DEPARTMENT OF NATURAL RESOURCES & ENVIRONMENTAL CONTROL
DIVISION OF WASTE & HAZARDOUS SUBSTANCES
SITE INVESTIGATION & RESTORATION BRANCH

STANDARD OPERATING PROCEDURE
MONITORING WELL/PIEZOMETER INSTALLATION/DEVELOPMENT AND GROUNDWATER SAMPLING

DNREC – SIRB QA Manager Approval: ________________

DNREC – SIRB Program Manager	DNREC – SIRB Program Manager	DNREC – SIRB Program Manager

DNREC – SIRB Branch Manager

Monitoring Well/Piezometer Installation/Development and Groundwater Sampling

The installation of monitoring wells/piezometers is contingent upon the existing conditions at the project site and the acquisition of a permit from the DNREC Well Permitting Branch. Monitoring wells are used to define the lateral and vertical extent of ground-water contamination by determining the chemical and physical properties of the groundwater. Piezometers are used to collect water level data not groundwater samples. The procedures described below are intended to provide access to ground water with minimum disturbance to the aquifer. Additionally, the procedures are intended to prevent cross-contamination between aquifers. A site-specific Work Plan should be reviewed for specific monitoring well or piezometer installation instructions.

Drilling will be performed by a Delaware licensed well driller and in accordance with the Delaware Regulations Governing the Construction and Use of Wells under the direction of a DNREC geologist or hydrologist. All appropriate DNREC permits shall be on-site for inspection by a DNREC geologist, hydrologist or project manager, if requested. The drilling field crew will consist of a driller and a driller's assistant(s). The DNREC field geologist will supervise drilling operations and conduct the geologic logging of the boreholes. A list of typical equipment needed for installation of wells/piezometers at a site is summarized below.

In general, the following steps should be performed at each drilling site:

- Have utilities marked out prior to arrival
- Arrive onsite
- Don appropriate PPE per site Health and Safety Plan
- Site well locations (mark with paint) in accordance with the site-specific work plan

- Place drilling rig appropriately at the drilling location
- Set up station away from rig for logging of cores/collecting samples
- Screen borehole/core with PID
- Log core and collect samples
- Construct well appropriately as described below
- Decontaminate rig and sampling equipment to ensure no cross contamination between well or boring locations
- Place drilling rig appropriately at the next drilling location

Drilling Equipment (the following may or may not be required depending on site-specific conditions):

Heavy Equipment

Hollow-stem auger drill rig
Air rotary drill rig
Mud rotary drill rig
Direct push sampling rig (Geoprobe®-type)
Roto-Sonic drill rig
500-gallon Water truck (if needed)
Grout mixer
Steam cleaner or pressure washer for decontamination of equipment
Generator for steam cleaner

Sampling Tools

2-inch I.D split-barrel samplers
Thin-walled direct push sampling tubes

Well Casing Materials

Various diameters of steel casing
Various diameters of PVC casing
Locking well plugs/pressure caps
Locking steel protector casing (stick ups or monitoring manholes for flush mounts)
Various diameters of flush-threaded casing and end caps
Various diameters of flush-threaded screen (0.010 or 0.020 inch slot size)
Various diameters of direct –push (Geoprobe®) type pre-packed well screens and seals

Other Well Construction Materials

Type I Portland cement
Bentonite pellets
#2 filter sand

Miscellaneous Equipment/Materials

55-gallon steel drums for investigation derived waste
Weighted steel tape
Tremie pipe
Shovels
Water Level Indicator
Heavy Plastic Sheeting
Sorbent material for spill control
Locks (one key for all wells at site)

Logging:

All borings for monitoring wells will be logged by a geologist. Logs will be recorded in a field logbook and/or a boring log in EQUIS-friendly fields. Field notes are to include, at a minimum:

- DNREC ID Number (see DNREC Well ID Policy, July 2007)
- Persons present at sampling
- Boring number
- Material description (as discussed below)
- Weather conditions
- Evidence of contamination
- Water conditions (including measured water levels)
- Notations on man-placed materials
- Drilling method and borehole diameter
- Any deviations from established field plans
- Blow counts for standard penetration tests
- Core and split-spoon recoveries

Material description for soil samples should include, if evident:

- Classification
- Unified Soil Classification symbol
- Secondary components and estimated percentages
- Color
- Plasticity
- Consistency
- Density
- Moisture content
- Texture/fabric/bedding and orientation
- Grain angularity
- Depositional environment and formation
- Incidental odors
- Photo ionization detector (PID) reading(s)
- Staining

Material description for rock samples should include, if evident:

- Classification
- Lithologic characteristics
- Bedding/banding characteristics
- Color
- Hardness
- Degree of cementation
- Texture
- Structure and orientation
- Degree of weathering
- Solution or void conditions
- Primary and secondary permeability
- Sample recovery
- Incidental odors
- Photo ionization detector reading(s)
- Staining

Descriptions for well construction should include:

- Borehole Depth
- Type and length of well screen/cap
- Type and length of well casing
- Top and bottom depth measurements of sand pack placement
- Top and bottom depth measurements of bentonite seal placement
- Top and bottom depth measurements of grout placement
- Details regarding surface finishing of well/piezometer (flush vs. stickup protection)
- GPS location coordinates of the well (include land surface elevation)

Drilling Procedures:

Two types of wells will be discussed in this SOP. One type of well is installed in an unconfined aquifer. The second type of well is installed in a confined aquifer. Before proceeding with any work, refer to the site specific Work Plan and the site specific Health and Safety Plan.

<u>Wells installed in Unconfined Aquifers</u>

The following procedure describes construction of a monitoring well/piezometer with flush threaded PVC well casing and screen. It should be noted that the diameter and type of well casing material may differ according to specific applications. Furthermore, the slot size of the screen and the gradation of the filter pack material depend upon the average grain size of the geologic formation in which the well is installed. Either a hollow stem auger rig or direct push type rig can be used to install wells in unconfined aquifers.

1. All well casing and screens shall be new and brought to the site enclosed in plastic. Contact of casing or screen with the ground prior to installation shall be avoided. Plastic sheeting shall be placed on the ground and used as a cover to protect stockpiled materials from cross contamination.

2. If monitoring for contaminants less dense than water, drilling will proceed to a depth of seven feet below the water table. The well will be screened across the water table using ten feet of appropriately sized screen.

3. If monitoring for contaminants more dense than water, drilling will proceed until the first confining layer (e.g., clay layer, top of bedrock, etc.) is encountered. Delaware Water Well Regulations state that a confining layer is at least 10 ft thick. In these situations, ten feet of appropriately sized screen will be placed immediately above the confining layer.

4. A sand pack composed of washed #2 or other appropriately sized sand will be installed in the annular space of each well from the base of the screen to two feet above the screened interval by gravity or a tremie pipe, as necessary. A bentonite seal will extend two feet above the sand pack and will be allowed to hydrate for the maximum time recommended by the bentonite manufacturer. All annular packs and seals will be measured and recorded in the field logbook. The remaining annulus to the ground surface will be filled with a cement-bentonite grout [not to exceed 14.2 pounds/gallon (less than 5 percent bentonite)] using a tremie pipe or pour method.

5. The wells shall extend 3 feet above grade with a 6-inch diameter protective steel surface casing. The surface casing will be surrounded by a square concrete pad at grade. The protective casing shall be fitted with a lockable water-tight cap.

   In cases where wells must be installed in high traffic areas, the 6-inch protective steel casing may be replaced with a protective steel manhole which is finished flush with surface grade.

<u>Wells installed in Confined Aquifers</u>

Wells installed in confined aquifers must penetrate a confining layer. That confining layer may be a clay layer in unconsolidated materials or un-fractured bedrock in consolidated materials. The appropriate type of drilling rig to drill through the worst expected conditions at a site shall be used (i.e., air rotary for drilling into bedrock, or mud rotary/direct push for drilling into unconsolidated materials).

1. Drill to the top of the confining surface. Appropriately sized steel or PVC casing will then be driven at least 6 inches into the confining layer. The casing will then be grouted in place. After the grout has cured and set, drilling will proceed with a smaller bit until the desired depth is reached.

   If drilling proceeds through more than 1 confining layer, the same process as described above will be repeated, except the first aquifer will be cased off with larger diameter casing and the second aquifer will be cased off with appropriately sized but smaller diameter casing, etc.

2. A well will then be constructed in this borehole in the same manner as described in steps 1 through 5 above.

   When installing a well in fractured rock, it may be possible to leave an open borehole, depending upon the competency of the rock.

Well Development

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 by removing fine-grained material, and stabilizes the formation and filter pack sands around the well screen. The volume of water removed during development and the duration to complete development should be noted in a field notebook.

Provided that the well has been properly installed and the grout seal has been properly hydrated, development may be initiated the same day that the well is installed/ drilled. Typically 24 hours is the time frame allowed for proper grout hydration and well sealing. DNREC-SIRB recommends a 24 period between installation and development to allow for proper hydration and complete sealing. 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.

Materials Required

The following materials will be required for well development:
- Submersible pump or bailer of appropriate capacity, surge block or other surging tool
- Conductivity, pH, ORP, turbidity, dissolved oxygen, and/or temperature meters
- Electric well sounder and measuring tape
- Containers for measuring the volume of purged water, if required by site Contaminated Materials Management Plan (CMMP).

Summary of Procedures and Data Requirements

Measure the water level and the total depth in the well with the electric well sounder (or equivalent device) and record the measurement in the field log book. Pump or bail the well to ensure that water flows into it, and to remove some of the fine-grained materials from the well. Removal of a minimum of one well volume is recommended at this point. The rate of removal should be high enough to stress the well by lowering the water level to approximately half its original level. Aquifer conditions will determine if this is possible. The volume of water removed and the duration to complete this should be noted in a field notebook.

Using the surging tool, 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 then pump or bail the well, rapidly removing at least one well volume.

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 surging tool 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.

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

Development will continue until little or no sediment can be pulled into the well, and target values for water quality parameters have been achieved. Visual observation may be the best tool for some of these.

At a minimum, development will remove 3-5 well volumes of water. Monitor water quality parameters of turbidity, pH, conductivity, ORP, potential, dissolved oxygen and temperature before beginning development procedures, and after removing 2, 2.5, and 3 well volumes of water.

1. If these parameters have stabilized over the three consecutive readings, the well will be considered developed.
2. If the parameters have not stabilized after these three readings, and the water is visually clear, continue pumping the well to develop, but stop surging, and continue readings for each well volume.
3. When the parameters have stabilized over three consecutive readings at one well volume intervals and the water is visually clear, the well will be considered developed.
4. Record the water level at the end of development using an electric well sounder.

All water removed must be managed as directed by the Work Plan and Contaminated Materials Management Plan (CMMP).

Record all data as required in the field log book. These data include:

- Depths and dimensions of the well, casing, and screen obtained from the well diagram.
- Water losses and uses during drilling, obtained from the boring log for the well.
- Measurements of water quality parameters.
- Notes on characteristics of the development water.
- Data on the equipment and technique used for development.
- Estimated recharge rate and rate/quantity of water removal during development.

Groundwater Sampling

The purpose of sampling is to obtain un-altered representative groundwater samples from an aquifer. This includes the collection of ground-water samples from wells, and direct push sampling equipment.

In general, the following steps should be performed at each sampling site:

- Arrive onsite
- Don appropriate PPE per site Health and Safety Plan (HASP)
- Set up sampling apparatus (generators, pumps, etc.)
- Open all site wells
- Perform organic vapor check, water levels, and well depth measurements
- Sample or measure non-aqueous phase liquids (NAPLs) as required
- Begin sampling procedure as described below
- Re-glove in preparation for laboratory sample collection
- Collect laboratory samples as described below
- Decontaminate non-disposable equipment/dispose of waste/move equipment to the next sampling location

Sampling Equipment/Materials:

Submersible pump(s) of appropriate size (e.g., 2-inch Grundfos® Rediflow pump and controller), teflon or stainless-steel bailers, dedicated tubing with check valve or peristaltic pump, generator, 5-gallon bucket(s), water quality measurements instrument, sample bottles and preservatives, bailing twine and rope, water level meters, filtration system with 0.45 um filters, appropriate PPE (gloves, respirator, safety glasses, etc.), sample paperwork, copies of work plan.

Sampling Procedures: Wells

Time Frame before sampling after well development
Direct push wells 48-72 hours
Drilled wells 72 hours to 1 week

1. Refer to the site Health and Safety Plan (HASP) before proceeding with any work. Describe all work in the field logbook.

2. The wells will be sampled from the least contaminated well to the most contaminated well, if information is known.

3. Prior to sampling, all wells shall be measured for the presence of organic vapors per the site HASP. A PID may be used. Any readings shall be noted in the field logbook, and activities shall proceed in accordance with the site HASP.

4. Using a clean, decontaminated electric well sounder, determine the water level in each well; then calculate the fluid volume in the casing using a multiplier which corresponds to the well casing diameter.

5. Using a clean, decontaminated submersible pump, bailer, or peristaltic pump, remove water from the well (purge) until one to three well volumes has been removed. Equipment should be lowered into the well slowly and carefully so as to minimize aeration and avoid possible agitation of sediments in the bottom of the well or mixing of less dense contaminants in the well casing.

   Measure the water level during purging to indicate well yield in relation to purging pump rate. Measure the purging rate by directing the pump discharge into a bucket or container of known volume, and timing how long it takes to fill the container (e.g., 5 gallons in 30 seconds equals 10 gallons/minute). If the water level drops during purging, lower the pump deeper into the well, and note that the purge rate exceeds the well yield.

   During purging, field measurements of selected parameters are performed. Calibrate field equipment per SOP-14. Measure the water quality parameters (use the same as used for well development) at the start of the purge and for each subsequent well volume, or other appropriate interval, until three consecutive measurements achieve stabilization (approximately +/-10% of the previous reading). All measurements may be made simultaneously using an in-line water quality meter, if available. The priority for stability is conductivity, pH, temperature, ORP, and DO, with any changes in water color, turbidity, or odor also being noted. If stability is not achieved, additional well volumes shall be purged, and readings collected, until stability is reached. As each well is purged, the data that are collected will be compared to the other wells on site and with historical data whenever possible.

   If sampling is to be conducted using a bailer, refer to #6, 7, and 8 below. If sampling is to be conducted directly from a low-flow submersible pump or peristaltic pump, proceed to #9.

6. Attach a new bailer line to a clean decontaminated bailer equipped with a single-check valve. Check the operation of the check valve assembly to confirm free operation.

7. Lower the single check valve bailer slowly into the well until it contacts the water surface. Then lower the bailer carefully to a level just below the water surface, minimizing the disturbance of the water to reduce aeration, loss of volatile organic compounds, and to avoid contacting the sediments that have settled at the bottom of the well. When filled with groundwater, slowly raise the bailer to the surface. Discharge the first bailer to the ground or to a bucket.

8. Repeat step #7 to refill the bailer and raise it to the surface. Tip the bailer to allow the water to slowly discharge from the top and to flow gently down the side of the sample bottle with minimum entry turbulence and aeration.

9. Fill all appropriate sample bottles from the bailer or directly from the low-flow pump tubing. The first sample collected should be the sample portion that is to be analyzed for volatile organic compounds, making absolutely certain that there are no bubbles adhering to the walls or the top of the sample container. Next collect the sample portions for the semi-volatile organics and pesticide/PCB. Then collect the sample for the inorganic parameter of cyanide.

10. Finally, collect a sample for total and dissolved metals analysis if the well is being sampled for the first time following installation. If this is a subsequent round of sampling please see Special Condition B below. Sample containers must not be rinsed with sample water before final filling due to the possible presence of floating, free phase products in the well, which can adhere to the sample container wall and bias the analyses.

    All groundwater samples typically consist of a total metals portion and a dissolved metals portion. The portion for the dissolved metals analysis will be filtered in the field using a single-use 0.45-µm acrylic copolymer filter in a prepackaged, disposable polypropylene in-line filter. The Grundfos® pump or peristaltic pump will be used to pump the ground-water through the in-line filter and into the sample container. To reduce the potential for redox reactions because of aeration, a very slow flow rate must be maintained (theoretically not to exceed 100 mL/minute). If sampling is being conducted using a bailer, a Q.E.D. filtration apparatus is filled with ground water, then pumped with a hand pump to slowly force the ground water through the filter assembly.

    Following the DNREC –SIRB Remediation Standards Guidance - Revised December 1999 ("Guidance"), page 7, "All aqueous standards are considered total concentration for water supply sample data (either ground water or surface water), and dissolved concentration for non-water supply ground-water and surface water sample data." In addition, the footnote on the Delaware Default Background Remediation Standards Table in Attachment 3-1 of the Guidance states that "All groundwater values are either total (water supply source) or dissolved (monitoring well) concentrations, depending on the application."

    Variance from this SOP may be obtained from DNREC-SIRB by written request. Variance may only be obtained for wells that have followed the SOP for initial sampling and require subsequent rounds of groundwater sampling for metals. Approval of a requested variance is at the Department's discretion.

11. Ground water samples should then be preserved using the appropriate preservative if it is not already present in the sample container. The samples for volatile organic compounds should be preserved with hydrochloric acid (HCl) to a pH of less than 2. The sample to be analyzed for cyanide should be preserved with several pellets of sodium hydroxide to a pH greater than 12. The samples to be analyzed for metals (both total and dissolved) should be preserved with nitric acid to a pH of less than 2; DO NOT ADD PRESERVATIVES PRIOR TO FILTRATION OF METALS SAMPLES!

12. After all sample containers are filled, recheck that the sample collected for the analysis of volatile organic compounds does not contain headspace or bubbles. If any air bubbles are present, the sample must be re-collected using a fresh sample container with fresh preservative. All samples collected will be filled to the capacity required for analysis.

13. Complete all sample labels and place the samples into a cooler with ice filled zip-lock style bags (**do not use loose ice**); maintain a sample temperature of 4 degrees C. Complete all relevant sample paperwork (tags, Chain-of-Custody form, etc.) depending upon the required analyses.

14. Decontaminate all non-disposable equipment used during purging and sampling..

15. Once all samples have been collected, pack samples for shipment to the laboratory for analysis.

<u>Special Conditions:</u>

Note that Steps #6-8 can be omitted if purging and sampling is being performed with a Grundfos® Rediflow or peristaltic pump. In this case, after well purging is completed, reduce the discharge rate for the pump to approximately 300 ml/minute or less. Sampling can then proceed as described above.

If at any time a well purges dry using any of the methods described above, record conditions in the field log book, allow groundwater to recover to near static conditions in the well, and sample immediately without additional purging of any additional groundwater.

Other methods of sampling in monitoring wells or piezometers such as discrete interval grab samplers (i.e. Kabis sampler) are not prohibited by this SOP. If such a sampling devise is proposed for use, note such in the investigation work plan and refer to the user's manual for instructions for proper usage.

Special considerations for direct push groundwater sampling:

A. Groundwater data collected (grabbed) from direct push sampling equipment are typically used for screening purposes only, and that the data are not necessarily similar to data collected from wells.

B. In spite of well development and pre-sampling purging, ground-water samples are often turbid and analytical results may not be truly representative of dissolved contaminants in groundwater. This is a special concern when sampling for metals in groundwater. Therefore, groundwater samples collected in newly constructed wells should be sampled both for total metals and field filtered for dissolved metals analysis prior to submission to the laboratory. Sampling for both provides a quality check of well development and water quality as a whole, as well as for the dissolved phase for metals.

C. Ground water may be collected from direct push sampling equipment using either dedicated tubing fitted with a check-valve, small diameter bailer, or a peristaltic pump. Purging multiple well volumes is useful to lower turbidity in the sample. However, under certain circumstances (such as limited groundwater availability), this may not be possible. The amount of purge volume shall be noted in the field logbook for all sampling locations.

D. When using the tubing check valve approach to obtain a sample from the direct push equipment, first oscillate the tubing to fill the tube. Then smoothly and quickly pull the tubing out of the sampler while rolling up the tubing. Remove the tubing check valve from the lower end of the sample tubing. Next, drain the sample from the lower end of the tubing directly into the vials. This procedure will minimize disturbance of the sample, especially for volatile compounds.

E. Free Product Measurement - Free product can usually be detected and sampled with the tubing check valve assembly in direct push equipment. To detect and sample the free product, first thread the check valve into the lower end of the tubing, but leave out the check ball. Smoothly lower the tubing with the check valve down the bore to the bottom of the equipment. Then, from the surface, drop the check ball down into the tubing. Allow enough time for the check ball to reach the bottom of the tubing. Then quickly and smoothly oscillate the tubing up and down 2 or 3 times to seat the check ball in the check valve. Firmly pinch the top of the tubing and smoothly and quickly pull the tubing out of the equipment. Visually check the tubing at the water level and at the base of the tubing for any separate free phase products. In coarse grained formations, only a few minutes or a couple of hours may be required to have free product collect in the direct push equipment. In fine-grained formations, it may be necessary to leave the direct push equipment installed overnight to allow product to collect.

F. Appropriate decontamination procedures must be used between sampling locations to eliminate the potential for cross contamination and incorrect data results.

Well Abandonment

Monitoring well/piezometer abandonment should only be conducted by a Delaware licensed well driller, and in accordance with the Delaware Regulations Governing the Construction and Use of Wells. Therefore procedures for well abandonment are not described herein.