Attachment A

Standard Operation Procedures

A-1 Surface Water, Sediment, Foam Sampling for PFAS
A-2 Groundwater Sampling for PFAS
A-3 Vertical Aquifer Profiling Sampling
A-4 Conventional Slug Testing Using a Transducer

Attachment A-1
Surface Water, Sediment, Foam Sampling for PFAS

Standard Operating Procedure

Surface Water, Sediment, and Foam Sampling for PFAS

Prepared by: Amanda Lanning and Hanna Temme

Approved by: Al Gorski and Drew Tarara

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1. Scope

The primary objective of the surface water, sediment, and foam sampling and investigation activities is to identify the magnitude and extent of per- and polyfluoroalkyl substances (PFAS) contamination and identify mechanisms by which PFAS-impacted water is traveling through the Project 1007 conveyance system (Project 1007 Corridor) and entering groundwater. This Standard Operating Procedure (SOP) describes the techniques and general considerations to be followed during the collection of surface water, sediment, and foam samples for analysis of PFAS and other parameters that will be used to evaluate the fate and transport of PFAS in the study area. This SOP is modified from the Michigan Department of Environmental Quality (MDEQ) sampling guidance for surface water, sediment, and foam (MDEQ, 2018; MDEQ, 2018; MDEQ, 2019).

The potential for field personnel to inadvertently contaminate field-collected samples is high because of the presence of PFAS in many commercially available products that include but is not limited to, personal care products, water-resistant clothing, and food packaging. To minimize contamination, all materials selected for sampling and described in this SOP have been vetted and determined to be PFAS-free. As an extra precaution, the sampling methods described also minimize direct contact between the sample and field personnel.

Procedures outlined in this SOP are expected to be followed. Procedural modifications may be warranted depending on field conditions and equipment limitations. The exact method and any modifications to this SOP will be noted on Field Sampling Forms as appropriate. Deviations from the SOP will be documented in the project records and in subsequent reports.

2. Objectives

The objectives of this SOP are to:

- Clearly define the means and methods necessary to collect surface water, sediment, and foam samples for PFAS analysis;
- Ensure uniformity and continuity in sample collection between qualified field personnel to allow the data to be comparable spatially and temporally; and
- Describe important aspects of sample collection to minimize the occurrence of inadvertent PFAS contamination.

3. Personnel Qualifications

Proper sample collection and the use of various field equipment requires formal training. Initial field sampling that is closely supervised by senior personnel with previous experience collecting samples for PFAS analysis is highly recommended. In addition, all field personnel will have completed the AECOM PFAS Sampling and Education Training course.

Field personnel must be health and safety certified as specified by the *Occupational Safety and Health Administration (OSHA) (29 CFR 1910,120(e))* to work on sites where hazardous materials may be present. Field personnel should also be first aid/CPR trained. Field personnel are responsible for becoming familiar with the sampling procedures outlined within this SOP, quality assurances, and the health and safety requirements associated with the participation in field sampling. Field personnel are responsible for sample collection, decontamination of equipment, and/or collecting proper documentation on the field forms.

4. Health and Safety

The health and safety considerations for work associated with this SOP, including physical, chemical, and biological hazards, are addressed in the site-specific HAZWOPER Health and Safety Plan (HASP). All work must be conducted in accordance with the HASP.

5. Interferences

PFAS is present in many modern materials; therefore, special care will be taken to minimize contamination of samples. Only PFAS-free personal protective equipment (PPE) and sampling tools will be used for the collection of PFAS analytical samples. The MDEQ General PFAS Sampling Guidance (MDEQ, 2018) should be consulted for additional information concerning PFAS in PPE and other sampling materials. Personnel must wear powderless nitrile gloves during sampling to reduce the risk of contamination. All clothing, especially clothing that will be worn during surface water sampling, must be well washed to minimize potential cross-contamination of samples. If sampling tools or sample containers are potentially contaminated, they will either be decontaminated or discarded as appropriate.

Potential interferences could also result from cross-contamination between sample locations. This will be minimized by decontaminating the sampling tools after arriving at each location and prior to sample collection. During surface water and sediment sampling, collection of samples must be conducted in the following order:

1) PFAS surface water sample
2) Other water quality parameters (optional)
3) PFAS sediment sample
4) Other sediment quality parameters (optional)

If a foam sample will be collected, this should only be done before the surface water is collected if collection of the surface water will disrupt the foam. If the surface water collection will not impact the foam, then the surface water sample should be collected first, followed by the foam. If the foam is collected first, collection of the water sample should be delayed slightly to allow any potential interferences or increases in PFAS concentration from incidental mixing of the foam into the water column downstream.

If entry into the water is required to collect a surface water sample, the sample location must be accessed from a downstream location. If both surface water and sediment are being collected at a single location, the water samples must be collected prior to collection of a sediment sample to prevent disturbed sediment from compromising the integrity of the water sample(s). Similarly, care must be taken when selecting a location to collect a sediment sample to ensure the location was not disturbed during water sampling.

6. Equipment

The following equipment list contains materials that may be necessary to carry out the procedures contained in this SOP. Not all equipment listed below will be necessary for every sampling location. The sampling technique will depend on site conditions, sediment type, and water depth. Additional equipment may be required, pending field conditions or as specified in a work plan. Additional information about materials and equipment that are acceptable for PFAS sampling are further detailed in the MDEQ General PFAS Sampling Guidance (2018).

Surface Water Sampling Supplies

- Ziploc freezer bags (quart, one gallon, and two gallon)
- Wet ice (blue ice is prohibited)
- Coolers
- Ballpoint pens (Sharpie brand and similar products are prohibited)
- PFAS-free distilled water (Market Pantry, Target; Good & Gather, Target; Great Value, Wal-Mart; Glenwood-Inglewood Distilled Water, Cub Foods)
- Nylon brush
- Alconox detergent
- Spray bottles for detergent and PFAS-free distilled water solution
- Laboratory-supplied sample kits (HDPE bottles for PFAS samples, various bottle types for other parameters, labels, chain of custody forms, sampling forms)

Personnel protective equipment

- Sunscreen (Neutrogena)
- Bug Spray (OFF! Deep Woods Repellent VII Dry; Sawyer Products SP6, Premium Permethrin Clothing Insect Repellent)
- Safety Shoes when not wading in the water
- Safety glasses
- High visibility safety vest
- Waders (neoprene or nylon/PVC)
- Powderless, disposable, nitrile gloves

Surface Water Sampling

- Telescoping dipper

Foam Sampling

- One- or two-gallon Ziploc bag
- Optional: Cheese cloth attached to a pool skimmer with zip ties

Sediment Sampling

- Auger buckets appropriate for sediment type (stainless steel)
- Rods and handle for auger (stainless steel)
- Adjustable wrenches that fit rods for sediment corer
- Shovel
- Stainless steel pail (4 quart or larger)

7. Methodology

7.1 Sample Locations

When possible, locations will be accessed through public property such as along roadways or from public parks. Public parks will also be used as staging areas whenever possible. For sample locations either on or accessed through private property, access agreements will be obtained prior to field sampling.

For the surface water investigation, each sample location will be visited during a scheduled field reconnaissance event to evaluate the best access to the location and to determine the optimal tools required to collect the samples. For streams and creeks, all water samples will be taken from the center of the stream channel. The telescoping dipper is the preferred water sample collection tool; however, wading may be required for surface water or sediment sample collection depending on the width of the stream. Should personnel enter the water to collect a sample, the water body will be entered downstream of the sample location to minimize contamination.

Sample locations will be identified with a Global Positioning System (GPS) unit. Pre-determined GPS coordinates will be used to determine correct sample placement whenever possible. The sediment sample will be collected as close to the water sample as possible but may be offset depending on stream bed composition. At times, the sediment sample may also be collected from a specific, targeted area in the stream bed or bank or within a wetland area. The sample location will also be documented with photos and sampling forms to capture the site conditions at the time of sampling. Detailed field notes will document the sample location with regards to relative location from the bank and depth of the water channel. Descriptions of the sediment samples and details of the stream or lake bottom will also be well documented to aid in data analysis.

During winter sampling, water will not be collected through ice due to safety concerns. Water sample locations may be altered so that water can be collected from an ice-free location of the waterbody. These changes will be documented.

7.2 Water Sampling Methods

When possible, water samples from streams will be collected with a telescoping dipper to avoid entering the water body and limiting the potential for cross-contamination. All personnel handling sampling equipment or sample bottles must wear disposable nitrile gloves that should be changed between sampling intervals, sample locations, and if they come into contact with materials that may contain PFAS. To collect the surface water sample, a laboratory-supplied sample bottle for the PFAS analytical samples will be attached to the end of the dipper. The bottle should be submerged with the opening facing down to the approximate center of the water column to be sampled (e.g., submerged to 3-4 inches in a 0-6-inch surface water sample). The bottle should then be rotated so it can fill thoroughly before being lifted to the surface. In some of the lakes and larger ponds in the Project 1007 Corridor, water samples will also be collected at elbow depth (18-21"). The sample ID will indicate the depth intervals sampled as designated in the corresponding Sampling and Analysis Plan (SAP). The same method will be used except the bottle will be submerged with the opening facing down to approximately 19-20". To prevent contamination, care will be taken to not touch the inside of the lid of a sample container or set the lid down. If there is any doubt if the lid or bottle was touched or dropped, a new sample bottle must be used.

7.3 Sediment Sampling Methods

7.3.1 Discrete Sample

The equipment used for sediment sampling will be determined based on the composition of the sediment and depth of the water body. A hand auger is the preferred sediment sampling tool to ensure the appropriate depth is being accurately and evenly collected over the targeted depth interval. The appropriate number of rods should be screwed together and attached to the handle and appropriate auger bucket. The standard closed-wall auger bucket will be used for loose, sandy or gravelly sediment. A clay auger bucket will be used for more compact sediment as the open-walled construction of the bucket will allow for easier removal of the sample. An alternative to using an auger is a shovel or hand trowel but care must be taken to collect to the sample from the correct depth. Depending on the water depth and targeted sample location relative to the bank, the sample will either be collected from the bank or the sample collector may wade to the sampling location by entering downstream of the predetermined location. Once retrieved, a second person will transfer the sediment with a gloved hand to a stainless steel pail. The sample will be well homogenized before being transferred to laboratory-supplied sample containers. If more sample volume is required for analysis, a second sample will be collected adjacent to the first and homogenized with the first sample in the pail before distribution to the sample containers. The sediment will be photographed and characterized based on the primary and secondary components, and descriptors such as color, moisture, plasticity, grain roundness, grain size, and grain distribution will be noted when applicable. After sample collection, the auger bucket or shovel will be rinsed in the surface water to dislodge large particles. Complete decontamination with Alconox and PFAS-free water will be conducted at the next sampling location to ensure the auger does not become contaminated between sample locations.

7.3.2 Channel Transect Composite Sample

Composite samples may be collected to acquire a representative PFAS concentration across a transect at a specified depth along a stream channel. When needed, individual subsamples (aliquots) will be collected in the same manner as described above for a corresponding discrete sample. Equal volumes of the sample from the left bank, right bank, and channel bottom locations (from the same depth interval) will be collected. Once retrieved, a second person will transfer the sediment with a gloved hand to a stainless-steel pail. The sample will be well homogenized before being transferred to laboratory-supplied sample containers. If more sample volume is required for analysis, a second sample will be collected adjacent to the first and homogenized with the first sample in the pail before distribution to the sample containers. The sediment will be photographed and characterized based on the primary and secondary components, and descriptors such as color, moisture, plasticity, grain roundness, grain size, and grain distribution will be noted when applicable.

7.3.3 Multiple Depths

In areas where multiple sediment depths are to be collected, a hand auger with the appropriate bucket will be used to ensure that discrete depths are accurately sampled. Samples will be collected from the same borehole whenever possible, taking care that slough is not included in the sample. The samples will be homogenized in the same way as described previously before being placed in the laboratory provided containers.

7.4 Foam Sampling Methods

Foam can be sampled using a gloved hand to scoop the foam into a bag or with a modified pool skimmer to remove the foam from the water surface. The modified pool skimmer method should only be used if it is not feasible to safely collect a foam sample using a gloved hand as the modified pool skimmer method is more likely to inadvertently collect the surface water directly below the foam.

Prior to sampling the foam directly with a gloved hand, the field personnel should ensure the nitrile gloves they are wearing have not been in contact with any other surfaces as these gloves will come into direct contact with the sample. As much foam should be removed from the water surface as possible without also collecting the water directly below the foam. This will ensure that surface water is not diluting the foam sample. The foam should then be placed in a one- or two-gallon Ziploc bag. Multiple handfuls may be required to transfer all accumulated foam into the bag. If the foam is actively accumulating, the field personnel may need to wait for additional foam to accumulate to ensure there is enough sample volume. Typically, a one-gallon Ziploc bag full of foam will condense to a large enough sample volume for laboratory analysis; however, the condensed volume is dependent on the foam properties and is variable so more foam should be collected if possible. The entire foam pile should be collected, and the condensed liquid mixed as a single sample to ensure the sample is representative of the observed foam. PFAS concentrations are known to vary through a pile of foam and collecting a portion of the pile may affect the results. The foam will be photographed prior to collection. The properties of foam collected including the height of accumulated foam mass, color, and behavior in response to the collection (e.g., rate of re-accumulation) will be documented on the field form. The location of the foam relative to the waterbody and any corresponding samples as well as any indicators of how and from where the foam has been generated and has accumulated will be also documented. Finally, any other media contained within the foam such as biomass or sediment will be noted on the field form.

If it is not feasible or safe to directly collect the foam with a gloved hand, a modified pool skimmer may be used. The skimmer is constructed by taking the net off a pool skimmer or dip net and replacing it with a single layer of cheese cloth, which is affixed to the pool skimmer with new zip ties. The cheese cloth net is then be used to skim the foam off the surface of the water. The foam should be transferred to a clean Ziploc bag with a clean gloved hand.

After the foam is collected, it should be placed on ice for at least 24 hours to allow it to completely condense into liquid form before it is transferred to a laboratory provided sample bottle. The final volume of the foam will be documented and photographed. Foam samples should be flagged on the chain of custody as having high PFAS concentrations so they can be correctly analyzed by the laboratory.

7.5 Sample Handling and Preservation

Samples will be labeled, entered on a Chain-of-Custody, double bagged in Ziplock brand freezer bags, placed on ice in coolers, and shipped via overnight transport to the designated laboratory for analysis. Each cooler will include trip blank and temperature blank.

7.6 Equipment Decontamination

Proper equipment preparation, cleaning, and field decontamination procedures are necessary to prevent cross-contamination of samples. Decontamination should be performed with a standard laboratory grade phosphate-free detergent such as Alconox. Four (4) different brands of distilled water have been submitted for laboratory analysis to determine the presence of PFAS prior to the sampling event (see Section 6). According to laboratory results, all four brands do not contain detectable amounts of PFAS. Other distilled water brands not listed in this SOP or previously vetted must be sampled and determined PFAS-free prior to use in equipment decontamination.

Prior to sampling, the dedicated sampling equipment must be scrubbed of particulate matter with a nylon brush and cleaned with an Alconox/water solution. The equipment must then be rinsed with PFAS-free distilled water. If the equipment is transported after decontamination, it must be wrapped with a clean plastic bag to prevent contamination.

8. Quality Assurance and Quality Control

In addition to the sampling program, quality control (QC) samples should be collected to document precision and accuracy of the analytical results, and to examine the sources of error introduced by field and laboratory practices.

8.1 Equipment Blanks

Equipment blanks are required in all phases of sampling and serve to confirm that decontamination procedures are adequately carried out and that there is no cross-contamination of samples due to the equipment itself. Collection of equipment blanks may be performed for all analytes of interest. Equipment blanks are collected by pouring PFAS-free distilled water over decontaminated sampling equipment and directly collecting that water using a laboratory-supplied sample bottle. An equipment blank should be taken for every new piece of equipment used in the sample collection process. For equipment that is reused for multiple field events, an equipment blank will be recollected every three field events. At minimum, one equipment blank should be taken per field event.

8.2 Field Duplicate Samples

Duplicate samples should be collected for every 10 field samples. A field duplicate consists of collecting two times the required volume of a sample and submitting separately labelled bottles for analysis. The two aliquots, taken from the same location at the same time, are analyzed separately to assess the consistency of sampling, sample homogeneity, and laboratory analytical consistency. These sample duplicates may be submitted as laboratory blind duplicates and may be analyzed for all analytes of interest. For sediment, this sample will be collected from the same homogenized media that the original sample was collected from. For water, this sample will be collected at the same location and as soon as is feasibly possible after the original sample is collected.

8.3 MS/MSD Samples

One matrix spike/matrix spike duplicate (MS/MSD) sample should be taken for every 20 field samples, based on the laboratory recommendation. For sediment, this sample will be collected from the same homogenized media that the original sample was collected from. For water, this sample will be collected at the same location and as soon as is feasibly possible after the original sample is collected.

8.4 Temperature Blank Samples

A previously prepared temperature blank consisting of de-ionized water stored inside a specially labelled sample bottle should accompany each sample cooler during transport to the laboratory. These bottles are used as a standard to ensure that samples were maintained within an acceptable temperature range during shipment per laboratory specifications.

8.5 Trip Blank Samples

A trip blank consisting of de-ionized, PFAS-free certified water previously prepared by the laboratory stored inside a specially labelled sample bottle should accompany each sample cooler during transport to the laboratory when possible. These samples are used as a standard to ensure the detection of any PFAS compounds in field samples were not due to improper handling or processing during sampling, shipping, or laboratory receipt.

9. Investigation – Derived Waste (IDW) Management

The IDW that may be generated during surface water investigations include the following:

- Disposable materials such as PPE, plastic sheeting, and Ziploc bags;
- Excess soil and water left over from sampling activities; and
- Decontamination water.

All these materials are considered non-hazardous. Disposable materials may be discarded in regular non-hazardous trash receptacles. The excess water and sediment from sampling may be returned to the water body that it was taken from; sediment may also be thin-spread along the banks of a water body. In general, *de minimis* quantities of Alconox used for decontamination is deemed non-hazardous by the MPCA (client); therefore, water generated from decontamination may be discarded in-place.

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10. References

MDEQ (2018). Surface Water PFAS Sampling Guidance.

MDEQ (2018). Sediment PFAS Sampling Guidance.

MDEQ (2019). Surface Water Foam PFAS Sampling Guidance.

MDEQ (2018). General PFAS Sampling Guidance.

Attachment A-2
Groundwater Sampling for PFAS

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Standard Operating Procedure

Groundwater Sampling for PFAS

Prepared by: Amanda Lanning and Hanna Temme

Approved by: Al Gorski and Drew Tarara

December 10, 2020

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1. Scope

The primary objective of the groundwater sampling and investigation activities is to identify the magnitude and extent of per- and polyfluoroalkyl substances (PFAS) contamination in groundwater and identify mechanisms by which PFAS-impacted water is traveling through the Project 1007 conveyance system (Project 1007 Corridor) and entering groundwater. This Standard Operating Procedure (SOP) describes the methodology for performing monitoring well sampling for PFAS and other parameters in the Project 1007 corridor. This SOP describes low flow sampling with a submersible bladder pump and peristaltic pump and passive sampling with a Hydrasleeve bag. These methods were specifically selected over other monitoring well sampling techniques based on the well construction and in effort to minimize investigation derived waste (IDW). The specific sampling method used will be dependent on the depth of the well and well construction as follows:

- Hydrasleeve passive sampling bags will be deployed in the deep bedrock aquifer wells to reduce cost and IDW (tubing, time, and purge water);
- A submersible bladder pump will be used in wells screened below 50 feet where well construction makes deploying and retrieving a Hydrasleeve bag unfeasible; and,
- A peristaltic pump will be used to sample wells less than 50 feet.

Side by side sampling was conducted between the bladder pump and Hydrasleeve bags to ensure the samples collected via these two methods are comparable. The low flow sampling techniques have been modified from the Michigan Department of Environmental Quality (MDEQ) Groundwater PFAS Sampling Guidance (2018).

2. Objectives

The objectives of this SOP are to:

- Clearly define the methods necessary to collect groundwater samples with low flow sampling techniques and Hydrasleeve passive sampling bags from monitoring wells for PFAS analysis and
- Ensure uniformity and continuity in groundwater sample collection between qualified personnel to allow the data to be comparable spatially and temporally.

3. Personnel Qualifications

Proper sample collection and the use of various field equipment requires formal training. Initial field sampling that is closely supervised by senior personnel with previous experience collecting samples for PFAS analysis is highly recommended.

Field personnel must be health and safety certified as specified by the *Occupational Safety and Health Administration (OSHA) (29 CFR 1910,120(e))* to work on sites where hazardous materials may be present. Field personnel should also be first aid/CPR trained. Field personnel are responsible for becoming familiar with the sampling procedures outlined within this SOP, quality assurances, and the health and safety requirements associated with those participation in field sampling. Field personnel are responsible for sample collection, decontamination of equipment, and/or collecting proper documentation on the field forms.

4. Health and Safety

The health and safety considerations for work associated with this SOP, including physical, chemical, and biological hazards, are addressed in the site-specific HAZWOPER Health and Safety Plan (HASP). All work must be conducted in accordance with the HASP.

5. Interferences

PFAS is present in many modern materials; therefore, special care will be taken to minimize contamination of samples. Only PFAS-free personal protective equipment (PPE) and sampling tools will be used for the collection of PFAS analytical samples. Personnel must wear powderless nitrile gloves during sampling to reduce the risk of contamination. All clothing must be well washed to minimize potential cross-contamination of samples. If sampling tools or sample containers are potentially contaminated, they will either be decontaminated or discarded as appropriate. Additional information concerning the sampling for PFAS and direction to prevent contamination from field personnel is included in the MDEQ General PFAS Sampling Guidance (2018)

Potential interferences could also result from cross-contamination between sample locations. This will be minimized by decontaminating the reusable sampling tools after arriving at each location and prior to sample collection. For low flow sampling, new tubing and rope will be used between each well to eliminate cross contamination. The bladder pump must be unassembled and thoroughly decontaminated between wells. The Hydrasleeve passive sampling bags are designed for single use, so a new bag and new rope will be used for every well sample. The weights can be reused between wells and must be washed with Alconox and rinsed with PFAS-free water between use. Prior to sampling, every well will be gauged using a water level, which will be decontaminated between wells.

6. Equipment

The following equipment list contains materials required to carry out the methods described in this SOP. Tubing and rope lengths should be determined before sampling based on the well depths. The number of Hydrasleeve bags and bladders is dependent on the number of wells to be sampled. Extra Hydrasleeve bags should be ordered, especially if a large sampling volume is required.

Additional information about materials and equipment that are acceptable for PFAS sampling are further detailed in the MDEQ General PFAS Sampling Guidance (2018).

General Supplies

- Ziploc freezer bags (quart, one-gallon, and two-gallon)
- Wet ice (blue ice is prohibited)
- Coolers
- Ballpoint pens (Sharpie brand and similar products are prohibited)
- PFAS-free distilled water (Market Pantry, Target; Good & Gather, Target; Great Value, Wal-Mart; Glenwood-Inglewood Distilled Water, Cub Foods)

- Nylon brush
- Alconox detergent
- Spray bottles for detergent and PFAS-free distilled water solution
- Laboratory-supplied sample kits (HDPE bottles for PFAS samples, various bottle types for other parameters, labels, chain of custody forms, sampling forms)
- Scissors
- Well construction logs

Passive Sampling with a Hydrasleeve Bag

- Universal HDPE skinny sleeve Hydrasleeve bag for PFC sampling
- Top weight with top collar (stainless steel)
- Solid bullet stainless steel bottom weight
- Stainless steel clip for bottom weight
- Nylon rope
- Water level
- 100' flexible measuring table

Low-Flow Sampling with a Bladder Pump

- Bladder pump
- Bladder pump controller
- Air compressor (ensure capable of pulling from deeper wells if applicable)
- Extra disposable bladders (at least one per well to be sampled)
- Extra sample grab plates (at least one per well to be sampled)
- HDPE bonded tubing (length dependent on depth of screened interval)
- Multiparameter water quality tool with flow through cell or similar device to measure water quality parameters
- Turbidity meter
- Nylon rope (length depend on well depths)
- Five-gallon bucket (or similar) to collect purge water
- Water level
- Portable generator
- 100' flexible measuring tape

Low-Flow Sampling with a Peristaltic Pump

- Peristaltic pump and battery
- HDPE Tubing (length dependent on well depth)
- Silicone tubing

- Multiparameter water quality tool with flow through cell or similar device to measure water quality parameters
- Turbidity meter
- Five-gallon bucket (or similar) to collect purge water
- Water level

Personnel Protective Equipment

- Sunscreen (Neutrogena)
- Bug Spray (OFF! Deep Woods Repellent VII Dry; Sawyer Products SP6, Premium Permethrin Clothing Insect Repellent)
- Safety Shoes
- Powderless, disposable, nitrile gloves

7. Methodology

The method of sampling is dependent on the well depth and well construction. A peristaltic pump can be used for wells less than 50 feet deep, while bladder pumps can be used up to depths of approximately 300 feet with an appropriate air compressor. Passive sampling is preferred for wells over 50 feet deep, especially those with 4-inch diameters, to minimize IDW and purge time. Passive samplers, however, do require at least six feet of screened interval to pull the bag through to fill. For well screens spanning the water table, this may not be possible depending on where the water table is within the screened interval. The amount of sample volume is also limited with a Hydrasleeve bag and thus may require multiple deployments of the sampler. Two deployments of the passive sampler, which will result in analyses collected over a 48-hour period, was determined to be acceptable for bedrock wells when other sampling methods are not feasible as bedrock water chemistry is not as variable across the necessary sampling period as could be the case with shallower wells that could be impacted by rain events. An understanding of the well construction, geology, and sample requirements will help determine the optimal sampling method.

7.1 Hydrasleeve Passive Sampling

Prior to sampling, the well construction logs must be consulted to verify the well depth and screened interval. The method for sampling with Hydrasleeve bags was developed from the Hydrasleeve field manual with slight alterations due to the well construction used for several of the bedrock wells and to avoid the use of PFAS-containing materials. Prior to deployment, rope is measured to allow the top of the bag to be at the bottom of the screen or open hole. In the majority of the wells, the bag will be collapsed at the bottom of the well. Excess rope is cut to allow for the Hydrasleeve bag to be securely tied to the well pro-top. The Hydrasleeve sampling system must be assembled according to the manufacturer's instruction. The bag is slid over the threading on the top adapter. The top weight is slid over the Hydrasleeve bag so it can be screwed onto the top adapter, effectively sealing the bag in place. The bottom weight is attached with the provided clip to the holes at the bottom of the bag. The rope is knotted securely to the top adapter. Hydrasleeve includes top clips with adapters but these cannot be used, especially in open hole wells, as the clips can become stuck within the well casing or open hole intervals. Hydrasleeve does also sell top adapter for 4" wells. These should not be used in the open hole wells because they catch on the borehole sidewall or at the bottom of the well casing.

Once the Hydrasleeve bag is assembled, it is lowered into the well until it is fully collapsed at the bottom of the well. The field personnel should be able to feel both the bottom and top weight hit the bottom of the well. If the bag is required to be pulled upwards for any reason, care must be taken to do this very slowly as quick upward motion through the water column will open the check valve on the bag and begin sample collection. The nylon rope is then securely tied to the well pro-top. The Hydrasleeve bag must be deployed for at least 48 hours before sampling but can also be left in the well for much longer. This allows for the well to restabilize after deployment for a representative sample to be collected since the well is not being purged and the deployment of the bag may have disturbed the water within the sample interval.

Two field personnel are required for sample collection with a Hydrasleeve bag. To sample, the Hydrasleeve bag is pulled upwards at a rate greater than 1 foot per second to open the check valve and allow water to enter the bag. This will be done from where the bag is positioned at the bottom of the well. With open hole wells, care should be taken to minimize the movement and number of times to the bag is moved up and down to reduce the potential for the Hydrasleeve bag to catch on the bedrock sidewall in the open hole interval or on the bottom of the well casing. Sample bottles should be prepared for collection before the Hydrasleeve bag is pulled from the well as the Hydrasleeve bag must be emptied immediately upon retrieval to prevent sample loss. To pour the water from the bag, the top weight is unscrewed from the top adapter and the bag carefully cut from the adapter with a second person holding the bag near the top to minimize sample lost. Water is then carefully poured into the sample containers from where the bag was cut. As the bag is emptied, additional sections can be cut off to allow for easier pouring. The PFAS sample containers must be filled first to reduce the potential for contamination. After sampling, the containers should be properly labeled and double-bagged with Ziploc bags and stored on ice. Complete decontamination with Alconox and PFAS-free water of all reusable equipment, including the weights and scissors, will be conducted at the next sampling location to ensure the equipment does not become contaminated between wells.

7.2 Bladder Pump Low-Flow Sampling

Prior to sampling, the well construction logs must be consulted to verify the well depth and screened interval. The appropriately sized air compressor and regulator must be ordered to ensure it is capable of sampling the specified well depth. Depending on the depth, a larger air compressor may be required. The tubing and rope are measured out to allow the pump intact to be in the middle of the screened interval with a flexible measuring tape. Mark where the top of casing should be on the rope and tubing with duct tape to ensure proper placement of the pump. Allow for excess tubing to connect to the bladder pump controller and flow-through cell and excess rope to tie the pump to the well pro-top.

The pump must be decontaminated prior to use and assembled with a new bladder and grab plate. Once the tubing and rope are measured, the tubing is inserted into the grab plate and rope tied to the pump. The pump is then carefully lowered into the well to the measured depth. The rope must be securely tied around the well pro-top. The air tubing is connected to the regulator and the water tubing connected to the YSI (or similar) flow-through cell. Tubing is then connected to the outlet of the flow-through cell to allow discharge into a five-gallon (or similar) bucket to monitor the purge volume.

Water is pumped at a rate ranging from 100 to 200 ml/min and must not exceed 500 ml/min. The water should be pumped through a flow-through chamber of a YSI or similar device to record periodic measurements of pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), temperature, and conductivity until the parameters have reached stabilization. In addition, turbidity and water level will be documented at the same periodic intervals of the other water stabilization parameters. If the depth to water is increasing, then the flow rate must be decreased. Purging will continue for at least one hour and until the water quality parameters and water level have stabilized.

Water stabilization parameters, water level, well volume calculations, and well construction information will be recorded on a sampling information form for each well.

Sample bottles should be prepared for collection prior to sampling to minimize the potential for contamination. The sampler must wear clean, new nitrile gloves. The tubing is disconnected from the flow-through cell to allow for sampling directly from the tubing. Samples must be collected directly into laboratory-supplied sampling containers. After sampling, the containers must be properly labeled and double-bagged with Ziploc bags and stored on ice.

7.3 Peristaltic Pump Low-Flow Sampling

Prior to sampling, the well construction logs must be consulted to verify the well depth and screened interval. A peristaltic pump can be used for wells less than 50 feet deep. To ensure a representative sample is collected from the groundwater, three well volumes must be purged to ensure all of the stagnant water above the screened interval is removed. Prior to purging, the water level and total well depth must be measured to calculate the volume of water in the well. As with the bladder pump, the water should be pumped through a flow-through chamber of a YSI or similar device to record periodic measurements of pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), temperature, and conductivity until the parameters have reached stabilization. In addition, turbidity and water level will be documented at the same periodic intervals of the other water stabilization parameters. If the water level begins to decrease, then the pumping rate must be reduced. Purging will continue until at least three well volumes have been removed and the water quality parameters and water level have stabilized.

When purging is complete, the tubing is disconnected from the flow through chamber to allow for sample collection directly from the tubing. Samples must be collected directly into laboratory supplied containers. After sampling, the containers must be properly labeled and double bagged with Ziploc bags and stored on ice.

7.4 Sample Handling and Preservation

The sample containers will be double bagged with Ziploc brand freezer bags and placed in a cooler on ice. The chain of custody and other documentation will be completed. The samples will be packaged for shipment to the laboratory with each cooler containing a trip blank and temperature blank.

7.5 Equipment Decontamination

Proper equipment preparation, cleaning, and field decontamination procedures are necessary to prevent cross-contamination of samples. Decontamination should be performed with a standard laboratory grade phosphate-free detergent such as Alconox. Four (4) different brands of distilled water have been submitted for laboratory analysis to determine the presence of PFAS prior to the sampling event (see Section 6). According to laboratory results, all four brands do not contain detectable amounts of PFAS. Other distilled water brands not listed in this SOP or previously vetted must be sampled and determined PFAS-free prior to use in equipment decontamination.

Prior to sampling, the dedicated sampling equipment must be scrubbed of particulate matter with a nylon brush and cleaned with an Alconox/water solution. The equipment must then be rinsed with PFAS-free distilled water. If the equipment is transported after decontamination, it must be wrapped with a clean plastic bag to prevent contamination.

8. Quality Assurance and Quality Control

In addition to the sampling program, quality control (QC) samples should be collected to estimate precision and accuracy of the analytical results, and to examine the sources of error introduced by field and laboratory practices.

8.1 Equipment Blanks

Equipment blanks are required in all phases of sampling and serve to confirm that decontamination procedures are adequately carried out and that there is no cross-contamination of samples due to the equipment itself. Collection of equipment blanks may be performed for all analytes of interest. Equipment blanks involve pouring PFAS-free distilled water over decontaminated sampling equipment and directly collecting that water using a laboratory-supplied sample bottle. One equipment blank should be taken per piece of equipment and repeated on each piece of equipment as needed when reusable sampling equipment is utilized in the sample collection process and in multiple field events. Appropriate equipment to sample for a groundwater sampling event include the weights from the Hydrasleeve sampling method, the bladder pump, the scissors used to cut the tubing, and the tubing.

8.2 Field Duplicate Samples

Duplicate samples should be collected for every 10 field samples. A field duplicate consists of collecting two times the required volume of a sample and submitting separately labelled bottles for analysis. The two aliquots, taken from the same location at the same time, are analyzed separately to assess the consistency of sampling, sample homogeneity, and laboratory analytical consistency. These sample duplicates may be submitted as laboratory blind duplicates and may be analyzed for all analytes of interest. This sample will be collected at the same location immediately after the primary sample is collected for the low flow sampling methods or from the same Hydrasleeve bag as the primary sample when possible.

8.3 MS/MSD Samples

One matrix spike/matrix spike duplicate (MS/MSD) sample should be taken for every 20 field samples, based on the laboratory recommendation. This sample will be collected immediately after the primary sample for the low flow sampling methods or from the same Hydrasleeve bag as the primary sample when possible.

8.4 Temperature Blank Samples

A previously prepared temperature blank consisting of de-ionized water stored inside a specially labelled sample bottle should accompany each sample cooler during transport to the laboratory. These bottles are used as a standard to ensure that samples were maintained within an acceptable temperature range during shipment per laboratory specifications.

8.5 Trip Blank Samples

A trip blank consisting of de-ionized, PFAS-free certified water previously prepared by the laboratory stored inside a specially labelled sample bottle should accompany each sample cooler during transport to the laboratory when possible. These samples are used as a standard to ensure the detection of any PFAS compounds in field samples were not due to improper handling or processing during sampling, shipping, or laboratory receipt.

9. Investigation – Derived Waste (IDW) Management

The IDW that may be generated during groundwater sampling include the following:

- Disposable materials such as PPE, plastic sheeting, and Ziploc bags;
- Excess water left over from sampling activities; and
- Decontamination water.

All of these materials are considered non-hazardous. Disposable materials may be discarded in regular non-hazardous trash receptacles. The purge water from sampling may be discharged to the ground. In general, *de minimis* quantities of Alconox is used for decontamination and is deemed non-hazardous by the MPCA (client), therefore water generated from decontamination may be discarded in-place.

10. References

MDEQ (2018). Groundwater PFAS Sampling Guidance.

MDEQ (2018). General PFAS Sampling Guidance

Attachment A-3
Vertical Aquifer Profiling Sampling

Standard Operating Procedure

Vertical Aquifer Profiling Sampling

Prepared by: Amanda Lanning

Approved by: Al Gorski and Drew Tarara

December 10, 2020

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1. Scope

The primary objective of vertical aquafer profiling (VAP) sampling and investigation activities are used to identify the magnitude and extent of per- and polyfluoroalkyl substances (PFAS) contamination in groundwater and identify mechanisms by which PFAS-impacted water is traveling through the Project 1007 conveyance system (Project 1007 Corridor) and entering groundwater. This Standard Operating Procedure (SOP) describes the methodology for performing VAP groundwater and soil sampling for PFAS and other parameters in the Project 1007 corridor. This SOP describes VAP sampling using submersible pumps and a peristaltic pump. The method used for VAP sampling is selected based off the drilling equipment. Sampling methodologies are as follows:

- Submersible Grundfos pump will be used to sample if the Sonic drill rig is being used;
- A peristaltic pump will be used to sample will be used to sample if the Geoprobe drill rig is being used;
- Soil sampling from Sonic drill rig liner and Geoprobe drill rig liner.

Side by side sampling was conducted between the bladder pump and Hydrasleeve bags to ensure the samples collected via these two methods are comparable. The low flow sampling techniques have been modified from the Michigan Department of Environmental Quality (MDEQ) Groundwater PFAS Sampling Guidance (2018).

2. Objectives

The objectives of this SOP are to:

- Clearly define the methods necessary to collect VAP samples from Sonic rig when a submersible pump is being used and from a Geoprobe rig when a peristaltic pump is being used.
- Ensure uniformity and continuity in groundwater sample collection between qualified personnel to allow the data to be comparable spatially and temporally.

3. Personnel Qualifications

Proper sample collection and the use of various field equipment requires formal training. Initial field sampling that is closely supervised by senior personnel with previous experience collecting samples for PFAS analysis is highly recommended.

Field personnel must be health and safety certified as specified by the *Occupational Safety and Health Administration (OSHA) (29 CFR 1910,120(e))* to work on sites where hazardous materials may be present. Field personnel should also be first aid/CPR trained. Field personnel are responsible for becoming familiar with the sampling procedures outlined within this SOP, quality assurances, and the health and safety requirements associated with the participation in field sampling. Field personnel are responsible for sample collection, decontamination of equipment, and/or collecting proper documentation on the field forms.

4. Health and Safety

The health and safety considerations for work associated with this SOP, including physical, chemical, and biological hazards, are addressed in the site-specific HAZWOPER Health and Safety Plan (HASP). All work must be conducted in accordance with the HASP.

5. Interferences

PFAS is present in many modern materials; therefore, special care will be taken to minimize contamination of samples. Only PFAS-free personal protective equipment (PPE) and sampling tools will be used for the collection of PFAS analytical samples. Personnel must wear powderless nitrile gloves during sampling to reduce the risk of contamination. All clothing must be well washed to minimize potential cross-contamination of samples. If sampling tools or sample containers are potentially contaminated, they will either be decontaminated or discarded as appropriate. Additional information concerning the sampling for PFAS and direction to prevent contamination from field personnel is included in the MDEQ General PFAS Sampling Guidance (2018)

Potential interferences could also result from cross-contamination between sample locations. This will be minimized by decontaminating the reusable sampling tools after arriving at each location and prior to sample collection. For VAP sampling from a Geoprobe drill rig, new tubing will be used between each VAP sample location to eliminate cross contamination. The Grundfos pump and tubing must be thoroughly decontaminated between sample locations. Prior to sampling, every VAP location will be gauged using a water level, which will be decontaminated between wells.

6. Equipment

The following equipment list contains materials required to carry out the methods described in this SOP. Tubing and pumps should be provided by the drilling contractor. Maximum depth of VAP sampling should be determined before sampling to assure the driller supplies the correct length of tubing for sampling.

Additional information about materials and equipment that are acceptable for PFAS sampling are further detailed in the MDEQ General PFAS Sampling Guidance (2018).

Sampling Supplies

- Ziploc freezer bags (quart, one-gallon, and two-gallon)
- Wet ice (blue ice is prohibited)
- Coolers
- Ballpoint pens (Sharpie brand and similar products are prohibited)
- PFAS-free distilled water (Market Pantry, Target; Good & Gather, Target; Great Value, Wal-Mart; Glenwood-Inglewood Distilled Water, Cub Foods)
- Nylon brush
- Alconox detergent
- Spray bottles for detergent and PFAS-free distilled water solution
- Laboratory-supplied sample kits (HDPE bottles for PFAS samples, various bottle types for other parameters, labels, chain of custody forms, sampling forms)
- Scissors
- Multiparameter water quality tool with flow through cell or similar device to measure water quality parameters

- Turbidity meter
- Water level meter
- Five-gallon bucket for discharged groundwater (submersible pump method)
- Two-gallon bucket for discharged groundwater (peristaltic method)

Contractor Supplied Equipment

- Peristaltic Pump and Battery
- ¼" HDPE Disposable tubing (length dependent on VAP sampling depth and provided by driller)
- ¾" HEDP re-usable tubing
- Silicone tubing
- Two-foot stainless steel screen for geoprobe, low-flow peristaltic VAP sampling
- Four-foot stainless steel screen for sonic rig, VAP sampling
- 55-gallon drum
- De-con water and alconox detergent

Personnel Protective Equipment

- Sunscreen (Neutrogena)
- Bug Spray (OFF! Deep Woods Repellent VII Dry; Sawyer Products SP6, Premium Permethrin Clothing Insect Repellent)
- Cold weather gear
- Safety Shoes
- Powderless, disposable, nitrile gloves

7. Methodology

The method for VAP sampling groundwater is dependent on the type of drill rig being used. A low-flow peristaltic pump is used with a Geoprobe drill rig, with disposable tubing. A submersible pump is used with a Sonic drill rig, with re-usable tubing and pump. A sonic drill rig method is used when the VAP sample exceeds a depth of approximately 50 feet below ground surface (bgs) (depending on subsurface geology). If a monitoring well is being installed using a sonic drill rig, VAP sampling typically occurs at depths during the well drilling process. The method for collecting a VAP soil sample is essentially the same for Geoprobe liner and Sonic liner.

7.1 Submersible Pump VAP Sampling (Sonic Drill Rig)

Prior to sampling the drilled depth must be confirmed to verify the screened interval for the VAP sample. The driller will set the 4-foot screen at the bottom of the casing. Once the screen is set at the bottom of the casing the driller will pull the casing up four feet, this allows groundwater to enter the casing from the 4-foot screened interval. The casing will generally be filled with drilling water up to ground surface. Record the gallons drilling water the used to drill to the VAP sample interval. Wait two to five minutes and collect a stabilized water level reading from the casing before the submersible pump is deployed down to the screened interval. The driller will lower the submersible pump down to the screened interval. Attach the end of the tubing so the groundwater discharges into a five-gallon bucket.

Water is pumped at a rate of approximately eight gallons per minute into the five-gallon bucket. Place the YSI or similar device probe in the five-gallon bucket. Let the water overflow the five-gallon bucket. Make sure discharge groundwater is discharging into a safe area. Record periodic measurements of pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), temperature, and conductivity until the parameters have reached stabilization. In addition, turbidity and water level will be documented at the same periodic intervals of the other water stabilization parameters. Purging will continue until water stabilization parameters are met or until the volume purged is greater than the volume of drilling water used to drill to the VAP interval.

In some instances when the VAP sample interval is in tight soils or shale formations where the groundwater recharge is poor, the driller will use a smaller submersible pump that will pump at a rate of approximately two gallons per minute. This will avoid large groundwater drawdown and possibly drying out the casing of groundwater.

Sample bottles should be prepared for collection prior to sampling to minimize the potential for contamination. The sampler must wear clean, new nitrile gloves. When purging is complete, sample directly from the tubing. Samples must be collected directly into laboratory-supplied sampling containers. After sampling, the containers must be properly labeled and double-bagged with Ziploc bags and stored on ice.

After the pump is pulled from the casing the drillers will de-contaminate the pump and HDPE tubing with PFAS free water and standard laboratory grade phosphate-free detergent such as Alconox.

7.2 Peristaltic Pump Low-Flow VAP Sampling (Geoprobe Drill Rig)

Prior to sampling the drilled depth must be confirmed to verify the screened interval for the VAP sample. The driller will pull the probe rods from the outer probe roads and set the two-foot screen at the bottom of the drilled depth. Once the screen is set at the bottom of the outer probe the driller will pull the outer probe up two feet, this allows groundwater to enter from the two-foot screened interval. Prior to purging, the water level and total drilled depth must be measured to calculate the volume of water in the well. Measure groundwater before with water level meter before deploying HDPE tubing. The driller will deploy HDPE tubing down to the screened interval, then connect it to the peristaltic pump. The water should be pumped into a two-gallon bucket, with the YSI or similar device to record periodic measurements of pH, oxidation-reduction potential (ORP), dissolved oxygen (DO), temperature, and conductivity until the parameters have reached stabilization. In addition, turbidity and water level will be documented at the same periodic intervals of the other water stabilization parameters.

When purging is complete, sample directly from the tubing. Samples must be collected directly into laboratory supplied containers. After sampling, the containers must be properly labeled and double bagged with Ziploc bags and stored on ice. The HDPE and silicon tubing used to purge can be discarded in regular non-hazardous trash receptacles.

7.3 Soil Sampling from VAP Interval

Prior to collecting the soil sample from the VAP interval, confirm with the driller the depth interval of the soil in the liner. The Sonic drill rig will have soil liner intervals in ten-foot segments. The drillers will bring the soil liner segments over to a designated table. Cut open the liner with a de-contaminated set of scissors. Collect a composite soil sample from the ten-foot liner, within the four-foot interval that the groundwater screen is going to be placed for the VAP groundwater sample. Follow these same procedures for collecting soil samples outside the VAP interval.

Prior to collecting the soil sample from the VAP interval, confirm with the driller the depth interval of the soil in the liner. The Geoprobe drill rig will have four-foot liners. The driller will bring the soil liner segments over to a designated table. Cut the liner with a de-contaminated Geoprobe Liner Cutter tool. Collect a composite soil sample from the four-foot liner, within the two-foot interval that the groundwater screen is going to be placed for the VAP groundwater sample. Follow these same procedures for collecting soil samples outside the VAP interval.

Sample bottles should be prepared for collection prior to sampling to minimize the potential for contamination. The sampler must wear clean, new nitrile gloves. Samples must be collected directly into laboratory-supplied sampling containers. After sampling, the containers must be properly labeled and double-bagged with Ziploc bags and stored on ice.

7.4 Sample Handling and Preservation

The sample containers will be double bagged with Ziploc brand freezer bags and placed in a cooler on ice. The chain of custody and other documentation will be completed. The samples will be packaged for shipment to the laboratory with each cooler containing a trip blank and temperature blank.

7.5 Equipment Decontamination

Proper equipment preparation, cleaning, and field decontamination procedures are necessary to prevent cross-contamination of samples. Decontamination should be performed with a standard laboratory grade phosphate-free detergent such as Alconox. Four (4) different brands of distilled water have been submitted for laboratory analysis to determine the presence of PFAS prior to the sampling event (see Section 6). According to laboratory results, all four brands do not contain detectable amounts of PFAS. Other distilled water brands not listed in this SOP or previously vetted must be sampled and determined PFAS-free prior to use in equipment decontamination.

Prior to sampling, the dedicated sampling equipment must be scrubbed of particulate matter with a nylon brush and cleaned with an Alconox/water solution. The equipment must then be rinsed with PFAS-free distilled water. If the equipment is transported after decontamination, it must be wrapped with a clean plastic bag to prevent contamination.

8. Quality Assurance and Quality Control

In addition to the sampling program, quality control (QC) samples should be collected to estimate precision and accuracy of the analytical results, and to examine the sources of error introduced by field and laboratory practices.

8.1 Equipment Blanks

Equipment blanks are required in all phases of sampling and serve to confirm that decontamination procedures are adequately carried out and that there is no cross-contamination of samples due to the equipment itself. Collection of equipment blanks may be performed for all analytes of interest. Equipment blanks involve pouring PFAS-free distilled water over decontaminated sampling equipment and directly collecting that water using a laboratory-supplied sample bottle. One equipment blank should be taken per piece of equipment and repeated on each piece of equipment as needed when reusable sampling equipment is utilized in the sample collection process and in multiple field events. Appropriate equipment to sample for a VAP sampling event include the submersible pump, the scissors used to cut the tubing, and the tubing.

8.2 Field Duplicate Samples

Duplicate samples should be collected for every 10 field samples. A field duplicate consists of collecting two times the required volume of a sample and submitting separately labelled bottles for analysis. The two aliquots, taken from the same location at the same time, are analyzed separately to assess the consistency of sampling, sample homogeneity, and laboratory analytical consistency. These sample duplicates may be submitted as laboratory blind duplicates and may be analyzed for all analytes of interest. This sample will be collected at the same location immediately after the primary sample is collected.

8.3 MS/MSD Samples

One matrix spike/matrix spike duplicate (MS/MSD) sample should be taken for every 20 field samples, based on the laboratory recommendation. This sample will be collected immediately after the primary sample.

8.4 Temperature Blank Samples

A previously prepared temperature blank consisting of de-ionized water stored inside a specially labelled sample bottle should accompany each sample cooler during transport to the laboratory. These bottles are used as a standard to ensure that samples were maintained within an acceptable temperature range during shipment per laboratory specifications.

8.5 Trip Blank Samples

A trip blank consisting of de-ionized, PFAS-free certified water previously prepared by the laboratory stored inside a specially labelled sample bottle should accompany each sample cooler during transport to the laboratory when possible. These samples are used as a standard to ensure the detection of any PFAS compounds in field samples were not due to improper handling or processing during sampling, shipping, or laboratory receipt.

9. Investigation – Derived Waste (IDW) Management

The IDW that may be generated during VAP sampling include the following:

- Disposable materials such as PPE, plastic sheeting, and Ziploc bags;
- Soil and bedrock cuttings from drill rig;
- Excess water left over from sampling activities; and
- Decontamination water.

All of these materials are considered non-hazardous. Disposable materials may be discarded in regular non-hazardous trash receptacles. The soil and bedrock cuttings generated during the drilling process can be thin spread in a designated area. The purge water from sampling may be discharged to the ground. In general, *de minimis* quantities of Alconox is used for decontamination and is deemed non-hazardous by the MPCA (client), therefore water generated from decontamination may be discarded in-place.

10. References

MDEQ (2018). Groundwater PFAS Sampling Guidance.

MDEQ (2018). General PFAS Sampling Guidance

Attachment A-4
Conventional Slug Testing Using a Transducer

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Standard Operating Procedure

Conventional Slug Testing Using a Transducer

Prepared by: Amanda Lanning and Hanna Temme

Approved by: Al Gorski and Drew Tarara

September 22, 2020

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1. Scope

This Standard Operating Procedure (SOP) describes the methodology for performing monitoring well slug testing for the determination of horizontal hydraulic conductivity of the screened unit. The intent of slug testing is to induce an instantaneous change in the static water level in the formation screened by a monitoring well, and then measure the resultant water level response (i.e., drawdown or recovery) of the groundwater in the well. The well response data is then evaluated using a number of analytical solutions that use the collected response data to determine the horizontal hydraulic conductivity of the monitored unit.

The provided scope describes the methods typically employed for the slug testing of standard two-inch interior diameter monitoring wells. Two-inch monitoring wells will allow for the insertion of both a corded transducer to collect the response data and a solid slug to cause sufficient groundwater displacement into the well. Though slug testing can be performed on one-inch monitoring wells and monitoring wells greater than two inches in diameter, a pneumatic (air) type slug should be employed. Pneumatic slug testing requires the use of specialized equipment on the well head; the methodology will not be described in this SOP.

2. Objectives

The objectives of this SOP are to:

- Clearly define the means and methods necessary for the performance of a slug test on a site monitoring well;
- Ensure uniformity and continuity in the application of the slug testing procedure by different qualified field personnel; and,
- Provide accurate, reproducible slug test water level response data for use in determining the horizontal hydraulic conductivity of the saturated geologic horizon of a monitored unit.

3. Equipment

The following equipment is needed to conduct the slug testing:

- Boring and Well Construction Logs for tested wells
- *Well and Aquifer Geometry Data Sheets for Fully and Partially Saturated Well Screens* (**Attachment 1**)
- *Manual Water Level Response Form* (**Attachment 2**) for manual record keeping (if applicable)
- Field notebook
- Nitrile gloves and other PPE appropriate to site contaminants of concern
- Water level indicator

- Interface Probe (if applicable)
- Pressure transducer (30 pounds per square inch (psi)) and data logger (if not performing manual measurements)
- Digital watch or stop watch
- 2 Solid slugs of different volumes (preferred)
- Parachute cord or equivalent line
- Waterproof marking pens/ink pens
- Duct tape

4. Pre-Test Preparation

The *Well and Aquifer Geometry Data Sheets* provided in **Attachment 1** should be used to compile the necessary well construction/aquifer geometry data necessary for the completion of slug test analysis. The accompanying *Manual Water Level Response Form* (**Attachment 2**) should also be used to record elapsed time and depth to water measurements if manual record keeping is necessary. There are two types of *Well and Aquifer Geometry Data Sheets:*

1) For a well with a partially saturated well screen case
2) For a well with a fully saturated well screen case

To determine the appropriate form to use for a given well, field personnel must first identify the position of static groundwater relative to the screened interval, which may be found on the boring and well construction logs. The slug test methodology for each screened condition (partially saturated or fully saturated) is provided in Section 5.

It is critical for personnel performing the slug test to have sufficient understanding of the screened geology and the position of the static water level relative to the monitoring well's screened interval to determine the type of slug test that should be performed. Therefore, it is important for field personnel and staff that analyze the data to have on-hand the well construction log for each tested well. In addition to identifying the depth of the static water level within or above the screened interval, the well construction log can be used to identify the screened interval, screen length, and boring and well diameters.

The boring log of the well can also enable field personnel to compare the screened material to the observed slug test response/recovery time during the test. For example, if the boring log specifies that the screened interval is screened across clay and the well recovers to a static level within one minute of the start of the test, it may be an indication that the test, the measurement, or some other factor has resulted in an unusually fast response time for a fine-grained material like clay that should ideally result in a considerably longer response time. Alternatively, if the material within the screened interval is predominantly coarse-grained, such as gravel, the test response time should be much faster (less than 30 seconds and often less than 10 seconds), and a pneumatic (air) slug type test may be the only suitable method of testing.

Field personnel must measure and document the water level and depth to bottom for each well prior to setting up for the test to determine the length of the water column in the well and whether the water column intersects the screened interval. Refer to the well construction log to determine if the water table intersects the screen or is above the screen. Field personnel can determine the type of slug test(s) to perform by identifying one of the following scenarios:

- If the water table is above the well screen, perform both FALLING HEAD (FH) (Slug-in) and RISING HEAD (slug -out) testing (in that order).
- If the water table intersects the well screen, perform only RISING HEAD (RH) (Slug-out) testing. In this scenario, the slug is inserted into the water column and water levels are allowed to return to static conditions prior to starting the test.

Record all well/aquifer geometry values on the applicable *Well and Aquifer Geometry Data Sheet* (**Attachment 1**). Slowly lower and secure the transducer at a sufficient depth in the water column to minimize the chances that the introduced slug will impact the transducer. Check and confirm that transducer is fully submerged, functioning, and allowed to equilibrate with the groundwater.

For slug testing, the data logger should be set to "Level-Surface Elevation" (Win-Situ Mobile (Troll) loggers), and the first logged reading should be set to "0". For older or non In-situ data loggers, set the datum to "0" (i.e., the datum is the water table). For data recording, a fast linear measurement (2 or 4 measurements/second) should be selected on newer In-situ data loggers, or logarithmic followed by linear rate on older Hermit style loggers.

The file name assigned to each dataset should be clear and understandable to both the person performing the test and the person analyzing the results, and at a minimum should include the well name, the test type ("RH" or "FH"), and the test series number if multiple tests were performed. For example:

"MW108RH1"

indicates that the dataset in the data logger is for a rising head (RH) test, test number 1, at monitoring well MW108.

5. Methodology

If time permits, it is best practice to perform at least two, and preferably three, separate tests at each well to confirm that the response data is reproducible and to ensure that multiple datasets are available in the event that one of the datasets is unusable. ***Additional tests should only be performed only after the water level was recovered to 90% of the original static water level in the tested well.*** In general, the testing duration in coarse-grained sand and gravel units is typically less than two minutes until full recovery; in fine-grained materials, the recovery time can range from several minutes to several hours or longer.

As discussed in Section 4, the position of the static water level relative to the well screen of the tested well will determine whether a slug-out (rising head) test can be performed, or if a slug-in (falling head) test and/or a slug-out (rising head) test can be performed.

The slug test methodology for each screened condition (partially saturated or fully saturated) is provided below.

For Wells with a Partially Saturated Well Screen (Slug-Out (Rising Head) Test):

1) Measure the static water level in the well.
2) Insert slug into the saturated screened interval. Avoid hitting the transducer. Wait until the water level returns to the static water level measured prior to the start of the test. Name the data file in the data logger and label the field data sheet.
3) Once the water level has returned to static conditions, start the data logger first and then pull the slug out of the water quickly. Carefully hang the slug just above the water table by wrapping the slug cord around the well riser several times.
4) Using the transducer, monitor the recovery of the water level. The readings on the transducer should become more positive (indicating a rising head); if a "0" datum was used, the numbers should approach "0" over time.
5) When the water level has recovered to at least 90% of the original static water level prior to the test, stop the test and store the response data from the test as a separate file in the data logger.
6) Repeat the slug-out test by repeating Steps 1 through 4. At least two rising head/slug-out tests should be performed.

For Wells with a Fully Saturated Well Screen (Slug-In (Falling Head) Test and/or Slug-out (Rising Head) Test:

1) Measure the static water level in the well.

2) A slug-in test typically will be performed first. Hang the slug just above the water level in the well by wrapping the slug cord around the riser. Name the data file in the data logger and label the field data sheet.

3) When ready, turn on the data logger and carefully lower the slug into the water without hitting the transducer. Carefully tie the slug off by wrapping the slug cord around the well riser.

4) Use the transducer to monitor the recovery of the water level. The readings on the transducer should become more negative (indicating a falling head); if a “0” datum was used, the numbers should approach “0” over time.

5) When the water level has recovered to at least 90% of the original static water level prior to the test, stop the test and store the response data from the test as a separate file in the data logger.

6) Perform a slug-out (rising head) test. Name the data file and zero the data logger.

7) When ready, turn on the data logger and carefully lower the slug into the water without hitting the transducer. Carefully tie the slug off by wrapping the slug cord around the well riser.

8) Use the transducer to monitor the recovery of the water level. The readings on the transducer should become more positive (indicating a rising head); if a “0” datum was used, the numbers should approach “0” over time.

9) When the water level has recovered to at least 90% of the original static water level prior to the test, stop the test and store the response data from the test as a separate file in the data logger.

10) Repeat the slug-in test by repeating Steps 1 through 8, if additional tests are required. At least one slug-in (falling head) test and one slug-out (rising head) test should be performed at each well location.

A supplemental slug test can be performed by employing a slug of a different displacement, or if the screen is fully saturated and the introduction of potable water into the well is allowed, a slug of water (one gallon) may be used after following the procedures above. Comparison of the original test to tests performed with a slug of a different displacement will further improve the validity of the slug test results if the results from the conventional slug and larger displacement slug are equivalent.

Unless the tested geologic zone of saturation is known to exhibit a low hydraulic conductivity and/or a solid slug cannot be employed due to well construction limitations, bailing or evacuation of the water using a pump is not recommended because analysis of the response data assumes a near-instantaneous removal of water. Bailers to remove a “slug” of water may be employed but the early response data from the test should be inspected to ensure that leakage from the bailer upon removal has not affected the response data. If extremely high hydraulic conductivities are anticipated and the well screen is fully saturated, a pneumatic slug may provide the best testing option.

6. Data Management

Water level response data stored in the data logger should be uploaded the same day it was collected to ensure that the data are not lost or overwritten in the field. The response curve analyst will require the following information from field personnel collecting the data and/or the project manager responsible for the test:

- All completed slug test response data (.bin) files.
- Monitoring well construction forms for each tested well.
- Field notes associated with the testing procedure and measured static water levels at the time of each test.
- Any information regarding aquifer geometry (i.e., confining units, aquifer thickness), as identified in the *Well and Aquifer Geometry Data Sheet* (**Attachment 1**) for each well tested.

The acquired slug test response data will typically be uploaded into the widely applied AQTESOLV® curve matching software or other software for determination of hydraulic conductivity values. A brief report summarizing the field collection procedures, curve matching methodology, and the calculated hydraulic conductivity values should be provided with the results following analysis of the slug test data.

There are several methods to analyze slug test data. The methods of Bouwer and Rice (BR) and Cooper, Bredehoeft, and Papadopulos (CBP) are frequently used in practice. The BR method was developed to determine the horizontal hydraulic conductivity using the measured values of head difference as a function of time. The method was originally developed for unconfined aquifers, but Bouwer extended the application to confined aquifers as well. The CBP method uses the same type of data by using a type-curve match method developed by its authors. Both of these methods may be employed to evaluate the collected slug test response data.