Well Development
FSOP 2.2.1 (March 8, 2011)
Ohio EPA Division of Environmental Response and Revitalization

1.0 Scope and Applicability

1.1 This field standard operating procedure (FSOP) describes standard monitoring well development practices used by the Ohio EPA Division of Environmental Response and Revitalization (DERR) for both newly installed wells and redevelopment of existing wells. Monitoring wells installed and/or developed by DERR are typically 0.5-inch to 2.0-inch inside-diameter wells. The practices and equipment discussed in this procedure focus on effective development of small-diameter wells used for ground water sampling.

1.2 The practices and equipment described herein may or may not be appropriate for the development of larger (> 2.0-inch inside diameter) wells used for aquifer testing, ground water remediation, gradient control, or water supply purposes (ASTM, 1994). For such situations this FSOP may serve as only a general guidance. Development of larger diameter wells may require techniques or equipment that are not discussed in this FSOP. Additional reference materials may need to be reviewed, and the site-specific work plan may need to specify additional well development procedures.

1.3 Monitoring well development is performed to (1) remove fluids that may have been added during drilling or during the well construction process, (2) remove fine sediment from the vicinity of the well screen, and (3) ensure good hydraulic interconnection between the sand filter pack and the adjacent geologic materials (formation) in which the well screen is installed. Proper development is especially critical for wells used to evaluate turbidity-sensitive ground water constituents such as metals, and for wells used to evaluate hydraulic conductivity or ground water yield (Ohio EPA, February 2009).

1.4 The terms “well development” and “well purging” (the removal of water from a well) are not synonymous. While purging is an integral part of the overall well development effort, simply purging a monitoring well generally does not provide adequate development of the filter pack and surrounding formation.

1.5 For the purposes of this FSOP, development techniques include (1) surging and pumping, (2) purging with an inertial lift pump, (3) overpumping, and (4) bailing:

1.5.1 Surging and pumping may be performed using an electric submersible pump or a bladder pump with or without a surge block. The surge block may be a separate assembly or attached to the pump assembly. If a surge block is not available, then the pump must be of sufficient diameter and weight to effectively surge the well. “Surging” means forcing the flow of water back and forth through the filter pack. This action optimizes the hydraulic interconnection between the well and surrounding formation by (1) removing fine sediments and (2) grading (sorting) and stabilizing the filter pack and adjacent (unconsolidated) formation. Pumping may be performed during or after surging. Surging and pumping is the preferred technique for wells installed in bedrock, gravel, or sand. This technique should not be used for wells installed in silt or clay.

1.5.2 Purging with a manually operated inertial lift pump (e.g., a Waterra Pump™) may be used to develop monitoring wells installed in bedrock, gravel, sand, silt, or clay. This technique removes water and sediment more slowly than surging and pumping but is a very effective development technique that may be applied over a wider range of formation materials. A surge block attachment may be used in wells that screen mostly bedrock, gravel, or sand, and also wells that screen mostly silt provided that surging is performed gently for a short duration (e.g., three one-minute intervals). The surge block attachment should not be used when developing wells that screen mostly clay.

1.5.3 Overpumping is the process of repeatedly pumping the monitoring well at a relatively high rate (as compared to the well yield) to rapidly draw down the water level as far as possible, and then turning off the pump and allowing the well to recharge. Overpumping may be performed with a submersible pump or peristaltic pump (depending on the well yield). This technique will remove fine sediments from the well casing and filter pack, but does not grade (sort) the filter pack and therefore develops the well less effectively than surging and pumping or an inertial lift pump with a surge block. In addition, it is generally less effective than an inertial lift pump at removing sediment that has accumulated at the bottom of the well screen. Overpumping is an acceptable alternative for wells that screen mostly silt or clay.

1.5.4 Bailing can be used to develop monitoring wells installed in bedrock, gravel, sand, silt, and clay. However, bailing is not a very effective well development technique and should generally be avoided. Surging and pumping or purging with an inertial lift pump are much more effective techniques for wells that screen mostly bedrock, gravel, or sand. For wells that screen mostly silt or clay, purging with an inertial lift pump or overpumping are likely to produce better results.

1.6 Well development data should be recorded using the DERR Monitoring Well Development Form (attached).

1.7 Development techniques and documentation should support the project data quality objectives and work plan. Specific requirements for well development are at least partially project- and site-dependent, and therefore, the specific technique, level of effort, and associated data will vary between projects and sites. Not all information on the DERR Monitoring Well Development Form will be applicable to every project or site.

1.8 Deviations from this procedure should be documented with a brief explanation of the reason(s) for the deviation.

2.0 Definitions

Not applicable

3.0 Health and Safety Considerations

3.1 Always review the site-specific health and safety plan (HASP) before performing well development activities. The HASP should address any site-specific hazardous that may be associated with well development activities.

3.2 Due to likelihood of direct contact with ground water during well development, eye and dermal protection are strongly recommended.

3.3 If a portable generator is being used to operate a development pump, ensure that the generator is properly grounded to avoid electric shock.

4.0 Procedure Cautions

4.1 If a monitoring well has been installed using liquid grout to seal the annular space above the filter pack, well development activities should not be performed until the grout has set for at least 24 hours. Otherwise, development activities could damage the well by drawing uncured grout into the filter pack and well screen.

4.2 Monitoring wells that contain nonaqueous phase liquids (NAPL) should not be developed. Typically, the presence of NAPL is confirmed if an immiscible fluid layer at least 0.01 inches thick can be detected with an interface probe or clear bailer. Often, NAPL occurs in a discrete layer within the screened formation. Well development will distribute the NAPL throughout the filter pack and surrounding formation and generate purge water that is time-consuming and costly to dispose. In addition, development will likely cause subsequent NAPL recovery efforts to be more difficult, and compromise any attempt to collect a representative ground water sample from the well.

4.3 Excessively or vigorously surging a monitoring well can permanently damage the filter pack. As a general rule, small-diameter wells should not be surged for a time interval longer than three minutes before pumping or manually purging sediment-laden water from the well, and should not be surged for more than 15 minutes in total. Surging always should be performed slowly and gently.

4.4 As a general rule, monitoring wells that screen mostly clayey silt or clay should not be surged, because an excessive amount of fine sediment could be drawn into the filter pack and significantly reduce the hydraulic interconnection between the well and surrounding formation. Removing such sediment from the filter pack is very difficult, if not impossible. If surging is deemed necessary based on well performance concerns, it should be performed very slowly and gently and for short time intervals (e.g., no more than three one-minute intervals), each followed by evacuation of at least one well volume to remove sediment from the well.

4.5 Only stainless steel or weighted non-disposable PVC bailers should be used for well development. Disposable Polyethylene, Teflon, or PVC bailers designed for ground water sampling should not be used for well development.

4.6 If the measured total depth of a monitoring well indicates that more than 10 percent of the screen has filled with sediment, excess sediment should be removed by using a bailer or inertial lift pump before lowering an electric

submersible pump or bladder pump into the well. Operation of an electric submersible pump or bladder pump in a well with significant sediment accumulation may result in the pump becoming lodged ("sand locked") within the well screen or casing. Additionally, an excessive sediment load can damage the internal components of some electric submersible pumps.

5.0 Personnel Qualifications

Ohio EPA personnel working at sites that fall under the scope of OSHA's hazardous waste operations and emergency response standard (29 CFR 1910.120) must meet the training requirements described in that standard. In addition, field staff assigned to perform monitoring well development should be DERR or Division of Drinking and Ground Water personnel who have a background in hydrogeology and/or well development experience.

6.0 Equipment and Supplies

6.1 Equipment and supplies needed for every well development event regardless of technique or site-specific criteria:

- 6.1.1 Boring logs and well construction diagrams
- 6.1.2 Decontamination equipment and supplies (refer to FSOP 1.6, Sampling Equipment Decontamination)
- 6.1.3 Graduated bucket or other container to estimate purge volumes
- 6.1.4 Personal protective equipment (protective eyewear, gloves, and footwear at a minimum)
- 6.1.5 Plastic sheeting
- 6.1.6 Purge water containers
- 6.1.7 Watch or cell phone
- 6.1.8 Water level meter
- 6.1.9 DERR Monitoring Well Development Form

6.2 Equipment and supplies needed for well development depending on the technique or site-specific criteria:

- 6.2.1 Bladder pump system
- 6.2.2 Electric submersible pump system
- 6.2.3 Inertial lift pump system
- 6.2.4 Monitoring instruments required to evaluate the following purge water stabilization parameters: temperature, pH, specific conductance (conductivity), oxidation/reduction potential, turbidity, or dissolved oxygen
- 6.2.5 Peristaltic pump system
- 6.2.6 Photoionization Detector (PID) and/or Lower Explosive Limit/Oxygen (LEL/O_2) meter for health and safety monitoring
- 6.2.7 Stainless steel or PVC bailer
- 6.2.8 Surge block

7.0 Procedures

7.1 Review the boring log(s) and well construction diagram(s) to determine the most appropriate well development technique.

7.2 Initial field activities:

7.2.1 If concerns exist regarding potentially toxic or explosive atmospheres within the well casings, open each monitoring well and screen the atmosphere (1) within the breathing zone above the open well casing and (2) within the well casing with a PID and/or LEL/O_2 meter.

7.2.1.1 If volatile organic compound (VOC) concentrations or the percentage LEL *in the breathing zone* exceed the health and safety action levels provided in Table 1 of FSOP 1.1, Initial Site Entry or site-specific action levels, close and secure the monitoring well. Development of the well will need to be delayed until appropriate health and safety measures can be implemented.

7.2.1.2 If VOC concentrations or the percentage LEL *in the well casing* exceed the health and safety action levels provided in Table 1 of FSOP 1.1 or site-specific action levels but VOC concentrations or the percentage LEL in the breathing zone do not, continue monitoring the breathing zone continuously while performing well development activities.

7.2.1.3 Record health and safety monitoring data using the DERR Monitoring Well Development Form or a field logbook or field logsheets (e.g., ranges of PID and LEL measurement values).

7.2.2 Measure the static water level and total depth of each well scheduled to be developed that day. Record these data using the DERR Monitoring Well Development Form.

7.2.3 Calculate the volume of the static water column in each well scheduled to be developed. At least three well volumes must be removed from every well for development efforts to be considered complete (refer to Step 7.3.5). Further, stabilization parameters should be monitored based on well volumes (rather than arbitrary time intervals) to avoid purging too little water between successive stabilization parameter measurements and prematurely concluding that purge water stabilization has been attained (refer to Step 7.4.2).

One Well Volume (gal) = (Total Depth, ft **–** Static Water Level, ft) **x** 3.14 **x** (Well Radius, ft)^{2} **x** 7.48 gal/ft^{3}

One Well Volume (L) = (Total Depth, ft **–** Static Water Level, ft) **x** 3.14 **x** (Well Radius, ft)^{2} **x** 28.32 L/ft^{3}

The following table summarizes volume (gallons and liters) per foot (of casing/screen length) for 0.5- to 4-inch inside diameters wells:

Well Inside Diameter (inches)	Volume per Foot (gallons)	Volume per Foot (liters)
0.5	0.01	0.04
0.75	0.02	0.09
1.0	0.04	0.15
1.5	0.09	0.35
2.0	0.16	0.62
3.0	0.37	1.39
4.0	0.65	2.47

Ideally, one "well volume" should include the water contained in the filter pack surrounding the screen. However, the filter pack contribution is typically less than 25 percent of the total well volume, and therefore is not a critical consideration for well development in most situations. Either well volume calculation (with or without the filter pack contribution) may be used at the discretion of the District Office Site Coordinator (based on the recommendation of the DDAGW Geologist assigned to the site.) If the District Office Site Coordinator does not indicate a preference, SIFU staff will decide based on their best professional judgment. Calculating the well volume with filter pack contribution requires the saturated length of the filter pack interval (which is usually longer than the screen), the boring diameter, and an estimation of the filter pack porosity (typically 25 to 30 percent):

One Well Volume Including Filter Pack (gal) = [(Total Depth, ft **–** Static Water Level, ft) **x** 3.14 **x** (Well Radius, ft)^{2}] **x** 7.48 gal/ft^{3} **+** [Filter Pack Length, ft x 3.14 **x** ((Boring Radius, ft)^{2} **–** (Well Radius, ft)^{2}) **x** 0.25 or 0.30] **x** 7.48 gal/ft^{3}

7.2.4 Calibrate all field monitoring equipment that will be used for well development.

7.2.5 At each well location, set up the well development equipment on a plastic sheet to avoid possible cross contamination through direct contact with the ground. Clean 5-gallon buckets may be used to hold pump hoses, air lines, bailer rope, etc.

7.2.6 Compare the total depth measurement to the total depth shown on the well construction diagram. If the measured total depth indicates that more than 10 percent of the screen has filled with sediment, remove the excess

sediment by using a bailer or an inertial lift pump before lowering an electric submersible pump or bladder pump into the well.

7.3 Specific procedures for development techniques:

7.3.1 Surging and pumping: start at the top of the well screen and gradually work downwards in 2 to 3 foot intervals to the bottom of the well, surging slowly with a surge block, a pump equipped with a surge block, or the pump itself. Surge for two to three minutes and then pump the well to remove at least one well volume of sediment-laden water. After repeating this process three to five times, continue to pump the well at a sustainable rate.

7.3.2 Inertial lift pump:

7.3.2.1 If using an inertial lift pump with a surge block attachment, start at the top of the well screen and gradually work downwards in 2 to 3 foot intervals to the bottom of the well, surging slowly. Surge for two to three minutes and then purge the well to remove at least one well volume of sediment-laden water. After repeating this process three to five times, continue to purge the well at a sustainable rate. The pump foot valve should be within 2 inches of the bottom of the well during purging to remove sediment.

7.3.2.2 If using an inertial lift pump without a surge block attachment, purge the well at a sustainable rate. The pump foot valve should be within 2 inches of the bottom of the well during purging to remove sediment.

7.3.3 Overpumping: lower the pump intake to the top of the well screen. Purge the well at a pumping rate high enough to drawdown the water level to the pump intake. Turn off the pump, allowing the water level in the well to recover to at least two feet above the pump intake. Lower the pump approximately two feet deeper into the well screen and repeat the process. After repeating this process three to five times, continue to purge the well at a sustainable rate.

7.3.4 Bailing:

7.3.4.1 If using a bailer to develop a monitoring well installed in bedrock, gravel, sand, sandy silt, or silt, surge the screened interval with the bailer, using the same method as described in paragraph 7.3.1 above. While surging, *gently* tap the bailer on the bottom of the well to remove sediment. Remove at least one well volume of water after each period of surging. Continue to bail the well at a sustainable rate; bail from the top of the water column (do not lower the bailer into the screened interval) to avoid resurging the filter pack and re-elevating the turbidity.

7.3.4.2 If using a bailer to develop a monitoring well installed in silty clay or clay, initially purge the well by lowering the bailer to the bottom

of the well for each withdrawal so that it is lowered and raised through the entire length of the well screen (*do not surge as described in Step 7.3.1 above*). *Gently* tap the bailer on the bottom of the well to remove sediment. After three well volumes have been removed, continue to bail the well at a sustainable rate. Bail from the top of the water column (do not lower the bailer into the screened interval) to avoid resurging the filter pack and re-elevating the turbidity.

7.3.5 Continue well development using one or more of the procedures described above until (1) the sediment thickness remaining in the wells is less than 1 percent of the screen length or 0.1 ft (whichever is larger), (2) required purge-water stabilization parameters have stabilized, and (3) at least three well volumes of purge water have been removed. If purge water stabilization parameters are not monitored, continue development until the turbidity of the purge water appears to stabilize based on visual inspection.

7.3.6 Record well development procedures and the volume of water removed from the well using the DERR Monitoring Well Development Form.

7.4 Stabilization parameter monitoring:

7.4.1 The use of temperature, pH, and specific conductance as purge water stabilization parameters for well development is recommended, but not required. Depending on the project data quality objectives and associated work plan requirements, stabilization parameters may include temperature, pH, conductivity, oxidation-reduction potential, turbidity, or dissolved oxygen. If the work plan does not include well development stabilization parameters, the District Office Site Coordinator will decide which, if any, stabilization parameters will be monitored (based on the recommendation of the DDAGW Geologist assigned to the site.) If the District Office Site Coordinator does not indicate a preference, stabilization parameters will be monitored at the discretion of SIFU staff.

7.4.2 If stabilization parameters are monitored during well development collect at least three successive measurements for each parameter to evaluate stabilization criteria, and at least one well volume should be purged from the monitoring well prior to each successive measurement. The following table summarizes purge water stabilization criteria:

Purge Water Parameters	Stabilization Criteria
Temperature	0.5° C
pH	+/- 0.2 Standard Units (S.U.)
Specific Conductance	+/- 3%
Oxidation-Reduction Potential (ORP)	+/- 20 millivolts (mV)

Purge Water Parameters	Stabilization Criteria
Turbidity	< 10 Nephelometric Turbidity Units (NTUs) or +/- 10% for turbidity > or = 10 NTUs
Dissolved Oxygen (DO)	+/- 10% or 0.2 mg/l, whichever is greater

7.5 Water level and pumping/purging rate monitoring:

7.5.1 Monitoring the water level in the well is recommended during well development activities if possible. Record water level data using the DERR Monitoring Well Development Form.

7.5.2 Monitoring the pumping or purging rate is recommended during well development activities if possible. Record data for calculating pumping or purging rates (water volumes withdrawn over time) using the DERR Monitoring Well Development Form.

7.5.3 Water level data and pumping or purging rates can provide general information about the formation hydraulic conductivity and the well yield, which in turn may be helpful for selecting appropriate ground water sampling techniques or for locating additional monitoring wells during future assessment activities.

7.6 Upon completion of well development activities, ensure that each well is properly closed and secured.

7.7 Purge water and other waste disposal:

7.7.1 Refer to FSOP 1.7, Investigation Derived Wastes.

7.7.2 Well development water with concentrations of petroleum or hazardous substances exceeding Voluntary Action Program generic potable use standards [OAC 3745-300-08(D)(3)] must be containerized and properly disposed.

7.7.3 If well development water is suspected to be a hazardous waste, contact SIFU for assistance.

7.8 Monitoring well redevelopment is needed if more than 10 percent of the screened interval has filled with sediment. In addition, redevelopment may be needed if:

7.8.1 The well produces excessively turbid water as compared to the turbidity typically observed or measured during prior sampling events.

7.8.2 The well exhibits anomalously high or low water levels as compared to its range of historic water levels.

7.8.3 The well casing or surface seal is damaged and subsequently repaired. Surface water, soil, or other foreign materials may have entered the well after it was damaged and/or during its repair.

8.0 Data and Records Management

Refer to FSOP 1.3, Field Documentation.

9.0 Quality Assurance and Quality Control

Not applicable

10.0 Attachments

DERR Monitoring Well Development Form

11.0 References

ASTM, 1994, Standard Guide for Development of Ground-Water Monitoring Wells in Granular Aquifers, D 5521-94

FSOP 1.1, Initial Site Entry

FSOP 1.3, Field Documentation

FSOP 1.6, Sampling Equipment Decontamination

FSOP 1.7, Investigation Derived Wastes

Ohio EPA Division of Drinking and Ground Waters, February 2009, Technical Guidance Manual for Ground Water Investigations, Chapter 8: Monitoring Well Development, Maintenance, and Redevelopment

DERR Monitoring Well Development Form

Site Name:		Well Diameter (in):	Screen Length (ft):
Well ID:		Initial Well Depth (X.X ft):	Final Well Depth (X.XX ft):
Developer(s):		Initial Water Level (X.XX ft):	Total Volume Purged (gal or ml):
Start Date:	End Date:	Weather Conditions:	
General Comments:		Well Development Methods Used & Success of Development Effort:	

Method	Date	Time	Volume Purged (gal or ml)	Water Level (ft TOC)	Purge Rate (gal/min or L/min)	Stabilization Parameters					Observations (*e.g., sediment removed, purge water clarity, stabilization, odor, presence of NAPL*)
						Temp (°C)	pH (S.U.)	Spec. Cond. (µS/cm)	Turbidity (NTUs)	Other:	

Stabilization Parameter Criteria:	Temperature, +/- 0.5 °C	Specific Conductance (µS/cm) +/- 3%	Oxidation-Reduction Potential, +/- 20 mV
	pH, +/- 0.2 S.U.	Turbidity (NTUs), +/- 10% if higher than 10 NTUs	Dissolved Oxygen, +/- 10% or +/- 0.2 mg/L, whichever is higher