DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL (DNREC)
DIVISION OF WASTE AND HAZARDOUS SUBSTANCES (WHS)
REMEDIATION SECTION (RS)

Standard Operating Procedure for Groundwater Monitoring Well Installation & Development

March 26, 2024

The procedure presented here are the typical procedures to be followed during any work completed under the Hazardous Substance Cleanup Act (HSCA). Any HSCA-certified consultant who wishes to deviate from the procedures contained within shall obtain a variance from the Department. If changes occur during work in the field, the consultant completing the work shall contact DNREC-RS and inform them of which procedures cannot be met and the plan for completing the work. All variances or deviations from this SOP shall be documented in reporting submitted to the Department.

Procedures:

The installation of groundwater monitoring wells should effectively achieve the following objectives at a facility (or site):

- Provide access to the groundwater aquifer(s) for the collection of samples to define the horizontal and vertical extent of groundwater contamination;
- Measure the hydraulic head at each discrete location to obtain data about the groundwater elevation and flow direction;
- Measure hydrologic or chemical properties and provide access for conducting aquifer testing; and
- Meet the appropriate data quality objectives (DQOs) in the sampling and analysis plan (SAP) or site-specific Work Plan (WP).

Groundwater monitoring wells are typically two inches or greater in diameter and are generally screened below the water table.[1] Groundwater monitoring wells less than two inches can be considered for a project; however, they may not be appropriate for any specialty uses and/or long-term monitoring.[2] Specialty uses of monitoring wells and long-term monitoring may include the following:

[1] Design and Installation of Monitoring Wells, USEPA Region 4 Guidance Document. (2018)

[2] Design and Installation of Monitoring Wells, USEPA Region 4 Guidance Document. (2018)

- Aquifer testing
- Pilot testing for remedial design
- Certain Passive Sampling Technologies
- Quarterly monitoring for trend analysis
- Long-Term Stewardship (LTS) Monitoring

Consideration of the entire project life cycle will factor into the location, diameter, depth, screen size, and screen placement of each monitoring well installed at the facility. These considerations should be made on a site-specific basis and should involve the entire project team during the initial stages of the project. The procedures described below are intended to provide access to groundwater with minimum disturbance to the aquifer as well as preventing cross-contamination between aquifers. A DNREC-RS approved sampling and analysis plan (SAP), site-specific work plan (WP), or associated Health and Safety Plan (HASP) should be reviewed for specific groundwater monitoring well installation instructions. Any deviations from this SOP should be documented in these plans.

The installation of the monitoring wells is contingent upon the existing facility conditions and the acquisition of a permit from the DNREC- Division of Water, Well Permit Branch. The drilling and installation of these wells will be performed by a Delaware licensed well driller[3] and in accordance with the Delaware *Regulations Governing the Construction and Use of Wells*[4]. All appropriate DNREC permits shall be on-site for inspection by DNREC personnel, if requested. The drilling field crew should consist of a licensed driller and a driller's assistant(s), and field geologist or field technician under responsible charge as defined in 7 DE Admin. Code 3600 who will supervise drilling operations and conduct the geologic logging of the boreholes. In general, the following steps should be performed at each facility during drilling:

1. Demarcate well locations (mark with paint) in accordance with the DNREC-RS approved SAP or site-specific WP,
2. Have utilities marked out prior land-disturbing activities (e.g., Miss Utility, One Call, third-party underground utility locators, private utility mark-out, etc.),
3. Consider soft dig in locations/sites where the possibility for hitting an unknown utility is high,
4. Review the site-specific HASP and don appropriate Personal Protective Equipment (PPE),
5. Place drilling rig appropriately at the drilling location,
6. Review drilling locations for potential safety issues such as proximity to power lines.
7. Set up a workstation away from rig for logging of cores and collecting samples,
8. Screen recovered core with photoionization detector (PID), or other gas and vapor detector, if screening for volatile organic compounds (VOCs),
9. Log core and collect samples,
10. Construct wells in accordance with State regulations,

[3] https://documents.dnrec.delaware.gov/wr/Information/WaterSupplyInfo/Documents/LicenseList.pdf

[4] https://regulations.delaware.gov/AdminCode/title7/7000/7300/7301.pdf

11. A plan to manage investigation derived waste (IDW) in accordance with Federal, State, and local regulations,
12. Decontaminate rig and sampling equipment to ensure no cross contamination between well or boring locations,
13. Move and place drilling rig appropriately at the next drilling location.

A list of typical equipment needed for installation of wells at a facility is summarized below.

Drilling Equipment

The equipment used for advancing a borehole to install monitoring wells should meet the project needs and goals presented in the SAP or site-specific WP. The rig type, size, mast height, and the rating of the hydraulically driven top-head should all be discussed and agreed upon before the project begins. These factors should ensure that the drill rig selected will be able to meet the project needs including, drilling depth and site-specific geology. Drillers and project managers should also make sure to use dedicated containers to mix Portland cement containing materials. To prevent mischaracterization of IDW, the field staff should make sure that Portland cement does not make its way into IDW drums for disposal. A list of different drilling methods is presented below in **Table 1** with advantages and limitations of each method.

Table 1: Listing of Drilling Methods

Drilling Method	Advantages	Limitations
Air-rotary	Quick advancement, advance in both unconsolidated and hard rock formations	Noise, dust controls, IDW production, difficult to log geology, increased materials demand to seal aquifers, time consuming for grout setting
Direct push (Geoprobe®-type)	Smaller footprint, ease of sampling, pre-pack well installation, can easily log geology, limited IDW, most prevalent drilling type for monitoring well installation	Shallow depths only (typically <50 feet), limited hydraulic power, generally limited to first aquifer
Hollow Stem Auger (HSA)	Most prevalent drilling type for general well installation, bores through most unconsolidated formations	Difficult to log geology (without samplers), unconsolidated formations only, limited depth (<100 ft), increased IDW production
Mud-rotary	Deeper borings, can log geology, can seal off shallower aquifers to investigate deeper aquifers, recirculates drilling fluids	Unconsolidated formations only, larger drilling footprint needed, increased IDW production
Roto-sonic	Quick advancement, can log geology, advance in unconsolidated and consolidated formations, reduced IDW	Bed rock cores can be pulverized, most expensive

<u>Additional drilling support equipment may include</u>:

- Water truck or tank (if needed)
  - Decontamination waters should comply with SAP or WP and specific DQOs (e.g., PFAS-free)
- Grout mixer
- Steam cleaner or pressure washer for decontamination of equipment
- Generator for steam cleaner
- Tank to capture contaminated water.

<u>Soil Sampling Tools</u>

- 2-inch inner diameter (ID) split-barrel samplers (also known as “split-spoons”)
- Direct-push acetate sleeves
- Thin-walled direct push sampling tubes (Shelby tubes)

Well Casing Materials

- Various diameters of steel casing
- Various diameters of polyvinyl chloride (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 IDW
- Appropriate drum labels
- 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)
- Ratchet
- Tubing cutter
- Decontamination supplies[5], brushes, phosphate-free laboratory detergent.

Geologic Logging

All borings for monitoring wells will be logged by a field geologist or field technician. Logs will be recorded in a field logbook and ultimately transcribed into an electronic data deliverable (EDD)-format for submission to DNREC-RS (see DNREC's EQuIS Data Submittal process[6]). Field notes should include, at a minimum the following parameters:

- Name and Location of Site
- DNREC-RS Site ID
- Well Permit ID Number
- Name and title of person maintaining logbook (with notation of change in logbook custody)

[5] https://www.epa.gov/sites/default/files/2016-01/documents/field_equipment_cleaning_and_decontamination205_af.r3.pdf

[6] https://dnrec.alpha.delaware.gov/waste-hazardous/equis/

- Boring number (or System Location Code)
- Surface conditions (eg, pavement, concrete, lawn, forest litter)
- Well material descriptions (as discussed below)
- Weather conditions
- Field Instruments (e.g., drilling rigs, gas/vapor detectors, etc.), any calibrations, readings, and any problems encountered while on-site.
- Evidence of contamination (e.g., odors, staining, buried debris)
- Visual groundwater conditions and type of observation (e.g., wet on spoon, saturated soils, borehole measurement, well measurement – borehole measurements and well measurements should include tool depth and/or time after completion, where applicable)
- Measurements of groundwater levels and well depths
- Measurements of non-aqueous phase liquids (NAPLs), as required,
- Drilling method(s) and borehole diameter(s)
- Any deviations from approved SAP or WP
- Blow counts for standard penetration tests,
- Core and split spoon recoveries
- Identification of samples (e.g., groundwater, soil, soil gas, etc.) collected;
    - Please refer to media-specific DNREC-RS SOPs
- Decontamination Procedures
- Identification of and amounts of IDW, location of storage, and how stored (e.g., secondary containment, overhead cover, etc.).

Material description for soil samples should follow the Unified Soil Classification system (USCS) and include at a minimum the following descriptors:

- Classification
    - Primary
    - Secondary
    - Minor descriptors
    - Determination of fill
- Symbol
- Color
- Plasticity (for fine-grained soils)
- Particle Size (for coarse-grained soils)
- Consistency/Density
- Water content (dry, moist, wet)
- Texture/fabric/bedding and orientation
- Grain angularity
- Depositional environment and formation
- Incidental odors
- Photoionization detector (PID), or other gas/vapor detectors, reading(s)
- Staining
- Description of materials in fill layers

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
- Rock quality designation (RQD) calculation
- Incidental odors
- Photo ionization detector reading(s)
- Staining

Descriptions for well construction should include:

- Borehole Depth
- Material type(s), diameter, slot size, and length of well screen/cap
- Material type(s), diameter, and length of well casing
- Top and bottom depth measurements of sand pack placement and sand size / gradation
- Top and bottom depth measurements of bentonite seal placement
- Top and bottom depth measurements of grout placement
- Details regarding surface finishing of well (flush vs. stickup protection)
- Global Positioning System (GPS) location coordinates of the well (include land surface elevation and note coordinate collection method) as listed in the SAP or site-specific WP.
    - Coordinates should be measured to a known datum.
    - Monitoring well location coordinates should be submitted to DNREC-RS immediately following soil sample collection/well installation for timely incorporation in the DNREC EQuIS database.

Drilling Procedures

Three 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. The third type of well is installed in bedrock. These procedures are general and may not be typical for drilling at all sites. Before proceeding with any tasks at the facility, refer to the SAP or site-specific WP and the site-specific HASP. All monitoring well construction shall be completed in accordance with 7 DE Admin. Code 7301.

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

The following procedure describes construction of a monitoring well 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.

1. All well casing and screens shall be new and brought to the site enclosed in manufacturer's packaging. 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. The Division of Water has recommendations about where to set well screens based upon time of year[7]

[7] https://dnrec.delaware.gov/water/residential/well-permits/monitor-wells/

3. If monitoring for contaminants denser than water, drilling may proceed until the first confining layer is encountered. Specific knowledge of the regional geology shall determine how to identify confining layers during drilling. These details shall be placed in the site-specific SAP or site-specific WP. *Regulations Governing the Construction And Use of Wells* state that a confining layer is a stratum of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers. 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 at least three (3) feet above grade with a 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 protective steel casing may be replaced with a protective steel manhole which is finished flush with surface grade.

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

Wells installed in an unconsolidated 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. To prevent cross contamination of aquifers, specific knowledge of the regional geology shall determine how to identify confining layers during drilling. These details shall be placed in the site-specific SAP or site-specific WP. The appropriate type of drilling rig to drill through the worst expected conditions at a site shall be used. Refer to Delaware Regulations for gravel pack and grouting requirements. 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 one 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 (also known as telescoping). A well will then be constructed in this borehole in the same manner as described in steps 1 through 5 above.

Wells installed in Bedrock Aquifers

The following are list of considerations when installing monitoring wells into consolidated (bedrock) formations:

- The overburden (unconsolidated soil and/or saprolite) shall be cased-off in the same manner as described above.
- It is highly recommended that down-hole geophysics be completed on open bedrock wells prior to well installation.
- If installing boreholes in fractured bedrock, the need to prevent cross-contamination of contaminated fracture zones is critical.
- If multiple fracture zones are to be monitored, nested wells, dedicated well clusters or a specialized multi-level monitoring system should be considered.
- When installing a well in fractured rock, it may be possible to leave an open borehole, depending upon the competency of the rock.

The specific procedures of installing this type of monitoring wells should be outlined in the SAP or site-specific WP. All considerations should be detailed and approved prior to work beginning at the site. Any wastes containing Portland cement should not be mixed with other IDW to prevent the generated IDW (either solid or liquid) from potentially being classified as hazardous.

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. Bailers should not be used to develop a monitoring well.

The development of a monitoring well shall commence following a 24-hour curing of the grout used to complete the well in accordance with 7 DE Admin. C 7301 Sec. 5.8.10. The two 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 movement of a plunger or surge block up and down within the well casing similar to a piston in a cylinder. The use of air to assist in development of a well must be carefully considered based upon the type of contaminants discovered or potentially present at a site.

Materials Required

The following materials will be required for well development:

- Pump of appropriate type and capacity;
- Surge block or another surging tool;
- A water quality meter that can measure the following parameters: temperature, pH, specific electrical conductance (SEC), oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity;
- Electric well sounder or other measuring tape;
- Containers for measuring the volume of and temporarily storing purged water, if required by site Contaminated Materials Management Plan (CMMP).
- Containers for contaminated groundwater or carbon treatment system for discharge to the ground surface.

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 logbook. Place the pump into the well to ensure that water flows into it and activate the pump to remove some of the fine-grained materials from the well. The 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 process 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 at least 5 minutes then pump the well to rapidly remove at least one additional 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.

After surging, pump the well and begin monitoring water quality parameters, including temperature, pH, SEC, ORP, DO, and turbidity over 3-minute increments. If the water still appears to have sediment, additional surging can be performed on the well screen.

1. When these parameters have stabilized over at a minimum of three consecutive readings, the well will be considered developed. There should be a least four recorded readings. The stabilization criteria for pH, SEC, ORP, DO, and turbidity are included in **Table 2** below.
2. If the parameters have not stabilized and the water is visually clear, continue pumping the well to develop, but do not surge the well and continue to perform water quality readings.
3. When the parameters have stabilized over three consecutive readings at one well volume interval 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.

Table 2: Stabilization Criteria with References for Water-Quality-Indicator Parameters

Parameter	**Stabilization Criteria**	**Reference**
pH	+/- 0.1	Puls and Barcelona, 1996; Wilde et al., 1998
specific electrical conductance (SEC)	+/- 3%	Puls and Barcelona, 1996
oxidation-reduction potential (ORP)	+/- 10 millivolts	Puls and Barcelona, 1996
turbidity	+/- 10% (when turbidity is greater than 10 NTUs)	Puls and Barcelona, 1996; Wilde et al., 1998
dissolved oxygen (DO)	+/- 0.3 milligrams per liter	Wilde et al., 1998

All water removed must be managed as directed by the SAP, site-specific WP, or Contaminated Materials Management Plan (CMMP).

Record all data as required in the field logbook; 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.
- Characteristics of the development water.
- Equipment and technique used for development.

The time to develop a monitoring well may vary depending on aquifer and Formation conditions. Development should continue until little to no sediment is visible in the purge water and target values for water quality parameters have been achieved. Visual observation may be the best tool for most wells.

Monitoring Well Maintenance

After the installation of monitoring wells at a facility, the wells should be periodically maintained to ensure the integrity of the well construction. Proper integrity is important to ensure the data obtained from the well meets the DQOs to be used in the reporting to DNREC-RS. Failure to properly maintain the wells could jeopardize the validity of the groundwater samples collected from the monitoring well.

The final placement of wells will need to consider traffic, accessibility, and sampling logistics to account for future maintenance needs. The well owner is ultimately responsible for the care and upkeep of these wells. The maintenance schedule should consider factors such as sedimentation, descaling, potential biofouling, and flooding. If a monitoring well could be used for long-term monitoring, a maintenance schedule should be included with any Long-Term Stewardship (LTS) plan. The plan should include contingencies for any fouling factors and/or replacement costs. If a well needs to be replaced because the damage is beyond repair, notify the DNREC Project Officer of the need to repair, replace, and/or abandon the monitoring well. The *Regulations Governing the Construction And Use of Wells* should be followed.

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