[DRAFT]

Draft Work Plan - Montlake Apartments Supplemental Remedial Investigation

2300 24th Avenue East, Seattle, Washington

(VCP Project No. NW3386)

Prepared for

Montlake Apartments, LLC
117 East Louisa #185
Seattle, Washington 98102

Prepared by

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August 21, 2024

Project Number W068.001.002

This document is a draft and the information contained herein is subject to change. It should not be relied upon; consult the final document.

File: Draft Work Plan-W068-001-001-F

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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
bgs	below ground surface
CAP	Cleanup Action Plan
CSCSL	Confirmed and Suspected Contaminated Sites List
CUL	Cleanup Level
DCA	Disproportionate Cost Analysis
Ecology	Washington State Department of Ecology
EIM	Electronic Information Management
EPA	U.S. Environmental Protection Agency
ESA	Environmental Site Assessment
MTCA	Model Toxic Control Act (Chapter 70.105D RCW; Chapter 173-340 WAC)
NFA	No Further Action
ORP	Oxidation-Reduction Potential
PCE	Tetrachloroethylene
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
Qob	Quaternary Olympia Beds
Qpf	Quaternary pre-Fraser glaciation deposits
Qpfc	Quaternary pre-Fraser glaciation, coarse-grained deposits
Qpff	Quaternary pre-Fraser glaciation, fine-grained deposits
REC	Recognized Environmental Condition
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROW	Right-Of-Way
Site	Montlake Apartments property
SOP	Standard Operating Procedure
TCE	Trichloroethylene
TEE	Terrestrial Ecological Evaluation
USGS	United States Geological Survey
VCP	Voluntary Cleanup Program
VI	Vapor Intrusion
VOC	Volatile Organic Compound

Signatures

August 21, 2024

Erica Whiting, Associate Geologist

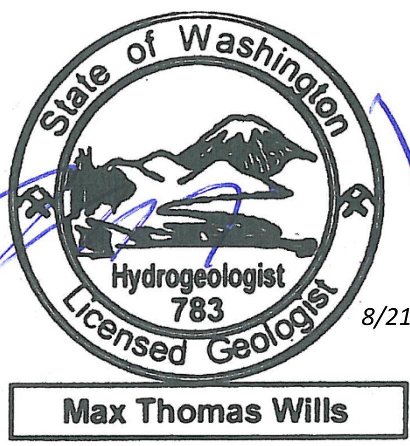
Date

All geologic information, conclusions, and recommendations in this document have been prepared under the responsible charge of a Washington Professional Hydrogeologist.

August 21, 2024

Max Wills, Principal Hydrogeologist

Date



8/21/2024

1 Introduction

Robinson Noble, a wholly owned subsidiary of Terraphase Engineering Inc. (Terraphase), has prepared this work plan on behalf of Montlake Apartments, LLC to conduct a supplemental remedial investigation (RI) of the Montlake Apartments property (referred to herein as the Site). The site is located at 2300 24th Avenue East in Seattle, Washington. Figure 1A presents a general vicinity map and Figure 1B presents a focused vicinity map (aerial) that includes neighboring environmental sites. Figure 2 presents a detailed aerial of the site.

The work proposed in this work plan is being conducted to further investigate tetrachloroethene (PCE) contamination that was discovered at the site during the completion of our initial RI, dated November 2, 2023. A copy of our initial RI is on-file with the Washington State Department of Ecology (Ecology) and, along with other key documents, can be accessed on Ecology's website at https://apps.ecology.wa.gov/cleanupsearch/site/16924.

As discussed in our initial RI, PCE was discovered in both soil and groundwater at concentrations above Model Toxic Control Act (MTCA) Method A soil and groundwater cleanup levels (CULs). Site investigations also found low levels of trichloroethene (TCE), a common breakdown product of PCE, in the groundwater at the site, but at concentrations well below applicable CULs. The original source of the PCE contamination is not currently known but may be related to a dry cleaner (Montlake Dye Works - Clothes Pressers and Cleaners) that operated at the site in the 1930s, or any one of several current or past dry cleaner operations on nearby properties.

The site is currently listed on Ecology's Confirmed and Suspected Contaminated Sites List (CSCSL) as having confirmed halogenated solvent contamination in both soil and groundwater. Ecology has assigned the Montlake Apartments site Facility/Site No. 99998923 and Cleanup Site No. 16924. The site is also enrolled in Ecology's voluntary cleanup program (VCP) and has been assigned VCP Project No. NW3386. Pertinent site and contact information are provided below in Table 1.

On April 11, 2024, representatives from Terraphase and Montlake Apartments, LLC met with Ecology's VCP Site Manager (Jing Song) at the Site to perform a site walk, discuss the data gaps and other concerns identified by the Initial RI, and discuss needed work to obtain regulatory closure. On April 25, 2024, following the site visit, Ecology drafted a technical assistance email with general guidance that was used to compile this work plan.

The proposed scope of work presented in this work plan will be completed under the auspices of Ecology's VCP with the overriding goal of obtaining regulatory closure through the issuance of a no-further-action determination (NFA) for the site. The general goals of this work plan, which are discussed in further detail below in Section 3, include resolution of existing data gaps and full delineation (to the degree possible) of soil, groundwater, and soil vapor contamination (as PCE and related breakdown products). The ultimate goal for the current effort is to establish sufficient site characterization on which to base appropriate cleanup standards (cleanup levels and points of compliance) and determine an appropriate cleanup action.

Table 1: Site and Contact Information

Site Information				
Site Name	Montlake Apartments			
Site Address	2300 24th Avenue East, Seattle, WA 98112			
Parcel No.	King County 6788201390			
Facility/Site No.	99998923			
Cleanup Site No.	16924			
VCP Project No.	NW3386			
Contact Information				
Name		Address	Phone	Email
Owner (Representative)	Montlake Apartments, LLC (Ron Danz)	117 E Lousia St. #185, Seattle, WA 98102	(425) 985-3570	Ron@nwcrei.com
Ecology (VCP Site Manager)	Jing Song	Ecology, NW Regional 15700 Dayton Ave N Shoreline, WA 98133	(425) 229-2565	Jing.Song@ecy.wa.gov
Consultant (Project Manager)	Terraphase (Max Wills)	17625 130th Ave NE STE 102, Woodinville, WA 98072	(206) 550-7215	Max.Wills@ Terraphase.com

2 Site Description and Previous Activities

This section provides a brief description of the site and an overview of the geology and hydrogeology as currently understood. This section also provides a summary of previous cleanup actions, both for the site and other nearby properties. Additional details can be found in our 2023 Initial RI, which is on-file with Ecology (https://apps.ecology.wa.gov/cleanupsearch/site/16924).

2.1 Site Description

The site is located in the Montlake neighborhood of Seattle just south of the University District (Figure 1). The site consists of one contiguous parcel listed by the King County Assessor as tax parcel number 6788201390. The address assigned to this parcel is 2300 24th Avenue East, Seattle, Washington 98112. The site is located within the NW ¼ of Section 21, Township 25N, Range 04E (Willamette Meridian) and covers an area of approximately 0.28 acres.

The topography of the site is generally flat; however, a very slight slope to the northeast (toward Ship Canal and Lake Washington) is present. Surrounding topography steepens upward southwest (toward

Capitol Hill). The closest surface water bodies are a marshland attached to Union Bay (Lake Washington) located approximately 0.3 miles northeast of the site, the Montlake Cut (Lake Washington Ship Canal) located approximately 0.5 miles north of the site, and Portage Bay located approximately 0.3 miles northwest of the site.

The site is currently developed with a U-shaped, two-story building that is constructed with wood, brick, and concrete. The site building has an unfinished basement that is used for storage. The building was originally constructed in 1914 and modified through 1936 into its current configuration. The building is occupied by the Montlake Apartments and several small retail stores. The footprint of the building covers the majority of the site with the exception of a central, open-air courtyard. The building is surrounded by city-maintained sidewalks, and except for a few minor planter areas, the entirety of the site is covered by the building, asphalt, and/or concrete. The surrounding area is developed with similarly mixed-use structures, apartments, and single-family residences.

2.2 Geology

The United States Geological Survey (USGS; Booth and others 2009) maps the surface geology of the site and surrounding area as unconsolidated deposits of pre-Fraser glaciation age (Qpf). This is a generic designation for the materials that occur stratigraphically below the better-defined Vashon sequence (i.e., Vashon recessional outwash, till, and advance outwash). The Qpf is described by the USGS as interbedded sands, gravels, silts, and diamicts of indeterminant age and origin. The USGS also describes the Qpf deposits as being very dense and hard. The Qpf is subdivided locally into coarse-grained deposits (Qpfc), which is predominately sands and gravels, and fine-grained deposits (Qpff), which is predominantly silts and clays. Within the site vicinity, it is presumed that the Qpf has been exposed through erosion and/or some degree of non-deposition of the younger Vashon deposits.

Materials encountered during exploratory borings drilled at the Site include the following:

- Engineered fill and concrete.
- Silt, sand and gravel to 15 feet below ground surface (bgs), generally consistent with Qpf.
- Layered silts, sands, and occasional gravels from 15 feet bgs to 23 feet bgs, generally consistent with Qpfc.
- Compact silt, below 21 to 23 feet bgs, generally consistent with Qpff.

Borings drilled at adjacent properties, specifically the former Montlake Dry Cleaner located directly east of the subject site across 24th Avenue East (Landau Associates 2013) were drilled to depths of up to 92 feet. A summary of the materials encountered in the offsite deeper borings include the following:

- Qpfc-like to 18 feet bgs, generally consistent with the materials observed in borings drilled at the Site.
- Compact silts referred to as till to 80 feet bgs, generally consistent with Qpff.
- Layered silts and organic silts to 92 feet bgs, indicative of older Olympia Beds (Qob).

2.3 Hydrogeology

Groundwater encountered at the Site ranged between 5 and 9 feet bgs during initial soil boring drilling activities. Shallow groundwater during monitoring well installation was encountered in the lower half of the coarser Qpfc materials from 12 to 13 feet bgs. Soil materials in the underlying Qpff (from 23 feet bgs) were observed to be dry, indicating that groundwater encountered at the Site is perched on top of the Qpff.

Potentiometric surface maps prepared and presented in the Initial RI indicate a western flow in February, and southwestern flow in April. The regional flow direction in this area would be expected to be more northly, toward the Lake Washington Ship Canal. Additionally, potentiometric surface maps from neighboring sites indicate a southeastern flow. Based on local observations, groundwater flow may reflect localized flow directions specific to the Site and immediate surrounding area; however, additional data as described within this RI Work Plan will be collected to further define groundwater flow beneath the Site.

Potentiometric surface maps have not been created for monitoring wells that are screened within the deeper aquifer. Based on reports available, the deeper aquifer appears to be confined and groundwater within the deeper aquifer generally flows north toward the Lake Washington Ship Canal (Landau and Associates 2013).

2.4 Previous Cleanup Actions

Cleanup actions previously completed at the subject site include the following:

- March 2022 Draft Phase I ESA: Investigations associated with a Phase I Environmental Site Assessment (ESA) identified one onsite recognized environmental condition (REC) associated with a former dry cleaning business that operated at the site in the 1930s. The Phase I ESA also identified several offsite RECs associated with nearby cleanup sites, which are described in Section 3 of our initial RI and summarized below.
- March 2022 Limited Phase II Environmental Site Assessment (ESA): In response to the RECs identified during the Phase I ESA, a limited subsurface investigation (Phase II ESA) was conducted at the site. The investigation included installation of four direct push borings (B1 through B4). These borings were located at the north end of the courtyard area (see Figure 2) and were drilled using direct-push drilling methods to refusal (15 feet bgs). Soil samples and grab-groundwater samples were collected and analyzed for gasoline-range through oil-range total petroleum hydrocarbons and chlorinated volatile organic compounds (VOCs). Analyses did not indicate the presence of petroleum hydrocarbons above laboratory detection limits in any of the soil or groundwater samples. However, analyses did indicate the presence of PCE at concentrations above the MTCA Method A CUL in most of the soil samples, and PCE above the CUL in all the groundwater samples.
- February 2023 Initial RI: Initial RI activities included the drilling and installation of five monitoring wells (MW-1 through MW-5) to further investigate the nature and extent of the PCE contamination. The well borings were drilled using hollow-stem auger drilling methods to accommodate deeper drilling and allow for completion of the borings as monitoring wells. The monitoring well-borings

were drilled to depths between 30 and 45 feet bgs. Soil and groundwater samples were collected and analyzed for PCE and related breakdown products (i.e. chlorinated VOCs). Analyses identified PCE above laboratory detection limits in all the soil samples and PCE above the MTCA Method A CUL in MW-3. Analyses also found PCE above the CUL in all the groundwater samples.

As described in our initial RI, in addition to the former onsite dry cleaner REC, four offsite RECs were identified during the Phase I ESA. These offsite RECs include:

- Circle K 01461, located adjacent to the north of the subject site (Facility/Site ID 2322)
- Montlake Cleaners, located west of the subject site across 24th Ave E. (Facility/Site ID 14643)
- Mason Apartments, located south of the subject site across E. Lynn St. (Facility/Site ID 7909)
- Mobil 99MPB, located adjacent to the south of the Mason Apartments site (Facility/Site ID 24792884)

Each of these sites is listed on Ecology's CSCSL and are described as currently undergoing active cleanup. As described in our Initial RI, groundwater impacts associated with these offsite RECs have potential to impact the subject site. The current VCP site manager, Jing Song, indicated in various communications that it should be possible to access many of the monitoring wells associated with these sites (at least the ones located in the public right-of-ways), as part of the current investigation of the subject property. Figure 1B shows the locations of each of these sites relative to the subject site. Figure 3 shows the locations of the monitoring wells associated with each of these sites.

3 Proposed Work Plan

Previous investigations at the site have been limited due to access and most of the site being covered by the site building. Based on the limited dataset, review of RECs on and offsite, and results from the previous investigations, several data gaps were identified. The following describes the data gaps and the cleanup actions proposed to resolve them:

- Shallow PCE contamination in the soil and groundwater at the site indicates a potential for vapor intrusion (VI) issues in the enclosed building spaces, and to date, no VI investigations have been conducted at the site. As such, a sub-slab soil-gas investigation should be completed to evaluate the potential for VI in the site buildings.
- Limited soil and groundwater data have been collected near the center of the site within the courtyard area and at MW-5 (see Figure 2). Additional data is needed to delineate and characterize contaminants near the margins of the Site, and to better understand groundwater flow beneath the Site. This work plan proposes using the existing monitoring wells around the site (see Figure 3), as available, to better characterize and delineate PCE groundwater contamination, and to better define local groundwater flow. We also propose additional monitoring wells (see Figure 4) to augment the existing wells.

- Analytical data collected during the Phase II ESA included limited analyses for petroleum hydrocarbons, and additional petroleum hydrocarbon analyses were not performed during our subsequent initial RI. As such, this work plan proposes conducting additional analyses for petroleum hydrocarbons and fuel-related VOCs.
- Additional groundwater sampling should be completed on a quarterly basis for a period of at least one year to characterize the seasonal fluctuation of water levels, gradients, and contaminants. This monitoring should incorporate existing wells (as available and applicable) together with the additional wells installed to augment the current network, and analyses should include petroleum hydrocarbons, fuel-related VOCs, and PCE and associated breakdown products.

The scope presented in this work plan incorporates the comments in Ecology's April 25, 2024 technical assistance email. Once Ecology has reviewed and commented on the sufficiency of the proposed work, any additional cleanup actions recommended by Ecology will be incorporated into a final work plan, and then implemented accordingly.

Prior to performing any of the activities outlined in this work plan, a site-specific health and safety plan identifying potential physical and chemical hazards and specifying required personal protective equipment will be prepared. The work proposed in this work plan will also require specific permitting to drill in public right-of-ways (ROWs), access to adjacent sites, and clearance of underground utilities. Specific details pertaining to permitting, access to other sites, and utility locates are provided in Appendix A.

3.1 Sub-Slab Soil-Gas Investigation

The objective of the sub-slab soil-gas investigation is to assess potential VI in the site building related to the PCE impacts detected in the soils and shallow groundwater at the site. To support this objective, Terraphase will complete a Tier 1 VI evaluation in accordance with Ecology's *Guidance for Evaluating Vapor Intrusion in Washington State* ("VI Guidance" Ecology 2022).

The soil vapor investigation will include the installation of 14 vapor pins in the basements of the west and east portions of the site building to access the sub-slab space below these areas, and then collecting soil vapor samples through each of the pins. The vapor pins will be installed initially using a 1 ¼-inch roto-hammer drill bit to drill an initial hole in the concrete to allow vapor pin steel cover caps to be seated flush with the floor surface. A smaller 5/8-inch-diamater hole will then be drilled through the concrete slab, and a vapor pin will be installed into the 5/8-inch-diameter hole with a silicone-rubber seal. Soil vapor samples will be collected through each of the pins using evacuated laboratory-provided 1-liter SUMMA® canisters. Samples will be delivered to the laboratory under appropriate chain-of-custody procedures and analyzed within prescribed holding times for the analytes described in Section 3.5. Additional details regarding vapor pin installation are provided in Appendix A.

3.2 Soil Sampling and Monitoring Well Installation

PCE concentrations above the MTCA Method A soil cleanup level were detected in soil samples collected in the courtyard of the Montlake Apartments building. The vertical extent of the soil impacts, based on previous soil sampling activities, is between 5 and 15 feet bgs. Additional soil borings/monitoring wells are necessary to delineate and characterize contaminants in areas where the current onsite and offsite monitoring networks are not sufficient.

Figure 4 presents the proposed locations for the additional monitoring wells to be installed in ROW areas outside of the Site property. A total of seven new monitoring wells (designated as MW-6 through MW-12) will be installed to the west and south of the Site. Final locations will be based on initial groundwater monitoring to be performed as described in Section 3.2.1 and access around utilities or other structural impediments. Two additional monitoring wells (MW-14 and MW-14) are tentatively proposed to the east of Montlake Apartments. These monitoring wells would be installed on private residence property, pending approval by the property owner.

Drilling activities will be performed using a hollow-stem auger drill rig to accommodate for deeper drilling. Drilling activities will be conducted by a subcontracted licensed driller and monitored by a Terraphase geologist. The soils encountered will be continuously logged during drilling activities. Borings will be advanced to the nearest confining unit, the pre-Fraser glacial silt beds (Qpff), or until refusal conditions are met. A permanent groundwater monitoring well will be installed in each boring as described below in Section 3.2.1. During drilling activities, materials encountered in each of the soil borings will be field screened for signs of impact using visual and olfactory indicators and a handheld photoionization detector (PID). Soil samples from the various borings will be delivered to the laboratory under appropriate chain-of-custody procedures and analyzed within prescribed holding times for the analytes described in Section 3.5.

3.2.1 Groundwater Monitoring Well Installation and Development Procedures

After reaching depth, groundwater monitoring wells will be installed in each of the borings. Monitoring wells will be installed by a licensed driller as directed by a Terraphase geologist. Each monitoring well will terminate at the first confining layer, Qpff, at an approximate depth of 25 feet.

The monitoring wells will be constructed with 2-inch-diameter PVC with a 10-foot screen interval. The blank PVC casing will be cut so that a flush mount monument can be used for final completion. The screen will consist of pre-perforated screen with 0.010-inch slots and enveloped with 10x20 silica filter pack. The sand pack will extend from the bottom of the screen to 2 feet above the top of the screen interval. Bentonite will be placed from the top of the sand pack to approximately 2 feet bgs. Concrete will be added to the upper 2 feet bgs and a flush mount well cover will be placed securely in the concrete. The monitoring wells will be fitted with water-tight locking well caps. The surrounding area will be restored to match the existing surface conditions to the extent feasible.

The completed wells will be allowed to set for a minimum of 72 hours before doing any additional work. Once set, each monitoring well will be developed to remove any loose formation material in preparation for sampling (see Section 3.5). The top-of-casing (TOC) of each monitoring well will be surveyed by a professional surveyor.

3.3 Groundwater Monitoring

The objectives of the groundwater monitoring program are to evaluate groundwater conditions at the Site and neighboring sites to further characterize impacts to groundwater and further delineate the PCE-impacted groundwater plume and the interaction with nearby PCE and petroleum plumes. To support these objectives, the groundwater monitoring program will be used to 1) conduct initial monitoring prior to installation of the new monitoring wells (see Section 3.2) to establish final locations to manage data gaps in the monitoring network; and 2) conduct quarterly monitoring to better characterize flow conditions and seasonal fluctuation patterns. The monitoring network for the initial sampling event will consist of the existing monitoring wells at the Site and the ROW wells associated with other offsite sources. Subsequent quarterly monitoring will include the wells sampled as part of initial monitoring and the new monitoring wells as appropriate.

Prior to sample collection, each monitoring well will be purged, and various field parameters including pH, temperature, conductivity, total dissolved solids, dissolved oxygen, and oxidation-reduction potential (ORP) will be measured and recorded during the purging process. Groundwater samples will be obtained from each monitoring well after the measured field parameters reach stabilization or a minimum of three well volumes have been purged. On occasion, more than three well volumes may need to be purged to try to reach better stabilization or clear turbidity. All groundwater samples will be collected using prescribed low-flow sampling protocols. Additional groundwater sampling procedures are provided in Appendix A. Groundwater collected from each monitoring well will be delivered to the laboratory under appropriate chain-of-custody procedures and analyzed within prescribed holding times for the analytes described in Section 3.5.

3.4 Soil Vapor

The objective of the soil vapor sampling is to evaluate potential for VI of PCE within the site building based on PCE concentrations detected in shallow groundwater above the MTCA Method B (cancer) VI groundwater screening level of 25 ug/L. To support this objective, Terraphase will complete a Tier 1 VI evaluation in accordance with Ecology's *Guidance for Evaluating Vapor Intrusion in Washington State* ("VI Guidance" Ecology 2022).

The soil vapor sampling program will include installation of 14 soil samples in the basements of the west and east portions of the site building. Soil vapor sampling will consist of performing sub-slab vapor sampling using sub-slab vapor pins installed within the basement building footprint. Vapor pins are specialized devices used to sample soil gas or vapor from beneath concrete slabs in buildings, typically for assessing vapor intrusion risks. These pins are small, robust, and designed to create a secure and sealed pathway through the slab, allowing for the collection of sub-slab vapor samples without significant disturbance to the structure. The pins typically consist of a stainless-steel body with a silicone sleeve that ensures a tight seal between the pin and the concrete, preventing air leakage and ensuring the integrity of the sample. Vapor pins are essential tools in environmental investigations as they enable the accurate measurement of VOCs and other hazardous vapors that might migrate from contaminated soil or groundwater into indoor air, thus facilitating the assessment and mitigation of potential health risks associated with vapor intrusion. As described within the VI Guidance, vapor pins are a suitable device to sample sub-slab soil vapor.

Permanent vapor pins will be installed and sub-slab soil gas samples collected. The vapor pins will be installed using a 1 ¼-inch roto-hammer drill bit to drill an initial hole to allow vapor pin steel cover caps to be flush with the floor surface. A smaller 5/8-inch-diamater hole will be drilled through the concrete slab 1 ¼-inch hole. A vapor pin will be installed into the 5/8-diameter hole with a silicone-rubber seal, and a silicone cap placed on a barbed fitting to allow for sub-slab sampling.

Sub-slab samples will be collected no less than two hours following installation of each vapor pin to meet the prescribed equilibration time. Soil gas samples will be collected in general accordance with the Terraphase standard operating procedure (SOP).

Prior to sample collection, a shut-in test will be performed to assess sample train integrity and apparatus fittings. The shut-in test will be performed by placing the valves at the sample canister and sub-slab soil gas point in the closed position. Using a manual purging device (i.e., gas-tight syringe with purge valve or SUMMA canister) to apply a vacuum to the sampling apparatus of at least 10 inches of mercury. The valve between the tee and the manual purging device will then be closed to observe whether vacuum was maintained in the sampling apparatus between the sub-slab soil gas point and the sample canister. Leaks observed in the sampling manifolds will be repaired and the shut-in test will be retaken.

To assess for potential leaks during sub-slab soil gas sampling, helium will be used as a leak check compound to evaluate ambient air breakthrough to samples. Prior to sampling, helium will be pumped into a plexiglass box (shroud) surrounding the sampling equipment. The helium concentration will be maintained between 15 and 35 percent inside the shroud. The presence of helium above 5 percent in the sample will indicate if an ambient air leak occurred within the sampling system or indicate permeability of the slab.

Once the leak check is complete, the soil vapor sample will be collected through the manifold and into laboratory provided 1-liter SUMMA canisters. Samples will be delivered to the laboratory under appropriate chain-of-custody procedures and analyzed within prescribed holding times for the analytes described in Section 3.7.

3.5 Analytical Requirements

Soil and Groundwater samples will be placed in ice-filled coolers immediately after collection and transported to an analytical laboratory using chain-of-custody procedures. Soil vapor samples will be packed and shipped in boxes to an analytical laboratory using similar chain-of-custody procedures. A summary of the analytical parameters for each media includes the following:

- Soil – PCE and breakdown constituents via EPA Method 8260.
- Groundwater – Groundwater from the initial round of groundwater sampling (initial event for all existing wells, first quarter for new monitoring wells) will be analyzed for PCE and breakdown constituents and fuel related VOCs via EPA Method 8260, and gasoline- through oil-range

hydrocarbons via Ecology Test Methods NWTPH-Gx and NWTPH-Dx/Dx extended. After the initial sampling at each well, the remaining samples will be collected for PCE and breakdown constituents alone via EPA Method 8260, unless the initial sampling results warrant additional analyses of petroleum compounds.

- Soil Vapor – PCE and breakdown constituents via TO-15; additional fixed gasses in accordance with the VI Guidance including oxygen, carbon dioxide, and methane via ASTM E2993-16, and helium (leak detection compound) by ASTM D-1946.

3.6 Quality Assurance/Quality Control

Through the execution of the cleanup actions described in this work plan, specific quality assurance/quality control (QA/QC) procedures will be performed and assessed to ensure usable and acceptable data quality. This will include, but not be limited to, collection and assessment of various laboratory and field QA/QC samples and analyses. Additional details regarding QA/QC analyses that may be utilized for this project are provided in Appendix A.

3.7 Equipment Decontamination

Decontamination will be performed to prevent the introduction of extraneous material into samples and to prevent potential cross-contamination. Downhole drilling equipment will be decontaminated by one of the following methods: steam cleaning, pressure washing, or washing with a non-phosphate detergent such as Liquinox™ or equivalent. Non-disposable sampling equipment will be decontaminated by the following:

1. Wash with non-phosphate detergent and water solution. This step will remove visible contamination from equipment. A 5-gallon bucket with solution and brushes will be used for this step, if feasible. Non-phosphate detergent will be diluted as directed by the manufacturer.
2. Rinse with potable water. This step will rinse the detergent solution from the equipment. Periodic changing of the rinse water will be performed.
3. Rinse with store bought distilled water. This step will rinse detergent solution and potable water residues. Rinsing is most effective when water is applied using a stainless-steel Hudson-type sprayer or Nalgene® squeeze bottle while holding equipment over a 5-gallon bucket.
4. Rinse with laboratory grade deionized water. This step will be a final rinse to remove any contaminants. Rinsing is most effective when water is applied using a stainless-steel Hudson-type sprayer or Nalgene® squeeze bottle while holding equipment over a 5-gallon bucket.

Decontaminated liquids will be containerized and stored in 55-gallon drums pending analysis and disposal.

3.8 Sample Labeling, Handling, and Shipment

Sample labels will be filled out with indelible black ink and affixed to each sample container. Each sample container will be labeled with the following information, at a minimum:

- Sample identification number
- Sample collection date (month/day/year)
- Time of collection (24-hour clock)
- Preservative (if any)

Each sample container will be placed in resealable plastic bags to keep the sample container and label dry. Ice will be placed in the coolers and regularly changed to ensure the temperature of the coolers does not exceed 4 degrees Celsius from the time of sample collection to receipt by the laboratory. A temperature blank will be placed in each cooler. A temperature blank is a sample container filled with tap water and stored in the cooler during sample collection and transportation. The temperature of the temperature blank will be recorded by the laboratory on the chain-of-custody form immediately upon receipt of the samples. The samples will be hand-delivered to the laboratory following completion of field activities, ensuring that proper hold times for each analysis are met. Additional information regarding labeling and field documentation is provided in Appendix A.

3.9 Investigation-Derived Waste Management

Soil cuttings and wastewater generated during the field activities will be contained in U.S. Department of Transportation approved 55-gallon steel drums. The drums will be appropriately labeled and temporarily stored onsite pending analytical results and profiling. Once profiled, the drums will be transported to an appropriate offsite disposal facility by a licensed disposal contractor.

The 55-gallon drums will be properly labeled with the following information:

- Description of waste (i.e., water or soil)
- Date generated
- Contact information
- Project name

Disposable personal protective and sampling equipment will be managed as non-hazardous solid waste. This disposable investigation-derived waste will be placed in plastic bags, removed from the Site by Terraphase and/or the drilling company, and transferred to an industrial waste container, the contents of which are routinely disposed of in a municipal landfill.

4 Reporting

Upon completion of the cleanup actions described in this work plan, Terraphase will prepare a report documenting our findings. At this time, we anticipate this report will be either in the format of an Interim RI with a draft Cleanup Action Plan (CAP) or an RI with a feasibility study (RI/FS). The appropriate level of reporting will be determined by our findings. The report will be prepared using a standard Ecology recommended format and will include complete descriptions of the site, detailed descriptions of the geology and hydrogeology, a complete summary of all previous remedial investigation work performed at the site, and detailed descriptions of all work completed for the current remedial investigation. Our description of the current work will include, as applicable, new site maps, well logs and well construction diagrams, cross sections depicting the extent of contamination, and a conceptual model describing our understanding of the contaminant pathways. It will also include a section that will address terrestrial ecological evaluations (TEE) and a discussion as to whether or not a TEE is required for site closure. Depending on the findings of our remedial investigation, the report may also include a discussion of data gaps and possibly recommendations for additional field work to address any areas of missing data.

If it is determined that the appropriate level of reporting is an RI with a draft CAP, the report will include a description of our proposed CAP for review and comment by Ecology. If it is determined that an RI/FS is the more appropriate level of reporting, along with the RI information the report will also include a feasibility study, which will address the various remediation options that might be applicable for site closure, and a disproportionate cost analyses (DCA) to evaluate the viability of the various closure options.

4.1 EIM Submission

For VCP projects, Ecology requires that all analytical data be submitted via their Electronic Information Management (EIM) portal prior to issuance of any closure determination. All analytical data collected to date for the Site has been submitted to the Ecology through their portal, and all additional data collected during the cleanup actions proposed herein.

5 References

Booth, D.B., Troost, K.G., and Schimel, S.A., 2009, Geologic map of northeastern Seattle (part of the Seattle North 7.5' x 15' quadrangle), King County; US Geological Survey Scientific Investigations Map 3065.

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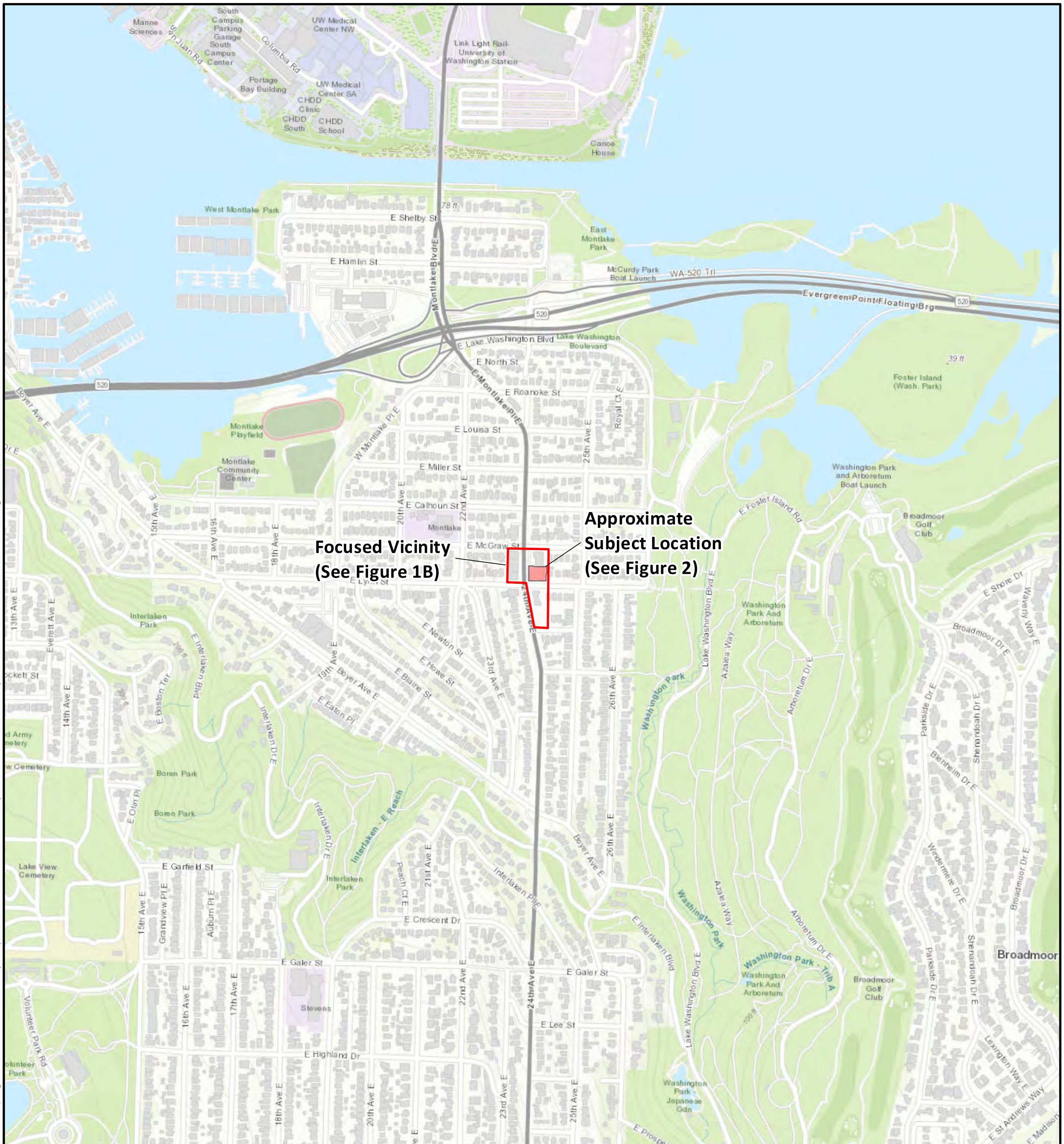
Figures



0 500 1,000 1,500 2,000 Feet

1 inch = 1,000 feet

N

Legend

Focused Vicinity

Approximate Site Boundary

Base Map: ESRI World Topographic Map
(data providers include HERE, Garmin, USGS, et al.)

SAFETY FIRST	CLIENT: Montlake Apartments, LLC	**General Vicinity Map**
terraphase engineering	PROJECT: RI Work Plan 2300 - 24th Avenue East, Seattle	
	PROJECT NUMBER: W068.001.001	**FIGURE 1A**

File: N:\GIS\Prj\W068.001_Montlake Apartments, LLC\MXDs\(20240617) Figure 1A - General Vicinity Map.mxd 6/18/2024 Created by: S.Lowe Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet

0 50 100 150 200 Feet

1 inch = 100 feet

N

Legend

Approximate Site Boundary

Parcel Boundary

Aerial Imagery Source: Nearmap (March 14, 2024)

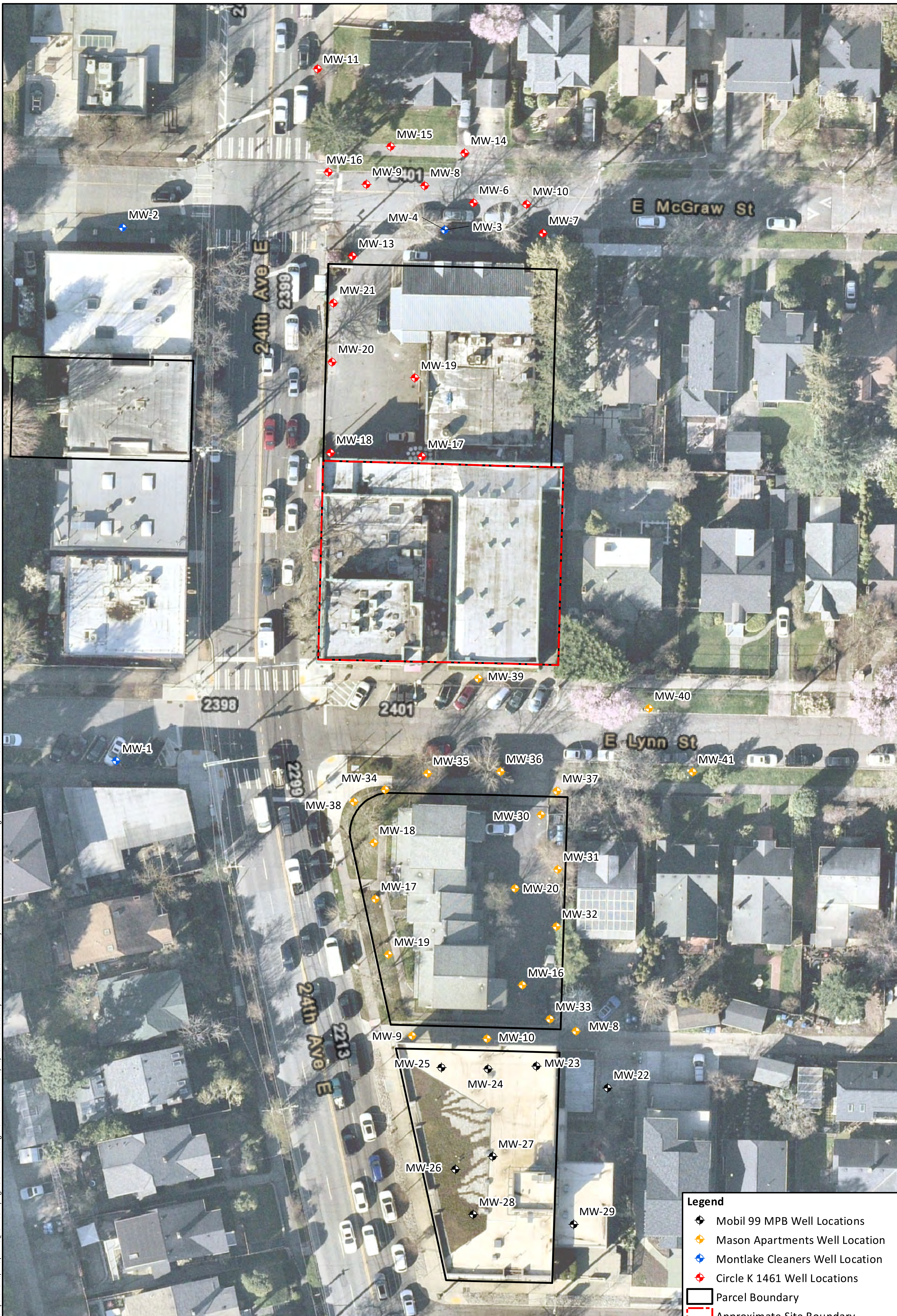
SAFETY FIRST	CLIENT: Montlake Apartments, LLC	**Focused Vicinity Map**
terraphase engineering	PROJECT: RI Work Plan 2300 - 24th Avenue East, Seattle	
	PROJECT NUMBER: W068.001.001	**FIGURE 1B**

File: N:\GIS\Prj\W068.001_Montlake Apartments, LLC\MXDs\(20240617) Figure 1B - Focused Vicinity Map.mxd 6/18/2024 Created by: S.Lowe Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Aerial Imagery Source: Nearmap (March 14, 2024)

File: N:\GIS\Prj\W068.001_Montlake Apartments, LLC\MXDs\(20240617) Figure 2 - Site and Boring Location.mxd 6/18/2024 Created by: S.Lowe Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet

SAFETY FIRST	CLIENT: Montlake Apartments, LLC	**Site and Boring Location Map**
terraphase engineering	PROJECT: RI Work Plan 2300 - 24th Avenue East, Seattle	
	PROJECT NUMBER: W068.001.001	**FIGURE 2**



N

0 22.5 45 67.5 90 Feet

1 inch = 45 feet

Aerial Imagery Source: Nearmap (March 14, 2024)

SAFETY FIRST

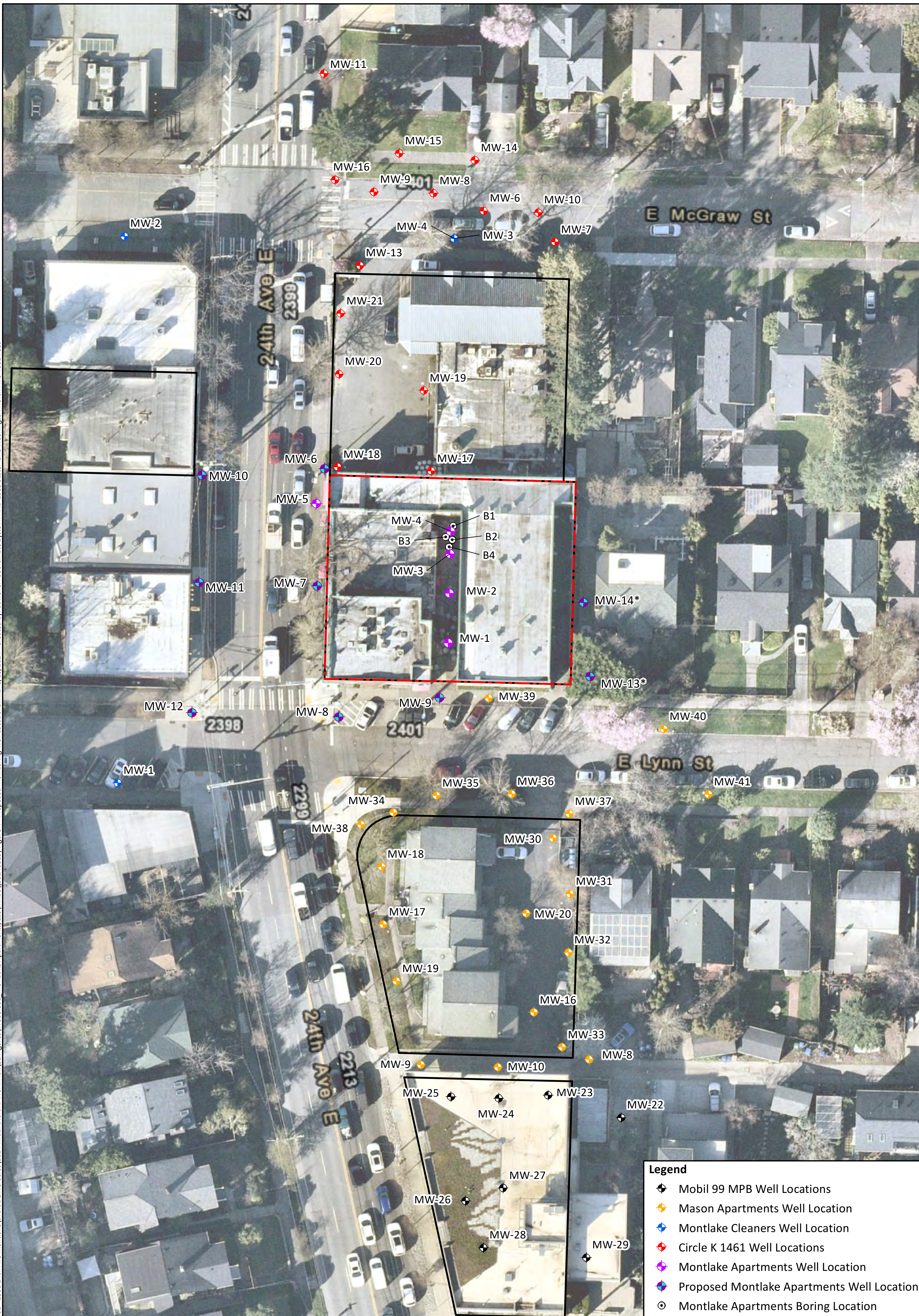
terraphase engineering

CLIENT:	Montlake Apartments, LLC
PROJECT:	RI Work Plan 2300 - 24th Avenue East, Seattle
PROJECT NUMBER:	W068.001.001

Offsite Monitoring Well Network

FIGURE 3

File: N:\GIS\Prj\W068.001_Montlake Apartments, LLC\MXDs\(20240617) Figure 3 - Monitoring Well Network.mxd 6/18/2024 Created by: S.Lowe Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet



Note*: MW-13 and MW-14 Tentative Wells Pending Review of Groundwater Elevation and Analytical Data.
Note2: All Locations Approximate Pending Initial Groundwater Monitoring and Utility Clearance.

N

0 22.5 45 67.5 90 Feet

1 inch = 45 feet

Aerial Imagery Source: Nearmap (March 14, 2024)

SAFETY FIRST

terraphase engineering

CLIENT:	Montlake Apartments, LLC
PROJECT:	RI Work Plan 2300 - 24th Avenue East, Seattle
PROJECT NUMBER:	W068.001.001

Proposed New Monitoring Well Locations

FIGURE 4

File: T:\Projects\W068 - Ron Dans\W068.001.001 - 2300 24th Ave Montlake\Draft Deliverables\2024 Initial Draft RI Work Plan\02 Figures\W068.001_Montlake Apartments, LLC\MXDs\(20240819) Figure 4 - Proposed Monitoring Well Locations.mxd 8/19/2024 Created by: daweiler Coordinate System: NAD 1983 StatePlane Washington North FIPS 4601 Feet

Appendix A

Additional Procedures

- A1 – Permitting, Access and Utility Clearance
- A2 – Vapor Pin Installation and Testing
- A3 – Groundwater Sampling Procedures
- A4 – Labeling and Field Documentation
- A5 – QA/QC Procedures

A1 – Permitting, Access, and Utility Clearance

1. Permitting

Terraphase will obtain the necessary permits required for the work, including but not limited to the following:

- Seattle Department of Transportation (SDOT) Right-of-Way (ROW) Minor Utility Permit: This permit allows for the installation of utility infrastructure, including soil borings and monitoring wells, that will have minimal impacts to the ROW.
- SDOT ROW Utility Major Permit: This permit allows for the larger projects that cover more than a 1-block radius with the potential to impact city assets and/or infrastructure. A Utility Major Permit may be necessary, at the discretion of SDOT, for soil boring and monitoring well installation.
- SDOT ROW Construction Permit: If exploration and/or well construction activities will significantly impact ROW use and require sidewalk or roadway closures, a ROW Construction Permit may be necessary, at the discretion of SDOT.
- Site-Specific Approval: Depending on the location and the nature of the well, site-specific approval may be required from relevant city departments or private entities to ensure underground utilities are not affected.
- SDOT ROW Impact Plan (aka, Traffic Control Plan): An approved ROW Impact Plan is a requirement of the permits listed above.
- SDOT Utility and Restoration Plan: A Utility and Restoration Plan may be required based on the necessary permits or at the discretion of SDOT.
- Insurance and Bonding: Based on the work performed and the permits required, proof of liability insurance covering work-related activities and/or a surety bond to cover potential damages may be required.

2. Adjacent Sites Access

As described in Section 4.6 of the Draft Work Plan, groundwater monitoring performed at the Site will include monitoring wells on the adjacent sites described in Section 2.3 and shown on Figure 3. Ecology has requested that groundwater monitoring wells installed in the city ROW by adjoining property owners be incorporated, at least initially, into the monitoring network for the Site. Terraphase will work with the adjoining site's consultants and owners to confirm access to the public right-of-way wells that have been requested by Ecology to be incorporated into the groundwater monitoring network.

Two monitoring wells identified in Section 3.4 of the Draft Work Plan as potential well locations pending initial groundwater monitoring are located at a private residence east of the Site. If work is necessary to the east of the Site, approval to perform work on the private residence property will be required.

3. Subsurface Clearance

Subsurface clearance will be conducted prior to the start of intrusive activities such as soil boring or concrete slab coring. Washington's OneCall will be notified at least one week in advance of intrusive activities in accordance with State regulations. An independent private utility locating service will be contracted to evaluate the presence of underground utilities and/or subsurface anomalies around the proposed locations. The private locator will employ geophysical survey methods (e.g., ground penetrating radar, radio frequency line, or similar) to locate potential subsurface utilities or features.

Proposed sampling locations will be adjusted in the field, as necessary, based on the results of the subsurface clearance effort to facilitate the health and safety of personnel, prevent property damage, and/or avoid or minimize interference with property operations. Prior to the commencement of soil boring activities, borings will be cleared by hand or vactor truck to a depth of 5-feet to verify the soil boring is clear of shallow utilities.

A2 – Vapor Pin Installation and Testing

1. Vapor Pin Installation and Testing

Soil vapor sampling will consist of performing sub-slab vapor sampling using sub-slab vapor pins installed within the basement building footprint. Vapor pins are specialized devices used to sample soil gas or vapor from beneath concrete slabs in buildings, typically for assessing vapor intrusion risks. These pins are small, robust, and designed to create a secure and sealed pathway through the slab, allowing for the collection of sub-slab vapor samples without significant disturbance to the structure. The pins typically consist of a stainless-steel body with a silicone sleeve that ensures a tight seal between the pin and the concrete, preventing air leakage and ensuring the integrity of the sample. Vapor pins are essential tools in environmental investigations as they enable the accurate measurement of volatile organic compounds (VOCs) and other hazardous vapors that might migrate from contaminated soil or groundwater into indoor air, thus facilitating the assessment and mitigation of potential health risks associated with vapor intrusion. As described within the VI Guidance, vapor pins are a suitable device to sample sub-slab soil vapor.

Permanent vapor pins will be installed, and sub-slab soil gas samples collected through them. The vapor pins will be installed initially using a 1 ¼-inch roto-hammer drill bit to drill an initial hole to allow vapor pin steel cover caps to be seated flush with the floor surface. A smaller 5/8-inch-diamater hole will then be drilled through the concrete slab. A vapor pin will be installed into the 5/8-inch-diameter hole with a silicone-rubber seal, and a silicone cap placed on a barbed fitting to allow for sub-slab sampling.

Sub-slab samples will be collected no less than two hours following installation of each vapor pin to meet the prescribed equilibration time. Prior to sample collection, a shut-in test will be performed to assess sample train integrity and apparatus fittings. The shut-in test will be performed by placing the valves at the sample canister and sub-slab soil gas point in the closed position, and using a manual purging device (i.e., gas-tight syringe with purge valve or SUMMA® canister) to apply a vacuum to the sampling apparatus of at least 10 inches of mercury. The valve between the tee and the manual purging device will then be closed to observe whether vacuum was maintained in the sampling apparatus between the sub-slab soil gas point and the sample canister. Leaks observed in the sampling manifolds will be repaired and the shut-in test will be retaken.

To assess for potential leaks during sub-slab soil gas sampling, helium will be used as a leak check compound to evaluate ambient air breakthrough to samples. Prior to sampling, helium will be pumped into a plexiglass box (shroud) surrounding the sampling equipment. The helium concentration will be maintained between 15 and 35 percent inside the shroud. The presence of helium above 5 percent in the sample will indicate if an ambient air leak occurred within the sampling system or indicate permeability of the slab. Once the leak check is complete, the soil vapor sample will be collected through the manifold and into laboratory provided 1-litter SUMMA® canisters.

A3 – Groundwater Sampling Procedures

General Procedures

Groundwater sampling will be performed in accordance with the following guidance documents:

- *Groundwater Issue: Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures* (Puls and Barcelona 1996).
- *Standard Operating Procedure EAP078, Version 2.3, Collecting Groundwater Samples for Volatiles and Other Organic Compounds from Monitoring Wells* (Ecology 2024b).

Groundwater monitoring field work will include the collection of groundwater level measurements, thicknesses of DNAPL and/or LNAPL, water quality parameters, and groundwater samples for laboratory analysis. A total of five monitoring events will be completed as part of this cleanup action. After the initial event is completed, Terraphase will confirm the locations of the proposed new monitoring wells and make adjustments as needed.

Groundwater Level Measurements

Groundwater elevation data will be collected from each of the monitoring wells prior to sampling activities. Groundwater elevation data collection will be completed using an oil/water interface probe that will also be used to measure possible DNAPL from chlorinated solvent releases and potential LNAPL from nearby historic petroleum releases. Measurements will be conducted in accordance with Terraphase SOP 200-23-00, Groundwater and Free Product Level Measurements. The full round of water level measurements will be completed in one day.

Groundwater Sample Collection Procedures

Samples will be collected using Ecology low flow sampling protocols and in accordance with Terraphase SOP 205-23-01, Groundwater Sampling – Low Flow. Terraphase plans to utilize a peristaltic pump for the collection of groundwater samples from wells in the shallow water bearing zone and a submersible pump for wells in the deeper water bearing zone. Terraphase may alter the type of sampling equipment used in subsequent groundwater sampling events based on the analytical data review.

Once Ecology stabilization criteria have been met, groundwater samples will be collected into appropriate sterile laboratory-supplied containers and immediately placed in a cooler containing ice and maintained at temperatures below 4° Celsius pending delivery to the laboratory. Samples will be delivered to the laboratory under appropriate chain-of-custody procedures and analyzed within prescribed holding times.

A4 – Labeling and Field Documentation

Field Documentation

At a minimum, sampling information will be recorded on a chain-of-custody form and on appropriate field forms. Both documents will be completed in the field at the time of sample collection. All chain-of-custody entries will be legible and will be recorded in indelible black ink. Field sample logs may be recorded electronically.

Field Logs

Field forms (daily, boring, and calibration logs) will be used to document field activities.

At a minimum, the daily logs will contain the following information:

- Project name and location
- Date and time
- Personnel in attendance
- General weather information
- Work performed
- Field observations
- Sampling performed, including specifics such as location, type of sample, type of analyses, and sample identification
- Field analyses performed, including results, instrument checks, problems, and calibration records for field instruments
- Descriptions of deviations from the Work Plan
- Problems encountered and corrective actions taken
- Identification of field quality control (QC) samples
- QC activities
- Verbal or written instructions
- Additional events that may affect the samples

Chain of Custody

The following will be recorded on the chain-of-custody form:

- Project name
- Project location
- Project number
- Sample ID
- Sampler name
- Sampler signature
- Project contact
- Air-bill number (if applicable)
- Date (of sample collection)
- Time (of sample collection to the nearest minute; 24-hour clock)
- Sample type (matrix)
- Turnaround time
- Sample depth in feet
- Laboratory name
- Number of sample containers
- Analyses required
- Comments
- Transfer signature (to relinquish samples)
- The sampler will be the first person to relinquish sample possession
- Courier/laboratory representative signature (for commercial carrier, record air-bill number)
- Date/time (of custody transfer)
- Special Laboratory instruction as necessary

A5 – QA/QC Procedures

Quality Assurance/Quality Control Procedures

The following describes the field and laboratory quality assurance (QA) and quality control (QC) procedures that may be used during the RI Work Plan activities

Data Quality Objectives and Criteria

The data quality objective (DQO) process comprises the following seven iterative steps, consistent with guidance presented in the EPA's 2006 Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA QA/G-4):

1. **State the Problem.** Additional assessment is necessary to address data gaps identified in Section 2 of this Draft Work Plan.
2. **Identify the Goal of the Study.** The objective of the activities described in this RI Work Plan is to fill the remaining data gaps to pursue a no further action.
3. **Identify Information Inputs** (the data types that will be required before project decisions can be made). The primary required data types will be analytical results from soil, groundwater, and soil-vapor samples. Additional inputs include groundwater flow direction, and survey data.
4. **Define the Boundaries of the Study** (the spatial and temporal features pertinent for decision making). The study includes fill and underlying native soil, and shallow groundwater within the property boundary and area adjacent to the Site.
5. **Develop the Analytic Approach** (how the study results will be analyzed and conclusions made from the data). The sample results will be used to assess the presence and evaluate the extent of soil, groundwater, and soil vapor at the Site. If sampling activities do not produce sufficient analytical data to meet project objectives, then additional sample collection may be warranted. The analytical results will be compared to the screening criteria described in Section 5 of this RI Work Plan.
6. **Specify Performance or Acceptance Criteria** (performance or acceptance criteria that the collected data will need to achieve). Data must be of known quality to withstand scientific and legal challenges relative to its intended purpose. Completeness is the measure of the amount of valid data obtained from a measurement system compared to the amount expected to be obtained under normal conditions. Based on evaluation of the data in terms of precision, accuracy, representativeness, comparability, and sensitivity, a completeness objective of 95 percent of the data set has been established for the sampling activities. If the completeness objective is not met, additional sampling may be warranted.
7. **Develop the Plan for Obtaining Data.** The sample data will be collected according to the process outlined in Section 3 of this RI Work Plan.

The DQO process establishes the acceptance criteria, which serve as the basis for collecting data of sufficient quality and quantity to support the goals of the project activities. To meet the DQOs for this project, the analytical results will be sufficient for comparison to the criteria described in Section 3 of this RI Work Plan.

Analytical Levels

Analytical levels are defined by EPA as follows:

- **Screening Data.** Generated by rapid, less precise methods of analysis with less rigorous sample preparation. Sample preparation steps may be restricted to simple procedures such as dilution with a solvent, instead of elaborate extraction/digestion and cleanup. Screening data provide analyte identification and quantitation, although the quantitation may be relatively imprecise. Screening data without associated confirmation data are not considered to be data of known quality. During sampling activities, the following screening data may be measured in the field: VOCs (from a photoionization detector), pH, temperature, specific conductivity, dissolved oxygen, oxidation-reduction potential, and turbidity (from a water quality device).
- **Definitive Data.** Generated using rigorous analytical methods, such as EPA reference methods. Data are analyte-specific, with confirmation of analyte identity and concentration. Methods produce tangible raw data in the form of paper printouts or computer-generated electronic files. Data may be generated at the Site or at an off-Site location as long as the QA/QC requirements are satisfied. For the data to be definitive, either analytical or total measurement error must be identified.

The QA/QC program described in this RI Work Plan was developed to assess adherence to DQOs. The specific approaches that will be taken to achieve the required DQOs are described below.

Precision describes the reproducibility of measurements under a given set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements that have been made in an identical manner, compared to their average value. Precision can be expressed in a variety of manners that include absolute methods such as deviation from the mean or median values, standard deviation and variance, or relative methods (e.g., relative deviation from the mean or median). The overall precision will be determined through the analysis of field duplicates, laboratory duplicates, and matrix spike and matrix spike duplicate (MS/MSD) samples.

Accuracy is defined as the degree of difference between measured or calculated values and the true value. The closer the numerical value of the measurement comes to the true value or actual concentration, the more accurate the measurement. Accuracy is expressed in terms of absolute or relative error. Accuracy will be determined through analysis of spiked samples and the analysis of standards with known concentrations.

Representativeness refers to the degree to which a sample taken from a Site accurately reflects the matrix at the Site. It is a qualitative parameter that is most concerned with the design of the sampling program. Factors that will be considered in the determination of representativeness include appropriateness of sampling and analytical methodologies, representativeness of the selected media, and representativeness of the selected analytical procedures. Representativeness will be achieved by use of the procedures for the collection of samples as described Section 3 of this RI Work Plan.

Comparability refers to the use of consistent procedures, second-source reference standards, reporting units, and standardized data format with document control. Adherence to standard procedures and the analysis of external source standard materials maximizes the probability that data generated from a particular method at a given laboratory can be validly compared to the data of another. This RI Work

Plan provides data that will be comparable to other data collected, as standard methods will be utilized for these sampling and analysis activities.

Completeness refers to the process of obtaining the required data as outlined in the RI Work Plan. Completeness is also defined as the percentage of measurements judged to be useable. Samples for which the critical data points fail completeness objectives will require reanalysis of samples (within the specified holding times) until the DQOs are met. The completeness goal has been specified at 95 percent for the sampling activities.

Sensitivity refers to a measurable concentration of an analyte that has an acceptable level of confidence. Method detection limits are the lowest concentration of an analyte that can be measured with 99% confidence that the analyte concentration is greater than zero. Reporting limits are levels above the method detection limits at which the laboratory has demonstrated the quantitation of analytes.

Field Sampling Objectives

The objective of the field sampling program is to obtain samples that represent the environmental matrix being investigated. This will be accomplished by using the sampling techniques and equipment as presented in this RI Work Plan.

Field screening activities may not require sample collection but, nonetheless, involve measurements for which QA concerns are appropriate. The primary QA objective of field screening is to obtain reproducible measurements to a degree of accuracy consistent with the intended use of the measurements and to document measurement procedures.

Laboratory Objectives

To obtain data of a quality sufficient to meet the project DQOs, the laboratory will adhere to the specific analyses and QA/QC requirements in the published analytical methods listed. The methods proposed in this RI Work Plan will provide data of sufficient quality for comparisons to regulatory criteria and project action levels.

Field QC Samples

Equipment blank samples consist of reagent water collected from a rinse of sampling equipment after the decontamination procedure has been performed. The purpose of equipment blank samples is to confirm the effectiveness of equipment decontamination procedures in place to minimize cross-contamination between samples. An equipment blank will be collected for each day of field work following decontamination of the downhole tooling by pouring laboratory-supplied deionized water across the sampling equipment directly into laboratory-supplied sample bottles. The samples will be submitted to the laboratory under standard chain-of-custody procedures and analyzed for the same constituents as the samples.

A laboratory-supplied trip blank sample will be submitted to an analytical laboratory under standard chain-of-custody procedures for each sample batch in which CVOCs are an analyte and analyzed for

CVOCs in accordance with EPA 8260. Trip blank samples consist of clean volatile organic analysis vials filled with deionized/organic-free water and preserved. These vials are supplied by the laboratory and returned to the laboratory for storage and analysis with the field samples. The trip blank data will demonstrate whether the samples were exposed to contamination during storage and transport to the laboratory.

One field duplicate sample per 20 samples will be collected for each matrix (drinking water, soil, grab-groundwater, discharge line water, and soil vapor) and submitted for the same analysis as the corresponding primary sample. Duplicate samples provide data to assess precision of the field sampling procedure and contract laboratory. However, variability in field duplicate sample results can be an indicator of matrix variability and heterogeneity.

Laboratory QC Samples

The laboratory QC samples will be used to assess the accuracy and precision of laboratory analyses. The following subsections describe the specific laboratory procedures to be followed.

Calibration Verification

Instruments will initially be calibrated at the start of the project or sample run, as required, and when any ongoing calibration does not meet control criteria. The number of points used in the initial calibration is defined in the analytical method. Calibration will be continued as specified in the analytical method to track instrument performance. If a continuing calibration does not meet control limits, analysis of project samples will be suspended until the source of the control failure is either eliminated or reduced to within control specifications. Any project samples analyzed while the instrument was outside control limits will be reanalyzed.

MS/MSD

MS/MSD samples are analyzed to assess the matrix effects on the accuracy of analytical measurements. MS/MSD samples will be prepared by spiking investigative samples with known amounts of analytes before extraction and preparation and analysis. The samples collected as part of the investigation will have sufficient excess volume for use as MS and MSD samples. The recoveries for the MS/MSD samples will be used to assess the accuracy and precision in the analytical method by measuring how well the analytical method recovers the target compounds in the investigative matrices. For each matrix type, at least one set of MS/MSD samples will be analyzed for each batch (i.e., 20 or fewer) of samples received.

Surrogate Spikes

Surrogate spiking consists of adding reference compounds to samples before sample preparation for organic analysis. Surrogate compound spiking is used to assess method accuracy on a sample-specific basis. Surrogate compounds will be added to samples in accordance with the analytical method requirements.

Method Blanks

Method blanks are prepared using analyte-free (reagent) water and are processed with the same methodology (e.g., extraction, digestion) as the associated investigative samples. Method blanks are used to document contamination resulting from the analytical process in the laboratory. One method blank per each analytical batch will be prepared and analyzed.

The method blank results are used to verify that reagents and preparation do not impart unacceptable bias to the investigative sample results. The presence of analytes in the method blank sample will be evaluated against method-specific thresholds. Investigative samples of an analytical batch associated with method blank results outside acceptance limits will be qualified, as appropriate, by the data validation contractor.

Laboratory Control Samples

Laboratory control samples (LCSs) are prepared by spiking laboratory-certified reagent-grade water with the analytes of interest or a certified reference material that is prepared and analyzed. The result for percent recovery of the LCS is a data quality indicator of the accuracy of the analytical method and laboratory performance.

Laboratory Duplicate Samples

LCS duplicates (LCSDs) are prepared by the laboratory by splitting an investigative sample into two separate aliquots and performing separate sample preparation and analysis on each aliquot. The results for relative percent difference (RPD) of the primary investigative sample and the LCSD are used to measure precision in the analytical method and laboratory performance. For nonaqueous matrices, sample heterogeneity may affect the measured precision for the LCSD.

Data Quality Measurements

As a QA/QC requirement, the following data quality measurements will be made during the data validation and verification procedures discussed in Section 4.5 of this RI Work Plan.

Data Precision

Precision is the measure of agreement among repeated measurements of the same property under identical or substantially similar conditions, calculated as either the range or the standard deviation (EPA 2002). Precision is measured by making repeated analyses on the same analytical instrument (e.g., LCSDs or MSDs) or replicate collections of samples in the field (i.e., field duplicates). Precision criteria are expressed as the RPD between the primary and duplicate samples.

The RPD is calculated using the following equation:

$$RPD = \frac{|X_{PS} - X_{DS}|}{\left(\frac{X_{PS} + X_{DS}}{2}\right)} * 100\%$$

Where:

X_{PS} = result for primary sample

X_{DS} = result for duplicate sample

Non-detects and results at or near the method reporting limit will be considered when interpreting data precision.

Data Bias

Bias is defined as the systematic or persistent distortion of a measurement process that causes error in one direction (EPA 2002). Data bias is addressed in the field and the laboratory by calibrating equipment, through collection and analysis of QC blank samples, and through the analysis of QC standard samples.

Data Accuracy

Accuracy is defined as the measure of the overall agreement of a measurement to a known value and includes a combination of random error (precision) and systematic error (bias) components of both sampling and analytical operations (EPA 2002). Inasmuch as the "true" concentration of sampled media is not known, the degree of accuracy in the measurement is inferred from recovery data determined by sample spiking and/or the analyses of reference standards. The criterion for accuracy is expressed as the percent recovery of the sample spiking.

Percent recovery is calculated using the following equation:

$$Percent\ Recovery = \frac{|X_{SS} - X_S|}{T} * 100\%$$

Where:

X_{ss} = result for spiked sample

X_s = result for sample

T = true value of added spike

Data Completeness

Data completeness is defined as a measure of the amount of valid data needed from a measurement system (EPA 2002). It is measured as the total number of samples collected for which the valid analytical data are obtained divided by the total number of samples collected and multiplied by 100. Data completeness criteria will be 95 percent.

Data Representativeness

Data representativeness is a qualitative term that expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition (EPA 2002). Data representativeness is evaluated by assessing the accuracy and precision of the sampling program. The criterion for evaluating representativeness will be satisfied by confirming that the sample collection procedures are consistently followed.

Data Comparability

Data comparability is a qualitative term that expresses the measure of confidence with which one data set can be compared to another or combined with another for decision making (EPA 2002). Data comparability will be achieved by using standard sampling and operating procedures and analytical methods. Data comparability will be assessed through documentation of QA/QC procedures.

Data Sensitivity

Data sensitivity is defined as the capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest (EPA 2002). Results measured between the reporting limits and the method or estimated detection limits will be reported for all analytes and assigned the appropriate qualifiers.

Data Verification and Validation

The following describes applicable data verification and validation procedures.

Field Data Verification

Field data collected during field activities will be evaluated for usability by a QA review that consists of checking procedures followed and comparing the data to previous measurements. Field QC samples will be evaluated to ensure that field measurements and sampling protocols have been observed and followed.

The field data verification process will be performed at two levels. The first level, which will be conducted at the time of collection, consists of following the standard procedures and QC checks. The second level, performed during compilation of field data, will include checks for data anomalies. Anomalies or inconsistent data will be resolved by seeking clarification from field personnel responsible for collecting the data and will be documented during the data verification process.

Laboratory Data Verification

The laboratory analyst will be responsible for the reduction of raw data generated at the laboratory bench and verification that data reduction performed by the laboratory instrument or laboratory information management system is correct.

The following data verification QC checks will be performed for all generated data:

- Verify that batch QC were analyzed at the specified frequency.
- Verify that calibrations and calibration checks comply with laboratory criteria.
- Verify that holding times for extraction, analysis, and sample preservation were met.
- Verify that the quantitation limits and method detection limits were met.
- Verify that all project and QC sample results were properly reported and flagged appropriately for any failing laboratory QC or as necessary to address other data quality issues.
- Review chain-of-custody documentation to verify completeness of the sample set for each data package submitted.
- Assess the impact of laboratory and field QC results.

These QC checks will be performed by laboratory analysts, the assigned laboratory project manager or supervisor, laboratory QC specialists, or a combination of these personnel. After the data reports have been reviewed and verified, the laboratory reports will be signed and released for distribution.

Data Validation

Terraphase will perform Tier II data validation on 100 percent of the data report packages. The Tier II process will consist of reviewing consistency with the chain of custody, holding times, surrogate recoveries, LCS and MS recoveries, field duplicate agreement, MSD and LCSD precision, equipment blanks, and method blank analyses. Data validation reports will be prepared for each data package and provided with the investigation report. The samples and analytes requiring qualification will be listed with the assigned qualifier and a brief description of the basis for qualification. Qualifiers applied by either the analytical laboratory or the data validator will be listed.

Any major or minor deficiencies noted during the data validation process will be documented. If the data are qualified due to any outlier in QC criteria, the specific sample and analyte affected by the deficiency will be identified. Data validation reports will include the definitions of the data validation qualifiers that are assigned to the analytical data.

terraphase engineering

Standard Operating Procedure 200-23-00

Groundwater and Free Product Level Measurements

This Standard Operating Procedure (SOP) describes the procedures established by Terraphase for groundwater level (depth to water) and free product level (depth of free product) measurements in groundwater monitoring wells or piezometers. These guidelines may also be applicable for measuring the depth to water or free product in other types of wells (potable and non-potable) or boreholes.

Groundwater level measurements are collected to determine the depth to groundwater within a well relative to ground surface, top of the well casing, and/or an established elevation datum. Similarly, free product measurements are collected to determine the depth to non-aqueous phase liquid (NAPL) accumulated within a well relative to an established elevation datum. The accumulated thickness of NAPL within a well can be determined if the bottom of the free product can be additionally measured. Properly collected and recorded measurements can be utilized for generation of potentiometric surface maps to establish groundwater flow direction, define horizontal and vertical hydraulic gradients, evaluate variations in groundwater elevations over time, evaluate NAPL mobility or recovery, and other project-specific tasks.

Although this SOP provides guidelines for groundwater and free product level measurements, certain projects will require site-specific sampling procedures, adhering to state- or regulatory program-specific guidelines, requirements, or procedures, as applicable. Specific requirements for these types of projects will be reviewed by the Terraphase principal-in-charge/project director (PIC) and project manager (PM) and any additional requirements will be defined in a project-specific work plan, sampling plan, and/or SOP(s). **These guidelines are not meant to be project-specific work plans but rather a general reference for developing project specific requirements.**

This SOP does not supersede Terraphase health and safety procedures or site-specific health and safety plan (HASP) requirements; in the event of conflict between this SOP and the site- specific HASP, the procedures outlined in the HASP shall prevail. All Terraphase employees shall follow the guidelines, rules, and procedures contained in the site-specific HASP, followed by procedures recommended in this SOP. The Terraphase PIC and PM shall ensure that all project personnel review and sign the applicable HASP, and the signed HASP and relevant project information are maintained in the project file for the duration of the project. The signatures of the PIC and PM indicate approval of the methods and precautions outlined in the HASP.

1. Materials and Equipment

Below is a general checklist of equipment that may be required for typical groundwater level measurement efforts. This checklist only suggests general equipment that may be necessary for a project or task and should not be considered exhaustive:

1. General water and free product level measurement equipment:
   - Electronic water level indicator
   - Electronic oil/water interface probe for wells containing known or suspected NAPL
   - GPS or other locating device
   - Site map showing locations of wells
   - Well construction records and previous water level measurements
2. Project- or task-specific water and free product level measurement equipment:
   - Well lock keys
   - Steel tape measure or submersible water level meter for use in measuring total well depth
   - Decontamination supplies/equipment (non-ionic detergent, tub, brushes, etc.)
   - Wash bottles/bucket
   - Trash bags (used to dispose of gloves and any other non-hazardous waste generated during sampling)
   - Appropriate waste container (used to dispose investigation-derived wastes and/or decontamination wastes)
   - Socket wrench (manhole bolt sizes vary; most commonly require a 9/16-inch socket)
   - Water valve gate box key (for older style flush-mounted wells)
   - Pry bar (or other equivalent tool to assist in the removal of the flush-mounted well cover or handhole)
   - Syringe (or other equivalent tool, such as a turkey baster, to assist in removing standing water in flush mounted wells)
   - Extra batteries for the water level meter (usually 9-volt)
3. Miscellaneous additional suggested equipment:
   - Extra vehicle keys
   - Metal locator (to find buried/obstructed flush mounted wells)
   - First aid kit
   - Mobile phone
   - Credit card for gas and emergencies
   - Road and site maps
   - Chemical protective gloves and other personal protective equipment, as required by the HASP
   - Field notebook and field data sheets
   - Waterproof pens

- Bolt cutters (to remove rusted padlocks)
- Replacement padlocks
- Camera and extra batteries

2. Procedures

This section discusses guidelines for field work preparation, measuring water levels, and quality assurance/quality control practices.

2.1 Field Work Preparation Guidelines

Before initiating field activities, the following tasks should be completed to prepare field staff for what may be expected during implementation of the work:

- Review and sign the site-specific HASP;
- Coordinate and obtain permission for site access;
- Review project-specific work plan/sampling plan;
- Review project-specific quality assurance project plan (QAPP), where applicable;
- Review and discuss with PIC and/or PM the proposed activities or work plan/sampling plan;
- Review the standard instruction manual provided by the manufacturer of the specific equipment to be used for water level monitoring and field screening;
- Inspect the water level meter(s) for any signs of damage and test for proper operation;
- Identify well locations, specific order in which they are to be collected, and confirm the measurement datum on each well casing;
- Obtain copies of recent or historical (i.e., same season) water or free product level data to be able to anticipate the approximate depth of water or free product, minimizing unnecessary wetting of the tape and as a check of the measured levels;
- Obtain copies of well construction records (these can be used to confirm the well identification if not clearly identifiable); and
- Identify wells that are known or suspected to contain NAPL or other free product. An electronic oil/water interface meter must be used in these wells in lieu of an electronic water level indicator.

All significant field activities will be approved by the PIC and/or PM before the initiation of field activities. The sampling plan should be designed for the collection of quality data that meets the goals of the study/monitoring program. The work plan/sampling plan should generally provide for some discretion in the field depending on encountered conditions; however, any significant departure from prescribed field activities shall be approved by the PIC and/or PM.

Prior to the commencement of the field effort, inspect, test, and/or calibrate equipment that will be used to take field measurements.

2.2 General Water Level Measurement Guidelines

Water level measurements are generally taken in monitoring wells, piezometers, or boreholes using electronic water level indicators. There are different manufacturers of electronic water level indicators (e.g., Solinst, Keck, and Heron). Electronic water level indicators consist of a reel of dual conductor wire embedded within a pre-marked tape, a probe with an insulating gap between the wire attached to the end of the tape, and an indicator on the reel. Generally, tapes are marked every 1/100 of a foot and/or millimeter. When the probe comes in contact with water, the circuit is closed, and the indicator signals this contact with an audible buzzer and/or an optical light. The meters typically run on 9-volt batteries located within the reel as a power source. Many water level meters include a sensitivity adjustment on the indicator. The sensitivity adjustment diminishes potential short circuiting of the probe in moist environments, such as those encountered in a well.

The following provides a recommended list of practices for water and/or free product level measurement activities:

- Where applicable, contact the identified key site personnel upon arrival to the site and assess proposed work areas.
- All wells to be gauged should be inspected for damage, access constraints, and/or vehicle traffic proximate to the well location.
- Because groundwater or free product depth can vary due to natural fluctuations in ambient conditions (e.g., barometric pressure), all measurements for a specific sampling event should be collected within as short of a time frame as possible.
- Although equipment should be decontaminated between uses, to further limit potential cross-contamination between wells, perform measurements from least to most contaminated locations.
- All depth to water or free product measurements should be completed prior to any planned groundwater and/or product withdrawals, sampling or disturbance of groundwater unless otherwise specified in the work plan/sampling plan.
- All water or free product level measurements should be made relative to an established reference datum and recorded in the field notes. The reference datum is usually marked, notched, or etched on the well or casing at the time of installation on the north side of the inner casing. In the absence of a marked, notched, or etched reference datum, water level and depth measurements should be taken from the north side of the inner casing and marked or etched for future reference. If a casing is notched or etched at a distinct angle, the measurements should be made from the highest point in the casing. Note this procedure in the field book.
- Record in the field book the model name, number, and serial number of the electronic water level meter or interface probe to be used.
- Identify the well to be measured and confirm by checking for proper identification markings on the well, comparing location on the site map, and if needed, historical water and/or product level measurements and well construction records. If the well cannot be positively identified, contact the PIC or PM before proceeding. It may be possible to identify the well by comparison of the total well depth with the well construction records; however, such measurement should be discussed with the PIC or PM before proceeding in cases where the well is to be sampled after water level/free product measurements are collected.

- Decontaminate the water level meter probe, interface probe, and/or tape (if total well depth measurements are obtained with a tape) prior to each use.
- Remove the well cover or equivalent protective casing cover. Inspect the interior of the well box for insects, etc., that could present a biological hazard. If there is water in the well box, remove all water (at least to a level below the top of the inner well casing) prior to removing the well cap or plug. Indicate that water was removed from the well box and identify possible causes (e.g., missing bolts, damaged well cover, etc.).
- Remove the well cap or plug, noting well identification, time of day, and date in field book. Also note any abnormal conditions in the well (e.g., damaged inner casing, limited clearance between the bottom of the well box and the top of the inner well casing, absence of reference datum, etc.) If the top of the well casing has been damaged, the reference datum may no longer be accurate.
- If present, remove expansion caps and the wells allowed to equilibrate for an appropriate period prior to the collection of water level measurements. This is especially critical for wells screened below the water table or in confined units. There are no set guidelines and appropriate equilibration times can range from minutes to hours depending on well recharge, local geology and topography, and project objectives.
- Record observance of positive or negative pressure in the well upon removal of the well cap. The presence of pressure/vacuum in the well could be qualitatively assessed during loosening and removal of an expansion cap (resulting in air either being audibly pushed out or drawn in to the well casing) or using a piece of paper or other light object (i.e., easily moved or displaced by light air flow) placed immediately above the inner well casing and observing its movement (i.e., if it adheres to well casing, there is a negative pressure in the well; if it moves from the well casing, there is a positive pressure in the well). If pressure is observed, the water level should be measured multiple times over a 5- to 10-minute period to allow time for equilibration and confirm that the water level has reached static conditions.
- Monitor the headspace of well with a field screening device in accordance with the applicable manufacturer instructions. Record field screening readings in field book. The necessity and methodology to conduct field screening should be detailed in the site-specific HASP and sampling plan.
- Check that the indicator on the water level probe is working properly by pushing the test button on the reel. Replace batteries in the electronic water level meter or product interface probe if testing or operation indicates the battery is not providing sufficient power. Battery replacement during a field measurement event must be recorded in the field book.
- Lower the probe slowly into the well taking care to minimize contact with the well casing. If significant kinks are observed in the tape, attempt to straighten manually and record observations in the project field book.
- When a strong and steady signal from the indicator signals water or free product has been encountered, slowly pull the tape up until the signal ceases.
- Manually lower and raise the probe to exactly locate the water or free product interface.
- At the point where the signal indicates free water surface or free product has been encountered, measure and record the depth of the probe using the marked tape.

- If free product is encountered, continue to manually lower the probe into the well until a strong and steady signal from the indicator signals that water has been encountered. Lower and raise the probe to exactly locate the water or free product interface. Measure and record the depth of the probe using the marked tape.
- Measurements should be taken according to the established reference datum.
- Repeat the measurement to verify accuracy. Measurement should be recorded to the nearest 1/100 of a foot or to the nearest millimeter.
- If total well depth measurements are required, these should be made in reference to the top of casing as well as the ground surface. These measurements should be performed after sampling.
- Withdraw the probe from the well, replace the well cap, and re-secure the well.
- Record in the field book any abnormal conditions within the well (e.g., evidence of blockage, root growth into the well casing, separated casing sections, etc.). Inform the PIC or PM so necessary maintenance, redevelopment, or repairs are conducted before the next planned water level measurement event.

To minimize potential cross-contamination across wells, decontaminate the probe and portions of the tape that contacted water and/or product as described in the project-specific sampling plan, QAPP, and/or SOP 109, “Sampling Equipment Decontamination.”

2.3 Quality Assurance/Quality Control

Quality assurance/quality control procedures described in the project-specific work plan/sampling plan and/or QAPP must be followed throughout the water level measurement process.

3. Precautions

All field activities require recording sufficiently detailed information throughout the implementation of field work. Additionally, implementation of the work may face some difficulties. However, the following precautions should be taken to ensure safety while conducting water level measurements:

- Operate electronic water level meters and product interface probes in accordance with the manufacturer’s instructions and recommendations.
- The protective casing of flush-mount wells often fills with run-off surface water. If upon removing the well cover the top of inner well casing is submerged, utilize a syringe, turkey baster, or equivalent tool to remove the excess water before removing the well cap to avoid surface water flow into the well.
- Well keys may not work with rusted/outdated well locks; bolt cutters may be used to remove the lock, which should be replaced upon completion of water level measurement. Do not use petroleum-based solvent sprays to free seized locks as this may impact water quality in the well.
- Wells with a water-tight cap may experience a buildup of pressure, especially if they are screened below the static water level. Keep your face and body away from the top of the well when loosening or removing the cap.

- Ensure that the water level has reached the static level prior to recording the depth to water. If the water level is in a state of flux due to pressure buildup, allow ample time for the water level to stabilize to static conditions before recording the measurement (refer to Section 4.2).
- Water level probe indicator response may be indicative of potential faults that could be corrected in the field, as follows:
  - If the signal from the indicator is intermittent or weak it may be necessary to decrease the sensitivity since it may be short circuiting prior to encountering free water.
  - If there is no signal it may be necessary to increase the sensitivity since some groundwater is less conductive and may not complete the circuit.
  - If the signal is still intermittent, weak, or absent then replace the battery and reattempt the measurement.
- Cascading water may interfere with the measurement of free water, particularly inopen boreholes or rock wells.
- Some well casings have sharp edges; care should be taken when lowering orwithdrawing the tape to avoid damaging the tape and water level probe.
- Oil or other product floating on the water column may insulate the contacts of the probe resulting in a misleading indication of the depth to free water. A separate oil/water level indicator should be used if there is known or suspected product in a well.
- Note some water level indicators will have a 2- to-3-inch weight on the tip of the probe which can displace water in a well before the water indicator detects it. These models also make it difficult to detect small amounts of water in wells (i.e., less than 3 inches). If this is expected to be a potential issue, then request a model with the water indicator located on the tip of the probe.
- Meters should be inspected periodically to ensure accurate readings. Electronic water level meters and interface probes may not function properly if the electric wire is broken or cut, or if insulation is removed, exposing the wire (resulting in short circuiting). Repaired meters may have had sections of the tape removed and/or spliced and may not meet data quality objectives. Damaged or suspected damaged tapes should be repaired by the manufacturer or replaced.
- If using the water level meter for total depth measurements, confirm that the probe is designed for total immersion and the maximum acceptable depth of immersion.
- Tape lengths can be confirmed using calibrated steel tape as necessary to adhere to data quality objectives. Discrepancies in tape length must be noted in the field logbook and/or field sheet.
- For high conductivity groundwater (brine) decreasing the sensitivity control prevents bridging so a moist probe is not detected in the water.

4. Recordkeeping

Document all water level measurement locations and record all information in accordance with SOPs 100, “Field and Lab Data Management,” and 106, “Field Notebook.”

Standard Operating Procedure 205-23-01

Groundwater Sampling - Low Flow

1. Performance Objective

This Standard Operating Procedure (SOP) presents general guidelines established by Terraphase for the collection of groundwater samples for laboratory analysis using low-flow purging and sampling (LFPS) techniques. The purpose of LFPS is to collect groundwater samples that are representative of ambient groundwater conditions in the aquifer. This is accomplished by adjusting the intake velocity of the sampling pump to a flow rate that limits drawdown inside the well. LFPS has the following benefits over conventional purging:

- It minimizes disturbance of sediment in the bottom of the well, thereby producing a less turbid sample;
- It minimizes turbulence and aeration of the groundwater sample during sample collection;
- The amount of groundwater purged from the well is usually reduced compared to conventional groundwater purging and sampling methods, thereby reducing water management requirements;
- Groundwater samples tend to be more representative of actual aquifer conditions with respect to mobile contaminants and turbidity as LFPS causes minimal disturbance of the formation adjacent to the screened interval; and
- It is generally less prone to sampling variability, and increases sample consistency and reproducibility of data.

Although this SOP provides guidelines for collection of groundwater samples using LFPS, more specific sampling procedures (i.e., site-, state-, or regulatory program-specific guidelines, requirements, or procedures) may be applicable to a particular project. Specific requirements for each project will be reviewed by the Terraphase client manager (CM) and project manager (PM). Any additional requirements will be defined in a project-specific work plan, sampling plan, and/or SOP. **The guidelines in this SOP are not meant to be project-specific work plans, but rather serve as a general reference for developing project-specific requirements.**

This SOP does not supersede Terraphase health and safety procedures or site-specific health and safety plan (HASP) requirements. In the event of conflict between this SOP and the site-specific HASP, the procedures outlined in the HASP shall prevail. All Terraphase employees shall follow the guidelines, rules, and procedures contained in the site-specific HASP followed by procedures recommended in this SOP. The Terraphase CM and PM shall ensure that all project personnel review and sign the applicable HASP, and that the signed HASP and relevant project information are maintained in the project file for the duration of the project. The signatures of the CM and PM indicate approval of the methods and precautions outlined in the HASP.

2. Equipment and Materials

A general checklist of equipment that may be required for typical LFPS is provided below. Additional equipment may be specified in the project-specific HASP and/or field sampling plan. This checklist includes an overall summary of general equipment typically required for LFPS but should not be considered exhaustive. More specialized sampling equipment may be required depending on project-specific preferences. Terraphase personnel should understand the equipment and materials that are required for groundwater sampling.

The following is a list of equipment necessary to carry out the procedures contained in this SOP:

1. General Groundwater Sampling Equipment Checklist:
   - Site information (e.g., maps, contact numbers, keys or lock codes for gates or access points).
   - Well construction specifications and diagrams.
   - Groundwater sampling logs and field forms from the previous sampling event, if applicable.
   - Field notebook and all-weather or permanent pens as outlined in SOP 106, “Field Notebook (without iPad).”
   - Plastic sheeting.
   - Cable ties.
   - Keys for wells.
   - Measuring tape.
   - Electronic water level indicator.
   - Sample containers (appropriate for various analysis to be performed).
   - Sample shipment containers and ancillary materials.
   - Sample labels, indelible pen or sharpie, and clear tape.
   - Chain-of-custody forms.
   - Trash bags for disposal of gloves and any other non-hazardous waste generated during sampling.
   - Department of Transportation-rated (for legal waste hauling) 55- gallon steel drums, or other appropriate waste container, for disposal of any investigation-derived wastes (IDWs) and/or decontamination wastes.
   - Labeling materials for IDW.
   - Bucket, spray bottle, distilled/deionized (DI) water, and Liquinox (or Alconox) for the decontamination of sampling and monitoring equipment.

- Personal protective and field screening equipment in accordance with the site-specific HASP (e.g., clean, chemical protective, dedicated gloves must always be worn when handling and using sample equipment).

2. Project- or Task-specific LFPS Equipment Checklist:
   - Pump and associated equipment (e.g., generator, extension cords, batteries, control box, compressor, carbon dioxide or nitrogen compressed gas cylinders).
   - Tubing to discharge water from the pump(s). The tubing must be either Teflon® or Teflon®-lined polyethylene; however, when sampling for metals analysis only, the tubing may be constructed of flexible polypropylene or polyethylene.
   - Water quality meter with flow-through cell that, at a minimum, measures temperature, pH, dissolved oxygen (DO), oxygen reduction potential (ORP), and specific electric conductance and associated manuals; turbidity measurements can be made using a separate turbidity meter (total capacity of the cell must be less than 300 milliliters [mL]).
   - Measuring container (e.g., 1-gallon plastic water jug, graduated measuring cup, or graduated cylinder).
   - Plumbing fittings (check valves, barbed “T” or “Y” fittings, stainless-steel needle valves or stainless-steel/Teflon ball valves).
   - Dedicated suspension line or tether constructed of material that minimizes interactions or alterations when in contact with groundwater or that may cause loss of analytes via sorption (e.g., poly twine, nylon string, stainless-steel, Teflon-coated stainless-steel wire, etc.) for lowering and raising the pump (pump tubing does not constitute a dedicated suspension line and should not be used for lowering and raising pump).
3. Additional Suggested Equipment:
   - Tool set (socket wrench/ set, screwdriver, multi-tool, tubing cutters, “turkey baster” and/or cup for water removal from flush-mounted well vaults).
   - Spare/replacement parts (gripper plug/well cap, well lid bolts).
   - Road and site maps.
   - Mobile phone.
   - Camera and extra batteries.

A description of the types of LFPS is provided in Attachment A.

3. Procedures

This section discusses planning considerations; initial field preparation; general LFPS guidelines; use, provision, and transport of sampling containers; and general quality assurance (QA)/quality control (QC) procedures.

3.1 Planning and Design Considerations

All significant sampling strategy decisions will be approved by the CM and/or PM before the initiation of associated field activities. A work plan/field sampling plan will be designed for the collection of quality data to meet the goals of the study/monitoring program and will include the number, location, and depths of sampling sites; number of samples; analyses and analyte detection limits to be performed on each sample; and QA/QC samples. The work plan/field sampling plan will generally provide for some discretion in the field depending on conditions encountered; however, any significant departure from prescribed sampling activities should be approved by the CM and/or PM.

When planning a low-flow sampling event for a well that will be purged, the following should be considered:

- **Pump selection.** The equipment needed for groundwater LFPS can vary greatly depending on specific site conditions and project objectives. LFPS is generally conducted at flow rates of 500 mL per minute or less. Submersible, positive-displacement pumps must be used for LFPS. In specific cases, peristaltic pumps may be appropriate and could be used for LFPS when previously approved by the CM and/or PM or defined in project-specific work plans. The more commonly used positive-displacement pumps include bladder, variable-speed submersible-centrifugal, and gear pumps. Pump selection should take into consideration a variety of well characteristics including, but not limited to, depth to water; analytes of interest; chemical incompatibilities; suspended solids concentrations; ease of decontamination; and availability of a power source. Descriptions of common LFPS equipment and a list of their advantages/limitations are provided in Attachment A.
- **Tubing.** The preferred inside diameter of tubing is one-quarter inch (1/4) and should be no greater than three-eighths of an inch (3/8). Larger tubing diameters reduce flow velocity, resulting in a corresponding increase of pump speeds to maintain flow. Increased pump speed will, in turn, elevate the potential for turbulent flow across the screened interval and this may affect the quality of the water being sampled. Conversely, any reduction in flow velocity may allow air to become trapped in the tubing and ultimately affect air-sensitive parameters or allow particulates to settle, which may affect turbidity values.
- **Flow-through cell (flow cell).** Typical flow-through cell design is not complicated and almost all share common features. Cells should be transparent to monitor the physical condition of the purge water or air bubbles passing through the system. For example, highly turbid or iron bacteria-laden water can be visually monitored for change as the purge progresses. The cell must also be sealed against unwanted exposure to the atmosphere, thus ensuring accurate measurement of air-sensitive parameters (DO, pH, etc.). The total capacity of the cell must be small (i.e., less than 300 mL) to maintain a desirable turnover rate of water coming into the cell and ensure real-time data integrity. The in-line design of the cell must also allow for purge water to enter the flow cell from a bottom port and exit at the top. The discharge of the flow cell may be fitted with a check valve.

- **Pump intake location.** When LFPS is performed correctly, the data collected should be reflective of water quality within a narrow zone along a length of well screen or fracture in an open borehole. Therefore, it is important to place the pump intake in the zone of highest contaminant concentration or contaminant flux along the screened/open-hole interval. This is particularly important in wells constructed with more than 5 feet of well screen.

  Information to be considered when selecting the pump intake depth should include:

  a. Evidence of soil contamination from boring logs and field screening techniques;

  b. Soil sampling analytical results;

  c. Vertical groundwater quality profiles; and

  d. Areas of high permeability as identified from drilling operations (i.e., water or drilling fluid injection/discharge rate changes, observation of fractures or staining on rock cores, etc.) or by borehole geophysical methods, hydrogeological field tests, or geotechnical laboratory testing results.

- **Other considerations.** Additional sampling objectives (e.g., targeted aquifer zones) may be defined in the project-specific work plan, field sampling plan, and/or SOPs that may determine different sample depths than those that would be defined based on the pump intake considerations above.

3.2 Pre-field Work Preparation Guidelines

Because samples will be collected from existing groundwater monitoring wells, field staff should review and complete pertinent tasks identified in SOP 204, “Groundwater Purging and Sampling.”

Non-dedicated sampling equipment (e.g., water level indicator, purge pump, water quality instrumentation) used to minimize potential cross-contamination of samples among wells should be decontaminated between wells, the project-specific work plan/field sampling plan, and/or QA project plan (QAPP). Used dedicated sampling equipment is considered IDW and should be managed, following the sampling event.

At a minimum, the following tasks should be completed to prepare field staff prior to implementation of the work:

- Review and sign the site-specific HASP.
- Coordinate and obtain permission for site access.
- Review project-specific work plan/field sampling plan/QAPP, where applicable.
- Review and discuss with the CM and/or PM the proposed work plan/field sampling plan or sampling strategy. Note that site geology and expected contaminants should be reviewed to determine if unpreserved bottles may be needed (e.g., anticipated effervescence due to high levels of dissolved calcium carbonate in groundwater reacting with acid preservatives).
- When contractors are used to perform the sampling or in states where sampling can only be performed by personnel licensed or certified by the state, discuss the work plan/field sampling plan with the contractor.

- Review the standard instruction manual provided by the manufacturer of the specific equipment to be used for groundwater sampling.
- Obtain the glassware/bottles in advance and check against sampling numbers to confirm that the appropriate containers and quantities are provided prior to mobilizing.
- Ensure that all equipment/materials required to complete the work have been packed prior to travel.

In addition, prior to initiating well sampling activities, Terraphase personnel should field-verify the well identity and construction against available documentation (site plans, well construction logs, etc.). It is imperative that a positive well identification be made prior to sampling using measured total well depth, well labels, site plans, and well construction records to ensure that the correct well is sampled. If total well depth is measured, proper decontamination of the water level indicator tape must be conducted before deploying the water level indicator into another well.

Further, prior to the commencement of the field effort, Terraphase personnel should inspect, test, and/or calibrate equipment that may be used to take field measurements. Pre-measuring the pump suspension line and/or discharge tubing to the individualized targeted well depths and/or pre-labeling sample containers in advance of field efforts may increase productivity. However, special care should be taken to ensure that the correct pre-labeled containers are used to collect each groundwater sample.

Unless otherwise required by the project-specific work plan/field sampling plan, sampling should begin with monitoring wells with the lowest expected groundwater contamination and proceed systematically to monitoring wells with the highest expected groundwater contamination.

3.3 General LFPS Guidelines

The purpose of LFPS is to collect groundwater samples that are representative of ambient groundwater conditions in the aquifer by adjusting the intake velocity of the sampling pump to a flow rate that limits drawdown inside the well. The following provides a general recommended list of practices for LFPS activities:

- Where applicable, contact the identified key site personnel upon arrival to the site and assess proposed work areas.
- All wells to be sampled should be inspected for damage, access constraints, and/or vehicle traffic proximate to the well location.
- Although equipment should be decontaminated between uses, to further limit potential cross-contamination between wells, perform measurements from least to most contaminated locations.
- Lay polyethylene sheeting around the well for placement of monitoring and sampling equipment and contain any accidental groundwater spilled during purging or sampling.
- Remove the well cover or equivalent protective casing cover and measure gas concentrations in accordance with the applicable manufacturer instructions and field-screening SOPs. Record field screening readings in the field notebook. The necessity and methodology to conduct field screening should be detailed in the site-specific HASP and sampling plan.

- Record the condition of the well (noting any damage to the well, plug, and/or protective casing) and any evidence of pressure (positive or negative).
- Complete all depth-to-water or free product measurements prior to any planned groundwater and/or product withdrawals, sampling, or disturbance of groundwater activities unless otherwise specified in the work plan/field sampling plan.
- Prepare the pump suspension line and discharge tubing by measuring the correct length needed so that the pump intake or bottom of discharge tubing rests at the target depth in the well. The measurements should account for the additional length needed at ground surface to appropriately anchor the suspension line and connect discharge tubing to water quality monitoring equipment. The length of tubing, from the top of the well casing to the flow-through chamber, should be the shortest length manageable to minimize (a) exposure to ambient temperature, direct sunlight, and air bubble formation, and (b) the likelihood of deposited solids or air bubbles being trapped in tubing bends and re-mobilized. If the suspension line and tubing were premeasured or ordered to premeasured lengths in advance of field efforts, make any necessary alterations based on field observations (e.g., unanticipated groundwater elevations).
- Assemble the pump, suspension line, and tubing. Inspect all sampling equipment prior to deployment, making certain that all connections are secure and equipment is in working condition. Troubleshooting pump issues is generally easier if the pump and tubing assembly are inspected prior to deployment. If not using dedicated sampling equipment, ensure all materials are properly decontaminated prior to conducting sampling.
- Slowly lower the assembly into the well using the suspension line to achieve minimal water column disturbance until the location of the tubing or pump intake reaches the predetermined depth within the well. Anchor the assembly in place by securing the suspension line at the surface and/or clamping the tubing in place via spring clamp.
- Measure and record depth to water following insertion of the pump and tubing assembly. Allow the water level to return to its static level prior to initiating purging.
- Prior to groundwater sampling, the well should be purged. Assemble the water quality meter sensor probe and flow through cell in accordance with the manufacturer's specifications.
- During initial pump startup, do not connect the pump discharge line to the flow-through cell. Monitor drawdown and adjust the flowrate as necessary to stabilize it and prevent fouling of probes by bacteria, sediment, or non-aqueous phase liquid.
- Once drawdown measurements indicate a relatively constant flow rate has been achieved, continue to run the pump for a few minutes to clear any unwanted material before connecting the pump discharge line to the flow cell.
- Carefully connect the pump discharge tubing to the influent port of the flow-through cell of the water quality meter and connect a section of clean tubing to the effluent port of the cell. The influent and effluent connections to the flow-through cell are unique and based on each meter's design; orientation of flow matters and influent/effluent ports should be marked on the flow cell.

- When water fills the cell, ensure the tubing is completely full of water, check for leaks, and make any necessary adjustments. If water is particularly turbid at the beginning of the purge, once the turbidity decreases, it can be helpful to disassemble the water quality meter sensor probe and flow through cell and rinse them with DI water to remove any residual particulates.
- For low-flow purging, evacuate groundwater at a flow rate of 100 to 500 mL per minute until the water quality parameters (e.g., pH, DO, ORP, temperature, specific conductance, and turbidity) specified in the work plan, field sampling plan, QAPP, and/or SOPs (developed based on state-specific or regulatory program-specific guidelines, requirements, or procedures) have stabilized. In the absence of specific stabilization guidance, the following parameters or any combination thereof established by the United States Environmental Protection Agency should be monitored to determine when parameter stability has been achieved:
  - pH: ± 0.1 units
  - Specific Conductance: ±3 percent
  - Temperature: ±3 percent [1]
  - DO: ± 0.3 milligrams per liter[2,3]
  - Turbidity: ±10 percent (when greater than 10 Nephelometric turbidity units)
  - ORP: ±10 millivolts
  - Water Level Drawdown: less than 0.3 feet from static[4]
- Collect measurements approximately once every 5 minutes or periodically as defined by the time it takes for purge water to adequately replace the water quality meter's flow-through cell.
  - If the purge rate decreases, the time required for purge water replacement will increase.
  - It is generally accepted that when the measurements of the monitored parameters fall within the stated range for three consecutive readings, chemical parameter stabilization has been achieved.

[1] Temperature generally tends to stabilize rapidly and is considered a relatively insensitive indicator of stability.

[2] Under some regulatory programs, the DO stability is defined in terms of percent change (e.g., in New Jersey, less than ± 10 percent change in DO indicates parameter stability).

[3] If there is a significant discrepancy between the DO and the ORP results; for example, if the DO result is greater than 2 milligrams per liter and the ORP measurement is negative millivolts (less than -100 millivolts), then either the DO and/or the ORP meter may not be appropriately calibrated or operating correctly. Recalibrate both meters and check the DO and ORP measurements again. If the issues with the DO measurements continue, consider using an in-situ probe (e.g., YSI) or Chemetrics sampler approach.

[4] During pump start-up, drawdown may exceed the 0.3-foot target and then recover as flow rate adjustments are made.

  - If the anticipated "third" reading of any individual parameter does not fall within the stated range, then the process to achieve three consecutive readings for that parameter must be restarted.
- In some situations, even with slow purge rates, a well may not recharge and be pumped dry. In these situations, under certain regulatory programs, this constitutes an adequate purge and the well can be sampled following sufficient recovery (enough volume to allow filling of all sample containers). In such cases, it is not necessary that the well be evacuated three times or that chemical parameters stabilize before it is sampled. Nonetheless, the pH, specific conductance, temperature, and turbidity should be measured and recorded during collection of the sample from the recovered volume. These data would serve as the field measurements of record for the sampling event.
- If flow rates are to be measured and a flowmeter is not available, the discharge from the effluent of the flow-through cell can be collected in a container of known volume (i.e., 1-gallon plastic water jug or a graduated cylinder) with the time to fill the container noted. When flow-rate measurements are complete, redirect the discharge as detailed above and dispose the contents of the jug or graduated cylinder into 5-gallon buckets or directly into 55-gallon drums.
- Containerize purge water. The discharge tubing should be secured such that all purged groundwater is collected in 5-gallon buckets or directly into labeled Department of Transportation-rated 55-gallon drums, depending on site conditions and purge volumes.
- Upon completion of well purging, reduce the pumping rate to less than or equal to 100 mL per minute and disconnect the water quality meter from the discharge tubing.
- Wells should be sampled as soon as possible after purging. Refer to SOP 204-23-00, "Groundwater Purging and Sampling," for guidance on groundwater sample collection procedures. If sampling for volatile organics, collect the sample for VOCs first to prevent loss of volatiles due to disturbance of the water, and fill volatile organic analysis vials to zero headspace, as described in SOP 204-23-00, "Groundwater Purging and Sampling."
- Withdraw the sampling equipment from the well, replace the well cap, and re-secure the well. If non-dedicated equipment comes in contact with groundwater, remove the equipment from the monitoring well and decontaminate. Dedicated equipment that comes in contact with groundwater should be disconnected from the non-dedicated equipment and managed as IDW.
- Record in the field book or appropriate field forms any deviations from standard procedures (i.e., sample collection prior to stabilization), the rationale for those modifications, and any abnormal conditions within the well (e.g., evidence of blockage, root growth into the well casing, separated casing sections, etc.). Inform the PIC or PM to ensure necessary maintenance, redevelopment or repairs are conducted before the next planned water sampling event.

3.4 Sample Containers

Equipment and sample containers that will come into contact with collected groundwater should be constructed of inert materials that will not affect the concentration of constituents in the water sample (i.e., glass, stainless steel, or Teflon). The level of care that needs to be taken with the materials used will depend on the level and types of groundwater constituents and the QA requirements and study goals. This should be outlined in the project-specific work plan/field sampling plan or QAPP.

The laboratory will provide appropriate sample containers prefilled with preservatives appropriate for each predetermined sample analysis. The sample volume is a function of the analytical requirements and will be specified in the work plan/field sampling plan or QAPP. Sample VOCs first to prevent loss of volatiles due to disturbance of the water and fill the volatile organic analysis vials to zero headspace, as described in Section 3.3.

3.5 Sample Transport and Storage

Samples shall be handled, transported, and stored to maintain structural and chemical qualities. All samples should be kept in an ice-filled transport container during fieldwork and covered to limit light penetration. If the cooler size allows for space between sample bottles, bubble wrap should be used to fill annular space and prevent breakage during travel. Glass bottleware should be wrapped individually in bubble wrap for further protection. If provided, pack glass sample vials in laboratory-issued foam packing cartons. If shipping groundwater samples with preservatives, confirm the sample shipments, packaging, and labeling are performed in accordance with applicable Department of Transportation requirements.

3.6 QA/QC

QA/QC procedures described in the project-specific work plan/field sampling plan and/or QAPP must be followed throughout purging, sample collection, processing, handling, and analysis. In their absence, SOP 209, “Field Quality Control Samples,” QA/QC guidelines should be reviewed.

4. Precautions and Other Considerations

All field activities require recording detailed information throughout the implementation of field work. However, certain precautions should be taken to ensure safety during groundwater sampling. Additionally, implementation of the work may face some of the following difficulties:

- Some states require that only personnel licensed or certified in the state where the work is being performed conduct the sampling. Therefore, state regulations and guidance governing groundwater should be consulted prior to conducting the work. In addition, local Terraphase staff should be contacted to review any other regional or local requirements.
- **Field staff must always remain alert and aware of their surroundings.** Groundwater sampling could involve the use of generators and associated equipment, and is subject to hazards posed by equipment, vehicle traffic, industrial machinery, hazardous chemicals and contaminants, and/or other physical, mechanical, and chemical hazards.

- Prior to mobilization, determine the location of wells and evaluate the need for security, barricading, and/or traffic control (e.g., when wells are located within a right of way).
- At sites with certain contaminants and/or subsurface conditions, potentially toxic and/or explosive gases may accumulate at and around the well as it is being sampled. Field staff will remain upwind of the well and ensure that air monitoring is conducted and personal protective equipment is used in accordance with the site-specific HASP.
- All sampler, tether, or suspension lines must be kept untangled. A plastic winder or spool winder should be used to retrieve the sampler/pump and keep the line from tangling.
- When working out of sight of the general public or when site employees are in potentially hazardous areas (e.g., wooded habitats), all field staff should utilize the “buddy system” and follow the safety measures and procedures delineated in the project-specific HASP.
- Care should be taken when opening well protective covers for the presence of spiders and insects, such as wasps or hornets.
- Well keys may not work with rusted/outdated well locks. Bolt cutters may be used to remove the lock, which should be replaced upon completion of well sampling. **Do not** use petroleum-based solvent sprays to free seized locks as it may impact water quality in the well.
- Wells with a water-tight cap may experience a buildup of pressure. Field staff must angle their face and body away from the top of the well when loosening or removing the cap.
- Certain sampling equipment configurations have tubing without a pump at the sample intake depth (e.g., bladder pump with drop tubing). Without a weight on the end of the tubing while lowering it into the well, the tubing can easily get caught on the joints between sections of the PVC well casing or on the open borehole wall due to the natural curl in the tubing from being stored in rolls. To remedy this, fasten a stainless-steel rod as a splint against the bottom few feet of tubing or simply secure a stainless-steel weight to the bottom of the tubing to straighten the curl and keep it from getting stuck. Some sampling equipment will include a weight for this purpose. Proper decontamination of the stainless-steel rod or weight is required prior to deployment into a subsequent well.
- It can be helpful to utilize Microsoft Excel to simplify purge stabilization calculations in the field and eliminate the need to transcribe purge notes into electronic form for reporting purposes. An Excel-based purge sheet can also reduce potential mistakes; however, a thorough understanding of the stabilization criteria calculations is necessary prior to use in the field. An example of a low-flow sampling purge sheet with auto-calculations is presented on Figure 1.

21	Well Evacuation Data										
23	Stabilization Criteria			± 0.1 SU	± 3 %	± 10 %	± 3 %	± 10 mV	± 10 %	0.3 ft	
24	Time	Vol.	Rate	pH	Cond.	Turb.	Temp.	ORP	DO	DTW	Appearance or Comments
25		L	mL/min	Std	ms/cm	NTU	C	mV	mg/L	ft	
27	9:54	--	550	9.86	0.240	78.9	10.18	16	11.89	23.80	Slightly silty
28	9:59	0.0	320	7.89	0.360	70.4	11.17	77	9.98	23.50	Slightly silty
29	10:04	1.6	250	7.71	0.364	58.2	11.14	93	9.84	23.30	Slightly silty
30	10:09	2.8	250	7.68	0.361	48.6	11.04	100	9.64	23.30	Clear
31	10:14	4.1	250	7.68	0.360	30.3	10.96	107	9.59	23.30	Clear
32	10:19	5.3	250	7.66	0.360	16.0	11.11	107	9.50	23.30	Clear
33	10:24	6.6	250	7.68	0.362	9.3	11.09	111	9.87	23.30	Clear
34	10:29	7.8	250	7.69	0.363	5.7	11.26	114	9.49	23.30	Clear
35	10:34	9.1	250	7.64	0.362	5.8	11.21	115	9.50	23.30	Clear
36	10:39	10.4	250	7.65	0.362	5.6	11.20	118	9.52	23.30	Clear
37	10:44	11.6	100	7.66	0.363	5.5	11.32	118	8.82	23.30	Clear

Figure 1 Groundwater Low-Flow Purge Sheet

*As each parameter stabilizes for three readings within its specified criteria, cells activate green. Purge rate and depth to water cells help guide adjustments needed to comply with low flow guidance. An example of a report-ready, completed sheet is provided in **Attachment B.***

- Pumping issues, particularly at deep wells using low-flow or intermittent-flow pumps, can be difficult to troubleshoot. A small cup of DI water can be used to test for flow. Place the end of the discharge tubing into the DI water cup during pumping to see if there is a discharge (i.e., bubbles occur). As purge water fills the tubing at depth, air is displaced and forced out the top, causing bubbles in the water. If bubbles are observed, the pump is operating and there is flow.
- Bladder pumps have several O-rings and check balls that are necessary for its operation. If bubbles are observed in the DI water during compressor discharge, but water is suctioned back into the tubing during the refill cycle, the pump's check ball isn't working properly or may be missing. Air bubbles in the discharge water that don't go away after purging for a few minutes are usually indicative of a failed O-ring.
- A small cup of DI water can be used to monitor the purge rate of intermittent-flowing bladder pumps before having water at the surface by observing the duration and/or speed of bubbles. Monitoring the duration and speed of bubbles at the beginning of the purge will allow the operator to adjust/fine-tune the air controls (refill, discharge, and pressure) to bring water to the surface.
- Stabilization of parameters when pumping at low flow rates can be difficult. Several adjustments can help make stabilization easier and enhance the rate of stabilization:
  - Minimizing the length of extra tubing at ground surface can help minimize the effect of atmospheric temperatures on purge water.
  - Insulating the tubing with tin foil and/or shading from direct sunlight can help minimize the effect of atmospheric temperatures on purge water.
  - Increasing the flow to the maximum allowable rate (based on drawdown and regulatory requirements) will help replace water in the flow-through cell more frequently, thus reducing the severity of parameter fluctuations.

- When purging with intermittently flowing pumps (i.e., bladder pumps), collection of readings should occur during the same portion of the flow cycle (ideally at the end of a discharge cycle, so measurements are based on fresh water entering the flow-through cell) to minimize parameter fluctuations between cycles.
- For wells with slow recovery, attempts should be made to avoid purging them dry as it may affect the quality of the sample. For example, as water enters a well that has been purged dry, it may cascade down the sand pack and/or the well screen, stripping volatile organic constituents that may be present and/or introducing soil fines into the water column. A possible remedy to purging the well dry is to reduce the purge rate.
- If possible, schedule sampling of wells that have a slow recovery on the same date they are purged, after adequate volume has recovered. These types of wells should not, unless it is unavoidable, be purged at the end of one day and sampled the following day.
- Sampling equipment (e.g., air compressors) are temperature sensitive and sampling in extremely cold temperatures can complicate even trivial tasks. When sampling in these conditions, keeping sampling equipment and discharge tubing from freezing is critical. Insulating the compressor from freezing temperatures and keeping it warm between use (within a vehicle, field trailer, etc.) will help keep it functioning properly. Any interruption of flow could cause purge water in the discharge tubing to freeze; insulating the tubing and maintaining higher flow rates (within regulatory guidelines) will help keep purge water from freezing.
- Adequate preparation prior to sampling each well will save time in the long run. Ensure the generator/air compressor has fuel or that spare batteries/air canisters are available in the event stabilization takes longer than anticipated. Stopping mid-purge to refuel or acquire additional air canisters will disrupt stabilization, greatly increasing the time required to sample a well.
- Each sampling effort should minimize exposure to ambient factors (e.g., atmospheric air, wind-blown dust, vehicular exhaust).
- While purging, the time between water quality measurements can be used to organize bottleware and confirm well-specific information (e.g., sample analyses, bottles appropriately labeled, duplicate collection, field filtering).
- If the work plan/field sampling plan involves analyses requiring field preservation, avoid direct contact with laboratory-provided preservative chemicals.

5. Recordkeeping

Document sampling locations and other information related to the sampling in accordance with SOP 106, “Field Notebook (without iPad),” or using an electronic field tablet, and SOP 100, “Field and Lab Data Management.”

Attachment A

Groundwater Purging and Sampling Equipment

Attachment A:
Groundwater Purging and Sampling Equipment

Several types of well water evacuation equipment exist for the collection of groundwater samples using low-flow purging and sampling techniques. Equipment choice will depend on a variety of factors including but not limited to cost, well specifications, and sampling parameters. Two basic collection scenarios have a bearing on pump selection:

1. **Dedicated System (a permanently installed pump system in a well).** A dedicated pump system consists of a single pump and tubing set up in each permanent monitoring well. This allows consistent sampling from a targeted monitor zone without the need to install/remove the pump during each monitoring event. Typically used for long-term monitoring at sites, a dedicated system usually consists of the pump and the associated tubing, with the controller mobilized for each sampling event.
2. **Portable System (transferable from well to well).** A portable low-flow purging and sampling system allows low-flow sampling from many monitoring wells using the same pump. Commonly available portable systems are easy to disassemble, without any tools, and simple to clean to eliminate any potential cross contamination.

Bladder pumps can be used for either system; however, only those with disposable bladders and easily cleaned parts are suitable when sampling on a well-to-well basis. Variable-speed submersible-centrifugal pumps, gear, or progressive-cavity pumps can be used for either operating system if they are constructed of easy to clean, stainless-steel/Teflon® parts. Pumps constructed with impellers, helicoils, or gears, which are difficult to clean or are constructed of unacceptable plastic parts, are not suitable for sampling.

Following are brief descriptions of more commonly used pumps for low-flow groundwater purging and/or sampling.

Bladder Pumps

Bladder pumps use pneumatic pressure, a liner or bladder, and a series of check valves that allow the bladder to fill with liquid then pneumatic pressure pushes on the bladder forcing fluid from the pump. Assembly typically includes a pump, a controller, an air compressor or compressed air, and tubing.

Figure A-1 Bladder Pump Setup (left) and Pump (right)

Source: www.soilinst.com

Pneumatic bladder pumps operate with a unique, gentle action ideal for low-flow sampling. Timed on/off cycles of compressed air alternately squeeze the flexible bladder to displace water out of the pump and release it to allow the pump to refill by submergence. Following the fill cycle, compressed air or nitrogen from a cylinder or compressor at the wellhead is driven down to the pump through tubing to compress the bladder, thus driving the water sample up to the surface through a second tubing line. The pumping sequence consists of repeated fill–compress cycles, using a pneumatic controller positioned at the wellhead. The controller is used to vary the duration and frequency of the fill–compress cycles to deliver the desired sample flow rate at the wellhead.

The bladder design offers the advantage of minimizing sample turbulence, which can result in loss of volatile organic compounds in the sample, as well as eliminating contact of the water sample with the compressed air or nitrogen used to lift the sample to the surface. Bladder pumps run easily at low rates for extended times without overheating (unlike high-speed electric pump motors, which can alter samples and ruin the pumps), and without creating any disturbance that could affect sample chemistry. Some manufacturers of bladder pumps include QED, Geotech, and Solinst.

Figure A-2 Submersible Pump
Source: www.geotechenv.com

Submersible Pumps

Submersible pumps consist of an electric motor in a stainless steel and Teflon housing that drives two or more impellers at high rates of rotation, bringing water to the surface at an uninterrupted flow during sampling. The assembly typically includes a pump, a controller, a power source, and tubing.

These pumps are light weight and versatile. To overcome potential overheating that could affect sample quality, the pumps can be provided with a cooling shroud. To avoid potential backflow issues, the pump should be provided with a check valve. In addition, to provide greater pump speed control (e.g., to account for changes in pressure and torque at the impellers) and minimize potential pump flow loss, the pump controller should be equipped with a "ten turn pot" frequency adjustment knob. Some manufacturers of submersible pumps include Geotech and Waterra.

Gear Pump

The gear pump is small and lightweight, constructed of stainless steel and Teflon®, and operates on positive displacement. The assembly typically includes a pump, controller, battery, and tubing. It functions using two or more internal Teflon® gears within a stainless-steel cavity that displaces water up the hose in a steady stream. As the gears rotate, they separate on the intake side of the pump, creating a void and suction which is filled by fluid. The fluid is carried by the gears to the discharge side of the pump, where the meshing of the gears displaces the fluid.

The pump's low rpm electric motor will not disturb the sample as it generates little heat. Compared to the submersible pumps, which have impellers, the gear pumps require less flow rate adjustments and provide more consistent flow. Fultz is a manufacturer of gear pumps.

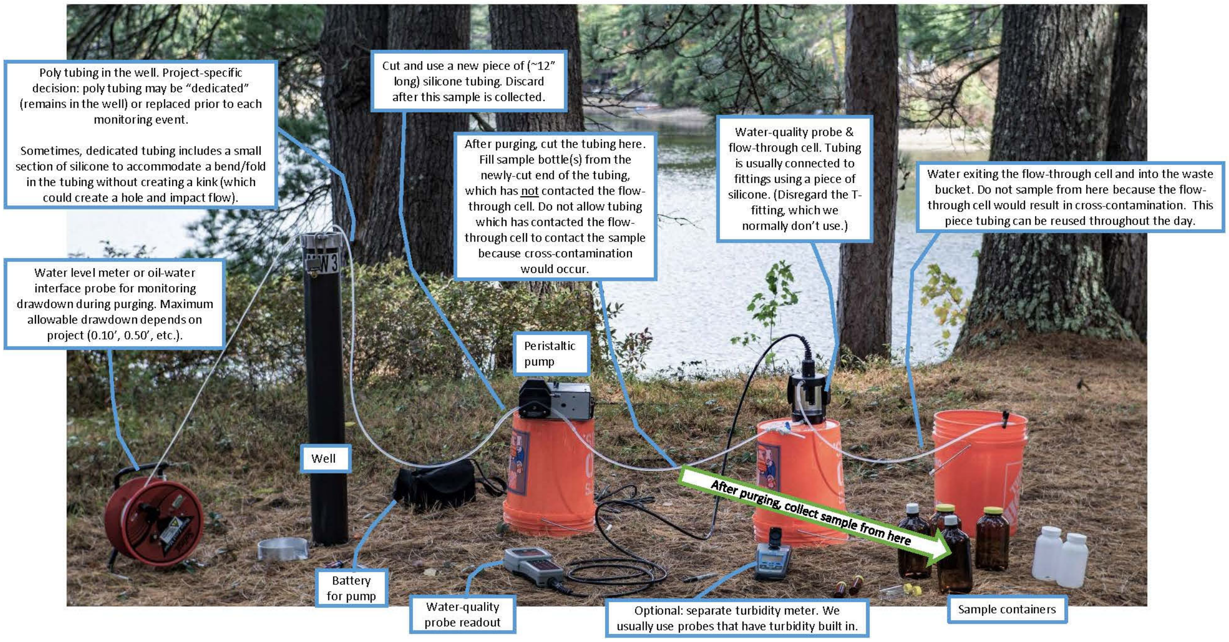
Figure A-3 Gear Pump
Source: www.fulzpumps.com

A comparison of the various pump options and their advantages/disadvantages is provided below.

Groundwater Sampling Pumps

Pump Type	Advantages	Disadvantages	Sampling Capability	Approximate Lift Capacity
Bladder Pump	• Acceptable for sampling for all parameters • Simple design and operation • Minimal disturbance of sample	• Large gas volumes may be needed • Only pumps with disposable bladders may be field cleaned for portable use when approved decontamination methods are employed	Acceptable for sampling for all parameters	Up to 1,000 feet
Submersible Centrifugal Pump	• Versatile and light weight. • Variable speed control for fine tuning of flow rate • Able to be thoroughly decontaminated due to ability of complete disassembly	• Sample temperature may be biased high during low- flow sampling due to high rotation rate of impellers • Motor stall possible at low pumping rates • Requires external power source • Impellers easily damaged by silty/sandy water • Difficult to clean and maintain in the field	May not be acceptable for sampling for trace contaminants, but useful for all other parameters	Up to 280 feet
Gear Pump	• Good variable speed control especially at low rates • Light weight • Does not have temperature issue as gears do not create excess heat like electric impeller pumps	• Difficult to decontaminate when in the field • Turbid purge water wears on the gears • Cannot properly handle suspended solids • Gears may be damaged in silty/sandy water • Gears may bind in water exceeding 85 degrees F.	Acceptable for sampling for all parameters	Up to 150 feet

Groundwater sampling – typical setup with peristaltic pump



Attachment B

Groundwater Purging Sheet

terraphase engineering

Groundwater Monitoring Field Data Form
Site: Client
Address

Project No.: X001.001.001

MW-01

Date:	07/06/2023	Casing Material:	PVC	Depth to Water (ft bmp):	29.23
Purge Method:	Low Flow - Peristaltic Pump	Casing Diameter (in):	2	Well Depth (ft bmp)	35.43
Volume Units:	mL	Pump Intake (ft bmp)	35	Water Column (ft)	6.20
Purge Start Time:	08:00	Screen Interval (ft bmp):	25-35	Water Quality Meter:	Horiba
Comments:	NA				

Sampling Summary

Sample Date:	07/06/2023	COC:	NA
Sample Time:	09:05	Analysis:	PFAS 6
Sample ID:	MW01-230706	Bottles:	2
Duplicate Sample ID:	NA	Odor:	NA
Duplicate Sample Time:	NA	Remarks:	First sample of the day

Field Stabilization Parameters

Time	Flow Rate	Cuml Volume	DTW (ft bmp)	Temp (C)	pH	Conductivity (us/cm)	ORP (mV)	Disssolved Oxygen (mg/l)	Turbidity	Remarks
Historical Range:										
08:40	280	11200	29.50	24.51	5.91	2350	251	5.65	9.8	
08:45	280	12600.0	29.49	24.6	5.94	2350	244	5.36	9.1	
08:50	280	14000.0	29.49	23.24	5.97	2380	231	5.40	10.2	
08:55	280	15400.0	29.49	23.9	5.97	2380	224	5.01	10.5	
09:00	280	16800.0	29.49	23.06	5.97	2370	218	5.19	10.8	

Well Integrity Checklist

Item	Yes	No	NA	Notes
Type of Well Head				stick up
Well secured on initial inspection	X			
Is well ID visible?	X			
Sleeve around the well box in good condition	X			

Photos