US Army Corps
of Engineers
Baltimore District

Draft
Work Plan

PFC SITE CHARACTERIZATION – OLD FIRE TRAINING PIT
FORT DRUM, NEW YORK

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DRAFT FIELD AND DATA SUMMARY REPORT

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FORT DRUM, NEW YORK

Prepared by members of the product delivery team including:

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1.0 Introduction

The Training Pit area consisted of an 80 foot diameter concrete basin with a drainage system and underground storage tank. The pit was removed and backfilled in the summer of 2016. On October 27, 2016 the Fire Pit Drainage System was removed, consisting of a tank and oil water separator that extended to 10-12 feet below ground surface. The metal piping that ran approximately 3-4 feet below ground surface from the fire pit to the tanks was largely left in place at the time of this Work Plan. During the drainage system removal action it was observed that the pipe was breaking apart, so a series of test pits were dug out along the line with soil samples taken for VOC and PFC analysis.

Historically fuel was poured into the pit and ignited, fire fighters would practice extinguishing the fires. One such practice for extinguishing the fires was to employ the use of Aqueous Film-Forming Foams (AFFF) which contained Perfluorinated Compounds (PFCs) as a principle compound. Fuels used included waste Petroleum, Oil, & Lubricants (POL) products, POL contaminated materials, JP-4, gasoline and diesel fuels. An investigation conducted in 1990 as part of the Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) did not indicate impacts to the environment from operations POLs or related constituents. PFCs that may have been present in the fire-fighting foam were not identified (and not known) as potential constituents of concern during the 1990 investigation.

Due to the know use of PFC containing AFFF at this site and initial spring 2016 Fort Drum potable water quality PFC sampling results from nearby potable wells 7 and 11, there was a risk of possible groundwater contamination. Therefore, a set of 4 wells were installed on the former Training Pit site in August 2016 for groundwater sampling and analysis for PFCs and VOCs as a screening level investigation. There were no VOCs associated with fuel related analytes detected. For PFCs all wells had detections and nearly all concentrations were very high. The dilution factor for many of the samples were extremely high due to the high concentrations, particularly for PFOS and PFOA. With dilution factors of 90 to 100 the concentrations in groundwater are greater than the results, as the actual results exceeds the instrument range even with the dilutions. The range of results for PFOS is >1500 ng/L to >4800 ng/L. The range of results for PFOA is 150 ng/L (MW-4) to >2100 ng/L.

Prior to execution of field activities for the PFC screening level investigation the Ft. Drum Directorate of Public Works conducted a sampling event on 9-June-2016 at the project site. Field samples that were collected for analysis during this effort were from various locations around and immediately under the concrete rim of the Fire Training Pit, all matrices were soil. Samples of the sludge and water perched in the pit were also collected for analysis. Results from this sampling event showed high levels of perfluoroctane sulfonate (PFOS) in the range of 150 to 11000 ng/g and low to high levels of perfluoroctanoic acid (PFOA) in the range of 1.3 to 200 ng/g.

Due to the results collected from the initial screening level event and soil sampling event a site characterization of the overall contamination will be conducted under this Work Plan (WP). This WP will cover activities to determine the extent and range of the PFC contamination in groundwater and soil as related to the Fire Training Area activities and the use of AFFF. Two wells will be installed within the glacial till material just above bedrock to assess if PFCs have broken through the semi-confining silt layer and pose a risk to the bedrock aquifer. One well will be installed just north of the former fire pit and the second will be installed directly downgradient. All other wells will be installed just above the semi-confining layer to determine extent in the upper aquifer.

1.1 Facility Information

Ft. Drum is located in upstate New York approximately 30 miles from the Canadian border. It is a 168 square mile Army installation that is home to the 10th Mountain Division (Light Infantry). The Old Fire Training Pit is located about 675 feet southeast of the intersection of Munns Corner Road and Garrison Drive.

2.0 Scope of Investigation

The task consisted of 3 parts; installation up to 13 permanent monitoring wells with 11 wells screened just above a semi-confining silt layer and 2 wells screened in the lower till level just above the limestone contact, soil sampling and analysis within a 150 foot radius of the former fire training pit area consisting of 16 borings (figure 1), and sampling & analysis of groundwater for PFC.

1. ***Staff are to read all instructions before proceeding to site and should not hesitate to call the project contacts with any questions.***

2. **Security and Considerations:** The project site is located on a secure Federal Facility. All personnel will be required to have their work ID (CAC) to access the facility and project sites. All in house and installation safety guidelines shall be followed.

3. **Site Layout:** No site layout is needed. All locations have been flagged and marked by the customer/facility. See Appendix A for table of coordinates.

4. **Utility Clearances:** No utility clearances need to be initiated by field crew. All utilities on location have already been marked out by the installation. Normal care and observation is required.

5. **Site Survey:** No professional survey is required. GPS coordinates will be acquired using the averaging function if a proposed location is moved.

6. **Health & Safety Issues:** Follow all safety guidelines according to the Health and Safety Plan, Site Safety & Health Officer, and Standard Operating Procedures for equipment and project task. It is very important to note that SOP 47 Sampling and Drilling for PFCs (Appendix B) must be followed during installation and sampling.

7. **Site Characterization:** The location for the soil borings is in a flat gravel lot with easy access from the roadway. Several boring locations are in a grassy area with some minor debris (glass and metal shards) on the surface, which do not restrict access in any way. Monitoring well locations very greatly in accessibility. Most borings are in areas with hard grasses surfaces varying in slope and elevation. Several borings are in wooded areas with fairly easy access which require little to some brush removal for best access. No overhead or subsurface issues have been noted.

8. **Subsurface Conditions:** Groundwater is expected to be encountered around 22.0-25.0 feet below ground surface at 685 feet elevation. From elevation of 685 feet the stratigraphy of soils consists of a fine to medium sand to about 57 feet in depth and then a fine grained silty sand to

sandy silt approximately 10-15 feet thick. For elevations higher than 685 feet (MW-7 & 13) the silty sand to sandy silt is expected to be at a depth of 80 feet, ending at 95-100 feet in depth.

Underlying the silty sand/sandy silt is a glacial till layer around 15 feet thick which overlays limestone bedrock. See site figure and cross-section for details.

9. **Equipment Decontamination:** Due to the nature of the investigation all intrusive tooling shall be steam cleaned prior to arrival on site and between each boring. No equipment shall be set on the ground after decontamination prior to placement into the boring. For all sampling and drilling SOP 47 Sampling and Drilling for PFCs must be followed.

10. **Well Installation:** Recommended method of drilling is open hole mud rotary. The following materials will be used for well construction; 2 inch diameter PVC casing, 10 foot of 2 inch diameter 0.020 inch slot PVC screen, flat bottom well cap, well plug, gravel pack equivalent to US Silica #1 gradation (Appendix D), ¼ inch coated bentonite pellets, and neat I/II portland cement grout.

Up to 13 wells will be installed; 10-12 shallow wells approximately 57 feet in depth and 2 deep wells approximately 100-120 feet in depth, table 1. The shallow wells will be installed just above the fine silty sand to sandy silt layer once encountered at approximately 57 feet. The deeper 2 wells (MW13D and MW-11D) will be screened in the glacial till with the base of the screen on top of the limestone bedrock. A double casing method will be implemented when drilling the two deeper borings to reduce the risk of any potential cross-contamination of the upper and lower aquifers. Once the silty sand/ sandy silt layer is encountered an outer casing will be set prior to advancing the borehole through the semi-confining layer.

Table 1: Proposed Monitoring Wells

Well	Estimated Depth (feet)	Completion Type
MW-5	57	Flush Mount
MW-6	57	Flush Mount
MW-7	77	Flush Mount
MW-8	57	Flush Mount
MW-9	57	Protected Steel Riser
MW-10	57	Protected Steel Riser
MW-11	57	Nested Flush Mount
MW-11D	95	
MW-12	57	Flush Mount
MW-13	80	Nested Flush Mount
MW-13D	115	

Table 2: Tentative Proposed Monitoring Wells

Well	Estimated Depth (feet)	Completion Type
MW-14	57	Protected Steel Riser
MW-15	57	Flush Mount

Cuttings from the drill fluid shall be logged and a GINT boring log shall be constructed for each well using the NAB GINT library.

The wells in grassy areas will be finished by the installation of a 6 inch diameter manhole and cover, set into a 2 foot square concrete pad. The base of the pad and manhole should be filled with sand to allow draining of water that collects inside. Wells in the wooded area shall be completed as stick-ups with protective steel casing with lockable lids (no bollards needed). When installing the protective casing the casing should not be grouted in with the well to avoid deformation or breakage should frost heave occur.

Wells MW-9, MW-10, and MW-12 shall be made priority. These wells shall be installed, developed, and sampled before completing any other wells. Analysis shall be rushed as priority turnaround time, fastest possible. The results from these wells will be used to determine if the wells in Table 2 need to be installed.

11. **Soil Borings:** The recommended drilling method is hollow stemmed augering. All proposed soil borings will have a maximum depth of 20 feet. Each boring will consist of collecting 4 soil samples at 4 discrete sampling intervals. Sample intervals are 3-5 feet, 8-10 feet, 13-15 feet, and 18-20 feet. Proper decontamination procedures shall be followed as outlined in *Part 9 Equipment and Decontamination*.

Each sample that is collected is to be mixed in a clean and decontaminated stainless steel bowl with a stainless steel trowel or spoon to homogenize the sample prior to packaging in laboratory provided bottle ware.

12. **Well Development:** Generally SOP 19 Monitoring Well Installation (Appendix C) will be followed for development activities. Development will be done by surging and pumping. Well development data will be recorded and submitted to the office contact at the completion of the project. Surging shall start from one foot above screened interval and work downward to the bottom of well. A well will be considered developed once NTU values below 200 have been reached and there is less than a 10% change in sediment per volume of water using an Imhoff cone has been achieved between intervals. Readings will start 15 minutes after the beginning of development. Readings shall be taken every 10 minutes thereafter until perimeters have been met.

13. **Investigative Derived Waste (IDW):** IDW shall be classified as solid or liquid waste. Solid waste is waste consisting of drill cuttings and drill fluids, while liquid waste consist of purged water and development water.

Soil Boring Solid Waste: All cuttings from soil borings shall be used as backfill from the boring from which it was derived.

Monitoring Well Solid Waste: All cuttings and drill fluids from the installation of monitoring wells shall be containerized in steel drums. No two investigation locations shall be co-mingled in the same container. All drums shall be labeled with; Project Name, Location, Location Sampled, Date, Contents, and Contact Information (Name and Number).

For all cuttings containing drilling fluids a mud solidification additive shall be used to solidify contents prior to sealing the container.

Each location shall have a TCLP analysis ran on a composite of any containers derived from any one investigation location. If TCLP analysis comes back as the sample being non-hazardous then contents will be disposed of at the site location in which it was derived. If analysis comes back as hazardous then containers shall be left on site at a central location for future disposal.

Development and Purge Liquid Waste: All liquid waste will be disposed of on-site around the investigative location from which it was derived.

14. **Groundwater Sampling:** Will be conducted by Baltimore District once the temporary wells have been installed and developed. Sampling will follow low-flow groundwater sampling standards and SOP 47. Samples will be shipped overnight to the contracted lab for analysis of PFCs via method 537.

15. **Soil Sampling:** Soil samples will be collected at the time of the investigation. SOP 47 and lab provided procedures shall be followed for sampling protocol. Samples will be shipped overnight to the contracted lab for analysis of PFCs via method 537.

15. **Deliverables:** Completed as built well diagrams, boring logs, development logs, site photos e.g. before and after photos. Summary and data report for site activities and analytical data. Copies of all Chain of Custodies (COC) and completed Groundwater Sampling Data Sheets (Appendix E)

Figures

Figure 1

Old Fire Training Pit - Ft. Drum, NY
Site Footprint and Proposed Investigation Locations

Legend

- Soil Delineation Borings
- Water Wells
- Monitoring Wells
- Proposed Monitoring Wells
- Site Footprint
- Treatment System

Feet
0 75 150 300 450

Author: Scott Forbes USACE Date Saved: 10/14/2016 2:51:02 PM

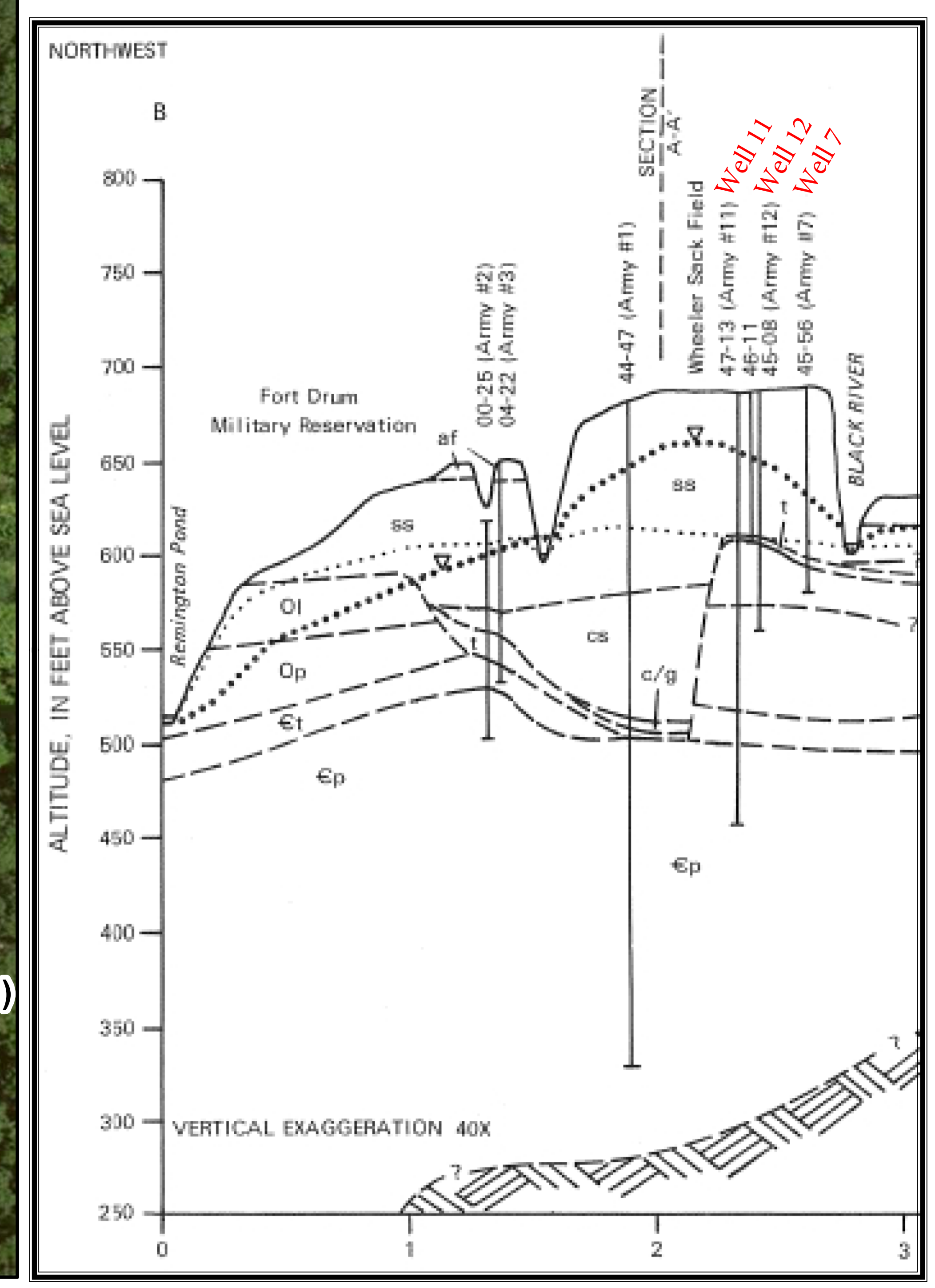
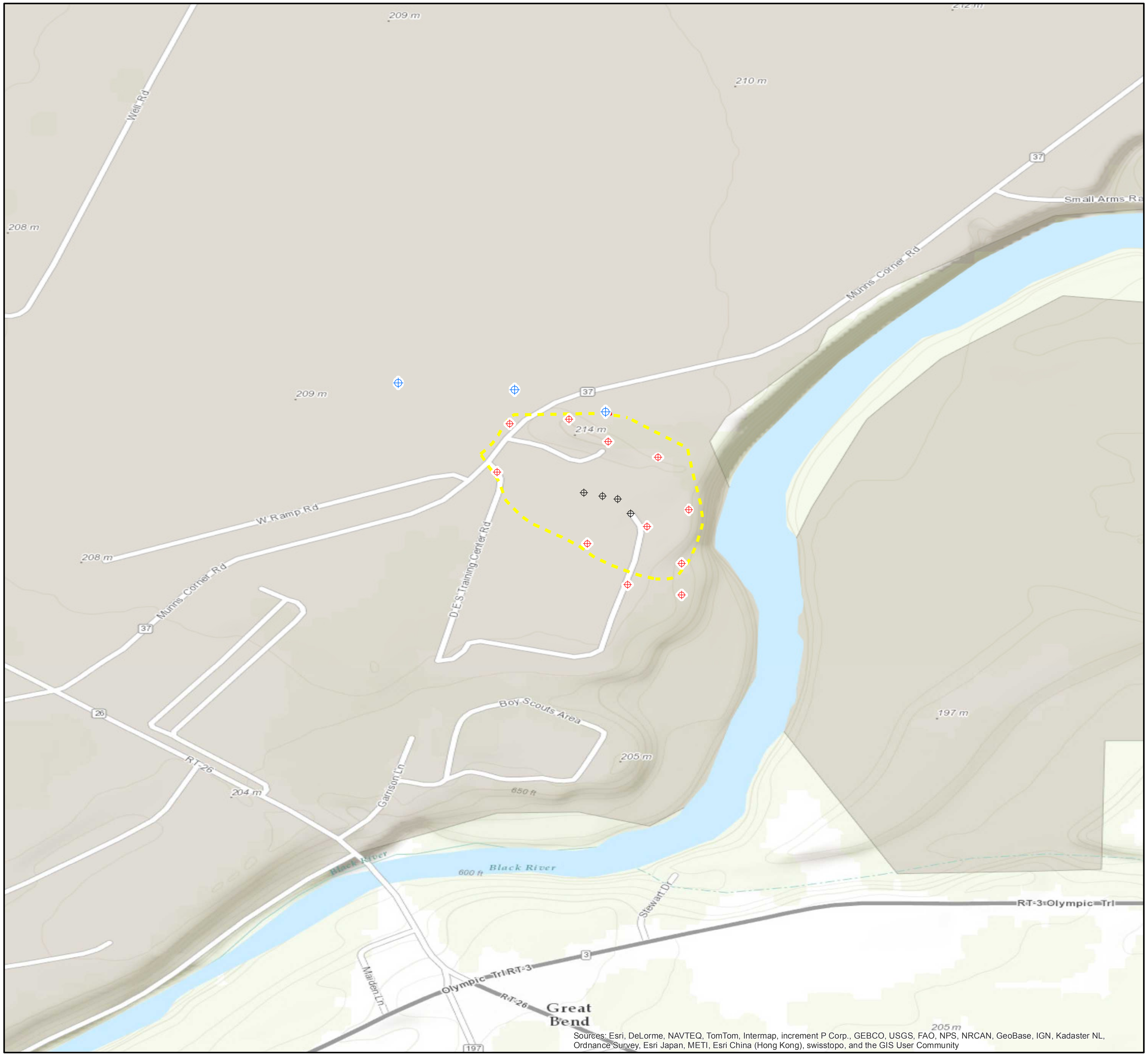


Figure 2

Old Fire Training Pit - Ft. Drum, NY
Topography of Project Area



Legend

- Water Wells
- Monitoring Wells
- Proposed Monitoring Wells
- Site Footprint
- Treatment System

Feet
0 375 750 1,500

N
W E
S

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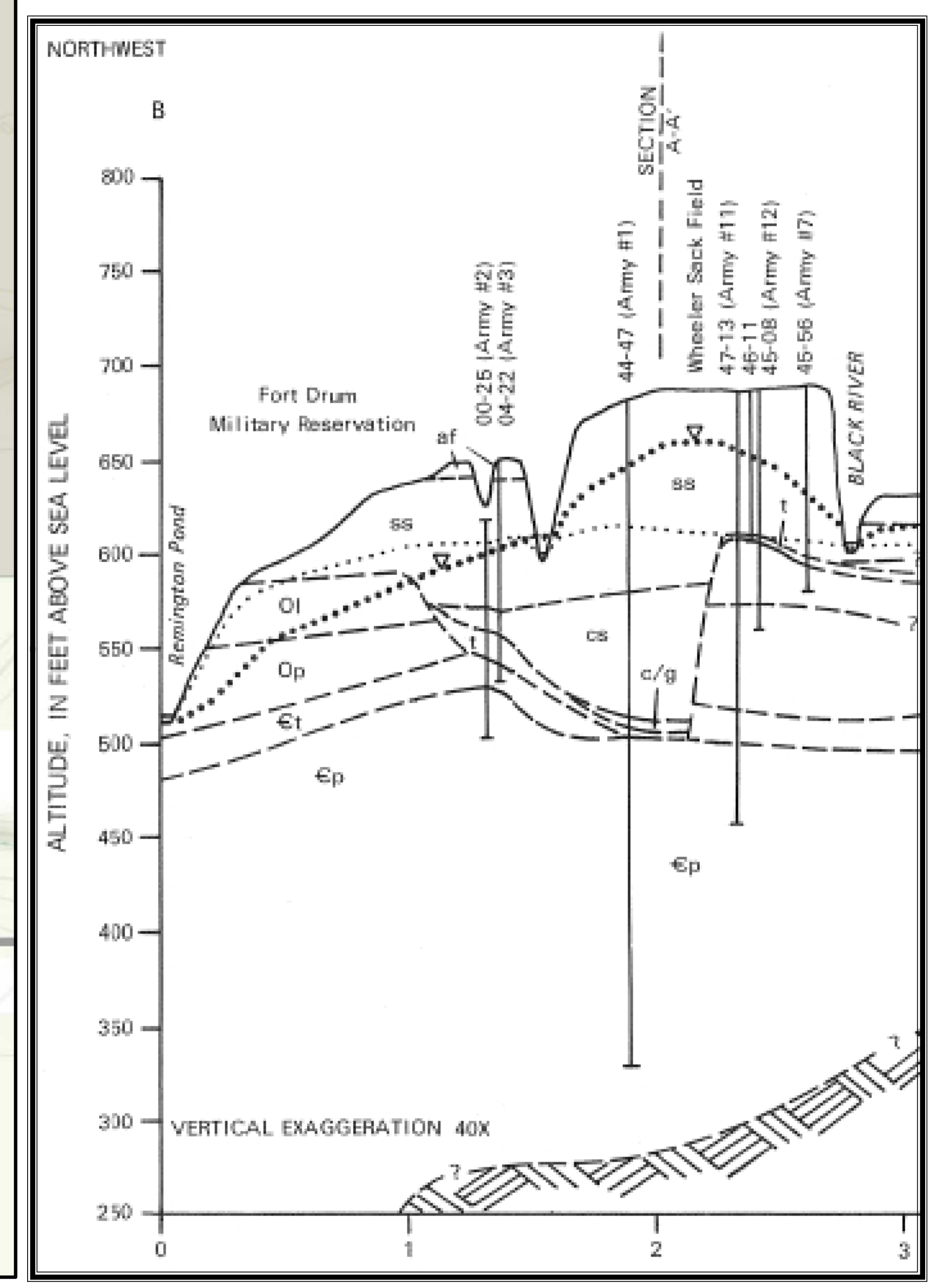
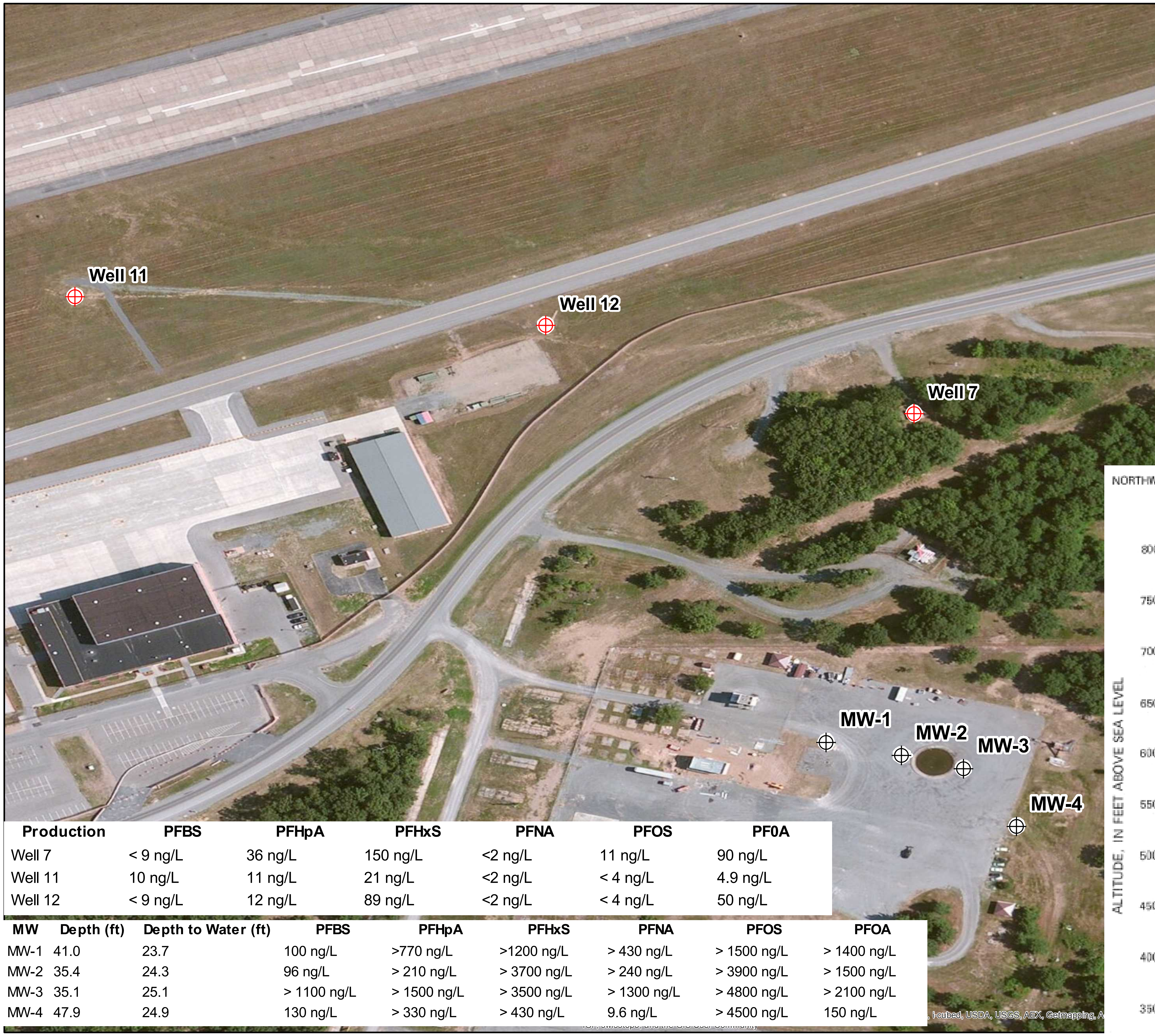


Figure 3

Old Fire Training Pit - Ft. Drum, NY
FY16 Monitoring Well and Water Well COC Summary



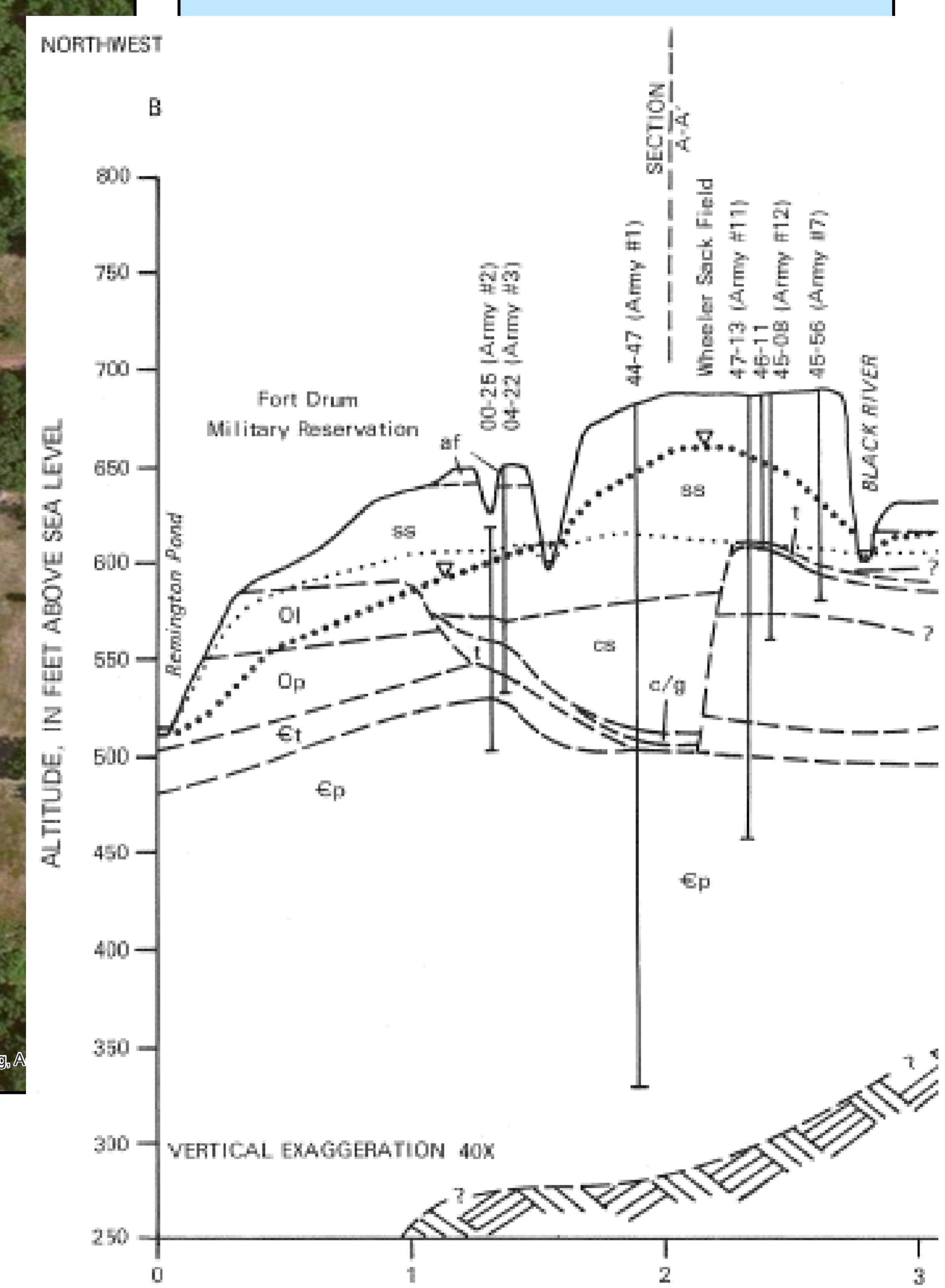
Production	PFBS	PFHpA	PFHxS	PFNA	PFOS	PF0A
Well 7	< 9 ng/L	36 ng/L	150 ng/L	<2 ng/L	11 ng/L	90 ng/L
Well 11	10 ng/L	11 ng/L	21 ng/L	<2 ng/L	< 4 ng/L	4.9 ng/L
Well 12	< 9 ng/L	12 ng/L	89 ng/L	<2 ng/L	< 4 ng/L	50 ng/L

MW	Depth (ft)	Depth to Water (ft)	PFBS	PFHpA	PFHxS	PFNA	PFOS	PFOA
MW-1	41.0	23.7	100 ng/L	>770 ng/L	>1200 ng/L	> 430 ng/L	> 1500 ng/L	> 1400 ng/L
MW-2	35.4	24.3	96 ng/L	> 210 ng/L	> 3700 ng/L	> 240 ng/L	> 3900 ng/L	> 1500 ng/L
MW-3	35.1	25.1	> 1100 ng/L	> 1500 ng/L	> 3500 ng/L	> 1300 ng/L	> 4800 ng/L	> 2100 ng/L
MW-4	47.9	24.9	130 ng/L	> 330 ng/L	> 430 ng/L	9.6 ng/L	> 4500 ng/L	150 ng/L

Legend

- Water Wells
- Monitoring Well Locations

Feet
0 125 250 500



Appendices

Appendix A

Boring	Longitude	Latitude	Sample Intervals (feet)				Test Method	Turn Around Time
DH1	-75.715813	44.044295	3-5	8-10	13-15	18-20	537	Standard
DH2	-75.716235	44.044325	3-5	8-10	13-15	18-20	537	Standard
DH3	-75.71644	44.044191	3-5	8-10	13-15	18-20	537	Standard
DH4	-75.716275	44.044133	3-5	8-10	13-15	18-20	537	Standard
DH5	-75.715693	44.044089	3-5	8-10	13-15	18-20	537	Standard
DH6	-75.71624	44.043894	3-5	8-10	13-15	18-20	537	Standard
DH7	-75.716038	44.04374	3-5	8-10	13-15	18-20	537	Standard
DH8	-75.715842	44.043881	3-5	8-10	13-15	18-20	537	Standard
DH9	-75.715681	44.043755	3-5	8-10	13-15	18-20	537	Standard
DH10	-75.71544	44.043861	3-5	8-10	13-15	18-20	537	Standard
DH11	-75.715428	44.044104	3-5	8-10	13-15	18-20	537	Standard
DH12	-75.715326	44.044299	3-5	8-10	13-15	18-20	537	Standard
DH13	-75.715502	44.044362	3-5	8-10	13-15	18-20	537	Standard
DH14	-75.71565	44.044468	3-5	8-10	13-15	18-20	537	Standard
DH15	-75.715834	44.044465	3-5	8-10	13-15	18-20	537	Standard
DH16	-75.716037	44.044435	3-5	8-10	13-15	18-20	537	Standard

Total Samples (not included QA/QC) **64**

* 3 Duplicate Samples (only on standard TAT) & 1 MS/MSD

Well	Longitude	Latitude	Approximate Well Depths (ft)	Test Method	Turn Around Time
MW-5	-75.71828384	44.0446269	57	537	Standard
MW-6	-75.71802041	44.04563038	57	537	Standard
MW-7	-75.71678567	44.04572314	77	537	Standard
MW-8	-75.71494518	44.04493373	60	537	Standard
MW-9	-75.7143	44.04385	57	537	Standard
MW-10	-75.71445164	44.04273369	57	537	*3 Day*
MW-11	-75.71517143	44.04350226	57	537	Standard
MW-12	-75.71640875	44.04314296	57	537	*3 Day*
MW-13	-75.71597843	44.0452624	80	537	Standard
MW-13D	-75.71597843	44.0452624	115	537	Standard
MW-11 D	-75.71517143	44.04350226	80	537	Standard
MW-14 (Tentative)	-75.71445	44.04208	57	537	Standard
MW-15 (Tentative)	-75.71557402	44.04229267	57	537	Standard
Well 7	Sample only			537	Standard
Well 11				537	Standard
Well 12				537	Standard

Total Samples (not included QA/QC) **16**

* 1 Duplicate Samples (only on standard TAT) & 1 MS/MSD

Appendix B

STANDARD OPERATING PROCEDURE 047
Per/Poly Fluorinated Alkyl Substances (PFAS) Field Sampling

1.0 Scope

Given the extremely low detection limits associated with PFAS analysis and the many potential sources of trace levels of PFAS, field personnel are advised to err on the side of caution by strictly following these protocols when sampling for PFAS to help mitigate the potential for false detections.

2.0 General Preparation and Considerations

Food considerations:

- Some food packaging has historically been treated with PFAS to improve its ability to resist wetting. As such, field personnel are to avoid the use of paper bags and not to bring food on site in any paper packaging (i.e. do not bring any fast food to the sites that uses and form of paper wrapping such as sandwiches, coffee in paper cups, etc.). If possible use cotton or hard plastic food containers. Avoid products such as aluminum foil, coated papers, and coated textiles.

- Foods that have been fried on a frying pan should not be brought to the site as the Teflon coating on most frying surfaces is made of a fluorinated coating and could represent a potential source of PFAS.

- Snacks and meals (lunch) are not to be eaten in the field vehicle or in the immediate vicinity of the monitoring wells (i.e. within 10m). When field personnel require a break to eat or drink, they should remove their gloves and coveralls and move to an appropriate location (preferably downwind). When finished, field personnel should then tidy up and put their coveralls and gloves back on prior to returning to the work area.

Field Gear:

- Water resistant, water proof or stain-treated clothing will not be worn during the field program. Field clothing to be worn on site should be restricted to natural fibers (preferably cotton) and not synthetic. Field clothing should be laundered with minimal use of soap, no fabric softener or scented products and after they have been cleaned, the clothing should be rinsed again with water only before drying (no fabric softener, etc.). Preferably, field gear should be cotton construction, old and well laundered. New cotton clothing may contain PFAS related treatments. The use of new clothing while sampling or sample handling shall be avoided. Gore-Tex™ consists of a PFAS membrane. Gore-Tex™ clothing shall not be worn during the sampling program.

- To avoid plastic coating or glue materials, waterproof field books are not to be used. Field reports should be on loose paper on masonite or aluminum clip boards (i.e. plastic clip boards, binders or spiral hard cover notebooks are not acceptable) using a pencil. Pens and sharpies should not be used.

- Most safety footwear are made from leather and synthetic fibers that have been treated to provide some degree of waterproofing/increased durability and represent a source of trace PFAS. For the health and safety of field personnel, the protection for footwear must be maintained. As such, contact with safety footwear will take place after field personnel remove themselves from immediate vicinity of the monitoring well (i.e. 10m). Contact with footwear will not begin until new gloves are donned to minimize any potential for skin contact. Gloves will be disposed of when footwear contact is prior to beginning any other activities.

- Disposable nitrile gloves must be worn at all times. Further, a new pair of nitrile gloves shall be donned prior to the following activities at each sample location:

  - Decontamination of re-usable sampling equipment;
  - Prior to contact with sample bottles or "PFAS free" water containers
  - Insertion of anything into the well (e.g. HDPE tubing, HydraSleeve, bailer, etc.);
  - Insertion of silicon tubing into the peristaltic pump;
  - Completion of monitor well purging, prior to sample collection;
  - Handling of any QA/QC samples including field blanks and equipment blanks; and,
  - After the handling of any non-dedicated sampling equipment, contact with non-decontaminated surfaces, or when judged necessary by field personnel.

Field Vehicle:

- The field vehicle seats may be treated with stain resistant products by the manufacturer. The seats of the vehicle shall be covered with a well laundered cotton blanket for the duration of the field program in order to avoid direct contact between field clothing and the seats of the vehicle.

Personnel Hygiene:

- Field personnel will not use shampoo, conditioner, body gel, cosmetic or hand cream as part of their personal cleaning/showering routine on the day of a sampling event, as these product may contain surfactants and represent a potential source of PFAS. It is strongly recommended that field personnel shower as per normal routine the night before and then rinse with water only on the morning of sampling event. Use of bar soap is considered acceptable, although soap containing moisturizing lotions should be avoided.

- Moisturizers, cosmetics and dental floss may contain PFAS and shall not be used throughout the duration of the field program, either on or off-site. Sunscreen and insect repellent also cannot be used.

- For washroom breaks, field personnel will remove themselves from the immediate vicinity of the sampling location (i.e. 10m) and then remove gloves and overalls. Field personnel should wash as normal with extra time for rinsing with water after soap use. When finished washing, the use of air dryer is preferred and the use of paper towel for drying is to be avoided (if possible).

Visitors:

- Visitors to the site are asked to remain at least 10m from sampling areas.

Rain Events:

- Field sampling will not take place when rain fall is consistent and persistent at a rate that it saturates the ground (i.e. formation of puddles) because rain gear is not permitted while sampling. Intermittent showers or fog are acceptable conditions to proceed. If/when showers occur; field gear will be removed from the monitoring well location until rain subsides.

- If project timelines are tight, teams should consider the use the gazebo tent, which can be erected overtop of the monitoring well and provide shelter from the rain. It should be noted that the canopy material is likely a treated surface and should be treated as such; therefore, gloves should be worn when moving the tent, changed immediately afterwards and further contact with the tent should be avoided until all sampling activities have been finished and the team is ready to move on to the next site.

3.0 Equipment Cleaning Procedure

Field equipment that is utilized at each sample location will require cleaning between uses. Upon donning a new pair of nitrile gloves, equipment will be:

- Rinse with a Citranox® cleaning solution;
- Rinse with laboratory-provided, "PFAS-free" water;
- Rinse with methanol; and,
- Rinse with laboratory-provided, "PFAS-free" water.

All rinsate should be collected in a sealed pail for disposal.

For groundwater sampling, the flow-through cell and any non-dedicated equipment (i.e. interface probe) that comes into contact with well water should be decontaminated between uses.

Field equipment used at locations that are suspected of containing AFFF (i.e. those that foam during shaking) will be cleaned as per above in triplicate.

4.0 Borehole & Monitoring Well Sampling and Installation Procedures

- If a drill rig is being used to drill for soil cores or to install monitoring wells, clean nitrile gloves shall be worn prior to the collection of each continuous soil sample collection. Soil samples are collected in laboratory-supplied, "PFAS free" HDPE jars and labelled in pencil. Samples should be stored in coolers and kept at 0 – 4 ºC until transported to the lab.

4.1 Well Condition Survey/Water Level Monitoring

- Under normal conditions, one of the first steps in conducting a groundwater sampling program is to complete a well condition survey (including the measurement of static water levels and monitor well depths). However, due to the extremely low detection limits for PFAS, the surveys should be conducted after groundwater purging and sampling to help mitigate the possibility of cross-contamination.

- Once all monitoring wells have been sampled, field personnel should conduct monitor well inspections and recorded water levels. An interface probe should be used to evaluate presence/absence of non-aqueous phase liquid (NAPL). Depth to water should be measured from the top of the PVC riser and the total depth of the well should also be measured. This information should be recorded on the Field Reports.

4.2 Monitoring Well Development and Purging

- Do not use Teflon or low density polyethylene tubing for purging or sample collection. High density polyethylene (HDPE) tubing is acceptable. No materials should be re-used between wells. Upon completion of use, all disposable materials (e.g. HDPE and/or silicon tubing) should be removed and placed in heavy duty garbage bags for disposal.

- During development of the well, sufficient energy should be created to agitate the water column and create flow reversals in the well screen, filter pack and formation to loosen fine-grained materials and draw them into the well. The pumping or bailing action should then draw all drilling fluids and fine-grained material out of the borehole and adjacent formation and then out of the well. Monitoring wells should be developed until visibly clear water is discharged from the well.

- Low flow purge and sampling techniques as per the US EPA "Low Stress (low flow) purging and Sampling Procedure for the Collection of Ground Water Samples from Monitoring Wells" and the ASTM "Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations" should be followed.

- To purge the well, if using HDPE tubing and a peristaltic pump, the end of the tubing should be inserted to the approximate depth of the midpoint of the screened section of the monitor wells. The length of HDPE tubing to be inserted into each monitoring well will be measured and pre-cut to approximate lengths (i.e. previously measured arm span of field technician) to avoid contact with any materials other than the monitoring well and peristaltic pump. The tubing should be kept at least 0.6 m from the bottom of the well to prevent intake of particulates. Flow rates should be as low as can be reasonably achieved. Purge water should be collected and disposed of appropriately.

- Silicon tubing should direct the purge water through a flow-through cell for field parameter measurements of pH, conductivity, temperature, dissolved oxygen and turbidity. The instrument should be calibrated in the field prior to use, and the instrument and flow-through cell should be decontaminated at each monitor well location prior to purging.

- Field parameters should be recorded in intervals (generally of three minute duration) to ensure purge water has cycled through the flow-through cell. Wells should be sampled after field parameter measurements indicate stabilization, which allows collection of representative formation water (generally acceptable standards are three consecutive pH readings to within ±0.1 units, and three consecutive conductivity, temperature and dissolved oxygen measurements to within three percent). Turbidity is monitored, but should not be used as an indicator of purge completion. Field parameter measurements should be recorded at each well. As outlined below, drawdown should not be monitored throughout the purge in order to mitigate possible cross-contamination of groundwater samples introduced by the interface probe.

- If wells are suspected to be dewatering throughout the purge (i.e. reduced flow rate/difficulty pumping water or bubbles begin to come through the flow through cell), the pump should be turned off, and the water level allowed to recover for ½ hour, followed by sample collection. This should be documented in the Field Reports.

5.0 Sample Collection

5.1 General

Sample Containers:

- Different laboratories may supply sample collection containers of varying sizes dependant on the type of media to be sampled (i.e. soil, groundwater, etc.).

- Results of ESG's inter-laboratory comparison suggest that standardizing sample container size and performing whole-sample analysis (i.e. no sub-sampling) will optimize inter-laboratory comparability and ensure result consistency for departments, regardless of which laboratory is used.

- The use of different laboratory testing methods (i.e., SPE and DI) could be responsible for result variability between laboratories. Sub-sampling is inherent to the direct injection method and introduces possible bias in either direction. To achieve "reportable quantitative results" in aqueous samples, the use of the SPE method is recommended.

- All samples should be collected in polypropylene or high density polyethylene (HDPE) bottles fitted with an unlined (no Teflon), polypropylene screw cap.

- Container Labels will be completed using pen/pencil (i.e. NO MARKERS) after the caps have been placed back on each bottle.

- Glass containers should also be avoided due to potential loss of analyte through adsorption.

Sample Shipping Requirements:

- Samples should be maintained between 0–4 ºC during shipping. Samples should be shipped via courier service with priority overnight delivery. Tracking numbers for all shipments should be provided once they have been sent out so to ensure their timely delivery.

5.2 Soil Sampling

- Clean nitrile gloves shall be worn prior to the collection of each sample.
- Samples are to be collected using a stainless steel trowel.
- Soil samples are collected in laboratory-supplied, "PFAS free" HDPE jars and labelled in pencil. Samples should then be placed in coolers and kept at between 0 – 4 ºC until transported to the lab.

5.3 Groundwater Sampling

- Sample collection will take place upon stabilization of field parameters. The silicon tubing should be disconnected from the flow-through cell, enabling collection of groundwater samples prior to passing through the cell.

- Prior to collection of samples, field personnel must wash their hands and don a new set of nitrile gloves. Gloved hands must not be used to subsequently handle papers, pens, clothes, etc., prior to the collection of PFAS samples. The PFAS samples bottle caps must remain on the bottle until immediately prior to sample collection and the bottle immediately sealed after sample collection. This will minimize potential loss of PFAS, through volatilization. The bottle cap must remain in the other hand of the sampler, until replaced on the bottle. PFAS sample bottles will not be rinsed during sampling.

- During PFAS sampling, water turbulence should be minimized to avoid potential volatilization from aqueous solution; this could include: adjusting pump discharge prior to sampling and inclining the sample bottle neck, during filling of the bottle. Ensure the rim of the bottle does not come into direct contact with the pumping equipment or tubing. Environment Canada states that while PFOS has low volatility, many of its precursors are volatile.

- Groundwater samples will be collected in pre-labelled, laboratory-supplied "PFAS free" HDPE sample vials. Each "PFAS clean" sample vial should then be placed in a sealed Ziploc© bag. Labelling information and time of sampling should be recorded on the Field Reports. All sampling materials should be treated as single use and disposed following completion of sampling at each monitor well.

- A small portion of the sample (~10-25mL) should be collected and shaken by the sample collector on site. If foaming is noted within the sample, this should be documented when samples are submitted for analysis; the 'shaker test' vial can then be disposed of. This shaker test provides information about how each of the samples should be handled analytically.

- Samples should be placed in coolers and kept at a cool temperature until transportation to the lab. Samples must be kept at between 0–4 ºC.

5.4 Sediment Sampling

- Sediment samples should be either collected manually using a stainless steel trowel or collected using petite ponar grab sampler depending on field condition at each sampling location during sampling program.

- Sediment samples will be collected within the upper 10 cm of sediment.

- For a sample to be acceptable the overlying water is present and has low turbidity; the sampler is not overfilled or contains vegetation; the sediment is undisturbed and sampler shows no signs of winnowing or leaking.

- Overlying water will be decanted and a stainless steel trowel will be used to collect only the upper 5 cm of sediment.

- Sediment will be placed directly into laboratory supplied containers suitable in both material and size, placed in supplied packaging and immediately stored in cooler with ice to ensure a whole sample is collected to mitigate issues with sample collection. Jar lids will remain in the gloved hand of the sampler until replaced on the bottle. Labels will be completed using pen/pencil (i.e. NO MARKERS) after the caps have been placed back on each bottle.

5.5 Surface Water Sampling

- Where surface water samples and sediment samples are collected at the same location, surface water samples will be collected first to minimize the siltation.

- Surface water pH, conductivity, temperature and total dissolved solids (TDS) will be measured at each location after sediment sampling.

- Surface water samples will be placed directly into laboratory supplied containers suitable in both material and size, placed in supplied packaging and immediately stored in cooler with ice to ensure a whole sample is collected to mitigate issues with sample collection. Jar lids will remain in the gloved hand of the sampler until replaced on the bottle. Labels will be completed using pen/pencil (i.e. NO MARKERS) after the caps have been placed back on each bottle.

- Sample collection will take place prior to measurement of water level and well depth as to minimize the potential for cross-contamination due to surface water/sediment contact with field equipment.

6.0 Quality Assurance & Quality Control Sampling

6.1 Equipment Blanks

- QA/QC sampling will include daily collection of equipment blanks using the laboratory supplied ‘PFAS free’ water. Sample will be collected in laboratory supplied containers. Bottle caps will remain in the hand of the sampler until replaced on the bottle. Labels will be completed using pen/pencil (i.e., **NO MARKERS**) after the caps have been placed back on each bottle. Samples will be sealed in suitable packaging and stored on ice in a cooler for shipment to the lab.

For peristaltic pump tubing, laboratory supplied “PFAS free” water should be poured into a clean HDPE sample bottle and then pumped through new HDPE tubing using the peristaltic pump (with new silicon tubing).

6.2 Field Duplicates

- QA/QC sampling will include the collection of one blind field duplicate for every 10 samples collected. These samples will be collected immediately after the initial samples into laboratory supplied “PFAS clean” sample containers. Bottle caps will remain in the hand of the sampler until replaced on the bottle. Labels will be completed using pen/pencil (i.e., **NO MARKERS**) after the caps have been placed back on each bottle. Samples will be sealed in suitable packaging and stored on ice in a cooler for shipment to the lab.

6.3 Field Blank

- QA/QC sampling will include daily submission of laboratory supplied field blanks. The samples will be brought to the site in the laboratory supplied sample bottles and opened during the collection of a sample and then released. Bottle caps will remain in the hand of the sampler until replaced on the bottle. Labels will be completed using pen/pencil (i.e., **NO MARKERS**) after the caps have been placed back on each bottle. Samples will be sealed in suitable packaging and stored on ice in a cooler for shipment to the lab.

6.4 Trip Blank

- QA/QC sampling will include the submission of one laboratory supplied trip blank. The sample will be brought to the site in laboratory supplied sample bottle and will remain inside the cooler during the sampling program. Labels will be completed using pen/pencil (i.e., **NO MARKERS**). Samples will be sealed in suitable packaging and stored on ice in a cooler for shipment to the lab.

6.5 Spiked Samples

- QA/QC sampling will include the submission of two laboratory supplied spiked samples of known concentration (one low level and one moderate level based on previous PFAS sample results) submitted blindly by the environmental consultant. These samples will be utilized in lieu of certified reference material (CRM) to assist in data validation. Labels will be completed using pen/pencil (i.e., **NO MARKERS**). Samples will be sealed in suitable packaging and stored on ice in a cooler for shipment to the lab.

6.6 Laboratory Analytical QA/QC

- Internal laboratory QA/QC should consist of one laboratory blank per batch of samples; one soil or water matrix spikes and generally isotopically-labelled surrogates for analysis. Labels will be completed using pen/pencil (i.e., **NO MARKERS**). Samples will be sealed in suitable packaging and stored on ice in a cooler for shipment to the lab.

- As part of the internal QA/QC, relative percent difference (RPD) should be calculated between samples and corresponding field or laboratory duplicates. The laboratory quality assurance portion of the laboratory certificates should be reviewed to verify that all calculations/recoveries were within acceptable limits as established by the laboratory method.

6.7 Laboratory Analytical Sub-sampling

The results of ESG's inter-laboratory comparison, however, still imply that subsampling is a significant cause of interlaboratory variability, and it is a practice inherent to the DI method. The Ontario Ministry of the Environment recommends use of the SPE method to achieve reportable quantitative results for drinking water samples.

7.0 Laboratories

An accredited laboratory for analysis of PFAS will be used.

Appendix C

STANDARD OPERATING PROCEDURE 019
MONITORING WELL INSTALLATION

1.0 Scope and Application

The installation of monitoring wells is contingent upon the existing conditions at the project site. The purpose of this Standard Operating Procedure is to delineate the quality control measures required to ensure the accurate installation of monitoring wells. The applicable Cluster Work Plan or site Sampling Design Plan should be consulted for specific installation instructions. The term "monitoring wells", as used herein is defined to denote any environmental sampling well. Subsections 6.7 *et seq*. and 6.8 *et seq*. of the Field Investigation Plan, as well as sections 1, 2, 3, and 6 of the Field Sampling Plan (Appendix A) are included by reference. Example well log forms are given at the end of this SOP. Alternate, equivalent forms are acceptable.

2.0 Material

2.1 Drilling Equipment

a. Appropriately sized drill adequately equipped with augers, bits, drill stem, etc.
b. Steam cleaner and water obtained from approved source for decontaminating drilling equipment.
c. PID: Microtip HL-200 (or equivalent)
d. Water level indicator
e. Weighted Steel tape measure
f. LEL-Oxygen monitor
g. Steel drums for intrusion derived wastes (drill cuttings, contaminated PPE, decon solutions, etc.)
h. Source of approved water
i. Heavy plastic sheeting
j. Sorbent pads and/or log

2.2 Well Installation Materials [1]

a. Well screen : [2]

Technical information on all installed materials (screens, riser pipe, filter pack, bentonite, cement, etc.) and representative samples of the proposed filter pack, bentonite powder, and bentonite pellets will be supplied to the Contracting Officer's Representative (COR).

Well screen slot size and filter pack gradation will be determined from sieve analysis of aquifer materials. Screen and casing material type will be determined based on field tests of groundwater chemistry and contaminants.

PVC: JOHNSON (or equivalent); PVC Vee Wire continuous slot, wire wrapped screen; 4-inch diam.; SCH 40; flush-threaded (leak-proof) joints; PVC complies with ASTM D2665, ASTM D1784, and ASTM F480; free of ink markings; cleaned and prepackaged by manufacturer

Stainless Steel: JOHNSON (or equivalent); Stainless steel Vee-Wire Continuous slot, wire wrapped screen; 304 stainless steel [3]; ASTM F480 flush threads; cleaned, wrapped, and heat sealed by manufacturer.

b. Riser pipe:

PVC: JOHNSON (or equivalent); STD. PVC; 4-inch diam.; SCH 40; flush-threaded (leak-proof) joints; PVC complies with ASTM D2665, ASTM D1784, and ASTM F480; free of ink markings; cleaned and prepackaged by manufacturer

Stainless Steel: JOHNSON (or equivalent); SCH 5; 304 stainless steel; ASTM type A312 material; 4-inch diam.; cleaned, wrapped and heat sealed by manufacturer.

c. Plugs/Caps: JOHNSON (or equivalent); standard PVC or stainless steel
d. Filter pack: MORIE, 100 well gravel (or equivalent) Note: final gradation may vary as a function of the gradation of the formation (see footnote 2)
e. Fine Ottawa sand
f. Bentonite seal: BAROID, bentonite pellets (3/8-inch diam.)
g. Cement: Type II Portland Cement (see table 19-1)
h. Bentonite powder: BAROID, Aquagel Gold Seal
i. Steel Protective Casing: BRAINARD-KILMAN (or equivalent) zinc-plated steel, lockable, painted.[4]
j. Geotextile: MIRAFI (or equivalent); GTF 130; non-woven; 4 oz.
k. Coarse (blanket) gravel: Crushed stone aggregate
l. Containers for purged water, as required.
m. Submersible pump or bailer of appropriate capacity, and surge block sized to fit well
n. Hach DREL 2000 portable laboratory (or equivalent)
o. Conductivity, pH, ORD, turbidity, dissolved oxygen, and temperature meters
p. Electric well sounder and measuring tape.
q. Portland Type II cement (see table 19-1)
r. Steel Posts (pickets), Painted (see footnote)

Unless the sum of Cl^-, F^-, and Br^- is >1000ppm, in which case type 316 should be used (see also "Field Investigation Plan" Section 6.8.6 and Appendix A, "Field Sampling Plan" § 3.3.2.)

All painted components (protector casing, steel pickets) will be painted high-visibility orange and allowed to dry completely prior to being brought onsite.

2.3 Documentation

a. Copy of appropriate Cluster Work Plan
b. Copy of Section 6 "Field Investigation Plan'
c. Copy of Appendix A 'Field Sampling Plan"
d. Copy of approved Health And Safety Plan
e. Copies of well and excavation permits
f. Copies of SOPs 003, 005, 008-010,012, 019(this SOP), 024, and 028
g. Boring log forms
h. Well completion diagram form
i. Well development form

2.4 Geologist's personal equipment

a. 1OX handlens
b. Unified Soil classification System chart
c. Munsell color chart
d. Sieve set (Keck model SS-81 or equivalent)
e. PPE as required by HASP

3.0 Procedure

3.1 Materials Approval

3.1.1 Water sources for drilling, grouting, sealing, filter placement, well installation, and equipment decontamination must be approved by the COR prior to arrival of the drilling equipment. Information required for the water source includes: water source, manufacturer/owner, address and telephone number, type of treatment and filtration prior to tap, time of access, Cost per gallon (if applicable), dates and results associated with all available chemical analyses over the past two years, and the name and address of the analytical laboratory (if applicable).

3.1.2 Pure sodium bentonite with no additives (bentonite) will be the only drilling fluid additive allowed, and its use must be approved by the COR prior to the arrival of the drilling equipment. The information required for evaluation includes: brand name, manufacturer, manufacturer's address and telephone number, product description, and intended use for the product.

3.1.3 Granular Filter Pack material must be approved by the COR prior to drilling. A one-pint representative sample must be supplied to the COR. Information required includes: lithology, grain size distribution, brand name, source, processing method, and slot size of intended screen.

3.1.4 Portland Type II cement will be used for grout (see table 19-1).

3.2 Drilling

3.2.1 The objective of the selected drilling technique is To ensure that the drilling method provides representative data while minimizing subsurface contamination, cross contamination of aquifers, and drilling costs. The preferred drilling method is with hollow stem auger. Other drilling methods [5] are approved as conditions warrant, and will not require variances be issued by EPA and MDE. The method used at a specific site will be proposed in the work plan and evaluated by the COR. Any drilling method not listed herein will require approval on a case by case basis by MDE and EPA.

3.2.2 A Site Geologist will be present during all well drilling and installation activities and will fully characterize all tasks performed in support of these activities into the monitoring well logbook. The Site Geologist will be responsible at only one operating rig for the logging of samples, monitoring of drilling operations, recording of water losses/gains and groundwater data, preparing the boring logs and well diagrams, and recording the well installation procedures of the rig. The Site Geologist will have onsite sufficient equipment in operable condition to perform efficiently his/her duties as outlined in the Field Investigation Plan (Section 6), and the Field Sampling Plan (Appendix A), and other contractual documents. Items in the possession of each Site Geologist will include, copies of Section 6, Appendix A, the approved HASP, this SOP, a hand lens (10X), a standard color chart, grain-size chart, and a weighted (with steel or iron) steel tape long enough to measure the deepest well, heavy enough to reach that depth, and small enough to fit readily within the annulus between the well and drill casing. The Site Geologist will also have onsite, a water level measuring device, preferably electrical.

3.2.3 Only solid vegetable shortening (*e.g.* Crisco®) without flavoring or additives may be used on downhole drilling equipment. Additives containing either lead or copper will not be allowed. In addition, polychlorinated biphenyls will not be permitted in hydraulic fluids or other fluids used in the drilling rig, pumps, or other field equipment and vehicles.

3.2.4 Surface runoff or other fluids will not be allowed to enter any boring or well during or after drilling/construction.

If the design depth of the well is < 100 ft., open, hollow stem augers will be used to drill the well unless "running sands" preclude the use of open augers. In that case, an inert "knockout" plug may be used in the bottom of the auger string. This plug will be driven out of the augers and left at the bottom of the hole when the well is installed.

If the design depth of the well is > 100 ft., rotary drilling methods may be used to install wells. The following drill fluids and methods are approved in the order listed: 1) Rotary drilling with water from an approved source as drilling fluid. Clays from the formations will tend thicken the fluid and coat the walls of the borehole and this is acceptable. 2) Rotary drilling with water as a fluid, advancing a temporary casing with the bit to maintain an open hole. 3) Mud rotary using water with additives as drill fluid. Due to the potential for aquifer contamination and plugging, mud rotary drilling is not recommended for monitoring wells. If; however, "running sands" are encountered and the aquifer is expected to have a relatively high flow rate, then mud rotary is considered an approved method. Pure sodium bentonite is the only approved additive. Mud rotary drilling must be halted at the last aquitard above the target aquifer. Casing must be set, all bentonite-bearing fluids flushed from the hole and drill rig, and drilling may be resumed using water only as the drill fluid until the target depth is reached.

3.2.5 Antifreeze used to keep equipment from freezing will not contain rust inhibitors and sealants. Antifreeze is prohibited in an areas in contact with drilling fluid. The ground surface at the well site will be protected from possible coolant, fuel, and hydraulic fluid spills and/or leakage by placement of plastic sheeting with raised edges, draining into a lined catch basin large enough to contain spills and/or leakage from motors, radiators, or vehicle tanks. Sorbent pillows will be placed to catch obvious leaks from the drill rig. Sorbent logs may be used instead of, or in conjunction with a lined catch basin to contain spills.

3.2.6 An accurate measurement of the water level will be made upon encountering water in the borehole and later upon stabilization. Levels will be periodically checked throughout the course of drilling. Any unusual change in the water level in the hole such as a sudden rise of a few inches may indicate artesian pressure in a confined aquifer will be the basis for cessation of drilling. The geologist will immediately contact his/her supervisor [6]. Particular attention for such water-level changes will be given after penetrating any clay or silt bed, regardless of thickness, which has the potential to act as a confining layer.

Anticipated depths of wells are given in well specific work plans (*e.g.* Appendix I). In case the previously defined criteria have not been met before the depth range for a given hole is reached, the geologist will stop the drilling and confer with her/his supervisor. The current boring conditions (depth, nature of the stratigraphic unit, and water-table depth) will be compared to those of other wells nearby to decide to continue drilling or to terminate and complete the well.

3.2.7 **<u>If the well is to be installed in the surficial aquifer</u>**: Drilling will be terminated before penetrating the basal aquitard. The basal aquitard is defined as the first 2 foot-thick clay below the water table, or below 5 feet in the case of a shallow aquifer (Field Investigation Plan, § 6.7.3)

3.2.8 **<u>If the well is to be installed in a lower, confined aquifer</u>**:

3.2.8.1 Penetrations of aquifers located lower than the water table aquifer will be limited to avoid cross-contamination.

3.2.8.2 Placement of new upper confined aquifer wells will be initially limited to those areas where contamination has been confirmed.

3.2.8.3 The location of upper confined aquifer wells will be based upon the findings of the water-table aquifer investigation. Areas of known contamination will be targeted for installing upper confined aquifer wells for the purposes of delineating vertical contamination.

3.2.8.4 Where possible, upper-confined aquifer wells will be located such that they afford triangulation with other wells within the same aquifer to allow for a determination of ground-water flow direction.

3.2.8.5 Some upper-confined aquifer wells will be installed approximately 10-15 ft from water-table wells to enable the accurate assessment of vertical hydraulic gradients. If the direction of ground-water flow is known, wells within a group will be located sidegradient of each other.

3.2.8.6 The boring will be advanced until the base of the surficial aquifer is reached (see § 3.2.7).

3.2.8.7 An outer, surface casing will be set 2 to 5 ft into the confining layer to minimize the potential for cross-contamination from the unconfined aquifer during drilling activities.

3.2.8.8 The surface casing will be driven into the confining bed and grouted into place. Grout will be tremied into the annulus around the outside of the casing to within 5 ft of the ground surface. A grout plug at least 2 feet thick will be tremied into the bottom of the surface casing. The grout will be permitted to cure for 24 hours. All drilling fluids within the surface calling will then be removed, and the casing will be flushed with clean potable water.

3.2.8.9 The drilling equipment will be decontaminated, a smaller bit or auger selected, and the hole will be continued through the grout plug into the confined aquifer.

3.2.8.10 If deeper aquifers are to be screened, repeat preceding steps until total depth is reached.

3.2.9 **<u>If DNAPL contamination is detected during drilling</u>**, the well will be terminated and completed at the base of the aquifer. Drilling will not continue through the confining unit.

3.2.9.1 Stainless steel screens will be used in DNAPL wells. Screen size selection will be according to criteria set forth in § 3.4.3.2 (below). The formation grain size will be multiplied by the higher factor (6) to determine filterpack grain size. This will ensure that the filterpack is sufficiently coarse to permit DNAPL to pass freely from the formation into the coarser filterpack, then into the open well (Cohen and Mercer, 1993).

3.2.9.2 DNAPL sampling cups are prohibited. The well screen will be capped, and set 0.3 ft (0.5 ft max.) into the top of the confining bed and rest on the bottom of the hole or bentonite backfill (if used). No sand will be placed below the screen.

3.2.9.3 The remainder of the well installation and completion will be accomplished according to section 3.4.

3.3 Logging

3.3.1 All borings for monitoring wells will be logged by a geologist. Logs will be recorded in a field logbook and/or a boring log. If the information is recorded in a logbook, it will be transferred to Boring Log Forms on a daily basis. Field notes are to include, as a minimum:

a. Boring Number
b. Material Description (as discussed below)
c. Weather conditions
d. Evidence of Contamination
e. Water Conditions (including measured water levels)
f. Daily Drilling Footage and Quantities (for billing purposes)
g. Notations on Man-Placed Materials
h. Drilling Method and Bore Hole Diameter
i. Any Deviations from Established Field Plans
i. Blow Counts for Standard Penetration Tests
k. Core and Split-Spoon Recoveries

3.3.2 Material description for soil samples must include:

a. Classification (Use ASTM D-2487/88 the Unified Soil Classification System)
b. Unified Soil Classification Symbol
c. Secondary Components and Estimated Percentages
d. Color
e. Plasticity
f. Consistency
g. Density
h. Moisture Content
i. Texture/Fabric/Bedding and Orientation
j. Grain Angularity
k. Depositional Environment and Formation
l. Incidental odors
m. OVA reading(s)
n. Staining

3.3.3 Material description for rock samples must include:

a. Classification
b. Lithologic Characteristics
c. Bedding/Banding Characteristics
d. Color
e. Hardness
f. Degree of Cementation
g. Texture
h. Structure and Orientation
i. Degree of Weathering
i. Solution or Void Conditions
k. Primary and Secondary Permeability
l. Sample Recovery
m. Incidental odors
n. OVA reading(s)
o. Staining

See also SOP003 and SOP016 for details on logbook entries.

3.4 Well Construction and Installation

After the hole is drilled and logged, backfill hole as required for proper screen placement. The integrity of the aquitard will be restored by placing a bentonite plug of an appropriate thickness, either to the top of the aquitard (normal well installation) or to within 0.3 ft of the top of the aqitard (DNAPL well). Aquifer fill will be clean filter pack.

Normal screen placement for the water table (surficial) aquifer will be with 2 ft of the screen extending above the static water level. The bottom of the screen will rest no more than 6 in. from the bottom of the hole or backfill material, whichever is applicable.

Note: the end cap in DNAPL wells will rest on the bottom of the bottom of the hole, or bentonite backfill if applicable. (see § 3.2.9.2 above)

Screen placement for a confined aquifer well will normally be at the top of the confined aquifer.

3.4.1 Screen lengths will not normally exceed 10 feet. If it appears advantageous in a given situation (e.g. to screen an entire aquifer which is thicker than 10 feet), approval must be sought on a case-by-case basis from USACE. Otherwise, wells will be screened as follows:

Thickness of Aquifer:	Action:
< 10'	Screen entire aquifer
> 10' < 30'	screen top 10' consider vertically nested well cluster
> 30'	install vertically nested well cluster

3.4.2 The installation of monitoring wells in uncased or partially cased holes will begin within 12 hours of completion of drilling, or if the hole is to be logged, within 12 hours of well logging, and within 48 hours for holes fully cased with temporary drill casings. once installation hall begun, work will continue until the well has been grouted and the drill casing has been removed. Exceptions MUST be requested in writing by the contractor to the Contracting officer's Representative prior to drilling. Unscheduled delays attributable to unforeseeable site occurrences will not require advance approval.

3.4.3 Well screens, casings, and fittings will conform to National Sanitation Foundation Standard 14 or American Society for Testing and Materials (ASTM) equivalent for potable water usage. These materials will bear the appropriate rating logo. If the logos are not present, a written statement from the manufacturer/supplier stating that the materials contain the appropriate rating must be obtained. Material used will be new and essentially chemically inert to the site environment.

3.4.3.1 Well screen and casing should be inert with respect to the ground water; therefore, the selection of screen and casing material will be based on select field tests of aquifer chemistry and potential contaminants as delineated in Appendix A, Table A.3.1. The screen will be capped without sediment trap or DNAPL sampling cup, and lowered into the hole. The well casing will be pre-cut to extend 2 to 2.5 ft above the ground surface. Prior to placement of the last piece of well casing, a notch or other permanent reference point will be cut, filed, or scribed into the top edge of the casing.

3.4.3.2 Screen slot size will be appropriately sized to retain 90 to 100% of the filter pack material, the size of which will be determined by sieve analysis of formational material (See § 3.4.3.2).

3.4.3.3 The tops of all well casing will be capped with covers composed of materials compatible with the products used in the well installation. Caps may either be vented, or a telescopic fit, constructed to preclude binding to the well casing caused by tightness of fit, unclean surfaces, or weather conditions. In either case it should be secure enough to preclude the introduction of foreign material into the well, yet allow pressure equalization between the well and the atmosphere.

3.4.4 Filter pack material will be placed, lightly tamped and leveled. Filter pack will extend from the bottom of the hole to a height of 1-2 ft above the top of the screen. The filter pack will be capped with a minimum of 1 ft of fine (Ottawa) sand to prevent the bentonite seal from infiltrating the filter pack. If the bentonite seal is placed as a slurry, a minimum of 2 ft of fine sand will be required.

If the hole is less than 20 ft deep, the filter pack may be poured into the annulus directly. If the hole is deeper than 20 ft, the filter pack must be tremied into place.

3.4.4.1 Granular filter packs will be chemically and texturally clean, inert, and siliceous.

3.4.4.2 Filter pack grain size will be based on formation grain-size analysis. The D30 (70% retained) sieve size multiplied by a factor of not less than 3 nor greater than 6 will be used to determine the appropriate grain size.

3.4.4.3 Calculations regarding filter pack volumes will be entered into the Field Logbook along with any discrepancies between calculated and actual volumes used. If a discrepancy of greater than 10% exists between calculated and actual volumes exists, an explanation for the discrepancy will also be entered in the Logbook.

3.4.5 Bentonite seals will be no less than two feet nor more than five feet thick as measured immediately after placement. The normal installation will include a five foot seal. Thinner seals may be used in special cases as defined in Section 3.12 of Appendix A. The final depth to the top of the bentonite seal will be measured and recorded.

3.4.6 GROUT

Grout used in construction will be composed by weight of:

- 20 parts cement (Portland cement, type II)(see table 19-1)
- 0.4 to 1 part (max.)(2-5%) bentonite
- 8-gallons (max.) approved water per 94-lb bag of cement.

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

3.4.6.1 All grout material will be combined in an above-ground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump prior to placement.

3.4.6.2 Grout placement will be performed using a commercially available grout pump and a rigid, side discharge tremie pipe.

3.4.6.3 The following will be noted in the Field Logbook: 1) calculations of predicted grout volumes, 2) exact amounts of cement, bentonite, and water used in mixing grout, 3) actual volume of grout placed in the hole, 4) any discrepancies between calculated and actual volumes used. If a discrepancy of greater than 10% exists between calculated and actual volumes exists, an explanation for the discrepancy will also be entered in the Logbook.

3.4.7 Well protective casings will be installed around all monitoring wells on the same day as the initial grout placement around the well. Any annulus formed between the outside of the protective casing and the borehole will be filled to ground surface with cement.

3.4.8 The construction of each well will be depicted as built in a well construction diagram. The diagram will be attached to the boring log and will graphically denote:

a. Screen location, length
b. Joint location
c. Granular filter pack
d. Seal
e. Grout
f. Cave-in
g. Centralizers
h. Height of riser
i. Protective casing detail

3.5 Monitoring well completion

3.5.1 Assemble appropriate decontaminated lengths of pipe and screen. Make sure these are clean and free of grease, soil, and residue.

3.5.2 Lower each section of pipe and screen into the borehole, one at a time, screwing each section securely into the section below it. No grease, lubricant, polytetrafluoroethelyne (PTFE) tape or glue, may be used in joining the pipe and screen sections.

3.5.3 If a well extends below 50 ft, centralizers will be installed at 50 ft and every 50 ft thereafter except within screened interval and bentonite seal. Centralizer material will be PVC, PTFE, or stainless steel. Determination of centralizer material will be based on the same criteria as screen and calling selection (see Field Investigation Plan, Section 6.8)

3.5.4 Cut the riser with a pipe cutter approximately 2-2.5 ft above grade. All pipe cuts MUST be square to ensure that the elevation between the highest and lowest point of the well casing is less than or equal to 0.02 ft Notch, file, or otherwise permanently scribe a permanent reference point on the top of the casing.

Torches and saws may not be used to cut the riser. Care must be taken that all filings or trimmings cut from the reference point fall outside the riser rather than into the well. Under no circumstances will a permanent marker or paint pencil be used to mark the reference point.

In some locations, accessibility requirements may mandate that a well be flush-mounted with no stick-up. If a flush-mounted well is required at a given location, an internal pressure cap must be used instead of a vented cap to ensure that rainwater cannot pool around the wellhead and enter the well through the cap.

3.5.5 When the well is set to the bottom of the hole, temporarily place a cap on top of the pipe to keep the well interior clean.

3.5.6 Place the appropriate filter pack (§ 3.4.4). Monitor the rise annulus with a weighted tape to assure that bridging is not occurring.

3.5.7 After the pack is in place, wait three to five minutes for the material to settle, tamp and level a capped PVC pipe, and check its depth weighted steel tape.

3.5.8 Add a 1-2 foot cap of fine-grained (Ottawa) sand to prevent infiltration of the filterpack by overlying bentonite seal. See §3.4.4 for guidance on appropriate thickness of fine sand layer.

3.5.9 Install the bentonite seal (2 ft to 5 ft thick) by dropping bentonite pellets into the hole gradually. If the well is deeper than 30 feet, a tremie pipe will be used to place either bentonite pellets or slurry. Tamp and level pellets. If the well is ≤ 30 ft, tamp with a capped PVC pipe, if > 30 ft, tamping bay be accomplished with the weighted end of the tape. In either case, check the depth to the top of the seal with a weighted tape as above.

If the bentonite pellets are of poor quality, they may have a tendency to hydrate and swell inside the tremie pipe and bridge. This situation may be solved by the following procedure:

- **a.** Use a different brand of pellets. Different brands may have longer hydration times.
- **b.** Freeze the pellets[7]. Note that this will require a longer wait-time to allow proper hydration after the pellets thaw.
- **c.** Place the bentonite seal as a slurry using a side-discharge tremie pipe as though installing grout. Note (§ 3.4.4) this will require that a minimum of 2 ft fine sand be placed as a cap on top of the filter pack material.

Bentonite pellets may be "flash-frozen" by brief immersion in liquid nitrogen (LN2). This can be accomplished by pouring LN2 over a small quantity (¼ to ½ bucket) of pellets, allowing the LN2 to boil off, then pouring the pellets into the tremie pipe. **NOTE:** use of LN2 is an additional jobsite hazard and must be addressed in the contractor's HASP. This contingency must be covered before drilling starts in order to avoid delays in well installation.

3.5.10 Wait a for the pellets to hydrate and swell. Hydration times will be determined by field test or by manufacturer's instructions. Normally this will be 30 to 60 minutes. Document the hydration time in the field notebook. If the pellets are above the water level in the hole, add several buckets of clean water to the boring. Document the amount of water added to the hole.

3.5.11 Mix an appropriate cement-bentonite slurry (§ 3.4.6). Be sure the mixture is thoroughly mixed and as thick as is practicable.

3.5.12 Lower a side discharge tremie pipe into the annulus to the level of the pellet seal.

3.5.13 Pump the grout slurry into the annulus while withdrawing the tremie pipe and temporary casing.

3.5.14 Stop the grout fill at 5 feet below the ground surface. Allow to cure for not less than 12 hours. If grout settles more than 6-in., add grout to bring level back up to within 5-ft. of ground surface. Place approximately 2 ft of bentonite pellets (minimum 0.5 ft) in annulus. Seat the protective casing in the bentonite seal, allowing no more than 0.2 ft between the top of the well casing and the bottom of the protective casing cap. Fill inner annulus (between well casing and protective casing) with bentonite pellets to the level of the ground surface. Cover bentonite pellets with 1 ft of clean granular material (coarse sand or pea gravel filter pack). Fill the outer annulus (between the protective casing and the borehole) with neat cement. Allow the cement to mound above ground level and finish to slope away from the casing. Lock the cap.

-or-

3.5.15 Continue the grout fill to the ground surface. Seat the protective casing in the grout, allowing no more than 0.2 - ft between the top of the well casing and the bottom of the protective casing cap. Lock the cap.

-and-

3.5.16 Allow the grout slurry to set overnight.

3.5.17 Fill the outer annulus (between the casing and the borehole) with neat cement. Allow the cement to mound above ground level and finish to slope away from the casing.

3.5.18 Slope the ground surface away from the casing for a distance of two feet, at a rate of no less than 1 inch in two feet. Surface this sloping pad with a geotextile mat covered by 3 in. of coarse gravel.

-or-

3.5.19 Frame and pour a 4 ft square by 6 in thick (4' X 4' X 6") concrete pad centered around the protective casing.

-and-

3.5.20 Set pre-painted protective steel pickets (3 or 4) evenly around and 4 feet out from well. These pickets will be set into 2 ft-deep holes, the holes will then be filled with concrete, and if the pickets are not capped, they will be filled with concrete also.

3.6 Well Development

3.6.1 Well development is the process by which drilling fluids, solids, and other mobile particulates within the vicinity of the newly installed monitoring well have been removed while restoring the aquifer hydraulic conductivity. Development corrects any damage to or clogging of the aquifer caused by drilling, increases the porosity of the aquifer in the vicinity of the well, and stabilizes the formation and filter pack sands around the well screen. Well development is not considered complete until the sediment thickness remaining in the well is less than 2 inches, or less than 1% of the screen length. The as-drilled depth of the well should be compared to the measured depth to determine the actual sediment thickness.

3.6.2 Well development will be initiated after 48 consecutive hours but no longer than 7 calendar days following grouting and.or placement Of surface protection. The record of well development will be submitted to the Contracting Officer's Representative within three working days after well development is completed.

3.6.3 Two well development techniques - over pumping and surging will be employed in tandem. Over pumping is simply pumping the well at a rate higher than recharge. Surging is the operation of a plunger up and down within the well casing similar to a piston in a cylinder.

3.6.4 Materials Required

a. Well Development Form
b. Boring Log and Well Completion Diagram for the well
c. Submersible pump or bailer of appropriate capacity, and surge block
d. Conductivity, pH, ORD, turbidity, dissolved oxygen, and temperature meters
e. Electric well sounder and measuring tape.
f. Containers for purged water, if required.

3.6.5 **Summary of Procedures and Data Requirements.**

3.6.5.1 Pump or bail the well to ensure that water flows into it, and to remove some of the fine materials from the well. Removal of a minimum of one equivalent volume (EV) is recommended at this point. The rate of removal should be high enough to stress the well by lowering the water level to approximately 1/2 its original level. If well recharge exceeds 15gpm, the requirement to lower the head will be waived.

3.6.5.2 Slowly lower a close-fitting surge block into the well until it rests below the static water level, but above the screened interval. (Note: this latter is not required in the case of an LNAPL well.)

3.6.5.3 Begin a gentle surging motion which will allow any material blocking the screen to break up, go into suspension, and move into the well. Continue surging for 5-10 minutes, remove surge block, and pump or bail the well, rapidly removing at least one EV.

3.6.5.4 Repeat previous step at successively lower levels within the well screen until the bottom of the well is reached. Note that development should always begin above, or at the top of, the screen and move progressively downward to prevent the surge block from becoming sand locked in the well casing. As development progresses, successive surging can be more vigorous and of longer duration as long as the amount of sediment in the screen is kept to a minimum.

3.6.5.5 Development is expected to take at least 2 hours in a small well installed in a clean sand, and may last several days in large wells, or in wells set in silts with low permeabilities.

3.6.5.6 Development will continue until little or no sediment can be pulled into the well, and target values for parameters listed in 3.6.4.9 (e.) (below) are met.

3.6.5.7 At a minimum, development will remove 3 to 5 development volumes (DV) of water. One DV is defined as (1) EV (see SOP013 for calculation), plus (1) the amount of fluid lost during drilling, plus (1) the volume of water used in filter pack placement.

a. Monitor water quality parameters (3.6.5.9 d) before beginning development procedures, and after removing 2, 2½, and 3 DV of water.

b. If these parameters have stabilized over the three readings, the well will be considered developed.

c. If the parameters have not stabilized after these three readings, continue pumping the well to develop, but stop surging. Monitor the stabilization parameters every ½ DV.

d. When the parameters have stabilized over three consecutive readings at ½DV intervals, the well will be considered developed.

3.6.5.8 All water removed must be disposed of as directed by the Sampling Design Plan.

3.6.5.9 Record all data as required on a Well Development Record Form (see example), which is made a part of the complete Well Record. These data include:

a. Depths and dimensions of the well, the casing, and the screen, obtained from the Well Diagram.

b. Water losses and uses during drilling, obtained from the boring log for the well.

c. Water contained in the well, obtained from calculations found in SOP013, § 3.3.6

d. Measurements of the following indicator parameters: turbidity, pH, conductivity, oxidation-reduction (ORD, Redox) potential, dissolved oxygen, and temperature.

e. Target values for the indicator parameters listed above are as follows: pH - stabilize, conductivity - stabilize, ORD - stabilize, DO stabilize, temperature - stabilize, turbidity NTU 5 or stabilize. A value is considered to have stabilized then 3 consecutive readings taken at ½ DV intervals are within 10% of each other.

f. Notes on characteristics of the development water.

g. Data on the equipment and technique Used for development.

h. Estimated recharge rate and rate/quantity of water removal during development. (See SOP 013 section 3.2.)

3.7 Refer to SOP003 (Field Logbook), 005 (Decontamination), 008 - 012 and 036 038 (Instrumentation for Groundwater Parameters).

4.0 Maintenance

Not Applicable.

5.0 Precautions

Refer to the site-specific Health and Safety Plan for discussion of hazards and preventive measures during well development activities.

6.0 References

Aller, Linda, *et al.*, 1989. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells, National Water Well Association

Cohen, Robert M., and Mercer, James W. 1993. DNAPL Site Evaluation, CRC Press, Inc.

COMAR 26.04.04 Well Construction

EPA Groundwater Handbook 1989

Nielsen, David M., 1993. Correct Well Design Improves Monitoring, in "Environmental Protection", Vol.4, No.7, July, 1993.

USATHAMA. 1987. Geotechnical Requirements for Drilling, Monitoring Wells, Data Acquisition. and Reports, March 1987.

ASTM D 2487-92 Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System)

ASTM D 5092-90 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers

Cement Type	Special Characteristics	Recommended Usage
I	No special properties.	General use as grout mix or cement plug (if sulfates <250 ppm), surface pad.
IA	Air-entraining Type I. (Note that air entrainment properties can be achieved by chemical admixtures.)	Air entrainment gives cement greater freeze-thaw resistance. Recommended for surface pads.
II	Moderate sulfate resistance, low heat of hydration.	General use as grout mix or cement plug where ground water sulfate >250 ppm and <1500 ppm, surface pad.
IIA	Air-entraining Type II	See type IA.
III	High early strength, high heat of hydration.	Elevated temperature can damage well casing and fracture grout/cement plugs. NOT RECOMMENDED.
IIIA	Air-entraining Type III	NOT RECOMMENDED.
IV	Low heat of hydration.	General use as grout mix or cement plug preferred type for well abandonment to ensure intact grout/cement plug.
V	High Sulfate resistance.	Use when ground water sulfate levels >1500 ppm.

Table 19-1 Portland Cement Types and Recommended Applications

WELL DESIGNATION: ______________________ DATE(S) OF INSTALLATION:_____/_____/_____

SITE GEOLOGIST: ____________________________ DEVELOPMENT DATE(S):_____/_____/_____

STATIC WATER LEVELS BEFORE AND AFTER DEVELOPMENT * :

BEFORE ______________ DATE ____________ 24 HR. AFTER ____________ DATE____________

DEPTH TO SEDIMENT BEFORE AND AFTER DEVELOPMENT * :

BEFORE ______________ DATE ____________ 24 HR. AFTER ____________ DATE____________

DEPTH TO WELL BOTTOM *: __________________ SCREEN LENGTH _______________

HEIGHT OF WELL CASING ABOVE GROUND SURFACE: ____________________

QUANTITY OF MUD/WATER:

LOST DURING DRILLING	(+)______________________	gallons
REMOVED PRIOR TO WELL INSERTION	(-)______________________	gallons
LOST DURING THICK FLUID DISPLACEMENT	(+)______________________	gallons
ADDED DURING FILTER PACK PLACEMENT	(+)______________________	gallons
TOTAL LOSSES	______________________	gallons

(a) Water column ht. (ft.) _______________ (b) Well radius (in.)______________

(c) Screen length (ft.) _______________ (d) Borehole radius (in.)______________

(e) QUANTITY OF FLUID STANDING IN WELL $(12 * a * \pi * b^2 * 0.0043) =$ 0 __________ gallons

(Show Calculation)

(f) QUANTITY OF FLUID IN ANNULUS $[12 * c * \pi 8(d^2 - b^2) * 0.0043 * 0.30]$ 0 _________gallons

(Show Calculation)

DEVELOPMENT VOLUME = (5 * TOTAL LOSSES) + [5 * (e + f)] = ______________ gallons

(Show Calculation)

* **ALL DEPTHS MEASURED FROM TOP OF WELL CASING**

EXAMPLE WELL DEVELOPMENT RECORD
(PAGE 2 OF 2)

WELL DESIGNATION _______________ DATE(S) OF DEVELOPMENT: _____/_____/_____

TYPE AND SIZE OF PUMP: ____

TYPE AND SIZE OF BAILER: ____

DESCRIPTION OF SURGE TECHNIQUE: ____
____

RECORD OF DEVELOPMENT

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color / clarity / odor / partic.)
(before)									
(during)									
(during)									
(during									
(after)									

TYPICAL PUMPING RATE _________ GAL./HR. EST. RECHARGE RATE ____________________

TOTAL QUANTITY OF WATER REMOVED ______________ TIME REQUIRED ____________________

REMARKS____
____
____

SIGNATURE OF SITE GEOLOGIST _____________________________________

Hole No.

DRILLING LOG	DIVISION	INSTALLATION	SHEET OF SHEETS

PROJECT	10. SIZE AND TYPE OF BIT
	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
DRILLING AGENCY	
HOLE NO. (As shown on drawing title and file number)	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN / DISTURBED / UNDISTURBED
NAME OF DRILLER	14. TOTAL NUMBER CORE BOXES
	15. ELEVATION GROUND WATER
DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ________ DEG. FROM VERT.	16. DATE HOLE / STARTED / COMPLETED
THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
TOTAL DEPTH OF HOLE	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g

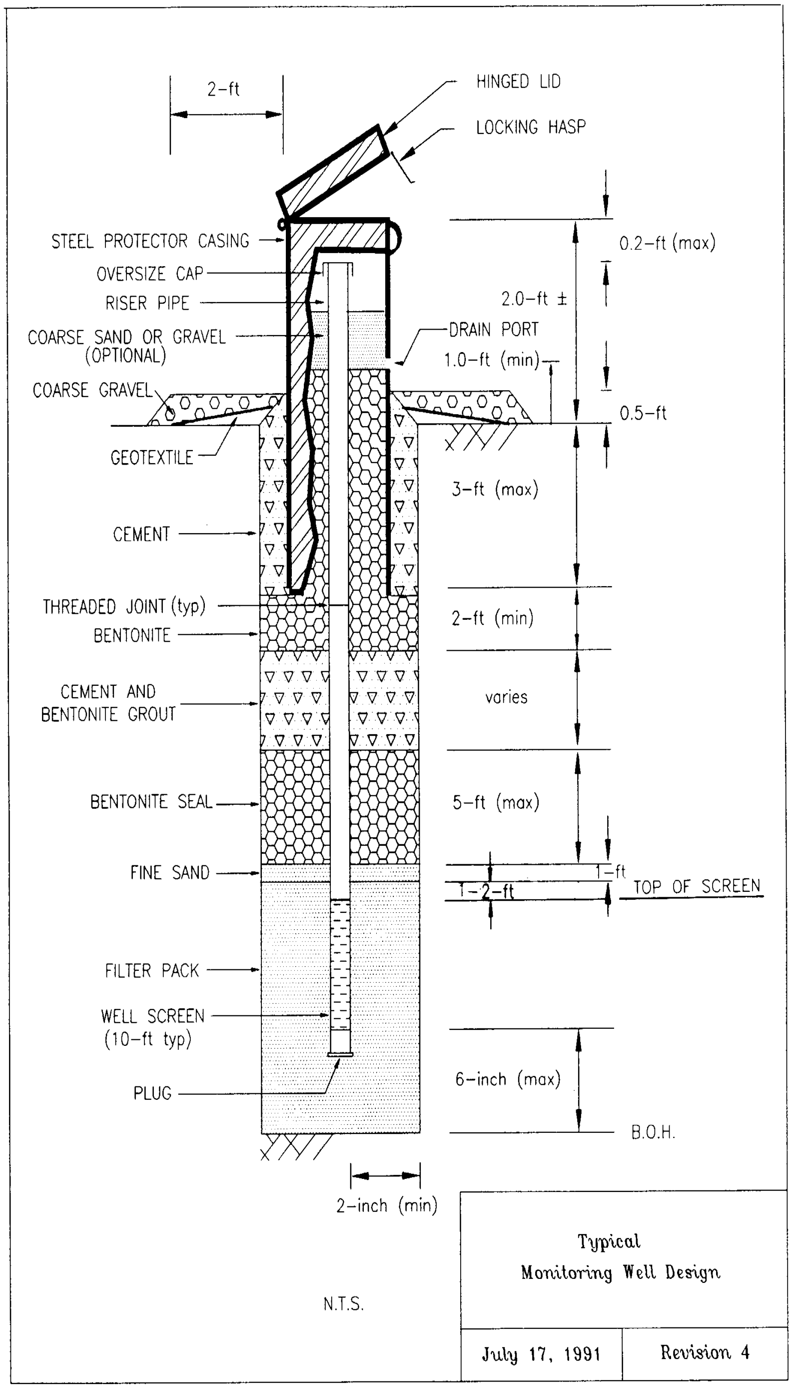


Figure 19.2. Typical shallow sampling well construction

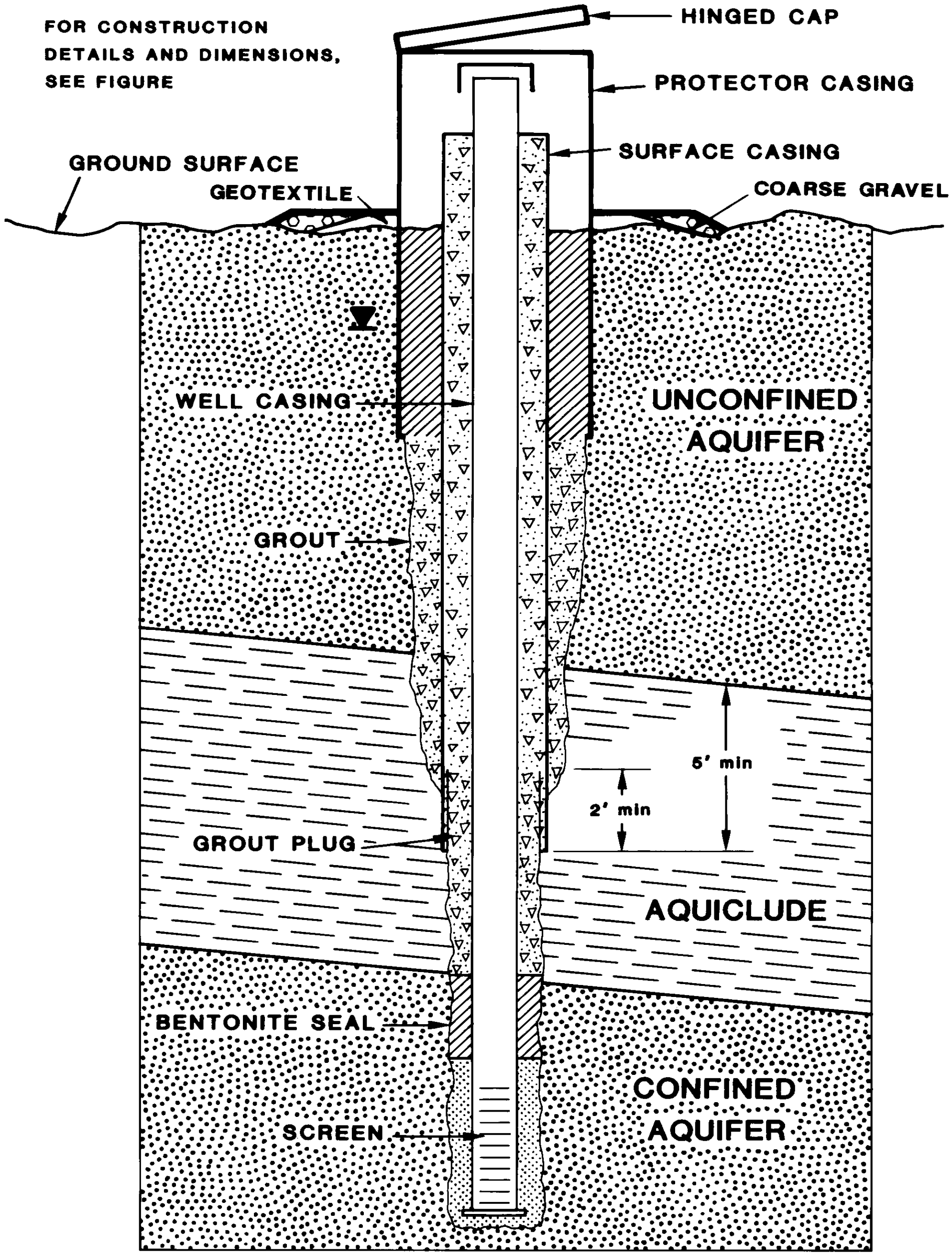


Figure 19.3. Typical well installation, confined aquifer.

Appendix D

PRODUCT DATA

FilPro â

WELL GRAVELS

PLANT: MAURICETOWN, NEW JERSEY

FilPro Well Gravel sands are produced from round and subround monocrystalline industrial quartz. Chemically inert and free of organic contaminants, they will not alter the chemistry of water-producing wells, nor distort the analytical results of effluents drawn from monitoring wells. These durable and dense sands are sized to uniformity coefficients that range from 1.35 to 2.5.

In water-producing wells, **FilPro Well Gravels** will increase the yield from the aquifer by increasing the permeable zone around the well screen. **FilPro's** ability to effectively bridge and filter finer or highly laminated formations at the interface offer drillers the option to use larger slot sizes for improved hydraulic transmission and faster development. With it's superior permeability, **FilPro Well Gravels** will maximize hydraulic conductivity with little or no head loss through the filter pack. Excellent structural support and placement properties also make them an effective gravel pack in environmental monitoring wells and a productive leachate in sanitary landfill or leak detection systems.

All **FilPro** well gravel grades are processed and sized with strict adherence to statistical and quality assurance controls, and meets AWWA B-100, ANSI, and NSF-61 standards for consistently uniform and chemically inert filter media.

TYPICAL PARTICLE SIZE ANALYSIS AND PROPERTIES

(THESE DO NOT REPRESENT A SPECIFICATION)

Mesh* ASTM E-11	#4	#3	#2	#1	#0	#00N	#00	#000
4	2.7	-	-	-	-	-	-	-
6	60.7	2.8	-	-	-	-	-	-
8	29.7	47.1	3.2	-	-	-	-	-
10	3.7	30.1	17.7	0.2	-	-	-	-
12	1.8	13.2	29.8	4.3	-	-	-	-
14	0.9	4.9	33.6	29.7	0.1	-	-	-
16	-	0.9	10.3	32.1	1.9	-	-	-
18	-	0.4	3.8	25.7	16.0	-	-	-
20	-	-	0.6	5.2	22.8	0.1	-	-
25	-	-	0.3	1.5	32.7	6.4	0.1	-
30	-	-	-	0.5	19.4	37.2	1.9	0.7
35	-	-	-	0.3	5.7	42.8	31.5	-
40	-	-	-	-	0.9	10.1	36.0	23.0
50	-	-	-	-	-	2.9	26.7	34.1
70	-	-	-	-	-	-	3.0	21.0
100	-	-	-	-	-	-	-	14.1
140	-	-	-	-	-	-	-	5.2
200	-	-	-	-	-	-	-	1.6
270	-	-	-	-	-	-	-	0.2
PAN	0.5	0.6	0.7	0.5	0.5	0.5	0.8	0.1

*Typical Mean % Retained on Individual Sieves

	#4	#3	#2	#1	#0	#00N	#00	#000
Recommended Screen Slot Size (in.)	0.090	0.060	0.050	0.030	0.025	0.020	0.010	0.005
Effective Size (mm)	2.47	1.76	1.29	1.02	0.61	0.48	0.33	0.16
Uniformity Coefficient	<1.8	<1.7	<1.6	<1.6	<1.6	<1.5	<1.6	<2.5

Bulk Density, Aerated (lb./ft.^{3})	92-95	ASTM C-29
Bulk Density, Compacted (lb./ft.^{3})	98-100	ASTM C-29
Hardness	7.0	Mohs Scale
Specific Gravity	2.65	ASTM C-128
Grain Shape	Subround	Visual
Acid Solubility	<0.5%	API RP56

July 17, 2000

DISCLAIMER: **The information set forth in this Product Data Sheet represents typical properties of the product described; the information and the typical values are not specifications. U. S. Silica Company makes no representation or warranty concerning the Products, expressed or implied, by this Product Data Sheet.**

WARNING: **The product contains crystalline silica - quartz, which can cause silicosis (an occupational lung disease) and lung cancer.** For detailed information on the potential health effect of crystalline silica - quartz, see the U. S. Silica Company Material Safety Data Sheet.

U. S. Silica Company **P.O. Box 187, Berkeley Springs, WV 25411-0187** **(800) 243-7500**

Appendix E

	U.S. ARMY CORPS OF ENGINEERS BALTIMORE DISTRICT GEOLOGY and HYDROGEOLOGY	GROUNDWATER FIELD DATA LOG

1. CLIENT: **DATE:**
SAMPLED BY: **TIME :**
WEATHER CONDITIONS:

Location:	Sample ID:

PRESERVATIVE: ______________________________
ANALYSES REQUESTED: ______________________________
 # OF CONTAINERS:
SAMPLING METHOD: ☐ Peristaltic Pump ☐ Bladder Pump
LOW FLOW: ☐ YES ☐ NO
DUPLICATE SAMPLE: ☐ YES ☐ NO
SAMPLES FILTERED: ☐ YES ☐ NO

2. WATER LEVEL DATA

MEASURING POINT: ☐ Top of casing ☐ Other:
METHOD OF MEASUREMENT:

3. WELL EVACUATION DATA

Well Depth (wd):		(ft)	Diameter (d):		(in)
Depth to Water (dw):		(ft)	Diameter (d):	0.000	(ft)
	Well Volume = $(5.904 \times d^2(wd-dw))$ =			0.00	(gallons)
Flow Rate:		(ml/min)	Purge Vol:	0.0	(gallons)
Length of Time Purged:		(minutes)	Purge Time:		
Amount Purged:		(gallons)	Pump Depth:		

4. FIELD PARAMETERS

INSTRUMENT	CALIBRATED
pH Meter –	☐
Conductivity Meter –	☐
Temperature –	☐
Turbidity Meter –	☐
DO Meter –	☐
ORP Meter –	☐
CO_2 –	☐

Time						
Temp. °C						
DO (mg/L)						
Sp. Cond. (mS/cm)						
pH						
ORP (mV)						
Turb. (NTU)						
Water Level						

5. Notes: