WORK PLAN FOR SITE CHARACTERIZATION
AREAS OF INTEREST 1 AND 4

SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

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1.0 INTRODUCTION

The Current Conditions Report and Comprehensive Remedial Plan (CCR), prepared by Sunoco, Inc., dated June 30, 2004, proposed Phase II site characterization and corrective action activities for Sunoco's Philadelphia Refinery (Refinery), including preparation of Site Characterization Reports for the individual Areas of Interest (AOIs). The CCR presented a prioritization of all of the eleven AOIs based on specific risk factors.

This Site Characterization Work Plan has been prepared exclusively for AOIs 1 and 4, and is the first Work Plan to be submitted to the Pennsylvania Department of Environmental Protection (PADEP) since submittal of the CCR. AOI 1 includes Belmont Terminal, No.1 Tank Farm, and No.2 Tank Farm, and AOI 4 includes the No.4 and No. 5 Tank Farms. The boundaries of both AOIs and the Belmont Terminal are shown in Figure 1.

Currently, AOI 1 is comprised of primarily light-end hydrocarbon Above Ground Tankage (No. 1 and 2 Tank Farms) and loading racks (the Belmont Terminal). The area is utilized for blending gasoline and additives as well as retail distribution through the Terminal. There are numerous underground process lines in AOI 1. The current usage figure for the Point Breeze South Yard provided in the CCR depicts existing facilities within the AOI. AOI 1 is generally covered by impervious surfaces except for the interior base of the diked areas of No.1 and No.2 Tank Farms. Belmont Terminal is entirely covered with impervious surfaces. Historically, there has been little change in use of AOI 1.

Currently, AOI 4 is comprised of primarily Crude Oil and Gas Oil aboveground storage tanks (ASTs). Numerous below ground pipelines are active within AOI 4. This is the largest storage area in the refinery. Several pump houses are also noted in this AOI, on the current usage figure for the Point Breeze South Yard provided in the CCR. All roads and tank berms are covered by impervious surfaces.

1.1 Objectives

The objective of the proposed activities is to characterize current environmental conditions at AOIs 1 and 4 in accordance with the 2003 Consent Order and Agreement

(CO&A) between Sunoco, Inc. and the Pennsylvania Department of Environmental Protection (PADEP) and the 2004 CCR. General Phase II site characterization activities proposed at AOIs 1 and 4 and summarized in this Work Plan include:

- Review of recent environmental reports relating to AOIs 1 and 4,
- Evaluation of existing and proposed remediation systems in AOI 1 and 4,
- Advancement of soil borings and collection of soil samples for laboratory analysis of Site Constituents of Concern (COCs);
- Installation of intermediate and deep groundwater monitoring wells,
- Monitoring and sampling of new and existing shallow, intermediate, and deep groundwater monitoring wells,
- Evaluation of apparent groundwater mounding conditions in shallow and intermediate groundwater,
- Collection and analysis of light non-aqueous phase liquid (LNAPL) samples from select monitoring wells,
- Completing LNAPL modeling to evaluate LNAPL specific volume and mobility,
- Installation and sampling of soil gas monitoring points adjacent to on-site, non-residential receptors,
- Evaluation of potential vapor migration pathways using the PADEP's vapor intrusion guidance,
- Fate and transport modeling of dissolved COCs in site groundwater, and
- Preparation of Site Characterization Reports.

The COCs for the proposed investigation activities include all constituents listed in Tables 5a and 5b of the CCR, and are included as Table 1 of this Work Plan. Data collected from the above activities will be evaluated as part of the AOI 1 and AOI 4 site characterization process, and will be presented in the Site Characterization Reports for AOI 1 and 4 which are to be submitted to the PADEP by June 29, 2005 and September 30, 2005, respectively.

1.2 Overview of Existing and Proposed Phase I Activities in AOIs 1 and 4

AOI 1

A total of 18 recovery wells are located throughout AOI 1. The current remediation program consists of 15 active recovery wells for automated groundwater and LNAPL recovery. In addition, non-system LNAPL recovery (manual bailing) is currently conducted via a monthly gauge and bail program.

Vapors from the 26th Street Sewer, Packer Avenue Sewer, and Shunk Street Sewer are currently processed by two Sewer Odor Control Systems (26th Street/Packer Avenue System and the Shunk Street System). Outfall control measures are also in place for the Pollock Street sewers. Eight recovery wells are located in Belmont Terminal, and six are operating in the remainder of AOI 1 for a total of 14 active recovery wells. Two wells (RW-6 and RW-7) in Belmont Terminal are inactive. One well (RW-401) along 26th Street is equipped with a passive bailer. The remediation program consists of groundwater depression with separate LNAPL recovery from wells in Belmont Terminal, and total fluids pumping from the wells along 26th Street.

System expansion is planned for the 26th Street border of AOI 1. An additional 20 recovery wells have been installed along 26th Street on the Sunoco property for perimeter control and an additional six recovery wells have been, or are planned to be installed across 26th Street on the CSX property. These wells will be included in a total fluids extraction system to be installed in the first quarter of 2005 and operational in the beginning of the second quarter of 2005.

AOI 4

Two active recovery wells, S-30 and S-36, are located in AOI 4. The remediation program consists of LNAPL recovery only from these wells. Sunoco is currently evaluating the expansion of the LNAPL recovery system in the vicinity of S-36 to include several proximal LNAPL bearing wells into the same product recovery system.

Subsequent to the installation of monitoring wells along the 26th Street border in AOI 4, a groundwater oxygen diffusion test will be performed in the vicinity of S-50 to evaluate the effectiveness of oxygen diffusion as a barrier to dissolved hydrocarbon migration.

1.3 Work Plan Support Activities

Several activities were performed to support the development of this Work Plan. These activities are summarized below by area:

AOI 1

- Aquaterra Technologies (Aquaterra) performed one round of groundwater monitoring and sampling in AOI 1 between October 12 and 21, 2004. Groundwater samples were collected from all accessible AOI 1 wells, with the exception of recovery wells and wells which contained measurable (>0.01 feet) LNAPL. The samples were submitted to Severn Trent Laboratories (STL) of Pensacola, Florida for analysis of Site COCs. The results of these samples are presented in Table 2 of this Work Plan. This data was obtained to enhance the Site Conceptual Model for AOI 1 and to refine Site characterization activities proposed in this Work Plan.
- A recent report entitled *26th Street Border Progress Report, January 1, 2003 through March 31, 2004,* prepared by SECOR International, Inc. (SECOR) was reviewed and the data was evaluated to refine Site characterization activities proposed in this Work Plan.
- Reports used in development of the CCR were reviewed for relevant soil and groundwater quality data; data was evaluated to refine Site characterization activities proposed in this Work Plan.

AOI 4

- Aquaterra performed one round of groundwater monitoring and sampling in AOI 4 between October 12, 2004 and October 21, 2004. Groundwater samples were collected from all accessible AOI 4 wells, with the exception of recovery wells and wells which contained measurable LNAPL. The samples were submitted to STL for analysis of Site COCs. The results of these samples are presented in Table 2 of this

Work Plan. This data was obtained to enhance the Site Conceptual Model for AOI 4 and to refine Site characterization activities proposed in this Work Plan.

- Reports used in development of the CCR were reviewed for relevant soil and groundwater quality data; data was evaluated to refine Site characterization activities proposed in this Work Plan.
- Recent reports generated for areas within AOI 4 were reviewed and the data evaluated to refine proposed Site characterization activities. These reports included:
    - *Aboveground Storage Tank No.846 Site Assessment Revised Report,* prepared by SECOR, dated January 20, 2004,
    - *26th Street Border Progress Report, January 1, 2003 through March 31, 2004,* prepared by SECOR, and
    - *Storage Tanks PB-880 and PB-881 Site Assessment Report,* dated October 6, 2004, prepared by SECOR.

2.0 PROPOSED SITE CHARACTERIZATION ACTIVITIES

Based on the identified data collection needs for AOIs 1 and 4, the following Site characterization tasks are discussed in this Work Plan:

Task 1: **Soil Borings and Sampling**
Task 2 **Installation of Intermediate and Deep Groundwater Monitoring Wells**
Task 3: **Groundwater Monitoring and Sampling**
Task 4: **Collection and Analysis of LNAPL Samples**
Task 5: **Installation and Sampling of Soil Gas Monitoring Points**
Task 6: **Aquifer Testing**
Task 7: **Fate and Transport Analysis**
Task 8: **Exposure Assessment**
Task 9: **Surveying**
Task 10: **Data Evaluation and Site Conceptual Model**
Task 11: **Reporting**

The individual Site characterization tasks are discussed in detail by area in the following sections.

2.1 Task 1: Soil Borings and Sampling

<u>AOI 1 - Belmont Terminal</u>

No soil borings are proposed in Belmont Terminal since the Terminal is entirely covered with impervious surfaces (refer to Figure 16 of the CCR), and since direct contact issues with soil are addressed through Sunoco's established excavation procedures, personal protective equipment (PPE) requirements and soil handling procedures. These procedures were provided in Appendix K of the CCR.

<u>AOI 1 - No.1 and No.2 Tank Farms</u>

As part of groundwater monitoring well installation activities, one soil sample will be collected from zero to two feet below the ground surface at each well boring that is located in an unpaved area in the No.1 and No.2 Tank Farm areas. These samples will be submitted for laboratory analysis of Site COCs to evaluate the potential direct contact pathway at these locations. In the No.1 and No.2 Tank Farm areas, a total of ten soil samples are proposed to be collected from ten well borings (S-198, S-205, S-206, S-207, S-208, S-210, S-211, S-212, S-213, and S-214), as shown on Figure 3 and summarized in Table 3.

One soil boring (SB-80D) will be advanced to bedrock for characterization of subsurface geology. This soil boring will be converted into a deep monitoring well (S-80D) as summarized in Section 2.2 of this Work Plan. It is estimated that bedrock will be encountered within 100 feet below the ground surface.

The proposed borings will be completed with a hollow stem auger drill rig. All soil boring and soil sampling activities will be performed following the procedures provided in Appendix J of the CCR, which is included as Appendix A of this Work Plan.

Available historical documentation pertaining to No.1 and No.2 Tank Farm areas was reviewed for relevant soil data. Relevant data reviewed included soil borings that were advanced in the vicinity of former Tank 174. Based on a review of this data, no soil borings are proposed at these formerly-investigated locations since direct contact criteria were not exceeded.

<u>AOI 4</u>

As part of groundwater monitoring well installation activities, one soil sample will be collected from zero to two feet below the ground surface at each well boring that is located in an unpaved area in AOI 4. These samples will be submitted for laboratory analysis of Site COCs to evaluate the potential direct contact pathway at these locations. A total of seven soil samples are proposed to be collected from seven well borings (S-59D, S-119D, S-216, S-217, S-219, S-220, and S-221), as shown on Figure 4 and summarized in Table 3.

One soil boring (SB-59D) will be advanced to bedrock for characterization of subsurface geology. This soil boring will be converted into a deep monitoring well (S-59D) as summarized in Section 2.2 of this Work Plan. It is estimated that bedrock will be encountered within 100 feet below the ground surface.

The proposed borings will be completed with a hollow stem auger drill rig. All soil boring and soil sampling activities will be performed following the procedures provided in Appendix A of this Work Plan.

Soil sampling information obtained by SECOR in response to the April 4, 2004 crude oil release in the vicinity of Tanks PB-880 and PB-881 was evaluated to determine whether additional soil quality data was needed at these locations. Based on a review of this data, no soil borings are proposed at these formerly-investigated locations since direct contact criteria were not exceeded in samples collected as part of SECOR's site assessment activities.

Soil sampling information obtained by SECOR during site assessment activities in the vicinity of Tank 846 was also evaluated to determine whether additional soil quality data was needed at these locations. SECOR conducted these soil sampling activities at this area in May of 2003 to evaluate the vertical and horizontal extent of impacted soil resulting from a crude oil release that occurred May 2002. Based on a review of this data, no soil borings are proposed at these formerly-investigated locations since direct contact criteria were not exceeded in samples collected as part of SECOR's site assessment activities.

2.2 Task 2: Installation of Intermediate and Deep Groundwater Monitoring Wells

<u>AOI 1 - Belmont Terminal</u>

Ten intermediate groundwater monitoring wells (MW-35 through MW-44) are proposed to be installed in the Belmont Terminal area, as shown on Figure 2 and summarized on Table 3. Each well will be installed using hollow stem auger drilling technology to a maximum depth of 35 feet below the ground surface in the Trenton Gravel below the property. Following installation of each well, the well will be developed. All well installation, well development and waste handling activities will be performed in accordance with the procedures provided in Appendix A of this Work Plan.

No deep groundwater monitoring wells are proposed to be installed in the Belmont Terminal area.

AOI 1 - No.1 and No.2 Tank Farms

Seventeen intermediate groundwater monitoring wells (S-198 through S-214) are proposed to be installed in the Tank Farm areas of AOI 1, as shown on Figure 3 and summarized on Table 3. The wells will be installed using hollow stem auger drilling technology to a maximum depth of between 30 and 35 feet below the ground surface, and screened within the Trenton Gravel. Each well will be developed subsequent to completion. All well installation, well development and waste handling activities will be performed in accordance with the procedures provided in Appendix A of this Work Plan.

Two deep groundwater monitoring wells (S-46D and S-80D) are proposed to be installed in areas adjacent to the existing wells S-46 and S-80 in AOI 1, as shown on Figure 3 and summarized on Table 3. The wells will be double-cased and will be installed using hollow stem auger and/or air rotary drilling technology. The screened interval of these wells will be set in the upper fifteen feet of the Lower Sand; the final depth of these wells will be determined following review of lithologic materials encountered during advancement of the deep boring to bedrock discussed in Section 2.1. Each well will be developed subsequent to completion. All well installation, well development and waste handling activities will be performed in accordance with the procedures provided in Appendix A of this Work Plan.

AOI 4

Ten intermediate groundwater monitoring wells (S-215 through S-224) are proposed to be installed in AOI 4, as shown on Figure 4 and summarized on Table 3. Each well will be installed using hollow stem auger drilling technology to a maximum depth of 30 feet below the ground surface, and screened within in the Trenton Gravel. Each well will be developed subsequent to completion. All well installation, well development and waste handling activities will be performed in accordance with the procedures provided in Appendix A of this Work Plan.

Two deep groundwater monitoring wells (S-59D and S-119D) are proposed to be installed in areas adjacent to the existing wells S-59 and S-119 in AOI 4, as shown on Figure 4 and summarized on Table 3. The wells will be double-cased and will be installed using hollow stem auger and/or air rotary drilling technology. The screened interval of these wells will be set in the upper fifteen feet of the Lower Sand; the final depth of these wells will be determined following review of lithologic materials encountered during advancement of the deep boring to bedrock discussed in Section 2.1. Following installation of each well, the well will be developed. All well installation, well development and waste handling activities will be performed in accordance with the procedures provided in Appendix A of this Work Plan.

2.3 Task 3: Groundwater Monitoring and Sampling

2.3.1 Groundwater Monitoring

AOI 1

Upon completion of the monitoring well installations and development in AOI 1, a complete round of groundwater water gauging measurements will be collected from all accessible new and existing monitoring wells. All well gauging activities will be performed in accordance with the Liquid Level Gauging Procedures provided in Appendix A of this Work Plan. Gauging data collected during this event will be used to evaluate groundwater flow conditions in this area.

The apparent groundwater mounding at S-116 and S-126 may be attributed to influence from the nearby Refinery fire line system. An investigation will be performed to assess whether the fire line system is influencing the static water level in this area by placing water pressure transducers in S-116 and S-126 while modifying the flow within the fire line. If it is determined that the fire line is not influencing the groundwater elevations in this area, then additional investigation will be performed to evaluate the apparent mounding in this area.

AOI 4

Upon completion of the monitoring well installations and development in AOI 4, a complete round of groundwater gauging measurements will be collected from all accessible new and existing monitoring wells in AOI 4. All well gauging activities will be performed in accordance with the Liquid Level Gauging Procedures provided in Appendix A of this Work Plan. Gauging data collected during this event will be used to evaluate groundwater flow conditions in this area.

2.3.2 Groundwater Sampling

AOI 1

Following completion of the groundwater gauging activities in the AOI 1, a full round of groundwater sampling will be conducted from all accessible new and existing monitoring wells which do not contain measurable LNAPL. All groundwater samples will be submitted for laboratory analysis of Site COCs, as listed in Table 1. Groundwater sampling will be conducted in accordance with well sampling procedures provided in Appendix A of this Work Plan.

Site wells S-43 and S-50 will be sampled using low-flow sampling methodology described in Appendix A. Samples will be collected from one foot below the top of liquid and one foot above the bottom of the screened interval at each well to assess vertical COC distribution in groundwater at these locations, and to provide support data for the proposed remediation system at this location.

AOI 4

Following completion of the groundwater gauging activities in AOI 4, a full round of groundwater sampling will be conducted from all accessible new and existing monitoring wells in AOI 4 which do not contain measurable LNAPL. All groundwater samples will be submitted for laboratory analysis of Site COCs, as listed in Table 1. Groundwater sampling will be conducted in accordance with well sampling procedures provided in Appendix A of this Work Plan.

2.4 Task 4: Collection and Analysis of LNAPL Samples

All LNAPL samples discussed below will be submitted to Torkelson Geochemistry of Tulsa, Oklahoma for characterization. The results of the LNAPL characterization analysis will be used to separate the apparent LNAPL plumes by product type and to assist in evaluating specific LNAPL volume and mobility.

<u>AOI 1</u>

LNAPL characterization data exists for 19 wells (RW-1, RW-7, RW-15, RW-401, PZ-400, RW-402, S-50, S-75, S-76, S-78, S-79, S-81, S-82, S-88A, S-89, S-98, S-100 (26th Street off-site well), S-117, and S-162) in AOI 1 as summarized in Table 3. This data was obtained from LNAPL sampling activities performed by SECOR and Aquaterra between 2002 and the present.

LNAPL samples will be collected from an additional 18 existing monitoring wells (RW-22, RW-23, RW-24, RW-25, OW-2, OW-12, OW-13, OW-17, OW-18, OW-19, MW-28, MW-33, MW-27, MW-29, S-160, S-161, S-77, and S-83) in AOI 1 as summarized in Table 3. LNAPL samples will also be collected from all newly-installed monitoring wells which have measurable LNAPL thicknesses. All LNAPL sampling activities will be completed in accordance with the LNAPL Sampling Procedures provided in Appendix A of this Work Plan.

<u>AOI 4</u>

LNAPL characterization data exists for eight wells (S-103, S-104, S-124, S-29, S-32, S-33, S-56, and S-97) in AOI 4. This data was obtained from LNAPL sampling activities performed by Aquaterra during 2004 in support of the CCR.

Additional LNAPL samples will be collected from four existing monitoring wells (S-31, S-35, S-37, and S-57) in AOI 4 as summarized in Table 3. LNAPL samples will also be collected from all newly-installed monitoring wells which have measurable LNAPL thicknesses. All LNAPL sampling activities will be completed in accordance with the LNAPL Sampling Procedures provided in Appendix A of this Work Plan.

2.5 Task 5: Installation and Sampling of Soil Gas Monitoring Points

AOI 1 -Belmont Terminal

Prior to commencement of any intrusive activities, all available utilities maps and information will be evaluated to identify potential preferential vapor migration pathways, and to finalize placement of the soil gas monitoring points.

A total of 12 soil gas monitoring points are proposed to be installed at the Belmont Terminal area. Eight soil gas monitoring points (SG-1 through SG-8) will be installed adjacent to the north, east, and south exterior walls of the Credit Union building located within the Belmont Terminal property boundary. Four soil gas monitoring points (SG-9 through SG-12) will be installed adjacent to the two office buildings located within the Belmont Terminal property. All proposed soil gas monitoring points are shown on Figure 2 and summarized on Table 3. The soil gas monitoring points will be installed using Geoprobe® drilling technology in accordance with the procedures provided as Appendix A of this Work Plan.

Following installation of the monitoring points, one round of soil gas samples will be collected from each monitoring point and analyzed via U.S. Environmental Protection Agency (EPA) Method TO-15. The soil gas sampling procedures are provided in Appendix A of this Work Plan. The soil gas monitoring points will be left as permanent monitoring points for use in future sampling events.

A sewer odor control system is operational in the Shunk Street sewer as it crosses the Belmont Terminal property. As such, no additional evaluation of vapors in the Shunk Street sewer will be performed.

AOI 1 - No.1 and No.2 Tank Farms

No non-residential receptors exist in the No.1 and No.2 Tank Farm areas; therefore, there are no potential vapor intrusion pathways of concern in this area.

A sewer odor control system is operational in the 26th Street and Packer Avenue sewers. As such, no additional evaluation of vapors in these sewers will be performed, however the effectiveness of this system on the Pollock Street sewer will be evaluated through PID monitoring of sewer manholes.

AOI 4

No non-residential receptors exist in AOI 4; therefore, there are no potential vapor intrusion pathways of concern in this area.

2.6 Task 6: Aquifer Testing

To evaluate hydrogeologic characteristics of the shallow and intermediate groundwater systems, and to collect the appropriate data to complete the fate and transport modeling, relevant historical documents will be reviewed in order to obtain site-specific aquifer data that may have been collected during previous environmental investigations. If insufficient information exists in any of the areas included in this Work Plan, two short-duration aquifer pumping tests or slug tests will be performed at that area to obtain site-specific values. A detailed description of the proposed aquifer testing procedures is included in Appendix A of this Work Plan**.**

2.7 Task 7: Fate and Transport Analysis

Fate and transport calculations will be completed for groundwater to evaluate potential migration pathways and potential impacts to receptors. Fate and transport modeling will be conducted for the constituents listed in Table 1 using Pennsylvania Department of Environmental Protection approved analytical models (QUICK_ DOMENICO.XLS and FATBACK.XLS). To support the fate and transport analyses, Sunoco will provide all assumptions, data and information used in the analytical modeling. The parameters used in the analyses will either be site-specific data obtained during previous investigations, values collected as part of future site characterization activities, and/or default parameters provided in the Act 2 regulations or guidance manual.

2.8 Task 8: Exposure Assessment

In accordance with Section V, subsection E of the PADEP Technical Guidance Manual, Revision 0, dated December 1997, a detailed exposure assessment will be completed for each area based on the completed site characterization activities. This exposure assessment will be based on an assumed non-residential current and future site use. The exposure assessment will also include an evaluation of the potential vapor migration pathway in accordance with Section IV, Subsection A.4 of the PADEP Technical Guidance Manual, dated January 24, 2004 (PADEP Vapor Intrusion Guidance). This evaluation will incorporate the results of the soil gas sampling at the Belmont Terminal.

2.9 Task 9: Surveying

Following completion of groundwater monitoring well installation activities, the new wells will be surveyed to establish the location and elevation of the inner and outer casing and ground surface at each well, where applicable. The well elevations will be determined to the nearest 0.01 foot relative to mean sea level. All survey activities will be performed by a Pennsylvania-licensed surveyor and tied to the NAVD 88 datum.

2.10 Task 10: Data Evaluation and Site Conceptual Model

Data collected from the site characterization activities will be reduced and evaluated in accordance with the objectives of the CCR. This data will also be used to modify and refine the Site Conceptual Model. Site characterization activities described in this Work Plan will provide the following information which will be used to refine the Site Conceptual Model:

- Throughout the characterization process of AOI 1 and 4, additional information regarding the current and historic uses of these areas will be obtained from available sources. Information obtained will be used to generate more detailed Current and Historic Usage figures which will be included in the Site Characterization Reports.

- Soil data collected between zero and two feet below the ground surface from select well borings will further characterize the potential direct contact pathway for soil.
- The advancement of the deep soil borings to bedrock in AOIs 1 and 4 will further characterize the relation between the Trenton Gravel, Middle/Lower Clay and Lower Sand in AOIs 1 and 4.
- Installation, monitoring and sampling of new groundwater monitoring wells will further characterize groundwater quality and flow in AOI 1 and AOI 4.
- LNAPL data collected in AOIs 1 and 4 will allow for more accurate product classification and occurrence, and will refine the LNAPL specific volume and mobility modeling predictions for these areas.
- Fate and transport modeling of dissolved phase COCs in groundwater will further characterize the potential for off-site migration in AOI 1 and 4.
- Soil gas data will be used to assess the potential for vapor migration into non-residential indoor air receptors at the Belmont Terminal.

Data collected during this characterization process will augment the existing geographic information system (GIS) for the Refinery. The GIS will be used to further evaluate characterization needs, and to visually depict current and future Site conditions.

2.11 Task 11: Reporting

Following completion of the activities listed above in Tasks 1-10, a Site Characterization Report will be prepared for AOI 1 and AOI 4 respectively, documenting the results of all Work Plan-related activities. Each report will include an executive summary, description of physical site characteristics, summary of field investigation and modeling activities, supporting maps, figures and data summary tables, an exposure assessment, refinement of the Site Conceptual Model based on field investigations, and conclusions and recommendations for future Site characterization activities or remedial systems, if any.

All data gathered with respect to the deep aquifer, AOI 11, will be presented in the respective AOI reports, however a formal AOI 11 characterization report will be compiled at the conclusion of all other AOI characterization efforts.

3.0 IMPLEMENTATION SCHEDULE

Site characterization activities are to commence immediately following receipt of the PADEP's approval of this Work Plan. It is anticipated that all field activities will be completed by April 2005, and the Site Characterization Reports for AOI 1 and AOI 4 will be submitted to the PADEP by June 29, 2005 and September 30, 2005, respectively. This schedule is consistent with the Phase II Corrective Action Activities Schedule which was included as Figure 19 of the CCR.

During its implementation, if any significant deviations are required from the proposed scope of work, the PADEP will be notified prior to implementation of any changes.

TABLES

Table 1
Constituents of Concern for Soil and Groundwater
AOI 1 and 4 Work Plan for Site Chracterization
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

SOIL	
METALS	**CAS No.**
Lead (total)	7439-92-1
VOLATILE ORGANIC COMPOUNDS	**CAS No.**
1,2-dichloroethane	107-06-2
Benzene	71-43-2
Cumene	98-82-8
Ethylbenzene	100-41-4
Ethylene dibromide	106-93-4
Methyl tertiary butyl ether	1634-04-4
Toluene	108-88-3
Xylenes (total)	1330-20-7
SEMI-VOLATILE ORGANIC COMPOUNDS	**CAS No.**
Anthracene	120-12-7
Benzo(a)anthracene	56-55-3
Benzo (g,h,i) perylene	191-24-2
Benzo(a)pyrene	50-32-8
Benzo(b)fluoranthene	205-99-2
Chrysene	218-01-9
Fluorene	86-73-7
Naphthalene	91-20-3
Phenanthrene	85-01-8
Pyrene	129-00-0

Notes:
1. Constituents are from Pennsylvania Corrective Action Process (CAP) Regulation Amendments effective December 1, 2001; provided in Chapter VI, Section E (pgs. 29-30) of PADEP Document, *Closure Requirements for Underground Storage Tank Systems,* effective April 1, 1998.

Table 1 (continued)
Constituents of Concern for Soil and Groundwater
AOI 1 and 4 Work Plan for Site Chracterization
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

GROUNDWATER	
METALS	**CAS No.**
Lead (dissolved)	7439-92-1
VOLATILE ORGANIC COMPOUNDS	**CAS No.**
1,2-dichloroethane	107-06-2
Benzene	71-43-2
Cumene	98-82-8
Ethylbenzene	100-41-4
Ethylene dibromide	106-93-4
Methyl tertiary butyl ether	1634-04-4
Toluene	108-88-3
Xylenes (total)	1330-20-7
SEMI-VOLATILE ORGANIC COMPOUNDS	**CAS No.**
Chrysene	218-01-9
Fluorene	86-73-7
Naphthalene	91-20-3
Phenanthrene	85-01-8
Pyrene	129-00-0

Notes:
1. Constituents are from Pennsylvania Corrective Action Process (CAP) Regulation Amendments effective December 1, 2001; provided in Chapter VI, Section E (pgs. 29-30) of PADEP Document, *Closure Requirements for Underground Storage Tank Systems,* effective April 1, 1998.

Table 2
Results of AOI 1 and 4 Sampling: October 2004
AOI 1 and 4 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, PA

Well Information						Constituents of Concern														
SAMPLE AREA	WELL IDENTIFICATION	SAMPLE DATE	DEPTH TO PRODUCT (feet)	DEPTH TO WATER (feet)	PRODUCT THICKNESS (feet)	BENZENE	TOLUENE	ETHYLBENZENE	TOTAL XYLENES	TOTAL BTEX	MTBE	ISOPROPYLBENZENE	NAPHTHALENE	EDB	EDC	CHRYSENE	FLOURENE	PHENANTHRENE	PYRENE	LEAD (mg/l)
PA MSC Non-Residential, Used Aquifer, TDS<2500						5.0	1000	700	10000	NA	20	2300	100	0.05	5.0	1.9	1900	1100	130	5.0
AOI 1 - BELMONT TERMINAL	MW-28	NS	24.23	25.53	1.30	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	MW-30	15-Oct-04	NP	27.27	0.00	490	3	24	18	535.0	<1.8	6.0	64	<0.020	7.3	<0.14	<10	<10	<10	<0.0050
	MW-31	NS	26.12	26.12	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	MW-32	NS	24.76	24.76	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	MW-33	NS	26.19	26.29	0.10	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	MW-34	NS	31.73	31.76	0.03	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	OW-2	NS	26.80	27.03	0.23	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	OW-12	NS	26.42	26.58	0.16	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	OW-13	NS	27.37	27.43	0.06	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	OW-14	15-Oct-04	NP	27.57	0.00	72	<5.0	<5.0	<10	72	16	<5.0	27	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	OW-15	NS	NM	NM	NM	CONVERTED TO RW-15; NOT SAMPLED														
	OW-16	NS	26.90	27.11	0.21	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	OW-17	NS	26.08	26.14	0.06	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	OW-18	NS	27.12	27.34	0.22	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	OW-19	NS	26.60	26.62	0.02	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	OW-20	NS	26.35	26.36	0.01	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-74	15-Oct-04	NP	25.27	0.00	<1.0	<5.0	<5.0	<10	<20	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	TW-3	15-Oct-04	NP	25.95	0.00	130000	48000	3500	20,000	201,500	170,000	<780	3,000	<0.020	2,200	80	320	640	210	0.05
	TW-5	14-Oct-04	NP	27.08	0.00	700000	12000	540	2,100	714,640	<200	<200	<1000	<0.020	<200	3.0	<14	<14	<14	<0.0050
	TW-8	15-Oct-04	NP	26.15	0.00	1500	<80	2100	1,800	5,400	290	210	14,000	<0.020	<74	270	800	1800	740	<0.0050
	TW-9	14-Oct-04	NP	27.15	0.00	7	<5.0	<5.0	<10	6.6	<5.0	<5.0	<5.0	<0.020	<5.0	NA	NA	NA	NA	<0.0050
	TW-10	NS	NM	NM	NM	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	TW-11	14-Oct-04	NP	27.40	0.00	2	<5.0	<5.0	<10	2.3	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050

Notes:
Liquid Levels collected on 4 & 5 October 2004 by Aquaterra
All Concentrations reported in µg/L.
TW-9: Insufficient water volume for analysis of Chrysene, Pyrene, Flourene, and Phenanthrene
TW-10: Well inaccessible during sampling event, vehicle parked on top of well
NA-Not analyzed
NM = Not Measured
NS = Not Sampled
NS-I = Not Sampled. Inaccessible
NS-P - Not Sampled, Product
NS-dry = Not Sampled, Insufficient Water Volume for Sample Collection
EDB - Ethylene Dibromide
EDC-1,2-Dichloroethane
"< 1.0" = result is less than the reporting limit (RL)
5.4 = Result exceeds PA MSC Non-Residential, Used Aquifer, TDS <2500
5.4 = Compound detected above the RL; the RL is greater than the MSC

Table 2
Results of AOI 1 and 4 Sampling: October 2004
AOI 1 and 4 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, PA

Well Information						Constituents of Concern														
SAMPLE AREA	WELL IDENTIFICATION	SAMPLE DATE	DEPTH TO PRODUCT (feet)	DEPTH TO WATER (feet)	PRODUCT THICKNESS (feet)	BENZENE	TOLUENE	ETHYLBENZENE	TOTAL XYLENES	TOTAL BTEX	MTBE	ISOPROPYLBENZENE	NAPHTHALENE	EDB	EDC	CHRYSENE	FLOURENE	PHENANTHRENE	PYRENE	LEAD (mg/l)
PA MSC Non-Residential, Used Aquifer, TDS<2500						5.0	1000	700	10000	NA	20	2300	100	0.05	5.0	1.9	1900	1100	130	5.0
AOI-1	MW-26	NS	22.20	22.43	0.23	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	MW-27	NS	24.06	24.73	0.67	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	MW-29	NS	24.05	26.33	2.28	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	PZ-400	NS	23.45	23.60	0.15	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	PZ-401	NS	19.51	19.87	0.36	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	PZ-402	13-Oct-04	NP	18.72	0.00	21000	230	810	1500	23540	2800	<78	310	<0.020	290	4.3	<10	84	11	0.017
	PZ-403	NS	24.15	24.16	0.01	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	PZ-404	NS	26.75	26.76	0.01	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-101	12-Oct-04	NP	47.08	0.00	1100	8	16	68	1191.5	<5.0	13	74	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-116	12-Oct-04	NP	12.85	0.00	1	<5.0	<5.0	<10	1.1	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-117	NS	16.92	16.92	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-118	19-Oct-04	NP	17.66	0.00	340	11	310	510	1171	<1.8	18	71	<0.020	5.0	<0.14	<10	<10	<10	<0.0050
	S-125	13-Oct-04	NP	21.65	0.00	7600	190	380	1300	9470	800	<39	91	<0.020	110	<0.14	<10	<10	<10	<0.0050
	S-126	12-Oct-04	NP	9.91	0.00	<1.0	<5.0	<5.0	<10	<5.0	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-127	19-Oct-04	NP	16.21	0.00	15000	130	1,400	1,700	18,230	6,400	66	720	<0.020	<20	<0.16	<11	<11	<11	<0.0050
	S-160	NS	16.99	17.09	0.10	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-161	NS	16.52	16.57	0.05	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-162	NS	16.80	17.05	0.25	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-164	18-Oct-04	NP	15.21	0.00	110	32	32	65	239	310	160	<5.0	<0.020	<5.0	0.73	<11	14	<11	<0.0050
	S-171	NS	14.80	16.13	1.33	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-172	19-Oct-04	NP	17.42	0.00	800	<5.0	52	300	1,152	93	9.6	33	<0.020	<5.0	<0.16	<11	<11	<11	<0.0050
	S-173	18-Oct-04	NP	17.20	0.00	2800	10	580	1,300	4,689.7	710	230	130	<0.020	<5.0	<0.78	11	18	2.1	<0.0050
	S-179	14-Oct-04	NP	19.77	0.00	2	<5.0	<5.0	<10	2.1	<5.0	97	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-180	14-Oct-04	NP	16.20	0.00	<1.0	<5.0	<5.0	<10	<20	<5.0	<5.0	<5.0	<0.020	<5.0	0.5	<10	<10	<10	<0.0050
	S-181	14-Oct-04	NP	21.98	0.00	1600	250	160	660	2670	200	12	40	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-182	13-Oct-04	NP	22.10	0.00	9500	130	130	250	10010	240	89	330	<0.020	120	<0.14	<10	<10	<10	0.011
	S-183	13-Oct-04	NP	22.29	0.00	9900	84	77	190	10251	<44	53	480	<0.020	140	<0.14	<10	<10	<10	0.011
	S-184	13-Oct-04	NP	21.73	0.00	460	11	19	51	541	<1.8	45	18	<0.020	6.9	<0.14	<10	<10	<10	0.006
	S-185	13-Oct-04	NP	22.88	0.00	45	<5.0	7.4	14	66.4	<5.0	8.5	12	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-186	13-Oct-04	NP	22.46	0.00	32	<5.0	5.0	12	49	<5.0	45	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-187	13-Oct-04	NP	23.35	0.00	270	29	22	50	371	<1.8	43	12	<0.020	3.70	<0.14	<10	<10	<10	<0.0050
	S-188	13-Oct-04	NP	23.54	0.00	3700	23	300	270	4293	<18	63	140	<0.020	56	<0.14	<10	<10	<10	<0.0050
	S-189	12-Oct-04	NP	24.79	0.00	1200	25	82	190	1497	<5.0	110	180	<0.020	<5.0	3.0	20	35	<10	0.014
	S-190	NS	24.68	24.73	0.05	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-191	NS	24.22	24.39	0.17	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-192	12-Oct-04	NP	24.61	0.00	930	11	380	600	1921	34	54	190	<0.020	<5.0	2.0	<11	16	<11	<0.0050
	S-41	19-Oct-04	NP	25.83	0.00	70	6	<1.8	<3.2	75.5	490	63	<3.6	<0.020	<1.5	<0.14	<10	<10	<10	<0.0050
	S-42D	19-Oct-04	NP	25.48	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-43	19-Oct-04	NP	24.21	0.00	720	31	150	90	991	<4.4	39	50	<0.020	11	<0.14	<10	<10	<10	<0.0050
	S-44	18-Oct-04	NP	25.80	0.00	1700	37	16	28	1,722	19	51	<10	0.058	<5.0	<0.16	<11	<11	<11	<0.0050

Notes:
Liquid Levels collected on 4 & 5 October 2004 by Aquaterra
All Concentrations reported in µg/L.
TW-9: Insufficient water volume for analysis of Chrysene, Pyrene, Flourene, and Phenanthrene
TW-10: Well inaccessible during sampling event, vehicle parked on top of well
NA-Not analyzed
NM = Not Measured
NS = Not Sampled
NS-I = Not Sampled. Inaccessible
NS-P - Not Sampled, Product
NS-dry = Not Sampled, Insufficient Water Volume for Sample Collection
EDB - Ethylene Dibromide
EDC-1,2-Dichloroethane
"< 1.0" = result is less than the reporting limit (RL)
5.4 = Result exceeds PA MSC Non-Residential, Used Aquifer, TDS <2500
5.4 = Compound detected above the RL; the RL is greater than the MSC

Table 2
Results of AOI 1 and 4 Sampling: October 2004
AOI 1 and 4 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, PA

Well Information						Constituents of Concern														
SAMPLE AREA	WELL IDENTIFICATION	SAMPLE DATE	DEPTH TO PRODUCT (feet)	DEPTH TO WATER (feet)	PRODUCT THICKNESS (feet)	BENZENE	TOLUENE	ETHYLBENZENE	TOTAL XYLENES	TOTAL BTEX	MTBE	ISOPROPYLBENZENE	NAPHTHALENE	EDB	EDC	CHRYSENE	FLOURENE	PHENANTHRENE	PYRENE	LEAD (mg/l)
PA MSC Non-Residential, Used Aquifer, TDS<2500						5.0	1000	700	10000	NA	20	2300	100	0.05	5.0	1.9	1900	1100	130	5.0
AOI-1 (continued)	S-45	19-Oct-04	NP	23.06	0.00	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-46	19-Oct-04	NP	21.19	0.00	260	32	52	35	379	880	180	33	<0.020	<5.0	<0.16	<11	<11	<11	<0.0050
	S-47D	19-Oct-04	NP	20.84	0.00	5.0	<5.0	<5.0	<10	5.4	140	100	<5.0	<0.020	<5.0	<0.16	<11	<11	<11	<0.0050
	S-48	NS	18.86	18.86	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-49	NS	NM	NM	NM	WELL DESTROYED														
	S-50	NS	22.25	22.62	0.37	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-51	18-Oct-04	NP	22.98	0.00	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry	NS-dry
	S-52	19-Oct-04	NP	22.98	0.00	57	5.3	<5.0	<10	62.3	960	30	34	<0.020	<5.0	<0.16	<11	<11	<11	<0.0050
	S-75	NS	26.44	26.55	0.11	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-76	NS	26.32	27.73	1.41	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-77	NS	12.92	13.24	0.32	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-77P	12-Oct-04	NP	28.61	0.00	16000	68	270	650	16988	4100	93	650	<0.020	<20	22	110	240	58	<0.0050
	S-78	NS	26.01	26.05	0.04	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-79	NS	23.57	23.87	0.30	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-79P	NS	NP	25.85	0.00	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-80	NS	NP	27.59	0.00	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-81	NS	20.75	21.30	0.55	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-82	NS	22.51	22.59	0.08	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-83	NS	18.82	19.26	0.44	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-84	NS	NP	14.60	0.00	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-84P	14-Oct-04	NP	13.62	0.00	66	<5.0	130	5000	5196	11	260	530	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-85	NS	23.18	23.18	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-86	NS	26.02	26.02	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-87D	NS	24.91	24.91	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-88	NS	24.98	24.98	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-88A	NS	24.90	24.90	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-89	NS	26.86	26.87	0.01	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-90	NS	NM	NM	NM	CONVERTED TO PUMPING WELL; NOT SAMPLED														
	S-94	NS	NM	NM	NM	CONVERTED TO PUMPING WELL; NOT SAMPLED														
	S-95	19-Oct-04	NP	22.55	0.00	14	<5.0	<5.0	<10	14	<5.0	61	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-98	12-Oct-04	NP	23.90	0.00	670	11	60	330	1071	<5.0	24	53	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-99	12-Oct-04	NP	25.14	0.00	150	25	6.2	25	206.2	<5.0	72	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
AOI 1 - 26th ST. OFF-SITE	S-100	NS	22.40	22.55	0.15	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-193	NS	NM	NM	NM	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-194	NS	NM	NM	NM	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-195	NS	NM	NM	NM	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-196	NS	NM	NM	NM	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-197	NS	NM	NM	NM	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I

Notes:
Liquid Levels collected on 4 & 5 October 2004 by Aquaterra
All Concentrations reported in µ/L.
TW-9: Insufficient water volume for analysis of Chrysene, Pyrene, Flourene, and Phenanthrene
TW-10: Well inaccessible during sampling event, vehicle parked on top of wel
NA-Not analyzed
NM = Not Measured
NS = Not Sampled
NS-I = Not Sampled. Inaccessible
NS-P - Not Sampled, Product
NS-dry = Not Sampled, Insufficient Water Volume for Sample Collectior
EDB - Ethylene Dibromide
EDC-1,2-Dichloroethane
"< 1.0" = result is less than the reporting limit (RL)
5.4 = Result exceeds PA MSC Non-Residential, Used Aquifer, TDS <2500
5.4 = Compound detected above the RL; the RL is greater than the MSC

Table 2
Results of AOI 1 and 4 Sampling: October 2004
AOI 1 and 4 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, PA

Well Information						Constituents of Concern															
SAMPLE AREA	WELL IDENTIFICATION	SAMPLE DATE	DEPTH TO PRODUCT (feet)	DEPTH TO WATER (feet)	PRODUCT THICKNESS (feet)	BENZENE	TOLUENE	ETHYLBENZENE	TOTAL XYLENES	TOTAL BTEX	MTBE	ISOPROPYLBENZENE	NAPHTHALENE	EDB	EDC	CHRYSENE	FLOURENE	PHENANTHRENE	PYRENE	LEAD (mg/l)
PA MSC Non-Residential, Used Aquifer, TDS<2500						5.0	1000	700	10000	NA	20	2300	100	0.05	5.0	1.9	1900	1100	130	5.0
AOI-4	S-102	21-Oct-04	NP	17.11	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	6.9	<5.0	<0.020	<5.0	1.5	<10	<10	<10	<0.0050
	S-103	NS	24.95	25.47	0.52	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-104	NS	16.43	16.72	0.29	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-111	NS	NM	NM	NM	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-115	NS	NM	NM	NM	WELL ABANDONED														
	S-119	20-Oct-04	NP	26.14	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-120	20-Oct-04	NP	19.16	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-121	20-Oct-04	NP	20.53	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-122	20-Oct-04	NP	25.03	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-123	20-Oct-04	NP	21.55	0.00	150	260	280	1,300	1,990	<4.4	19	220	<0.020	<3.7	<0.14	13	24	<10	<0.0050
	S-124	NS	22.42	22.43	0.01	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-26	21-Oct-04	NP	20.05	0.00	<1.0	<5.0	<5.0	<10	<21	39	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-27	21-Oct-04	NP	26.22	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-28	21-Oct-04	NP	22.83	0.00	57	<5.0	<5.0	<10	57	180	5.3	<5.0	<0.020	<5.0	<0.70	260	550	29	<0.0050
	S-29	NS	21.00	27.38	6.38	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-30	NS	22.40	23.57	1.17	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-31	NS	20.55	20.55	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-32	NS	23.48	23.64	0.16	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-33	NS	20.99	21.85	0.86	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-34	NS	22.91	23.69	0.78	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-35	NS	24.30	25.00	0.70	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-36	NS	23.86	24.35	0.49	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-37	NS	25.54	25.75	0.21	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-38	21-Oct-04	NP	18.28	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-38D	21-Oct-04	NP	18.65	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-38I	21-Oct-04	NP	19.41	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-39	20-Oct-04	NP	22.21	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	<0.020	<5.0	<0.14	<10	<10	<10	<0.0050
	S-40	NS	NP	24.08	0.00	NS-1	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I	NS-I
	S-55	NS	NM	NM	NM	WELL DESTROYED														
	S-56	NS	14.35	14.35	Trace	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-57	NS	11.86	12.25	0.39	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P	NS-P
	S-58	NS	NM	NM	NM	WELL DESTROYED														
	S-67	NS	NM	NM	NM	WELL DESTROYED														
	S-96	20-Oct-04	NP	17.97	0.00	<1.0	<5.0	<5.0	<10	<21	<5.0	<5.0	<5.0	NA	<5.0	NA	NA	NA	NA	NA
	S-97	20-Oct-04	NP	29.88	0.00	290	19	55	160	524	<1.8	23	55	<0.020	4.0	<0.14	<10	<10	<10	<0.0050

Notes:
Liquid Levels collected on 4 & 5 October 2004 by Aquaterra
All Concentrations reported in µg/L.
TW-9: Insufficient water volume for analysis of Chrysene, Pyrene, Flourene, and Phenanthrene
TW-10: Well inaccessible during sampling event, vehicle parked on top of well
NA-Not analyzed
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NS-P - Not Sampled, Product
NS-dry = Not Sampled, Insufficient Water Volume for Sample Collection
EDB - Ethylene Dibromide
EDC-1,2-Dichloroethane
"< 1.0" = result is less than the reporting limit (RL)
5.4 = Result exceeds PA MSC Non-Residential, Used Aquifer, TDS <2500
5.4 = Compound detected above the RL; the RL is greater than the MSC

TABLE 3
Summary of Proposed Sampling Locations for AOI 1 and 4
AOI 1 and 4 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Proposed Sampling ID	Existing	Proposed	Media	Collection of Soil Sample from 0-2 ft	Soil Boring Advanced to Bedrock	Completion and/or Sample Depth for Proposed Monitoring Wells and Points	Included in Monitoring and Sampling Programs	LNAPL Data Exists	Collection of LNAPL Sample From Existing Well	Objective of Proposed Activity
AOI 1 - Belmont Terminal										
RW-1	X		GROUNDWATER					X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-4	X		GROUNDWATER							Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-6	X		GROUNDWATER							Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-7	X		GROUNDWATER					X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-15	X		GROUNDWATER					X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-21	X		GROUNDWATER							Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-22	X		GROUNDWATER						X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-23	X		GROUNDWATER						X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-24	X		GROUNDWATER						X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-25	X		GROUNDWATER						X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
RW-400	X		GROUNDWATER							Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
OW-2	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
OW-12	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
OW-13	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
OW-14	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
OW-16	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
OW-17	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
OW-18	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
OW-19	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
OW-20	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
TW-3	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
TW-5	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
TW-8	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
TW-9	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
TW-10	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
TW-11	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
S-74	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-28	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-30	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-31	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-32	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-33	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-34	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-35		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-36		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-37		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-38		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-39		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-40		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-41		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-42		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-43		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
MW-44		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in Belmont Termina
SG-1		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor:Credit Union Building
SG-2		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor:Credit Union Building
SG-3		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor:Credit Union Building
SG-4		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor:Credit Union Building
SG-5		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor:Credit Union Building
SG-6		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor:Credit Union Building
SG-7		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor:Credit Union Building
SG-8		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor:Credit Union Building
SG-9		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor: Office Building #1
SG-10		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor: Office Building #1
SG-11		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor: Office Building #2
SG-12		X	SOIL GAS			15 ft bgs	X			Characterize Soil Gas Quality Adjacent to Potential Non-Residential Receptor: Office Building #2

TABLE 3
Summary of Proposed Sampling Locations for AOI 1 and 4
AOI 1 and 4 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Proposed Sampling ID	Existing	Proposed	Media	Collection of Soil Sample from 0-2 ft	Soil Boring Advanced to Bedrock	Completion and/or Sample Depth for Proposed Monitoring Wells and Points	Included in Monitoring and Sampling Programs	LNAPL Data Exists	Collection of LNAPL Sample From Existing Well	Objective of Proposed Activity
AOI 1 - #1 and #2 Tank Farms										
MW-26	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
MW-27	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
MW-29	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
PZ-400	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
PZ-401	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
PZ-402	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
PZ-403	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
PZ-404	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
RW-401	X		GROUNDWATER					X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
RW-402	X		GROUNDWATER					X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
RW-403	X		GROUNDWATER							Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
RW-404	X		GROUNDWATER							Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
RW-405	X		GROUNDWATER							Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
RW-406	X		GROUNDWATER							Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-101	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-116	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-117	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-118	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-125	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-126	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-127	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-160	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-161	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-162	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-164	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-177	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-178	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-179	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-180	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-181	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-182	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-183	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-184	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-185	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-186	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-187	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-188	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-189	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-190	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-191	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-192	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-41	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-42D	X		GROUNDWATER				X			Characterize Deep Groundwater Flow and/or Quality in AOI 1
S-43	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-44	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-45	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-46	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-46D		X	GROUNDWATER			75 ft (estimate)	X			Characterize Deep Groundwater Flow and/or Quality in AOI 1
S-47D	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-49	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-50	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1

TABLE 3
Summary of Proposed Sampling Locations for AOI 1 and 4
AOI 1 and 4 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Proposed Sampling ID	Existing	Proposed	Media	Collection of Soil Sample from 0-2 ft	Soil Boring Advanced to Bedrock	Completion and/or Sample Depth for Proposed Monitoring Wells and Points	Included in Monitoring and Sampling Programs	LNAPL Data Exists	Collection of LNAPL Sample From Existing Well	Objective of Proposed Activity
S-51	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-52	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-75	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-76	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-77	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-77P	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-78	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-79	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-79P	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-80	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-80D		X	GROUNDWATER		X	75 ft (estimate)	X			Characterize Deep Groundwater Flow and/or Quality in AOI 1
S-81	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-82	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-83	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-84	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-84P	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-85	X		GROUNDWATER							Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-86	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-87D	X		GROUNDWATER				X			Characterize Deep Groundwater Flow and/or Quality in AOI 1
S-88	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-88A	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-89	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-90	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-94	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-95	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-98	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-99	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-198		X	GROUNDWATER	X		35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-199		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-200		X	GROUNDWATER			35 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-201		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-202		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-203		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-204		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-205		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-206		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-207		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-208		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-209		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-210		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-211		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-212		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-213		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
S-214		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 1
AOI 1 - 26th STREET OFF-SITE										
S-100	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality at 26th St. off-site location
S-193	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality at 26th St. off-site location
S-194	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality at 26th St. off-site location
S-195	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality at 26th St. off-site location
S-196	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality at 26th St. off-site location
S-197	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality at 26th St. off-site location

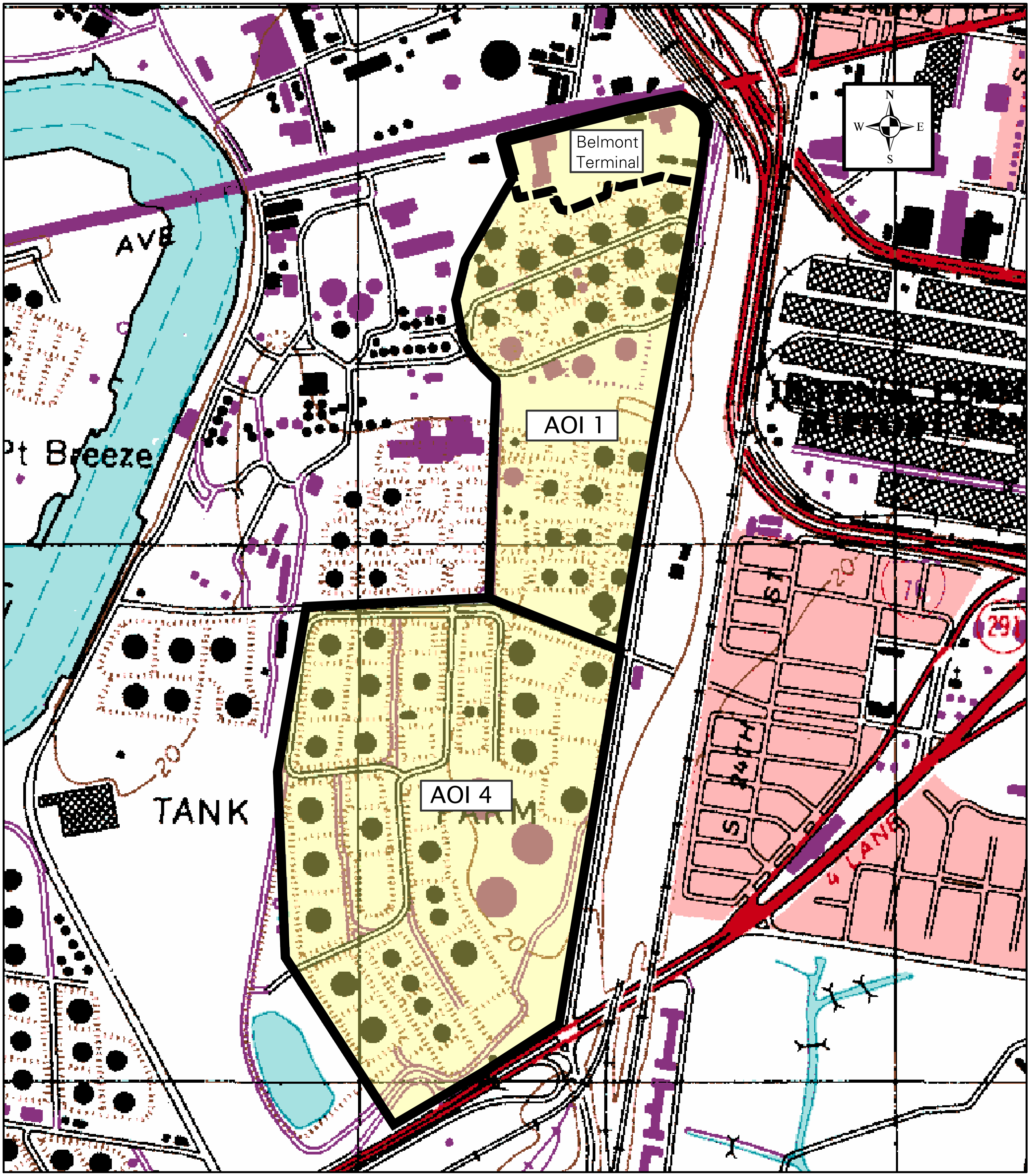
TABLE 3
Summary of Proposed Sampling Locations for AOI 1 and 4
AOI 1 and 4 Work Plan for Site Characterization
Sunoco Philadelphia Refinery
Philadelphia, Pennsylvania

Proposed Sampling ID	Existing	Proposed	Media	Collection of Soil Sample from 0-2 ft	Soil Boring Advanced to Bedrock	Completion and/or Sample Depth for Proposed Monitoring Wells and Points	Included in Monitoring and Sampling Programs	LNAPL Data Exists	Collection of LNAPL Sample From Existing Well	Objective of Proposed Activity
							AOI 4			
S-102	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-103	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-104	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-111	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-119	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-119D		X	GROUNDWATER	X		70 ft (estimate)	X			Characterize Deep Groundwater Flow and/or Quality in AOI 4
S-120	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-121	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-122	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-123	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-124	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-26	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-27	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-28	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-29	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-30	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-31	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-32	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-33	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-34	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-35	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-36	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-37	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-38	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-38D	X		GROUNDWATER				X			Characterize Deep Groundwater Flow and/or Quality in AOI 4
S-38I	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-39	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-40	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-55	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-56	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-57	X		GROUNDWATER				X		X	Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-58	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-59D		X	GROUNDWATER	X	X	70 ft (estimate)	X			Characterize Deep Groundwater Flow and/or Quality in AOI 4
S-67	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-96	X		GROUNDWATER				X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-97	X		GROUNDWATER				X	X		Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-215		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-216		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-217		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-218		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-219		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-220		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-221		X	GROUNDWATER	X		30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-222		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-223		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4
S-224		X	GROUNDWATER			30 ft bgs	X			Characterize Shallow and Intermediate Groundwater Flow and/or Quality in AOI 4

Notes:

1. All samples to be analyzed for constituents listed in Table 1 of the Workplan
2. Field procedures will be performed in accordance with Appendix A of the Workplan
3. ft bgs = feet below ground surface

FIGURES



USGS Topographic Map, Philadelphia, PA. Quadrangle, USGS 1995

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA. 19145

Figure 1: AOI 1 and 4 Boundaries
Sunoco Philadelphia Refinery

Philadelphia
Pennsylvania

Job Number	Scale: 1" = 800'	Date
2574601	0 400 800 Feet	December 30, 2004

G:\Data6\2574601\ArcGIS\MapDocuments\AOI 1&4 work plan\Figure 1- AOI 1 and 4 Boundaries.mxd

N
W E
S

Legend

- MW-32 — Existing Groundwater Monitoring Well
- RW-21 — Existing Recovery Well
- MW-36 — Proposed Intermediate Groundwater Monitoring Well
- SG-1 — Proposed Soil Gas Monitoring Point
- Belmont Terminal Property Boundary

Figure 2: Proposed Sampling Locations:
AOI 1- Belmont Terminal
AOI 1 & 4 Work Plan for
Site Characterization
Sunoco Philadelphia Refinery

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 50 100
Feet

SCALE: 1" = 50'
DATE: December 28, 2004
DRN. BY: DT
CKD. BY: CC
JOB#: 2574601

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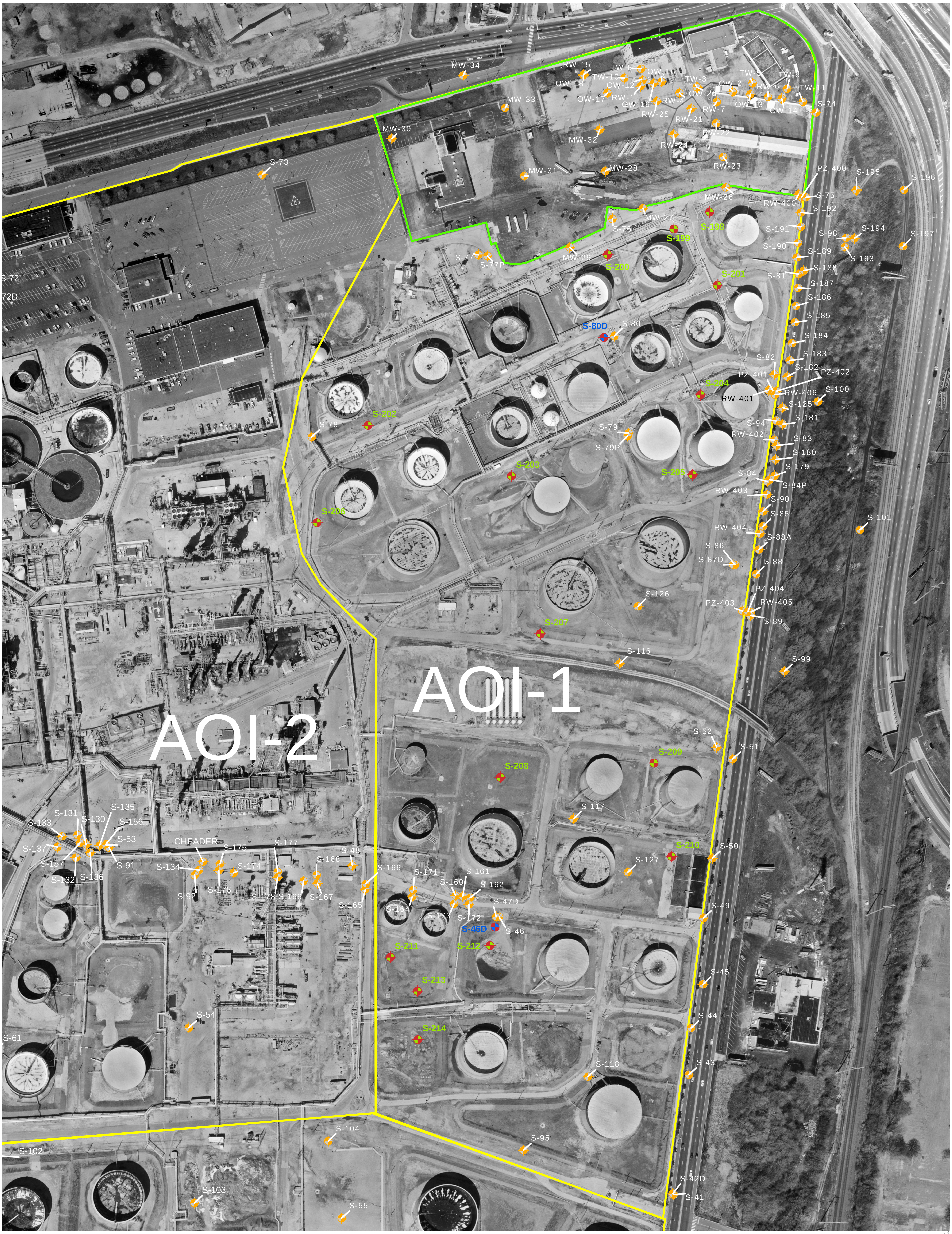
Figure 2- Proposed Sampling Locations AO1 Belmont Term.mxd



Legend

AOI 1 Proposed Groundwater Monitoring Wells

S-198 — Intermediate Wells

S-80D — Deep Wells

S-98 — Existing Monitoring Points

Area of Interest Boundary

Belmont Terminal Boundary (See Figure 2 for Proposed Sampling Locations in Belmont Terminal)

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W E
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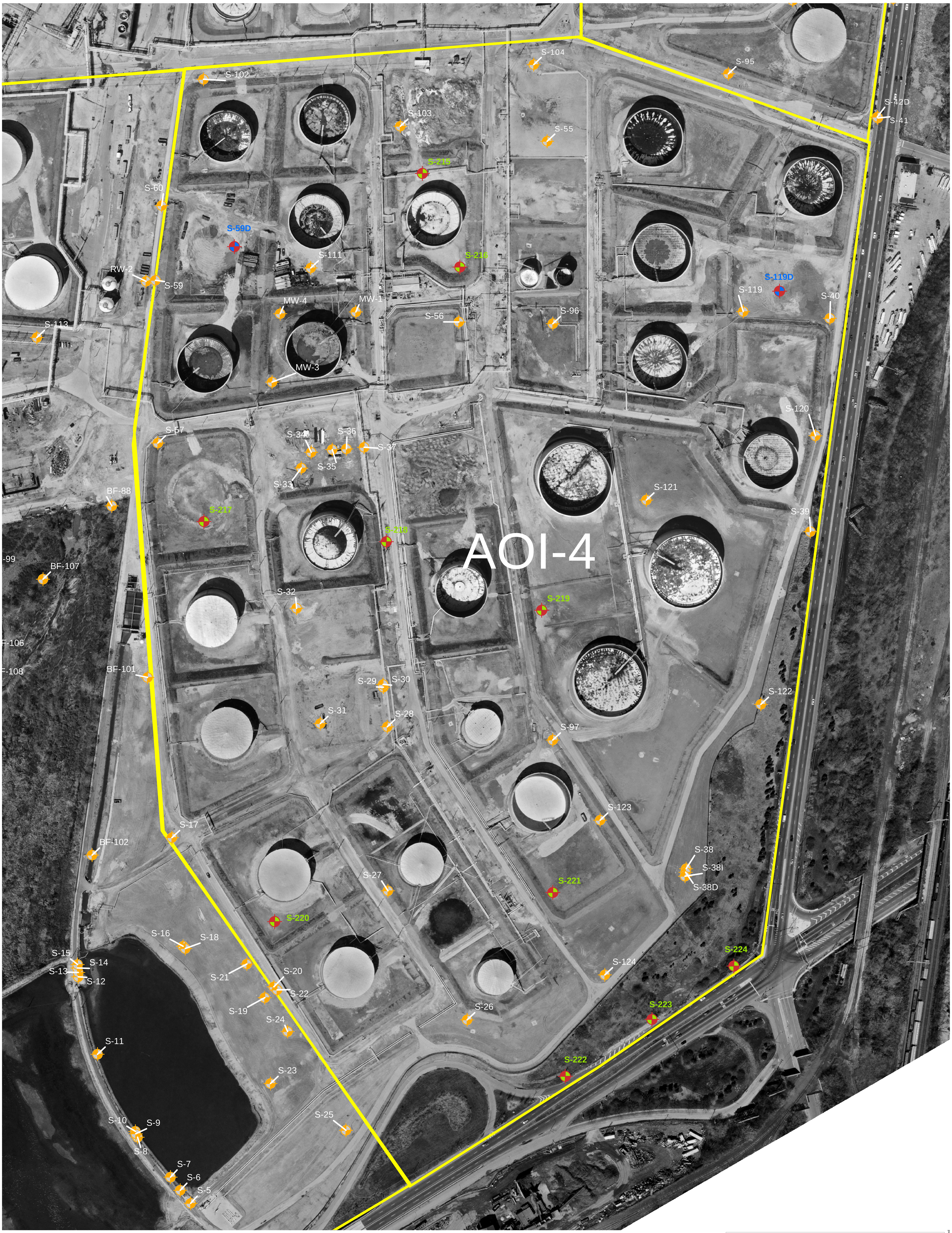
Figure 3: Proposed Sampling Locations : AOI-1 - #1 and #2 Tank Farms AOI 1 & 4 Work Plan for Site Characterization Sunoco Philadelphia Refinery

SUNOCO

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 100 200 Feet

SCALE: 1" = 100'
DATE: December 30, 2004
DRN. BY: JC
CKD. BY: JH
JOB#: 2574601



Legend

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S

AOI 4 Proposed Groundwater Monitoring Wells

S-215 Intermediate Wells

S-119D Deep Wells

S-93 Existing Monitoring Points

Area of Interest Boundary

Figure 4: Proposed Sampling Locations: AOI 4
AOI 1 & 4 Work Plan for
Site Characterization
Sunoco Philadelphia Refinery

Sunoco, Inc. (R&M)
Philadelphia Refinery
3144 Passyunk Avenue
Philadelphia, PA.
19145

0 100 200 Feet

SCALE: 1" = 100'
DATE: December 30, 2004
DRN. BY: JC
CKD. BY: JH
JOB#: 2574601

G:\Data6\2574601\ArcGIS\MapDocuments\AOI 1&4 work plan\Figure 4- Proposed Sample Locations AOI 4.mxd

APPENDIX A

FIELD PROCEDURES

APPENDIX A
FIELD PROCEDURES
AOI 1 AND 4 WORK PLAN FOR SITE CHARACTERIZATION
SUNOCO PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

A.1. LIQUID LEVEL ACQUISITION

Responsible Personnel: Technicians and Geologists

Training Qualifications:

All field personnel involved in liquid level acquisition shall have, as a minimum, completed OSHA 40 HOUR HAZWOPER training and completed the 3-day minimum field training requirements as specified within the Corporate Health and Safety Plan. Prior to solo performance of liquid levels, all field personnel will have performed a minimum of three site visits under the direct supervision of experienced personnel.

Health and Safety Requirements:

Personal Protective Equipment (PPE) Required:

Level D attire including steel toe/steel shank boots. Based on previous site visits or current air monitoring results, Level C attire may be required. The PPE required to upgrade to Level C may include: nitrile gloves, disposable outerboots, Tyvek coveralls, and a respirator. Safety glasses or hard hats may also be required in certain areas.

Site Controls:

Safety cones and or caution tape should be used in high traffic areas. The "Buddy system" may also be employed in high traffic areas.

Potential Hazards:

Traffic, pinch and trip, chemical (airborne and physical contact) and biological. Additional hazards are mentioned in site-specific HASP.

Materials and Equipment Necessary for Task Completion:

Electronic oil/water interface probe or conductivity water line, decontamination supplies (Liquinox, deionized-distilled water, appropriate containers, scrub brush, and sorbent pads or paper towels), air monitoring instrument (optional, based on previous site visits).

Methodology:

The task involves the deployment of a liquid sensing probe into a well (in most cases), recording the reading, and decontaminating the probe. The recorded field readings can then be utilized for one of several applications including: well sampling, water table gradient mapping, separate-phase hydrocarbon occurrence, thickness, and or gradient mapping, and various testing procedures.

The proper procedure for liquid level acquisition from a well is as follows:

1) The wells should be gauged in order of least to most contaminated based on existing sampling data or separate-phase hydrocarbon occurrence
2) The gauging instrument is decontaminated prior to initial deployment and after each well to prevent cross contamination between wells
3) Decontamination procedures include the following steps:
    a) Remove gross contaminants with sorbent pad or towel.
    b) Rinse/scrub equipment with water.
    c) Scrub equipment in Liquinox@/deionized-distilled water solution.
    d) Double rinse with deionized-distilled water.
    e) Air dry.
4) The well(s) to be gauged may need to be marked off with safety cones and or caution tape in order to protect personnel from auto traffic; the "Buddy system" may also be employed.
5) The manhole cover is then lifted off of the well head. A pry bar may be needed to prevent personal injury in the case of large manhole covers.
6) The probe is lowered into the well until the instrument signals contact with liquid.
7) The corresponding reading is recorded when the instrument signals either water or product. A clear bailer may be used to verify the existence or approximate amount and appearance of product.
8) The probe is then retracted from the well and decontaminated accordingly.
9) The well is then secured appropriately.
10) Note the start and stop time for gauging round in the field book.

A.2. GROUNDWATER MONITORING PROCEDURES

Responsible Personnel: Technicians and Geologists

Health and Safety Requirements:

Site specific HASP must be completed and reviewed by field personnel. Ambient air monitoring will be performed quarterly at all treatment areas to determine the necessity of PPE upgrade. As a minimum, level "D" attire will be worn. No persons shall enter any structure with a background air concentration over 10% or less than 19% oxygen.

Training Qualifications:

All field personnel involved in groundwater monitoring shall have, as a minimum completed OSHA 40 HOUR HAZWOPER training and completed the 3 day minimum field training requirements. Prior to groundwater monitoring, all field personnel will have sampled a minimum of three sites under the direct supervision of experienced personnel. Field personnel will also have experience in vapor monitoring techniques and sampling equipment decontamination.

Materials and Equipment Necessary for Task Completion:

A list of equipment required to access, gauge, purge, and sample site monitoring wells is presented below. Also listed are materials necessary to store, label, preserve, and transport groundwater samples.

- Current site map detailing well locations.
- Field data book for recording site data.
- Liquid level gauging device (graduated, optical interface probe).
- Keys and tools to provide well access.
- Appropriate sample containers and labels: volatile samples will be collected in laboratory provided 40 milliliter (ml) glass vials with plastic caps fitted with Teflon ® lined septa; all sample bottles will be laboratory sterilized and will contain the appropriate preservative, if applicable.
- Appropriate well purging apparatus as determined by volume of groundwater to be purged and compounds to be analyzed.
- Teflon ® (or equivalent) bottom-loading bailer to extract groundwater sample.
- Clean nylon or polypropylene bailer cord.
- Disposable nitrile sampling gloves.
- Decontamination supplies.
- Calibrated five-gallon bucket and watch or stopwatch to determine discharge rate during purging.

- Blank chain-of-custody forms.
- Cooler and ice for sample preservation.

Methodology for Three Well Volume Sampling:

Prior to actual site visitation for the groundwater sampling event, the following data will be reviewed to ensure proper preparation for field activities:

- Most recent liquid level data from all wells.
- Most recent analytical data from all wells to determine gauging and sampling sequence.
- Well construction characteristics.

Each monitoring well to be sampled will be gauged to obtain liquid level data immediately prior to initiation of the sampling process. Refer to Liquid Level Gauging SOP for appropriate well gauging procedures. Liquid level data will be recorded in a field book. Should free-phase petroleum product be detected by the gauging process and verified through inspection in a pre-cleaned acrylic bailer, groundwater sampling will not be conducted at that location.

The sampling procedure will be initiated by purging from the well a minimum of three well volumes, except in cases where the well is pumped dry, as referenced below. Well purging is performed to remove stagnant water and to draw representative water from the aquifer into the well for subsequent sampling and analysis for the established parameters. In extreme cases where a well is pumped dry and/or shows little recharge capacity, the well will be evacuated once prior to sample procurement. Well volume calculations will be based on total well depth as determined during well installation and depth-to-water measurements obtained immediately prior to sampling.

Well purging is performed with various equipment including 1) a dedicated bailer for hand bailing low volumes of water, 2) a surface mounted electric centrifugal pump with dedicated polyethylene tubing, or 3) submersible pump (when the depth to water is greater than 20 feet) with dedicated polyethylene tubing. During pumping, the intake will be placed directly below the static water surface and slowly lowered during the purging process. This procedure may not prove necessary in low-yielding wells but is important in high-yielding, permeable strata where an intake initially placed deep in a well may draw laterally and have little influence in exchanging water from shallower depths within the well bore.

Flow rate during well purging will be approximated by the bucket and stop watch method. The duration of pumping required to remove three well volumes will be calculated directly from this flow rate. After purging, the well will be allowed to recover for a period of approximately two hours prior to sample collection. This action will permit a consistent groundwater flux into each well and allow for VOC stabilization prior to sample extraction. All fluids removed during purging will be treated on-site with activated carbon.

The sequence of obtaining site groundwater samples will be based upon available historical site data for existing wells and soil organic vapor analyzer (OVA) readings for newly installed wells. Site wells will be sampled in order from the lowest to highest concentration of water quality indicator parameters based upon the most recent available set of laboratory analyses to reduce the potential for sample cross-contamination. Groundwater samples will not be obtained for analysis from any well containing a measurable free product layer.

The following sequence of procedures will be implemented for the collection of groundwater samples from monitoring wells.

1) Establish a clean work area where sampling equipment will not come in contact with the ground or any potentially contaminated surfaces.
2) Use a laboratory, pre-cleaned Teflon@ sampling bailer for each well.
3) Don an unused, clean pair of nitrile gloves.
4) Attach an appropriate length of unused, clean nylon or polypropylene cord to the designated sampling bailer.
5) Select appropriate laboratory-sterilized sample containers.
6) Slowly lower sampling bailer into well until water surface is encountered; continue to lower the sampling bailer into the standing water column to one foot below the water surface.
7) Retrieve bailer at a steady rate to avoid excess agitation.
8) Visually inspect bailed sample to ensure that no free product or organic detritus has been collected.
9) Uncap first designated sample vial and fill from bailer as rapidly as possible but minimizing agitation; secure septum and lid.
10) Inspect sealed sample for entrapped air; if air is present within sample vial. Remove lid and repeat vial filling, sealing and inspection process until no air is present.
11) Repeat Steps 9 and 10 for the second designated vial; all volatile parameter samples will be collected in duplicate.
12) Complete and attach labels to sample containers noting sample collector, date, time, and location of sample; record same data in field book.
13) Place samples in ice-filled cooler in such a manner as to avoid breakage. Samples collected for VOC analysis will be maintained at a temperature of 4oC.

Discard gloves and bailer cord and move to next sample location.

Methodology for Low-Flow Purging and Sampling:
For wells that will be Low-Flow purged and sampled, the USEPA Region III Bulletin QAD023: *Procedure for Low-Flow Purging and Sampling of Groundwater Monitoring Wells* will be followed. The following data will be reviewed for each well in order to set the pump intake for the low flow sampling:

- Soil boring (lithologic) log and continuous soil sample PID;

- Well construction log showing the screened interval;
- Identification of the most permeable zone screened by the well;
- Approximate depth to static water;
- Proposed pump intake setting; and,
- Technical rationale for the pump intake setting, preferably across from the most impacted/contaminated subsurface interval.

Equipment

Adjustable rate, submersible, bladder pumps in conjunction with Teflon or Teflon-lined polyethylene tubing for purging and sampling will be used. The tubing diameter will be between 3/16-inch to ½-inch inner diameter and the length of the tubing extended outside the well will be minimized. Flow through cells will be used to evaluate parameters during sampling. Monitoring well information, equipment specifications, water level measurements, parameter readings, and other pertinent information will be recorded during monitoring well purging and sampling.

Sampling Procedure

The following protocol details the low-flow sampling procedure that will be used for sampling the monitoring wells.

1. PID Screening of Well. A PID measurement will be collected at the rim of the well immediately after the well cap will be removed and recorded on the sampling form.

2. Depth to Water Measurement. A depth to water measurement will be collected and recorded. To avoid disturbing accumulated sediment and to prevent the inadvertent mixing of stagnant water, measuring the total depth of the well will be done at the completion of sampling on an annual basis.

3. Low Stress Purging Startup. Water pumping will commence at a rate of 100 to 400 milliliters per minute (mL/min). This pumping should cause very little drawdown in the well (less than 0.2-0.3 feet) and the water level should stabilize. Water level measurements are made continuously and will be recorded in milliliters per minute on the sampling form.

4. Low Stress Purging and Sampling. The water level and pumping rate will be monitored and recorded every five minutes during purging, and any pumping rate adjustments will be recorded. During the early phase of purging, emphasis will be placed on minimizing and stabilizing pumping stress, and recording any necessary adjustments. Adjustments, when necessary, will be made in the first 15 minutes of purging. If necessary, pumping rates will be reduced to the minimum capabilities of the pump to avoid well dewatering. If the minimal drawdown exceeds 0.3 feet, but the water level stabilizes above the pump intake setting, purging will continue until indicator field parameters stabilized, as detailed in Step 5 below. If the water level drops below the pump intake setting at the absolute minimum purge rate, the pump will remain in place and the water level will be allowed to recover

repeatedly until there will be sufficient water volume in the well to permit the collection of samples.

5. Indicator Field Parameters Monitoring. During well purging, indicator field parameters (DO, turbidity, pH, specific conductance, and redox potential) will be monitored every five minutes (or less frequently, if appropriate). Purging will be considered complete and sampling began when all the aforementioned indicator field parameters had stabilized. Stabilization will be achieved when three consecutive readings, taken at five (5) minute intervals (or less frequently, if appropriate), are within the following limits:

   - DO (±10 percent)
   - turbidity (±10 percent)
   - specific conductance (±3 percent)
   - pH (± 0.1 unit).
   - redox potential [Eh] ±10 mv)

   Temperature and depth to water will be also monitored during purging. Should any of the parameter-reading components of the flow-through meter fail during sampling, the sampling team will attempt to locate a replacement flow-through meter. If none is available, the sampling team will measure that parameter with an individual criteria meter. Any other field observations relating to sample quality, such as odor, foaming, effervescence, and sheens, will also be recorded on the sampling form.

6. Collection of Ground Water Samples. Water samples for laboratory analyses will be collected before the groundwater had passed through the flow-through cell by either using a by-pass assembly or by temporarily disconnecting the flow-through cell. All sample containers will be filled by allowing the pump discharge to flow gently down the inside of the container with minimal turbulence. During purging and sampling, the tubing remains filled with water in order to minimize possible changes in water chemistry upon contact with the atmosphere. Methods employed to ensure that the outlet tubing will be filled include (i) adjusting the tubing angle upward to completely fill the tubing and (ii) restricting the diameter of the tubing near the outlet of the tubing.

   The order in which samples will be collected is as follows:

   - Volatile organics
   - Gas sensitive (e.g., Fe^{+2}, CH_4, H_2S/HS)
   - Base/Neutrals or PAHs
   - Total Petroleum Hydrocarbons
   - Total metals
   - Dissolved metals
   - Cyanide
   - Sulfate and chloride

- Nitrate and ammonia
- Preserved inorganic
- Non-preserved inorganic
- Bacteria

Decontamination Requirements:

Numerous practices are employed throughout the processes of site investigation and sampling to assure the integrity of the resulting data. Of particular significance to the procedures of groundwater measurement and sampling is the limitation, whenever possible, of materials inserted into a well bore and, even more importantly, of materials transferred from well to well.

Many items can be discarded between well sampling and/or gauging locations without significantly impacting project costs. Dedicated sampling equipment which can be discarded between well sampling locations without significantly impacting project costs, will be used whenever possible to preclude decontamination requirements. Sampling equipment included in this category are Teflon ® bailers, nitrile gloves, and bailer cord. However, other investigative and sampling equipment, including such items as liquid level probes, must be reused from well to well.

The danger in multi-well equipment applications lies in the potential of cross-contamination. While the threat of cross-contamination is always present, it can be minimized through the implementation of a consistent decontamination program during sensitive site measurement and data collection activities. The decontamination procedure is outlined below:

All site equipment used in a multi-well capacity will be decontaminated immediately prior to initial use and between each well. Standard site decontamination procedures for the optical interface probes between wells will be performed according to the following schedule:

- Initial rinse with clean tap water to remove excess residuals.
- Scrub equipment with sponge or clean, soft cloth in a distilled water/Liquinox@ (or equivalent) solution.
- Double rinse with deionized/distilled water.

Rinse water generated during decontamination procedures will be treated on-site by passing the water through a bucket filled with activated carbon prior to disposal.

A.3. SOIL SAMPLING & WELL INSTALLATION

Responsible Personnel: Geologist

Training Qualifications: All field personnel supervising drilling activities shall have completed OSHA 40-Hour training, and three days of field training. Personnel supervising the well installation shall have observed drilling procedures for a minimum of three under the direct supervision of experienced personnel. Field personnel will have experience in operating the following field equipment: interface probe and photo-ionization detector (PID). Personnel should be able to describe soils encountered during drilling for generation of well logs.

Health and Safety Requirements:

A site specific HASP must be completed and reviewed by all field personnel. Prior to deploying a rig to the site, a utility call must be made (i.e. Pennsylvania One-Call) to allow mark-out of known subsurface utilities and associated laterals proximal to the site. Site plans, if available, should be reviewed to document and avoid the location of on-site utilities. No drilling should occur on retails sites within the exclusion zone. This zone is defined as the area between the pumps, the tank field and the station building. The area is excluded from drilling activities due to the likely occurrence of subsurface petroleum distribution lines. After review of all known mapped and marked utilities, a site reconnaissance will be performed to document the location of utility meters and storm sewer drains. In addition, the location of overhead utilities must be documented. After completing the subsurface and overhead utility review, the area to drill may be observed as clear or the location may be adjusted to a "clear" location.

Once the drilling location is established, the area must be marked with cones to alert area traffic of the work area. Other health and safety concerns include slip/trip hazards, working with heavy equipment and overhead work hazards. During drilling activities, a minimum of protective work gloves, steel toed boots, hard hats, and safety goggles must be worn.

A final health and safety requirement includes hand clearing the borehole, prior to advancing the borehole with the drill rig. To ensure the safety of workers, the borehole will be cleared by hand or air knife, to depth of 5 feet below ground surface. This will serve to clear the area of utilities, prior to drilling.

Decontamination Requirements:

All down-hole equipment must be steamed cleaned prior to drilling at each boring/well location. All soil sampling equipment must be cleaned with detergent and rinsed with distilled water prior to deployment into the borehole. All well construction materials (i.e. PVC well casing, PVC well screen, sand pack, bentonite seal) should be clean and dedicated to each hole.

Methodology:

1) Borehole Advancement

During soil sampling or well installation activities, a borehole is advanced into the unconsolidated subsurface materials or bedrock via a drill rig. Various types of drilling methods could be deployed to advance the hole. A description of each drilling method is included below:

a) Hollow Stem Auger

A spiral tool form is used to move material from the subsurface to the surface. A bit at the bottom cuts into the subsurface material. Spiral augers on outside convey the material to the surface while spinning. The center of the auger is hollow like a straw when the inner drive rods and plug are removed. During drilling or formation cutting, the center is filled with rods connected to a plug at the bottom bit. Once the desired drilling depth is reached, the center plug and rods can be pulled out, leaving the hollow augers in place. The hollow augers hold the borehole to remain open for sediment sampling and well installation.

b) Air Rotary

A drill big at the bottom of rods is used to cut into the subsurface material. Air injected into the drill rods escape through small holes in the drill bit and conveys the drill cuttings to the surface.

2) Soil Sampling

Soil samples will be obtained for lithologic logging and laboratory analysis for chemical contaminants with one of two different sampling devices: Split barrel spoon sampler or Geoprobe ® soil sampler. For either method, the sampling devices are lowered through the hollow-stem augers or open borehole to allow sampling of the undisturbed sediments below the auger bit.

a) Split barrel spoon sampler (split spoon)

The split spoon sampler will be driven into the soil column in accordance with ASTM Standard Method D1586 (Reference A6, Appendix E). Soil sampling by split barrel spoon will entail drilling a borehole with a hollow-stem auger to the desired sampling depth (standard five foot intervals). After augering to the desired depth, slowly and carefully lower the split barrel spoon sampler attached to the drill rod extension into the borehole. Drive the sampler into the soil by repeated blows from a 140 Lb. hammer with 30 inch travel. Record the blow counts required to drive the split spoon sampler each successive six inch interval. Remove sampler for borehole, split barrel open, remove soil sample utilizing a stainless steel knife to trim the top and edges of the sample and containerize sample in appropriate sample jar.

b) Geoprobe

The geoprobe sampling allows collection of soil by directly pushing a sampling device lined with a plastic tube into the soil column. The liner is dedicated to each soil sampling interval. After retrieval of the sample, the liner may be sliced open and the soil sample can be logged and containerized in the appropriate sample jar. During shallow soil sampling from fine-grained sediments, the geoprobe can advance the sampler directly into the ground, without the advance of an augered borehole.

3) Well Construction

After drilling to the desired depth or the desired interval, permanent monitoring wells can be installed to allow groundwater sampling. In general, wells are constructed with slotted screen, which allows groundwater to flow into the well at the desired monitored interval and well casing, which restricts groundwater flow into the well from undesired interval. In most cases the well materials are constructed of PVC. In conditions where the shallowest groundwater interval is monitored, a single case construction monitoring well is installed. In conditions where multiple water bearing units occur and deep groundwater conditions are selected for monitoring, a double cased well is installed.

a) Single Casing Construction

The construction details of a monitoring well are determined by soil type, depth to groundwater and relative fluctuation of groundwater level. After drilling to the desired depth, a monitoring well is constructed for installation into the evacuated borehole. The well consists of a bottom cap, a length of screen and length of well casing. To determine the length of screen used, seasonal groundwater table or tidal fluctuations should be considered to allow the water table to intercept the well screen throughout the year. The assembled well is then inserted into the borehole.

The annular space between the well screen and subsurface is filled with a sand pack, which consists of clean, sorted sand. The sand pack allows water flow into the well but acts as a filter to prevent subsurface sediments from silting in the well. The sand pack extends one to two feet above the top of well screen. Above the sand pack, a seal is installed in the annular space between the well casing and the subsurface. The seal is comprised of hydrated bentonite and prevents surface water from infiltrating the well screen. Above the well seal, the annular space is backfilled with drill cuttings or cement. A cap is placed on the top of the well to further prevent infiltration of the surface water. The top of the well is protected with either a stand-up pipe or a locking, flush mount box.

b) Double Casing Construction

In cases where multiple water bearing zones occur, a double case well is installed to allow monitoring of the deeper water bearing zones. Construction of a double cased well is similar to that of a single case well; however, to prevent groundwater infiltration from shallower water bearing zones, a second casing is installed. This type of construction requires drilling two different diameter boreholes.

During drilling through the shallower groundwater zones, large diameter augers/bits are used to create a large diameter borehole. The borehole is advanced through the shallower water bearing area which will not be monitored. An outer casing is installed to seal the deeper monitoring well from infiltration from the shallow water bearing zones. After the outer casing is installed, the borehole is advanced deeper with smaller diameter auger/bit. The outside diameter of second augers fit within the inside diameter of the outer casing. The borehole is advanced to allow monitoring of the deeper water bearing zone. Once the desired depth is obtained, a monitoring well is installed within the outer casing, using similar methods as described in the single casing construction (3a, above). The outside casing prevents shallow groundwater infiltration into the well. The inside casing prevents surface water infiltration into the well.

4) Soil Cutting Handling

Cuttings generated from drilling will be containerized or stock-piled, undercover, until appropriate disposal is determined. In the case the soils are not impacted, the cuttings may remain on-site. Impacted soils will be removed using appropriate hazardous waste handling procedures and disposed of with an approved hazardous waste handler.

5) Well Development

After installation, monitoring wells are developed to remove residual sediments within the well and annular space. Water is pumped from the well a low flow rate (to minimize turbulence within the well and associated sand pack) until groundwater flowing from the well appears relatively free of sediments.

Documentation:

All site activities should be detailed in the site investigators fieldbook. The entry shall include the date, time, weather, address, and persons present on-site. In addition, data required to create well construction logs or boring logs (if no well is constructed) should be collected. This data includes soil type, relative moisture content, depth of water table, observed impact, soil screening measurements (if PID is used), blow counts (if split spoon samples are collected), sample recovery, depth of borehole, length of well screen, length of well casing(s), sand pack interval, well seal interval. The site investigator should identify the relative location and number.

A.4. SOIL GAS MONITORING POINT INSTALLATION AND SAMPLING

Responsible Personnel: Geologist

Training Qualifications: All field personnel supervising drilling activities shall have completed OSHA 40-Hour training, and three days of field training. Personnel supervising the monitoring point installation shall have observed drilling procedures for a minimum of three under the direct supervision of experienced personnel. Field personnel will have experience in operating the following field equipment: interface probe and photo-ionization detector (PID). Personnel should be able to describe soils encountered during drilling for generation of boring/monitoring point logs.

Health and Safety Requirements:

A site specific HASP must be completed and reviewed by all field personnel. Prior to deploying a rig to the site, a utility call must be made (i.e. Pennsylvania One-Call) to allow mark-out of known subsurface utilities and associated laterals proximal to the site. Site plans, if available, should be reviewed to document and avoid the location of on-site utilities. No drilling should occur on retails sites within the exclusion zone. This zone is defined as the area between the pumps, the tank field and the station building. The area is excluded from drilling activities due to the likely occurrence of subsurface petroleum distribution lines. After review of all known mapped and marked utilities, a site reconnaissance will be performed to document the location of utility meters and storm sewer drains. In addition, the location of overhead utilities must be documented. After completing the subsurface and overhead utility review, the area to drill may be observed as clear or the location may be adjusted to a "clear" location.

Once the drilling location is established, the area must be marked with cones to alert area traffic of the work area. Other health and safety concerns include slip/trip hazards, working with heavy equipment and overhead work hazards. During drilling activities, a minimum of protective work gloves, steel toed boots, hard hats, and safety goggles must be worn.

A final health and safety requirement includes hand clearing the borehole, prior to advancing the borehole with the drill rig. To ensure the safety of workers, the borehole will be cleared by hand or air knife, to depth of 5 feet below ground surface. This will serve to clear the area of utilities, prior to drilling.

Decontamination Requirements:

All down-hole equipment must be steamed cleaned prior to drilling at each boring/well location. All monitoring point construction materials (i.e. steel well casing, steel well screen, sand pack, bentonite seal) should be clean and dedicated to each hole.

Methodology:

1) Borehole Advancement

During monitoring point installation activities, a borehole is advanced into the unconsolidated subsurface materials via a Geoprobe® rig to a maximum depth of 15 feet. Soil core samples will be collected continuously and inspected in the field.

2) Soil Gas Monitoring Point Construction

Each monitoring point will be constructed using five feet of 2-inch diameter PVC solid riser and 10 feet of 2-inch diameter slotted PVC screen to the desired sample depth by direct push methods. Flexible tubing (<0.5-inch diameter Teflon-lined poly) will extend from the top of the PVC riser to the ground surface. A sand pack will be placed around the slotted portion of the monitoring point to at least on foot above the top of screen. A bentonite/grout slurry will be used to create an annular seal from the top of the sand pack to approximately one foot bgs. The monitoring point will be completed with flush-mount protective casing secured by a concrete collar.

3) Soil Sampling

Three undisturbed soil samples will be prepared and analyzed for key physical parameters that affect vapor migration. One soil sample will be collected from one of the proposed soil gas monitoring points in the vicinity of the Credit Union Building, and one soil sample will be collected from one of the soil gas monitoring points adjacent to each office building. All three soil samples will be collected from a depth equivalent to the approximate elevation of the buildings' basement floors or bottoms of their foundations. The undisturbed soil samples will be collected using a piston-type sampler deployed by a static hydraulic push.

The analytical program for soils has been designed to provide site-specific input parameters for soil vapor intrusion modeling using the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings. Input parameters derived from soil analyses will be:

- *Soil vapor permeability* - the ability of a soil to transmit vapors though its pore spaces.
- *Soil dry bulk density* - the weight of a unit volume of soil, including its pore space, devoid of any liquids (e.g., groundwater, etc.).
- *Soil total porosity* - the total volume of pore space within a unit volume of soil.
- *Soil water filled porosity* - the percentage of pore space that is occupied by groundwater within a unit volume of soil.

4) Monitoring Point Development

After installation, a minimum of three volumes of air will be purged from each monitoring point to ensure soil gas inflow. This will be accomplished by attaching an air sampling pump to the flexible tube and pumping for the calculated duration.

5) Soil Gas Sampling

Soil gas samples will be collected from the soil gas monitoring points during at least two events to characterize soil gas conditions which can vary seasonally. Optimally, soil gas samples should not be collected within 24-hours after a significant precipitation event or during the wet-rainy season. Based upon historic monthly regional precipitation trends, the optimal time of year to collect soil gas samples is early winter (January/February), mid summer (July/August), and early fall when rainfall is typically lowest during the year.

All soil gas samples will be collected following the procedure described in USEPA Standard Operating Procedure SOP 2042 (2/16/04) which is included in Attachment A.1. Prior to, and following sampling, soil gas will be collected in a tedlar bag for screening with a photoionization detector (PID).

6) Soil Cutting Handling

Cuttings generated from drilling will be containerized or stock-piled, undercover, until appropriate disposal is determined. In the case the soils are not impacted, the cuttings may remain on-site. Impacted soils will be removed using appropriate hazardous waste handling procedures and disposed of with an approved hazardous waste handler.

Documentation:

All site activities should be detailed in the site investigators fieldbook. The entry shall include the date, time, weather, address, and persons present on-site. In addition, data required to create monitoring point construction logs. This data includes soil type, relative moisture content, depth of water table, observed impact, soil screening measurements (if PID is used), sample recovery, depth of borehole, length of well screen, length of well casing(s), sand pack interval, well seal interval. The site investigator should identify the relative location and number.

A.5. NON-AQUEOUS PHASE LIQUID (NAPL) SAMPLING PROCEDURES

Responsible Personnel: Technicians and Geologists

Training Qualifications:

All field personnel involved NAPL sampling, as a minimum completed OSHA 40 HOUR HAZWOPER training. Prior to NAPL sampling, all field personnel will have worked a minimum of three sites under the direct supervision of experienced personnel. Field personnel will also have experience in sampling and vapor monitoring techniques and sampling equipment decontamination.

Materials and Equipment Necessary for Task Completion:

A list of equipment required to sample NAPL from a monitoring well is presented below:

- Current site map detailing well locations.
- Field data book for recording site data.
- Liquid level gauging device (graduated, optical interface probe).
- Keys and tools to provide well access.
- Appropriate sample containers and labels. NAPL samples will be collected in laboratory provided 40 milliliter (ml) glass vials with plastic caps fitted with Teflon ® lined septa; all sample bottles will be laboratory sterilized and will contain the appropriate preservative, if applicable. A minimum of 10 ml is required for laboratory analysis. In the case that sufficient volume is not obtained, a swabbing technique (described below) will be used.
- Sorbent pads (required for swabbing technique).
- Teflon ® (or equivalent) bottom-loading bailer to obtain NAPL sample.
- Clean nylon or polypropylene bailer cord.
- Decontamination supplies.
- H&S supplies (tyvek, nitrile gloves, safety goggles)
- Blank chain-of-custody forms.
- Cooler and ice for sample preservation.

Health and Safety Requirements:

Site specific HASP must be completed and reviewed by field personnel. As a minimum, modified Level "D" attire will be worn. Individuals performing NAPL sampling are required to wear safety goggles, tyvek suit, and nitrile sampling gloves.

Decontamination Requirements:

During NAPL sampling activities, dedicated sampling equipment (i.e. Teflon ® bailers, nitrile gloves, and bailer cord) are utilized; thereby, eliminating decontamination requirements. The interface probe, used to record the presence of NAPL and relative thickness prior to sampling, does require decontamination between sampling locations.

All site equipment used in a multi-well capacity will be decontaminated immediately prior to initial use and between each well. Standard site decontamination procedures for the optical interface probes between wells will be performed according to the following schedule:

- Initial rinse with clean tap water to remove excess residuals.
- Scrub equipment with sponge or clean, soft cloth in a distilled water/Liquinox@ (or equivalent) solution.
- Double rinse with deionized/distilled water.

Methodology:

Each monitoring well to be sampled will be gauged to obtain liquid level and relative NAPL thickness immediately prior to initiation of the sampling process. Refer to SOP No. 1 for appropriate well gauging procedures. Liquid level data will be recorded in a field book.

Sampling of the NAPL will occur via two different methods: 1) direct sample or 2) swabbing.

The following sequence of procedures will be implemented for the collection of groundwater samples from monitoring wells.

1) Establish a clean work area where sampling equipment will not come in contact with the ground or any potentially contaminated surfaces.
2) Use a laboratory, pre-cleaned Teflon@ sampling bailer for each well.
3) Don an unused, clean pair of nitrile gloves.
4) Attach an appropriate length of unused, clean nylon or polypropylene cord to the designated sampling bailer.
5) Select appropriate laboratory-sterilized sample containers.
6) Slowly lower sampling bailer into well until water surface is encountered; continue to lower the sampling bailer into the standing water column to one foot below the water surface.
7) Retrieve bailer at a steady rate to avoid excess agitation.
8) Visually inspect bailed sample to ensure for relative thickness of NAPL. If sufficient volume is present (>10 ml) place a direct sample of the NAPL into the laboratory vial. If less than 10 ml of NAPL is present, use a sorbent pad to absorb the NAPL from the surface of the groundwater sample. Place is swab sample into the laboratory vial.
9) Complete and attach labels to sample containers noting sample collector and date. time, and location of sample; record same data in field book.

10) Place samples in ice-filled cooler in such a manner as to avoid breakage. Samples collected for VOC analysis will be maintained at a temperature of 4oC.
11) Discard gloves and bailer cord and move to next sample location.

Documentation:

All site activities should be detailed in the site investigators fieldbook. The entry shall include the date, time, weather, address, persons present on-site, and the aforementioned parameters. Only relevant observations should be recorded. The nature of the work being performed is also appropriate.

A.6. PUMPING TESTS

Responsible Personnel: Hydrogeologists, Engineers and Technicians.

Training Qualifications: All field personnel performing pumping tests shall have completed OSHA 40-Hour training, and three days of field training. Personnel directing the pumping test shall have assisted with a minimum of three tests under the direct supervision of experienced personnel. Field personnel will have experience in operating the following field equipment: interface probe, data logger, submersible pump, related piping and fittings, flow meter and portable generator.

Health and Safety Requirements:

A site specific HASP must be completed and reviewed by all field personnel. Caution must be exercised in set up of electrical equipment, particularly the placement of pumps in a well which could be impacted by floating product. Other health and safety concerns include slip/trip hazards, and area traffic.

Decontamination Requirements:

Pump, discharge lines, hand held probes and all pressure transducers must be cleaned with Alconox and distilled water prior to installation in wells at site, and again following removal. Any water sampling activities to be incorporated during the test must be prepared and used in accordance with the Groundwater Monitoring SOP.

Methodology:

A) Pre-test Considerations:

Some site specific information regarding the geology and hydrogeology of the subject site is needed to determine the most appropriate type of pumping test and to estimate the reliability of the test results. Lithologic logs of the subject site will indicate whether the zone of interest is an unconsolidated formation or a bedrock formation. They should also give a strong indication as to whether the zone of interest is a water table formation, a confined formation or a leaky-confined formation, and whether any preferential (vertical or horizontal) transmissivity may be expected. Logs and/or slug test data will also provide indications as to what test yield is sustainable, and provide a rough indication of the areal extent pumping will influence. Additional pre-test considerations include any obvious positive or negative hydraulic barriers, any tidal effects, and /or any influence from other wells pumping in the area.

Often times, budget considerations and/or time limitations will necessitate the use of a monitoring well as the test pumping well. While this is generally acceptable, the well must be screened deep enough to allow design drawdown to be achieved and friction losses (well loss) in the pumping well must be taken into consideration when the test data are analyzed. A minimum of three monitoring wells in the vicinity of the test pumping well are needed to evaluate formation response. Ideally, the wells should all be at varying distances from the test pumping well and screened across the same zone.

Pumping tests are broken into two general classifications: step tests and constant rate tests. Step tests involve pumping a well at progressively higher rates, at set intervals of one or two hours per step. They are often used to determine the yield a well will sustain during a constant rate test and to evaluate well loss (frictional head loss between the screen/gravel pack and the formation). Constant rate tests are used primarily to evaluate aquifer coefficients for design of groundwater treatment systems and/or water supply purposes. In high sensitivity sites, where budgets permit, the best method is to do a step test first, to evaluate well loss and long term sustainable yield, allow 24 hours of recovery and then initiate the constant rate test.

The test duration is subject to site specific data requirements (i.e. sensitivity. required test goals, etc.) and to budget considerations. Optimally, a constant rate test will be run until all drawdowns have stabilized, and gravity drainage effects are curtailed; however, this is seldom practical due to time limitations. In most instances, an 8 hour constant rate test will be adequate, and a 24 hour test will be sufficient for higher sensitivity sites. Occasionally a 72 hour pumping test is warranted, though this is usually reserved for large scale water supply work. If there are any unexplained water level anomalies observed toward the scheduled end of a test, the test should be continued if at all possible.

The approximate test flow rate needs to be determined in advance for proper pump and discharge design selection. If it is not appropriate to perform a step test, sustainable yield can be estimated from slug test data or a brief (<30 minutes) pumping episode the day before the actual test. Generally, it is best to pump the well at as high a rate as is feasible order to obtain the greatest formation response data from the test. However, if floating product is present at or near the pumping well, drawdown needs to be limited so as not to impact uncontaminated soils below the water table. In these instances drawdown should be limited to less than 5 feet. In water table formations, if there is no concern regarding floating product, drawdown should not exceed two-thirds of the wetted screen depth due to the effects of friction loss.

If the test discharge is contaminated, it must either 1) treated prior to discharge or 2) containerized for off-site disposal. If it is to be discharged directly on- site and allowed to re-infiltrate (verses discharged to a catch basin) it must be routed sufficiently far enough from the test area as to avoid any artificial recharge effects. All appropriate discharge permits must be obtained and complied with. If discharge water is to be treated on-site, proper contaminant loading calculations for the test flow rate, approximate contaminant loading and test duration must be done in advance to insure treatment is completely effective. Any on-site treatment should also have at least one discharge effluent sample lab analyzed to document treatment effectiveness.

B) Pumping Test Set Up:

Prior to starting the test, all well measuring points (i.e. top of casing) should be clearly marked and vertically surveyed to the nearest 0.01 feet. The horizontal distance and orientation of all wells should be surveyed to the nearest 0.1 feet, and illustrated on the site base map. If there are any surface water bodies in the vicinity, a staff gauge should be set up and surveyed in to evaluate possible influences.

The preferred pump to be used for a pumping test is a submersible centrifugal pump ("Grundfos", or equivalent), run off either existing site power or a portable generator. These pumps are not explosion proof, so a conductivity probe must be tied into the pump controls to alleviate any possibility of product coming into contact with the pump. If the test pump is designed to pump total fluids (e.g. air operated double diaphragm pump, jack pumps, etc.) discharge must either be containerized, or treatment must include an oil/water separator to handle any floating product. The submersible pump should be positioned just above the bottom of the well, using a handling line to support the pumps weight.

NOTE: extreme care must be taken that the power cord is neither bearing any of the pumps weight, nor damaged during installation due to the potential for sever electric shock.

Discharge piping from the pump should include a flow meter (preferably with totalizer), followed by a flow adjustment valve. The flow meter should be installed in a straight section of hard piping of sufficient length to avoid meter distortion caused by turbulence (typically about 10 pipe diameters on either side of the meter). In low flow pumping tests, flow rate can be calculated by measuring the exact time required to fill a known sized container.

Ideally, groundwater levels should be static prior to starting the test, so that pumping influences alone can be readily evaluated. Water levels in all monitoring wells and/or nearby surface waters should be gauged a minimum of two times during the 24 hours prior to starting test pumping; readings should not have varied by more than 0.10 feet. Any significant precipitation events within the previous several days will usually result in noticeable water level changes (barometric changes have significant influences in confined and semi-confined formations). If there are any major water level changes that cannot be accounted for prior to test pumping, additional investigation into possible area influences (e.g. local well pumping or construction de-watering) should be conducted.

Exact water level measurements (to the nearest 0.01 feet) and exact time denotations during the test are critical to achieving accurate test results. All personnel involved with taking measurements during the test should have watches with a second hand, and they should all be calibrated to the same time. Adequate liquid level measurements can be obtained using an interface probe ("ORS", "Solinst", etc.) for those wells with floating product. In wells clear of floating product, an electric water level detector ("Solinst", "Hazco", "M-Scope", etc.) or chalked steel tape will provide accurate measurements. All non-dedicated probes must be properly decontaminated after each level reading to prevent any possibility of cross contamination between wells.

Automatic water level recorders are typically used during pumping tests to augment hand measurements and to obtain reliable early time-drawdown data. A pressure transducer allows measure of changes in groundwater levels by measuring differences in pressure experienced by the transducer. The pressure transducers are manufactured by "In-Situ" and are available with many types of data loggers. Some data loggers are capable of connecting to several transducers (Hermits) while others collected data from one transducer (Trolls and Mini-Trolls). The measured depth data for each probe is digitally stored in the data logger as depth (in feet) at a specific elapsed time. At the conclusion of the test, the data logger is brought back to the office, and the test data is down loaded into a computer for analysis.

The transducer is installed in each well to a depth several feet lower than the greatest drawdown depth anticipated. The transducer cable is secured at this depth with duct tape or cable ties attached to the well head, and the transducer is plugged into the data logger. The transducer must not be submerged deeper than the allowable operating pressure, which is noted on each transducer cable spool in PSI. Care must be taken that the transducer cable is not damaged from rough edges at the well head, and that no vehicles run over the cable. In addition, any wells with floating product require an inner PVC stilling well to be installed to prevent the transducer cable from being damaged from contact with product. The stilling well will also eliminate the need for any water level corrections for product thickness.

In terms of prioritization, transducers should be utilized in the wells closest to the pumping well and then pumping well. Wells further from the pumping well can be successfully monitored by hand, due to the reduced likelihood that early time drawdown will be critical. Despite having transducers in given wells, back up hand readings should be taken at least hourly during the first 8 hours of the test, and then at least every 3 hours, to verify the transducer levels.

After the transducers are installed in the wells, and connected to the data logger, hand measurements are taken at each well with a transducer. These levels are then entered into the data logger as initial reference points for comparison to the depths measured by the transducers. Readings from the transducers are not completely reliable until they have be emerged for at least 30 minutes, due to the effects of probe temperature equilibrium.

C) Running the Test:

Prior to starting the pumping test, the data logger must be completely formatted for that particular test, and the operator must be completely familiar with the start up sequence. If possible, the pump discharge control valve should be pre-set to the desired flow rate prior to turning on the pump. However, depending on the test pumps performance curves, minor flow rate adjustments are generally needed during the first hour or two of the test to correct for the additional head experienced by the pump due to increasing drawdown. In addition, movement of the discharge hose after the test has been started should be avoided, since any change in the elevation of the discharge will affect the pumping rate. All changes in flow rate should be recorded with the exact time noted.

A minimum of two field personnel are needed to run a pumping test, with additional personnel required for tests with high complexity. One person should be designated to turn on the pump, adjust the flow rate, check on discharge treatment, etc. The second person should be stationed at the data logger to turn it on at the exact moment the pump is turned on. The data logger will record liquid levels very rapidly during the first part of the test, dropping off logarithmically to what ever intervals are formatted (one measurement every 20 minutes is normal). When the data logger has been activated and is running, early time drawdown measurements should be taken by hand from any wells near the pumping well that do not have transducers.

Any hand monitored wells near the pumping well should be measured frequently during the first few hours of the test, with less frequent measurements during the remainder of the test. A rough rule of thumb is one measurement every half minute during the first 5 to 10 minutes, one every 3 to 5 minutes during the first hour, and one every 10 to 20 minutes for the second hour, and then each well hourly. After the test has been running for a few hours, the transducer level readings should be compared to the hand measurements for verification, or later correction.

It is essential that some data reduction be accomplished in the field, so that major water level trends are recognized during the test. At a minimum, drawdown trends from the pumping well and two of the nearest monitoring wells need to be semi-log plotted against time so that deviations indicative of boundary conditions can be discerned before pumping is ceased. This will allow decisions to be made about whether the test should go for longer than planned.

Generally, water quality samples are taken during a test for laboratory analysis of compounds of interest. These are generally taken after the first hour of pumping and just prior to pump shutdown. If the test is of more than 24 hours duration, it is advisable to get running samples during the middle of the test as well. All samples should be obtained following sampling SOP's.

At the conclusion of the test, water level recovery data should be taken. The recovery data should plot out to an approximate inverse mirror image of the drawdown curve, with feet of recovery measured from the theoretical drawdown that would have been observed if pumping had continued. Recovery data behaves as if there were a nearby well recharging the formation, following image well theory. It has the advantage that there are no variations in the curve produced by variations in pumping rate. In water table aquifers, however, the effects of formation de-watering can cause the recovery trends to be substantially different from drawdown trends. Consequently, recovery data should be used for comparison purposes only, but not relied upon as heavily as drawdown data.

D) Data Analysis:

The data produced by pumping tests are analyzed to estimate aquifer performance characteristics, such as transmissivity, conductivity and storage, which in turn are used to predict groundwater flow under various circumstances. One of the more useful analytical products is a determination of capture zone, which is widely utilized in aquifer contamination work. Capture zone (Keely & Tsang, 1983) calculations describe the radial area (down gradient and side gradient) that a pumping well will draw groundwater in from. In the case of a contamination site, this equals to that portion of the plume a given recovery well(s) will influence, at a given pumping rate(s). Aquifer coefficients determined from a pumping test can be applied to a capture zone analysis for the determination of the best recovery system for a given plume. When the recovery system is operational, capture zone calculations can then be used to evaluate the effectiveness of the system at addressing the contamination plume, what pumping rate is optimal for controlling the plume, and the need for any additional wells. It must be noted, however, that capture zone calculations are relatively simplistic, and far from absolute. Consequently, they should be used with considerable margin for safety, and employed with a large measure of common sense.

The mathematical solutions used in pumping test analysis include many assumptions typical "real world" formations violate in one or more way (E.g. "the formation is of uniform thickness and of infinite areal extent"). In addition, some of the values incorporated into typical pumping test solutions are not actually measured, but are educated estimates (E.g. porosity based on lithology, etc.). Consequently, even the most carefully designed and executed pumping tests have severe precision limitations, and the solutions should never be considered absolute. This is why groundwater flow evaluations are generally conceded to be "a mixture of science and art", and all solutions require a strong application of common sense and experience.

Many problems associated with pumping test data evaluation are due to not recognizing, and/or correcting for, deviations from the theoretical solution employed. Some of the more common errors occur due to: partial penetration effects, formation de-watering effects, casing storage effects, poor pumping well efficiency and/or the application of incorrect equations or units. Consequently, a thorough understanding of the underlying assumptions inherent to the solution employed is required before the validity of the results can be trusted. There are numerous references that describe pumping test analyses. Some of the more recommended references include: Driscoll's "Groundwater & Wells" (1986); Lohmans "Ground-water Hydraulics" USGS Professional Paper 708 (1979) and Fetter's "Applied Hydrogeology" (1980). In addition, the USGS published "Aquifer-test Design, Observation, and Data Analysis" in 1983 by Robert W. Stallman (Applications of Hydraulics, Book 3, Chapter B 1). This is an excellent, common sense, guide to pumping test set up, measurements and data analysis.

Two of the more common pumping test equations used and their applications are listed below:

1) Cooper-Jacob (1946); time-drawdown & distance-drawdown methods: Test data is plotted on semi-log paper, and the slope is used in the solution. Both solutions assume the formation is confined; however, this distinction lessens over time as drawdown becomes stabilized. Distance-drawdown has an added advantage in that it allows water level to respond from across the site to be used, which accounts for some lithologic variations.

2) Boulton (1963), modified by Neuman (1975): This solution is used for determining aquifer coefficients in water table formations, taking gravity drainage (delayed yield) effects into

account. Time- drawdown data is plotted on log-log paper and two Theis type curves are matched to get early time-drawdown and late time drawdown, respectively. While this solution most closely matches typical floating product recovery work, it is difficult to apply and often subjective, due to the inherent nature of curve matching solutions.

It is usually appropriate to analyze pumping test data by more than one solution to get a range of aquifer performance values. These values can be averaged, or the most conservative value can be used, or the best fit based on experience can be presented. The computer program "Aqtesolv", produced by Geraghty & Miller, is a very useful tool for solving pumping test solutions. Data from an Insitu data logger can be imputed to the Aqtesolv, and curve matching solutions can be produced automatically, or with some adjustments.

A.7. SLUG TESTS

Responsible Personnel: Hydrogeologists, Engineers, and Technicians

Training Qualifications:

All field personnel performing pumping tests shall have completed 40 HOUR OSHA training and 3 day field requirements. Personnel directing slug tests shall have assisted in at least 3 previous slug tests under the supervision of experienced personnel.

Materials and Equipment Necessary for Task Completion:

"Insitu " Hermit data logger, with one pressure transducer; interface tape or equivalent water level measuring device; "slug in" water displacement cylinder, or large bailer, 5 gallon pail, traffic cones and/or barricades, decontamination water and brush, alconox and decontamination pail.

Health and Safety Requirements:

A site specific HASP must be completed and reviewed by all field personnel. Caution must be exercised in test set up, particularly regarding vehicular traffic. Other concerns regard possible handling of free product, and slip/trip hazards.

Decontamination Requirements: Any water level measuring probes, bailers and the water displacement cylinder must be cleaned with alconox and distilled water prior to use, and between uses at each well monitoring. Any groundwater and/or free product bailed must be disposed of in an approved manner, preferably in a properly installed, on-site holding tank.

Methodology:

Slug tests are utilized to obtain rough estimates of aquifer performance coefficients. They involve calculations based on the water level response of a well to the addition or subtraction of a known volume. They can be broken into two basic types of field exercises: slug-in tests and slug-out tests. As their names imply, slug-in tests involve the addition of water (volume) to the well, while slug-out tests involve the removal of water (volume). Water level response is monitored immediately following the displacement change, and for the next hour or so until the well has returned to approximately 90% of its original static level. Water level responses can be measured either rapidly by hand or with an "Insitu" Hermit data logger (or equivalent).

A) <u>Field Procedures:</u>

Exact well completion details are needed to perform slug test calculations. These include: total depth, total screened interval, depth to static water, casing diameter, screen diameter, gravel pack diameter and gravel pack interval. While these details should be documented on the well log, static water level and total depth should be field confirmed before the test. Where possible, several wells per site should be slug tested to obtain an average conductivity value for a site, or to evaluate lithologic variables across a site. Addition data comparisons are accomplished by performing both slug-in and slug-out tests on the same well, where time permits.

Slug-In Tests: The slug-in method is best accomplished by lowering a cylinder of known volume into the well, and measuring the water level response over time. The displacement volume should be sufficient to cause a several foot initial change in the water level. In the case of a typical 4 inch diameter monitoring well, a simple displacement cylinder can be constructed using a 3 inch diameter PVC casing, capped at both ends and filled with clean sand. An over all length of 5 feet provides adequate displacement volume for a typical water table well having about 10 feet of standing water. A steel eye should be bolted into one cylinder cap for attachment of a disposable lowering rope (discard lowering rope between wells to prevent any cross contamination).

If a Hermit data logger is to be used for a slug-in test, the transducer should be set in the well at least one foot below where the bottom of the displacement cylinder will rest upon insertion, but not lying on the bottom (beware of silt clogging the transducer tip). Depth to water should be measured and compared to the transducer reading for correlation. When the Hermit has been properly imputed for the slug test, the hermit should be activated and the displacement cylinder should be rapidly, but carefully, lowered into the well to below the water surface. *NOTE: Take particular care that insertion of the displacement cylinder does not damage the transducer or cable.* When activated, the Hermit will be automatically recording time and water levels, starting at 6 readings per second, then decreasing exponentially over time. If water level changes are to be taken by hand, they must be carefully obtained at least every minute. When the well has recovered to about 90% of its original static level, the test may be concluded. If the test has proceeded for an hour and not recovered to at least 90% of the original static, additional data will be of marginal value and the test may be concluded.

2) Slug-out Tests: Slug-out tests are performed in the same basic manner as slug-In tests, only by removing a known volume from the subject well. In wells that recharge rapidly during slug-in tests, a slug-out test can be performed by merely resetting the Hermit and extracting the displacement cylinder. The more conventional method of performing a slug-out test is to use a single long hand bailer to remove a known volume of water from the well. Typical bailers used for 4 inch diameter monitoring wells are either long steel bailers (similar to those often used by drillers to develop monitoring wells) or 2 Lexan sample bailers joined end to end to form one single long bailer. The bailer is lowered into the well prior to starting the Hermit, and the slight water level rise from the bailer is allowed to stabilize back to static. The Hermit is then activated, and the bailer is rapidly removed from the well, thereby creating the instantaneous. The test is run to 90% recovery, or one hour, like the slug-in test. If the bailed water is contaminated, it must be disposed of properly via either storage in an on site holding tank or on-site treatment with a portable carbon treatment container.

The validity of slug test values are highly field dependant. Some of the more common field oriented problems arise from:

1) Subject wells are not adequately developed prior to testing.

2) Formation slough occurred during drilling, so gravel pack volume is underestimated.

3) Water displacement is not instantaneous due to the bailer leaking during extraction.

4) The pressure transducer is jarred during water displacement.

5) Water level changes are too rapid to get accurate measurements.

B) Data Analysis: Field data from slug tests can be analyzed by hand or using "Geraghty & Millers" Aqtesolv computer program. If the field data was taken with the Hermit, the data can be transferred to Aqtesolv for analysis, saving considerable time over hand analysis. There are four well recognized analytical methodologies general employed. These methods and their assumptions are listed below:

Application	Hvorslev	Bouwer & Rice	Cooper	Nguygen-Pinder
Confined Fm.	**X**	**X**	**X**	**X**
Unconfined Fm.	**X**	**X**		**X**
Screened acroos water level		**X**		
Accounts for partial penetration	**X**	**X**		**X**
Specific torage >0			**X**	**X**
Allows for anisotropy	**X**			
Assumes infinite borehole storage	**X**	**X**	**X**	**X**

As illustrated on the chart above, slug tests performed in water table formations can be solved using either Hvorslev or Bouwer & Rice methods. The Bouwer & Rice method has the advantage of accounting for screening across the water table, while the Hvorslev method allows for anisotropy. Confined formation slug tests can be analyzed by any of the four methods, though the Cooper method is most often used. It is often beneficial to solve slug tests by more than one method to evaluate possible conductivity ranges.

It must be stressed that slug test data is very approximate and limited in its accuracy. It is generally conceded that conductivity' values derived from slug tests are usually within an order of magnitude of the real conductivity, and therefore are only approximations. Consequently, any judgments based on slug test values must be used with extreme caution and incorporate a large measure of common sense and experience.

Attachment A.1

USEPA SOP#2042: Soil Gas Sampling

SOP#: 2042
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SOIL GAS SAMPLING

1.0 SCOPE AND APPLICATION

Soil gas monitoring provides a quick means of waste site evaluation. Using this method, underground contamination can be identified, and the source, extent, and movement of the pollutants can be traced.

This standard operating procedure (SOP) outlines the methods used by U.S. EPA/ERT in installing soil gas wells; measuring organic vapor levels in the soil gas using a Photoionization Detector (PID), Flame Ionization Detector (FID) and/or other air monitoring devices; and sampling the soil gas using Tedlar bags, Tenax sorbent tubes, and/or Summa canisters.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent on site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0 METHOD SUMMARY

A 3/8" diameter hole is driven into the ground to a depth of four to five feet using a commercially available slam bar. Soil gas can also be sampled at other depths by the use of a longer bar or bar attachments. A 1/4" O.D. stainless steel probe is inserted into the hole. The hole is then sealed around the top of the probe using modeling clay. The gas contained in the interstitial spaces of the soil is sampled by pulling the sample through the probe using an air sampling pump. The sample may be stored in Tedlar bags, drawn through sorbent cartridges, or analyzed directly using a direct reading instrument. The air sampling pump is not used for Summa canister sampling of soil gas. Sampling is achieved by soil gas equilibration with the evacuated Summa canister.

Other field air monitoring devices, such as the combustible gas indicator (MSA CGI/02 Meter, Model 260) and the Organic Vapor Analyzer (Foxboro OVA, Model 128), can also be used dependent on specific site conditions. Measurement of soil temperature using a temperature probe may also be desirable. Bagged samples are usually analyzed in a field laboratory using a portable Photovac GC.

Power driven sampling probes may be utilized when soil conditions make sampling by hand unfeasible (i.e., frozen ground, very dense clays, pavement, etc.). Commercially available soil gas sampling probes (hollow, 1/2 = O.D. steel probes) can be driven to the desired depth using a power hammer (e.g., Bosch Demolition Hammer or Geoprobe™). Samples can be drawn through the probe itself, or through Teflon tubing inserted through the probe and attached to the probe point. Samples are collected and analyzed as described above.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

3.1 Tedlar Bags

Soil gas samples are generally contained in 1.0-L Tedlar bags. Bagged samples are best stored in dark plastic bags placed in coolers to protect the bags from any damage that may occur in the field or in transit. In addition, coolers insure the integrity of the samples by keeping them at a cool temperature and out of direct sunlight. Samples should be analyzed as soon as possible, preferably within 24 - 48 hours.

3.2 Tenax Tubes

Bagged samples can also be drawn onto Tenax or other sorbent tubes to undergo lab GC/MS analysis. If Tenax tubes are to be utilized, special care must be taken to avoid contamination. Handling of the tubes should be kept to a minimum and only while wearing nylon or other lint-free gloves. After sampling, each tube should be stored in a clean, sealed culture tube; the ends packed with clean glass wool to protect the sorbent tube from breakage. The culture tubes should be kept cool and wrapped in aluminum foil to prevent any photodegradation of samples (see Section 7.4.).

3.3 Summa Canisters

The Summa canisters used for soil gas sampling have a 6 liter sample capacity and are certified clean by GC/MS analysis before being utilized in the field. After sampling is completed, they are stored and shipped in travel cases.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

4.1 PID Measurements

A number of factors can affect the response of a PID (such as the HNu PI 101). High humidity can cause lamp fogging and decreased sensitivity. This can be significant when soil moisture levels are high, or when a soil gas well is actually in groundwater. High concentrations of methane can cause a downscale deflection of the meter. High and low temperature, electrical fields, FM radio transmission, and naturally occurring compounds, such as terpenes in wooded areas, will also affect instrument response.

Other field screening instruments can be affected by interferences. Consult the manufacturers manuals.

4.2 FID Measurements

A number of factors can affect the response of an FID (such as the OVA model 128). High humidity can cause the FID to flame out or not ignite at all. This can be significant when soil moisture levels are high, or when a soil gas well is actually in groundwater. The FID can only read organic based compounds (they must contain carbon in the molecular structure). The FID also responds poorly to hydrocarbons and halogenated hydrocarbons (such as gasoline, propane fuel). High and low temperature, electrical fields and FM radio transmission will also affect instrument response.

4.3 Factors Affecting Organic Concentrations in Soil Gas

Concentrations in soil gas are affected by dissolution, adsorption, and partitioning. Partitioning refers to the ratio of component found in a saturated vapor above an aqueous solution to the amount in the solution; this can, in theory, be calculated using the Henry's Law constants. Contaminants can also be adsorbed onto inorganic soil components or "dissolved" in organic components. These factors can result in a lowering of the partitioning coefficient.

Soil "tightness" or amount of void space in the soil matrix, will affect the rate of recharging of gas into the soil gas well.

Existence of a high, or perched, water table, or of an impermeable underlying layer (such as a clay lens or layer of buried slag) may interfere with sampling of the soil gas. Knowledge of site geology is useful in such situations, and can prevent inaccurate sampling.

4.4 Soil Probe Clogging

A common problem with this sampling method is soil probe clogging. A clogged probe can be identified by using an in-line vacuum gauge or by listening for the sound of the pump laboring. This problem can usually be eliminated by using a wire cable to clear probe (see Section 7.1.3.).

4.5 Underground Utilities

Prior to selecting sample locations, an underground utility search is recommended. The local utility companies can be contacted and requested to mark the locations of their underground lines. Sampling plans can then be drawn up accordingly. Each sample location should also be screened with a metal detector or magnetometer to verify that no underground pipes or drums exist.

5.0 EQUIPMENT/APPARATUS

5.1 Slam Bar Method

- Slam Bar (1 per sampling team).
- Soil gas probes, stainless steel tubing, 1/4" O.D., 5 ft length.
- Flexible wire or cable used for clearing the

tubing during insertion into the well.

- "Quick Connect" fittings to connect sampling probe tubing, monitoring instruments, and Gilian pumps to appropriate fittings on vacuum box.
- Modeling clay.
- Vacuum box for drawing a vacuum around Tedlar bag for sample collection (1 per sampling team).
- Gilian pump Model HFS113A adjusted to approximately 3.0 L/min (1 to 2 per sample team).
- 1/4" Teflon tubing, 2 ft to 3 ft lengths, for replacement of contaminated sample line.
- 1/4" Tygon tubing, to connect Teflon tubing to probes and quick connect fittings.
- Tedlar bags, 1.0 L, at least 1 bag per sample point.
- Soil Gas Sampling labels, field data sheets, logbook, etc.
- PID/FID, or other field air monitoring devices, (1 per sampling team).
- Ice chest, for carrying equipment and for protection of samples (2 per sampling team).
- Metal detector or magnetometer, for detecting underground utilities/pipes/drums (1 per sampling team).
- Photovac GC, for field-lab analysis of bagged samples.
- Summa canisters (plus their shipping cases) for sample, storage and transportation.
- Large dark plastic garbage bags

5.2 Power Hammer Method

- Bosch demolition hammer.
- 1/2" O.D. steel probes, extensions, and points.
- Dedicated aluminum sampling points.
- Teflon tubing, 1/4".
- "Quick Connect" fittings to connect sampling probe tubing, monitoring instruments, and Gilian pumps to appropriate fittings on vacuum box.
- Modeling clay.
- Vacuum box for drawing a vacuum around Tedlar bag for sample collection (1 per sampling team).
- Gilian pump Model HFS113A adjusted to approximately 3.0 L/min (1 to 2 per sample team).
- 1/4" Teflon tubing, 2 ft to 3 ft lengths, for replacement of contaminated sample line.
- 1/4" Tygon tubing, to connect Teflon tubing to probes and quick connect fittings.
- Tedlar bags, 1.0 L, at least 1 bag per sample point.
- Soil Gas Sampling labels, field data sheets, logbook, etc.
- HNu Model P1101, or other field air monitoring devices, (1 per sampling team).
- Ice chest, for carrying equipment and for protection of samples (2 per sampling team).
- Metal detector or magnetometer, for detecting underground utilities/pipes/drums (1 per sampling team).
- Photovac GC, for field-lab analysis of bagged samples.
- Summa canisters (plus their shipping cases) for sample, storage and transportation.
- Generator w/extension cords.
- High lift jack assembly for removing probes.

5.3 Geoprobe™ Method

The Geoprobe is a hydraulically-operated sampling device mounted in a customized four-wheel drive vehicle. The sampling device can be deployed from the truck and positioned over a sample location. The base of the sampling device is positioned on the ground. The weight of the vehicle is hydraulically raised on the base. As the weight of the vehicle is transferred to the probe, the probe is pushed into the ground. A built-in hammer mechanism allows the probe to be driven past some dense stratigraphic horizons. When the probe reaches the sample depth, up to 50 feet under favorable geologic situations, samples can be collected.

Soil gas can be collected from specific depths in two general ways. One method involves withdrawing a sample directly from the probe rods, after evacuating a sufficient volume of air from the probe rods. The other method involves collecting a sample through tubing attached by an adaptor to the bottom probe rod section. Correctly used, this method provides more reliable results. Manufacturer's instructions and the SOP for the Model 5400 Geoprobe™ Operation should be followed when using this method.

6.0 REAGENTS

- PID/FID or calibration gases for field air monitoring devices (such as methane and isobutylene).

- Deionized organic-free water, for decontamination.
- Methanol, HPLC grade, for decontamination.
- Ultra-zero grade compressed air, for field blanks.

- Standard gas preparations for Photovac GC calibration and Tedlar bag spikes.
- Propane Torch (for decontamination of steel probes)

7.0 PROCEDURES

7.1 Soil Gas Well Installation

1. Initially a hole slightly deeper than the desired depth is made. For sampling up to 5 feet, a 5-ft single piston slam bar is used. For deeper depths, a piston slam bar with threaded 4-foot-long extensions can be used. Other techniques can be used, so long as holes are of narrow diameter and no contamination is introduced.

2. After the hole is made, the slam bar is carefully withdrawn to prevent collapse of the walls of the hole. The soil gas probe is then inserted.

3. It is necessary to prevent plugging of the probe, especially for deeper holes. A metal wire or cable, slightly longer than the probe, is placed in the probe prior to inserting into the hole. The probe is inserted to full depth, then pulled up three to six inches, then cleared by moving the cable up and down. The cable is removed before sampling.

4. The top of the sample hole is sealed at the surface against ambient air infiltration by using modeling clay molded around the probe at the surface of the hole.

5. If conditions preclude hand installation of the soil gas wells, the power driven system may be employed. The generator powered demolition hammer is used to drive the probe to the desired depth (up to 12 Ft may be attained with extensions). The probe is pulled up 1-3 inches if the retractable point is used. No clay is needed to seal the hole. After sampling, the probe is retrieved using the high lift jack assembly.

6. If semi-permanent soil gas wells are required, the dedicated aluminum probe points are used. These points are inserted into the bottom of the power driven probe and attached to the Teflon tubing. The probe is inserted as in step 5. When the probe is removed, the point and Teflon tube remain in the hole, which may be sealed by backfilling with clean sand, soil, or bentonite.

7.2 Screening with Field Instruments

1. The well volume <u>must</u> be evacuated prior to sampling. Connect the Gilian pump, adjusted to 3.0 L/min, to the sample probe using a section of Teflon tubing as a connector. The pump is turned on, and a vacuum is pulled through the probe for approximately 15 seconds. Longer time is required for sample wells of greater depths.

2. After evacuation, the monitoring instrument(s) (i.e. HNu or OVA) is connected to the probe using a Teflon connector. When the reading is stable, or peaks, the reading is recorded on soil gas data sheets.

3. Of course, readings may be above or below the range set on the field instruments. The range may be reset, or the response recorded as a greater than or less than figure. Recharge rate of the well with soil gas must be considered when resampling at a different range setting.

7.3 Tedlar Bag Sampling

1. Follow step 7.2.1 to evacuate well volume. If air monitoring instrument screening was performed prior to sample taking, evacuation is not necessary.

2. Use the vacuum box and sampling train (Figure 1) to take the sample. The sampling train is designed to minimize the introduction of contaminants and losses due to adsorption. All wetted parts are either Teflon or stainless steel. The vacuum is drawn indirectly to avoid contamination from sample pumps.

3. The Tedlar bag is placed inside the vacuum box, and attached to the sampling port. The sample probe is attached to the sampling port via Teflon tubing and a "Quick Connect" fitting.

4. A vacuum is drawn around the outside of the bag, using a Gilian pump connected to the vacuum box evacuation port, via Tygon tubing and a "Quick Connect" fitting. The vacuum causes the bag to inflate, drawing the sample.

5. Break the vacuum by removing the Tygon line from the pump. Remove the bagged sample from the box and close valve. Record data on data sheets or in logbooks. Record the date, time, sample location ID, and the PID/FID instrument reading(s) on sample bag label.

CAUTION: Labels should not be pasted directly onto the bags, nor should bags be labeled directly using a marker or pen. Inks and adhesive may diffuse through the bag material, contaminating the sample. Place labels on the edge of the bags, or tie the labels to the metal eyelets provided on the bags. Markers with inks containing volatile organics (i.e., permanent ink markers) should not be used.

Chain of Custody Sheets must accompany all samples submitted to the field laboratory for analysis.

7.4 Tenax Tube Sampling

Samples collected in Tedlar bags may be adsorbed onto Tenax tubes for further analysis by GC/MS.

7.4.1 Additional Apparatus

A. Syringe with a luer-lock tip capable of drawing a soil gas or air sample from a Tedlar bag onto a Tenax/CMS sorbent tube. The syringe capacity is dependent upon the volume of sample begin drawn onto the sorbent tube.

B. Adapters for fitting the sorbent tube between the Tedlar bag and the sampling syringe. The adapter attaching the Tedlar bag to the sorbent tube consists of a reducing union (1/4" to 1/16" O.D. -- Swagelok cat. # SS-400-6-ILV or equivalent) with a length of 1/4" O.D. Teflon tubing replacing the nut on the 1/6" (Tedlar bag) side. A 1/4" I.D. silicone O-ring replaces the ferrules in the nut on the 1/4" (sorbent tube) side of the union.

The adapter attaching the sampling syringe to the sorbent tube consists of a reducing union (1/4" to 1/16" O.D. -- Swagelok Cat. # SS-400-6-ILV or equivalent) with a 1/4" I.D. silicone O-ring replacing the ferrules in the nut on the 1/4" (sorbent tube) side and the needle of a luer-lock syringe needle inserted into the 1/16" side. (Held in place with a 1/16" ferrule.) The luer-lock end of the needle can be attached to the sampling syringe. It is useful to have a luer-lock on/off valve situated between the syringe and the needle.

C. Two-stage glass sampling cartridge (1/4" O.D. x 1/8" I.D. x 5 1/8") contained in a flame-sealed tube (Manufacturer: Supelco Custom Tenax/Spherocarb Tubes) containing two sorbent sections retained by glass wool:

Front section: 150 mg of Tenax-GC
Back section: 150 mg of CMS (Carbonized Molecular Sieve)

These tubes are prepared and cleaned in accordance with EPA Method EMSL/RTP-SOP-EMD-013 by the vendor. The vendor sends ten tubes per lot made to the REAC GC/MS Laboratory and they are tested for cleanliness, precision, and reproductability.

D. Teflon-capped culture tubes or stainless steel tube containers for sorbent tube storage and shipping. These containers should be conditioned by baking at 120 degrees C for at least two hours. The culture tubes should contain a glass wool plug to prevent sorbent tube breakage during transport. Reconditioning of the containers should occur between uses or after extended periods of disuse (i.e., two weeks or more).

E. Nylon gloves or lint-free cloth. (Hewlett Packard Part # 8650-0030 or equivalent.)

7.4.2 Sample Collection

Handle sorbent tubes with care, using nylon gloves (or other lint-free material) to avoid contamination.

Immediately before sampling, break one end of the sealed tube and remove the Tenax cartridge.

Connect the valve on the Tedlar bag to the sorbent tube adapter. Connect the sorbent tube to the sorbent tube adapter with the Tenax (white granular) side of the tube facing the Tedlar bag. Connect the sampling syringe assembly to the CMS (black) side of the sorbent tube. Fittings on the adapters should be finer-tight. Open the valve on the Tedlar bag. Open the on/off valve of the sampling syringe. Depending on work plan stipulations, at least 10% of the soil gas samples analyzed by this GC method must be submitted for confirmational GC/MS analysis (according to modified methods TO-1 [Tenax absorbent] and TO-2 [Carbon Molecular Sieve (CMS) absorbent]). Each soil gas sample must be absorbed on replicate Tenax/CMS tubes. The volume absorbed on a Tenax/CMS tube is dependent on the total concentration of the compounds measured by the photovac/GC or other applicable GC:

Total Concentration (ppm)	Sample Volume (mL)
>10	Use Serial Dilution
10	10 - 50
5	20-100
1	100-250

After sampling, remove the tube from the sampling train with gloves or a clean cloth. DO NOT LABEL OR WRITE ON THE TENAX/CMS TUBE.

Place the sorbent tube in a conditioned stainless steel tube holder or culture tube. Culture tube caps should be sealed with Teflon tape.

7.4.3 Sample Labeling

Each sample tube container (not tube) must be labeled with the site name, sample station number, date sampled, and volume sampled.

Chain of custody sheets must accompany all samples to the laboratory.

7.4.4 Quality Assurance (QA)

Before field use, a QA check should be performed on each batch of sorbent tubes by analyzing a tube by thermal desorption/cryogenic trapping GC/MS.

At least one blank sample must be submitted with each set of samples collected at a site. This trip blank must be treated the same as the sample tubes except no sample will be drawn through the tube.

Sample tubes should be stored out of UV light (i.e., sunlight) and kept on ice until analysis. Samples should be taken in duplicate, when possible.

7.5 Summa Canister Sampling

1. Follow step 7.2.1 to evacuate well volume. If PID/FID readings were taken prior to taking a sample, evacuation is not necessary.

2. Attach a certified clean, evacuated 6-liter Summa canister via the 1/4" Teflon tubing.

3. Open valve on Summa canister. The soil gas sample is drawn into the canister by pressure equilibration. The approximate sampling time for a 6 liter canister is 20 minutes.

4. Site name, sample location, number, and date must be recorded on a chain of custody form and on a blank tag attached to the canister.

8.0 CALCULATIONS

8.1 Field Screening Instruments

Instrument readings are usually read directly from the meter. In some cases, the background level at the soil gas station may be subtracted:

Final Reading = Sample Reading - Background

8.2 Photovac GC Analysis

Calculations used to determine concentrations of individual components by Photovac GC analysis are beyond the scope of this SOP and are covered in ERT SOP #2109, *Photovac GC Analysis for Soil Water and Air/Soil Gas*.

9.0 CALIBRATION

9.1 Field Instruments

It is recommended that the manufacturers' manuals be consulted for correct use and calibration of all instrumentation.

9.2 Gilian Model HFS113A Air Sampling Pumps

Flow should be set at approximately 3.0 L/min; accurate flow adjustment is not necessary. Pumps should be calibrated prior to bringing into the field.

10.0 QUALITY ASSURANCE/ QUALITY CONTROL

10.1 Sample Probe Contamination

Sample probe contamination is checked between each sample by drawing ambient air through the probe via a Gilian pump and checking the response of the FID/PID. If readings are higher than background, replacement or decontamination is necessary.

Sample probes may be decontaminated simply by drawing ambient air through the probe until the HNu reading is at background. More persistent contamination can be washed out using methanol and water, then air drying. For persistent volatile contamination, use of a portable propane torch may be needed. Using a pair of pliers to hold the probe, run the torch up and down the length of the sample probe for approximately 1-2 minutes. Let the probe cool before handling. When using this method, make sure to wear gloves to prevent burns. Having more than one probe per sample team will reduce lag times between sample stations while probes are decontaminated.

10.2 Sample Train Contamination

The Teflon line forming the sample train from the probe to the Tedlar bag should be changed on a daily basis. If visible contamination (soil or water) is drawn into the sampling train, it should be changed immediately. When sampling in highly contaminated areas, the sampling train should be purged with ambient air, via a Gilian pump, for approximately 30 seconds between each sample. After purging, the sampling train can be checked using an FID or PID, or other field monitoring device, to establish the cleanliness of the Teflon line.

10.3 FID/PID Calibration

The FID and PIDs should be calibrated at least once a day using the appropriate calibration gases.

10.4 Field Blanks

Each cooler containing samples should also contain one Tedlar bag of ultra-zero grade air, acting as a field blank. The field blank should accompany the samples in the field (while being collected) and when they are delivered for analysis. A fresh blank must be provided to be placed in the empty cooler pending additional sample collection. One new field blank per cooler of samples is required. A chain of custody sheet must accompany each cooler of samples and should include the blank that is dedicated to that group of samples.

10.5 Trip Standards

Each cooler containing samples should contain a Tedlar bag of standard gas to calibrate the analytical instruments (Photovac GC, etc.). This trip standard will be used to determine any changes in concentrations of the target compounds during the course of the sampling day (e.g., migration through the sample bag, degradation, or adsorption). A fresh trip standard must be provided and placed in each cooler pending additional sample collection. A chain of custody sheet should accompany each cooler of samples and should include the trip standard that is dedicated to that group of samples.

10.6 Tedlar Bag Check

Prior to use, one bag should be removed from each lot (case of 100) of Tedlar bags to be used for sampling and checked for possible contamination as follows: the test bag should be filled with ultra-zero grade air; a sample should be drawn from the bag and analyzed via Photovac GC or whatever method is to be used for sample analysis. This procedure will ensure sample container cleanliness prior to the start of the sampling effort.

10.7 Summa Canister Check

From each lot of four cleaned Summa canisters, one is to be removed for a GC/MS certification check. If the canister passes certification, then it is re-evacuated and all four canisters from that lot are available for sampling.

If the chosen canister is contaminated, then the entire lot of four Summas must be recleaned, and a single canister is re-analyzed by GC/MS for certification.

10.8 Options

10.8.1 Duplicate Samples

A minimum of 5% of all samples should be collected in duplicate (i.e., if a total of 100 samples are to be collected, five samples should be duplicated.) In choosing which samples to duplicate, the following criteria applies: if, after filling the first Tedlar bag, and, evacuating the well for 15 seconds, the second HN (or other field monitoring device being used) reading matches or is close to (within 50%) the first reading, a duplicate sample may be taken.

10.8.2 Spikes

A Tedlar bag spike and Tenax tube spike may be desirable in situations where high concentrations of contaminants other than the target compounds are found to exist (landfills, etc.). The additional level of QA/QC attained by this practice can be useful in determining the effects of interferences caused by these non-target compounds. Summa canisters containing samples are not spiked.

11.0 DATA VALIDATION

11.1 Blanks (Field and Tedlar Bag Check)

For each target compound, the level of concentration found in the sample must be greater than three times the level (for that compound) found in the field blank which accompanied that sample to be considered valid. The same criteria apply to target compounds detected in the Tedlar bag pre-sampling contamination check.

12.0 HEALTH AND SAFETY CONSIDERATIONS

Due to the remote nature of sampling soil gas, special considerations can be taken with regard to health and safety. Because the sample is being drawn from underground, and no contamination is introduced into the breathing zone, soil gas sampling usually occurs in Level D. Ambient air is constantly monitored using the HNu PI101 to obtain background readings during the sampling procedure. As long as the levels in ambient air do not rise above background, no upgrade of the level of protection is needed.

When conducting soil gas sampling, leather gloves should be worn, and proper slam bar techniques should be implemented (bend knees). Also, an underground utility search should be performed prior to sampling. (See Section 4.5).

13.0 REFERENCES

Gilian Instrument Corp., Instruction Manual for Hi Flow Sampler: HFS113, HFS 113 T, HFS 113U, HFS 113 UT, 1983.

HNu Systems, Inc., Instruction Manual for Model PI 101 Photoionization Analyzer, 1975.

N.J.D.E.P., Field Sampling Procedures Manual, Hazardous Waste Programs, February, 1988.

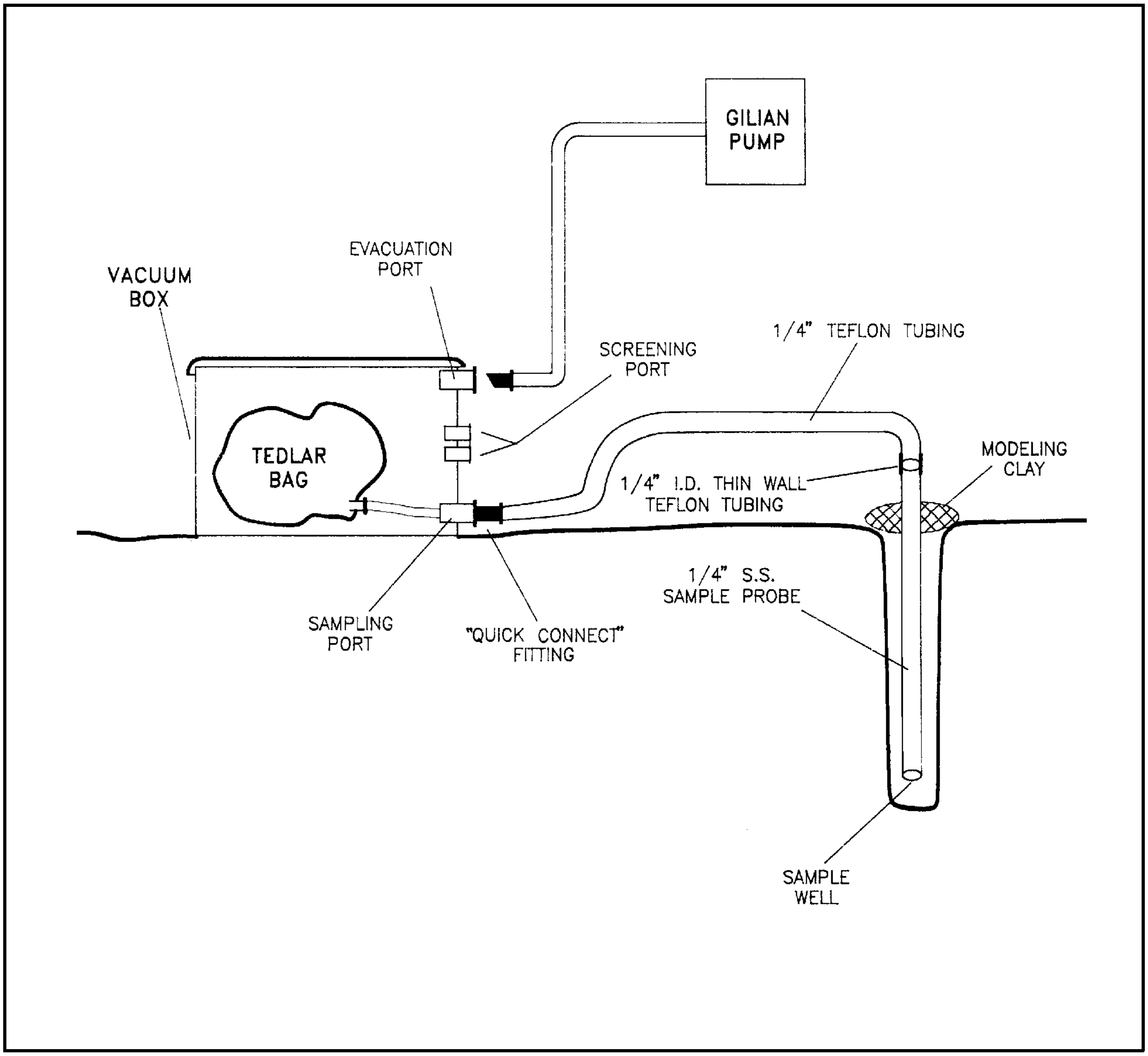
Roy F. Weston, Inc., Weston Instrumentation Manual, Volume I, 1987.

U.S.E.P.A., Characterization of Hazardous Waste Sites - A Methods Manual: Volume II, Available Sampling Methods, 2nd Edition, EPA-600/4-84-076, December, 1984.

APPENDIX A

Figure

FIGURE 1. Sampling Train Schematic



APPENDIX B

HNu Field Protocol

Field Procedure

The following sections detail the procedures that are to be followed when using the HNu in the field.

Startup Procedure

a. Before attaching the probe, check the function switch on the control panel to ensure that it is in the off position. Attach the probe by plugging it into the interface on the top of the readout module. Use care in aligning the prongs in the probe cord with the plug in; don't force.

b. Turn the function switch to the battery check position. The needle on the meter should read within or above the green battery are on the scale. If not, recharge the battery. If the red indicator light comes on, the battery needs recharging.

c. Turn the function switch to any range setting. Look into the end of the probe for no more than two to three seconds to see if the lamp is on. If it is on, it will give a purple glow. Do not stare into the probe any longer than three seconds. Long term exposure to UV light can damage eyes. Also, listen for the hum of the fan motor.

d. To ZERO the instrument, turn the function switch to the standby position and rotate the zero adjustment until the meter reads zero. A calibration gas is not needed since this is an electronic zero adjustment. If the span adjustment setting is changed after the zero is set, the zero should be rechecked and adjusted, if necessary. Wait 15 to 20 seconds to ensure that the zero reading is stable. If necessary, readjust the zero.

Operational Check

a. Follow the startup procedure.

b. With the instrument set on the 0-20 range, hold a solvent-based major market near the probe tip. If the meter deflects upscale, the instrument is working.

Field Calibration Procedure

a. Follow the startup procedure and the operational check.

b. Set the function switch to the range setting for the concentration of the calibration gas.

c. Attach a regulator (HNu 101-351) to a disposable cylinder of isobutylene gas (HNu 101-351). Connect the regulator to the probe of the HNu with a piece of clean Tygon tubing. Turn on the value on the regulator.

d. After fifteen seconds, adjust the span dial until the meter reading equals the concentration of the calibration gas used. Be careful to unlock the span dial before adjusting it. If the span has to be set below 3.0, calibration internally or return to equipment maintenance for repair.

e. Record in the field logbook: the instrument ID no. (EPA decal or serial number if the instrument is a rental); the initial and final span settings; the date and time; concentration and type of calibration has used; and the name of the person who calibrated the instrument.

Operation

a. Follow the startup procedure, operational check, and calibration check.

b. Set the function switch to the appropriate range. If the concentration of gases or vapors is unknown, set the function switch to the 0-20 ppm range. Adjust it if necessary.

c. While taking care not to permit the HNu to be exposed to excessive moisture, dirt, or contamination, monitor the work activity as specified in the Site Health and Safety Plan.

d. When the activity is completed or at the end of the day, carefully clean the outside of the HNu with a damp disposable towel to remove any visible dirt. Return the HNu to a secure area and place on charge.

e. With the exception of the probe's inlet and exhaust, the HNu can be wrapped in clear plastic to prevent it form becoming contaminated and to prevent water from getting inside in the event of precipitation.