using this rule of thumb, it is apparent that the ROI from PH-RW-W2 extends from at least past the distance of the nearby vapor monitoring points VP-1 and VP-2 (greater than 30ft) and ROI from PH-RW-B2 appears to reach between 40 to 60 ft. No vacuum influence was observed when PH-RW-U was tested even though its closest vapor monitoring points VP-5 is less than 10ft away. This development suggests that recovery well PH-RW-U is less effective than other wells in the vicinity; however, newer recovery wells such as PH-RW-B2 provide vacuum influence almost to the location of PH-RW-U. The results of these tests will be used to both optimize the VES well network as well as determine well spacing in a future bioventing approach.

8.5.4.2 Respirometry Testing Results

Respirometry testing was conducted by extracting soil vapor from a recovery well utilizing the existing VES system infrastructure, while using a nearby monitoring or recovery well as an air inlet well, and monitoring the changes in the biochemical parameters (VOCs, O_2, CO_2, CH_4) in both the extracted soil vapor and headspace in the air inlet well. Tests were conducted at the air inlet well using both ambient air inlet and pressurized air injection; the latter conducted via a one horsepower (hp) regenerative blower connected to the inlet well.

After operation with air inlet to the subsurface for a period of time, a respirometry test was conducted on both the recovery and air inlet wells by stopping vacuum extraction and air inlet and collecting samples of the headspace in each well for monitoring of biochemical parameters. The rate of depletion of the O_2 and return of VOCs, CH_4 and CO_2 were recorded and then used to determine the rate of respiration, or O_2 utilization, in the smear zone.

The respirometry test conducted at PH-1 yielded O_2 depletion curves suggestive of microbial uptake (e.g., starting at 20% per hour O_2 at PH-1 and 11% per hour O_2 at RW-A during the same period). In contrast, other tested well pairs showed a 9 to 10% per hour O_2 utilization rate illustrating treatment is observed beyond the location immediately adjacent to the air introduction (PH-1) well.

The PH-2 respiration test also provided a strong O_2 utilization rate without showing linkage back to the extraction well, RW-B. Similar to the results of the respirometry test conducted at PH-1, the biodegradation at this well is achievable with a bioventing remedial strategy.

9 PLANNED AND CONTRACTED FIRST QUARTER ACTIVITIES

The following are a list of projected tentative activities planned or under consideration for the First Quarter of 2017. These include:

- Conducting a groundwater gauging and sampling event in February 2017.
- Continued operation of mobile skimming systems at DSCP-MW-3A and DSCP-MW-65.
- Ongoing design of a biovent/biosparge system, based on a Basis of Design report and accompanying optimization test results (Arcadis 2013). Findings will also support the future evaluation of the Former DSCP Site regarding Act 2-based cleanup criteria.
- Continuation of soil gas/VES system vapor influent isotopic sampling from wells and the VES system that commenced in the Third Quarter of 2013. Isotopic sampling will be performed once per quarter.
- To reduce sampling frequency at appropriate well locations, continued evaluation of groundwater Short List COC concentration trends via the statistical methods outlined in this report. The purpose of evaluating Short List COC data trends within wells that consistently show measurable LNAPL is to support closure under an Act 2 SSS approach for the shallow aquifer.
- Continued VES system operation and optimization, to maximize LNAPL recovery through the extraction of hydrocarbon vapors.

- Repair of thermal oxidizer TOX-200 for use as a backup as necessary in the First Quarter 2017.

As discussed with PADEP and approved by email on January 12, 2017, abbreviated quarterly reports will be prepared for the First, Second, and Third Quarters of the calendar year, beginning with the First Quarter of 2017. These reports will include summaries of gauging, sampling, and O&M activities, tables of results of these activities, and figures showing shallow and deep potentiometric surfaces and inferred LNAPL thickness. The Fourth Quarter report will provide this information for the Fourth Quarter, as well as summarize activities conducted during the entire calendar year.

Finally, and as discussed with the PADEP during the meetings held on January 19, 2012, March 13, 2012, and March 16, 2016, the overall goal of the ongoing optimization testing and related activities described above is to improve LNAPL remediation at the Former DSCP Site. As lessons are learned, data will continue to be applied and remediation O&M procedures modified within the contracting and funding constraints and as feasible using existing Site remediation infrastructure.

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