

GROUNDWATER MONITORING PLAN
for
Miller Excavating, Inc.
Stillwater, MN
Sand and Gravel Mining Operation

INTRODUCTION

Miller Excavating, Inc. (Miller) operates a sand and gravel mine on a 148 acre site located in Section 15, Township 30 North, Range 20W, in the Township of Stillwater in Washington County, Minnesota (Site). Miller has been operating in accordance with the current zoning ordinance and Conditional Use Permit. As part of Miller's 2022 Annual Operator Permit renewal request, Miller has requested to excavate 8 feet deeper than previously allowed, to elevation 806 feet above mean sea level (MSL) and is proposing to implement groundwater monitoring. The Township has required Miller to provide a new groundwater monitoring plan that includes a new on-site monitoring well network.

Miller is proposing to install on-site monitoring wells both upgradient and downgradient of the mining limits. A map showing the proposed monitoring well locations along with existing on-site wells is attached as Figure 1, Groundwater Testing Map. The monitoring wells will be installed by a MN licensed well driller and constructed so that the screens intersect the water table elevation of the sand and gravel aquifer. A third-party, independent accredited environmental testing company will collect the samples bi-annually from the three on-site monitoring wells and perform the analysis of the parameters listed in the section below. Miller will provide the results to the Township on an annual basis. All sampling, analysis, and reporting will be conducted in accordance with all Township, state and federal methods, procedures, rules and regulations.

SAMPLE PARAMETERS AND SCHEDULE

Groundwater monitoring will include collecting samples and recording water levels at each monitoring well. Sample collection and analysis will be performed by a third-party, independent accredited environmental testing company. Samples are to be tested for Diesel Range Organics (DRO), BETX (benzene, ethylbenzene, toluene and xylenes), pH, and temperature.

The groundwater contaminant of concern at a sand and gravel mining operation is diesel fuel which is stored on-site with secondary containment and used to operate on-site equipment. BETX are primary groundwater contaminants associated with spills of gasoline and diesel fuel because of their high water solubility and associated health risks. Detection of any of the BETX analytes in the groundwater is indicative of a diesel fuel spill or release. Testing for BETX analytes will enable faster detection of potential groundwater impacts potentially resulting from the mining operation and allow a faster response and mitigation if impairments are detected. All four of the BETX compounds have Maximum Contaminant Levels (MCLs) established by the federal government and Heath Risk Levels (HRLs) and Health Based

Values (HBVs) adopted by the Minnesota Department of Health (MDH). BETX results will be compared to the federal MCLs, the MDH HRLs and HBVs.

The following tables list the parameters to be collected for and analyzed. The tables provide the current federal and state drinking water criteria and the method detection and reporting limits for each parameter to be analyzed. These values are subject to change as state and federal values may change.

Table 1: Analytical Parameters, Methods, Reporting Limits, and Action Limits

Compound	CAS Number	Method	Method Detection Limit (ug/l)	Min. Reporting Limit (ug/l)	EPA MCLs (ug/l)	MPCA/MDH Groundwater Health Advisory Summary (ug/l)	Groundwater Action Limit (ug/l)
Benzene	71-43-2	8260D	0.071	1.0	5	2 HRL09	1.5
Ethylbenzene	100-41-4	8560D	0.28	1.0	700	40 HBV20	30
Toluene	108-88-3	8260D	0.10	1.0	1,000	70 HBV20	52.5
Xylenes	1330-20-7	8260D	0.57	2.0	10,000	300 HRL11	225
Diesel Range Organics	DRO	WI DRO	20	100	-	200 HBV	150

MCL: Maximum Contaminant Level (United States Environmental Protection Agency (EPA))

HRL: Health Risk Limits (MDH)

HBV: Health Based Values (MDH)

Table 2: Groundwater Monitoring Schedule

Sample Location	Parameter	Frequency	Report
Groundwater MW-1*, MW-2*, and MW-3*	DRO, BETX	Twice per year, samples to be collected in the same months every year	Lab to submit results to Miller within 14 days. Miller to provide analysis summary in the annual report to Township.
	Water Level Measurements	Twice per year, measurements to be taken in the same months every year	Submit results to Miller immediately. Miller to record results and include in annual report to the Township

*See Figure 1 for monitoring well locations. Reference Unique Well Identification Numbers for each well at each sampling event.

BACKGROUND CONCENTRATIONS

Monitoring well, MW-1, is to be installed upgradient of the mining operation. Groundwater will be collected from MW-1 to be analyzed annually along with the two downgradient monitoring wells, MW-2 and MW-3. All parameters listed in Table 1 above are to be sampled for from MW-1 and analyzed to establish existing background concentrations which can be used to compare to downgradient and future results.

FIELD SAMPLING PROCEDURES AND PROTOCOL

Field sampling will be performed by a third-party, independent accredited environmental company. A field sampling event is a single sampling of all three monitoring wells at the facility, and may stretch over a one to three day period. All field sampling will follow the procedures and protocol outlined in the Minnesota Pollution Control Agency's (MPCA) document Water Quality Program Sampling Procedures for Ground Water Monitoring Wells, July 1997 by Laura A. Triplett, as Reviewed and re-approved September 2006. This document is included in this report as Attachment A. Field sampling includes, but is not limited to field inspections, quality assurance and quality control (QA/QC), field measurements, well purging and stabilization, record keeping, sample collection, field filtering of samples as required, and sample preservation, handling and transport.

LABORATORY SAMPLE ANALYSIS

Sample analysis will be performed by a third-party, independent MDH accredited laboratory. All parameter analysis is to be performed in accordance with current federal and state standards. Report/detection limits are to be well below any applicable standards as provided in Table 1 above.

ACTIONS / ACTION LIMITS

Water Table Measurements: Review water table readings within 7 days of a measurement event.

Sample Analysis: Groundwater monitoring results are to be reported to Miller within 14 days of a sampling event. The results will be reviewed to determine if groundwater impacts may have occurred. Results of the two downgradient wells, MW-2 and MW-3, will be compared to the results of the upgradient well, MW-1, to determine if there is a notable increasing trend in contaminate concentrations that are above action levels. If an increasing trend is noted and verified, actions described in Table 3 below will be taken.

Table 3 below summarizes action limits and actions to be taken in the event that sampling results identify groundwater impacts. In addition to the action items identified below, MPCA will be notified and in accordance with state regulations, the operator will work with the MPCA to conduct the required investigations and remedial actions in accordance with state regulations. Final groundwater cleanup goals are site specific and dependent upon the suite of groundwater contaminants and the characteristics of the plume of impacted groundwater. Groundwater containing contaminants at concentrations below final groundwater cleanup goals should not cause adverse effects on human health or the environment as established by the MDH. The operator bears the cost of sampling and remediation.

Table 3: Action Limits/Actions

Monitoring ID	Action Limit	Action
Downgradient MW-2 MW-3	At or above 75% of the lowest guidance value established by MN for petroleum indicating volatile organic compounds (Table 1 above)	<ul style="list-style-type: none">• Resample within 14 days of receiving result to verify.• If the result is verified at or above 75% of the lowest MN guidance value, notify Township and MPCA within 7 days of receiving result.• Work with MPCA for appropriate remedial investigation/remedial action plan in accordance the MPCA rules.

REPORTING

All sampling results will be submitted to the Township on an annual basis unless sampling results exceed an action limit, then the reports will be sent to the Township, the County and the MPCA within seven days of receiving the result as described in Table 3 above. Amendments to this plan may be requested in the annual review, based on data collected over the course of the mining operation.

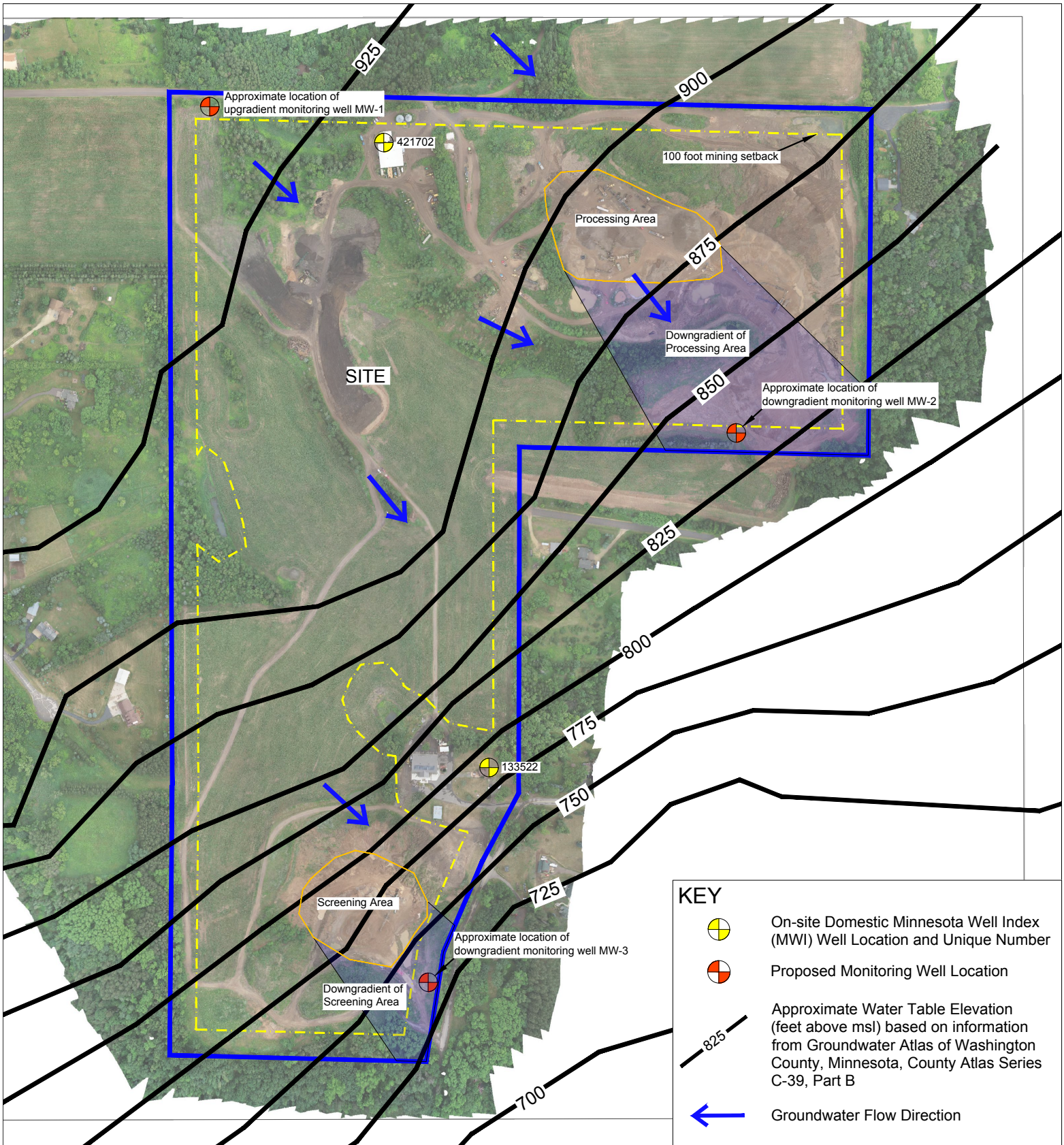
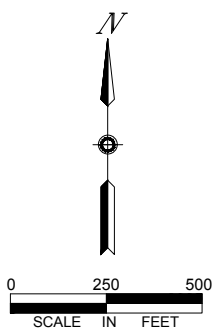


Figure 1
Groundwater Testing Map

Miller Excavating
Stillwater Township, Washington County, MN



ATTACHMENT A

Water Quality Program Sampling Procedures for Ground Water Monitoring Wells,
July 1997 by Laura A. Triplett, as Reviewed and re-approved September 2006.

MINNESOTA
MINNESOTA POLLUTION CONTROL AGENCY
WATER QUALITY DIVISION

SAMPLING PROCEDURES FOR
GROUND WATER MONITORING WELLS

July 1997;
Reviewed and re-approved September 2006*

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*September 2006 review by Municipal Water Quality Unit (contact Teri Roth)

Check the Minnesota Pollution Control Agency Internet Web site for the most recent version of this document:
<http://www.pca.state.mn.us/water/groundwater/sampleguide.html#part2>

This book is not a health and safety manual and should be supplemented with other references on recommended health and safety practices.

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Sampling Protocol For Ground Water Monitoring Well

1.0 INTRODUCTION

This document defines procedures to be used for ground water quality measurements and for collecting and handling ground water samples obtained from monitoring wells. These procedures shall be used for ground water quality measurements taken to meet the requirements of a National Pollutant Discharge Elimination System (NPDES) or State Disposal System (SDS) permit, or where referenced in any other enforceable document. This document shall be referenced as Water Quality Program Sampling Procedures for Ground Water Monitoring Wells, July 1997 by Laura A. Triplett. It is based on the Minnesota Pollution Control Agency Ground Water Sampling Guidance: Development of Sampling Plans, Protocols and Reports, 1995 by Tim Thurnblad, and it replaces Procedures for Ground Water Monitoring: Minnesota Pollution Control Agency Guidelines, December 1986 by Gretchen V. Sabel and Thomas P. Clark. This document takes effect on September 1, 1997.

This document is divided into 4 sections. Section one establishes applicability and provides an overview of the document; section two describes the decisions and preparations that should be addressed before sampling takes place; section three describes each step of the field sampling procedure; and section four contains a brief summary of the field sampling procedures for easy reference. There are five appendices which provide additional information and examples of forms referenced in this document.

Deviations from these procedures may be required by unforeseen circumstances that develop during the sampling event. Such deviations shall be approved by the hydrogeologist or the field crew leader and documented as described in the protocol.

2.0 BACKGROUND INFORMATION FOR SAMPLING

This section describes the decisions and preparations that should be addressed well in advance of the actual sampling event. A "sampling event" is a single sampling of all of the permitted wells at a facility, and may stretch over a one to three day period.

2.1 Selection Of Analytical Parameters

The selection of analytical parameters, which are generally analyzed in a laboratory, shall be dictated by the individual NPDES/SDS or SDS permit. Specific conductance, temperature, and pH shall be measured in the field for all sampling events to assess well stabilization, as discussed in sections 2.5 and 3.4. Where measurement of trace metal concentration is required, reduction/oxidation potential (Eh) shall be measured in the field.

A state certified laboratory must perform the analysis of samples as required by the permit. The permittee should work closely with the laboratory analyzing the samples to ensure that sample collection and preservation methods meet their quality standards.

2.2 Detection Limits

Except where noted, detection limits must be at or below the intervention limits in your permit. *Laboratories must report their practical quantitation limits in order to evaluate their ability to analyze data to meet this requirement.*

2.3 Quality Assurance For Field Procedures

Contamination Prevention

Contamination of samples can occur prior to and during sampling. Good management and quality control can minimize the chances of contamination. Exercise care to avoid the following common ways in which cross-contamination or background contamination can occur:

- storing or transporting sampling equipment improperly
- contaminating equipment or sample bottles on site by setting them on or near potential contamination sources such as uncovered ground, a contaminated vehicle, vehicle exhaust, or blowing dust
- handling bottles or equipment with dirty hands or gloves
- cleaning well purging or sampling devices inadequately

Prevent cross-contamination of sampling equipment, sampling bottles, or anything else that could potentially compromise the integrity of samples. Field personnel should assume that contamination exists on the soil surface and vegetation, near sampling points, in wash water, etc.

Minimize exposure to these media by taking the following precautions:

- minimize the amount of rinse water left on washed materials
- minimize the time sampling containers are exposed to airborne dust or volatile contaminants in the air
- place equipment on clean ground-covering materials instead of on the ground

All field crew shall wear clean gloves made of appropriately inert material. Keep gloves clean while handling sampling-related materials. Replace gloves with a new pair when soiled and between each sampling site.

Decontamination, Storage, and Transport of Equipment

In order to obtain valid ground water monitoring results, it is important that equipment used for sampling is decontaminated after each use, and stored and transported properly. This section outlines accepted practices for decontamination, storage, and transportation of equipment.

Before mobilizing for field work or performing any decontamination, select and evaluate a source of control water of known chemistry and organic-free reagent grade deionized water. Ten percent nitric or hydrochloric acid solution made from reagent grade acid and deionized water wq-gw1-01

shall be used as the inorganic desorbing agent. The organic desorbing agent shall be hexane, or pesticide grade isopropanol. *{The user is responsible for verifying that the procedures and materials discussed below present no potential health, safety, or materials incompatibility problems for the specific situation. At highly contaminated sites, additional measures may be necessary to minimize the spread of contaminants on site or beyond site boundaries.}*

Decontaminate equipment in the following manner:

1. **Equipment that does not contact sample water or the inside of the well**
 - clean inside and outside where possible, with clean water and a phosphate-free detergent/clean-water solution, applied with a scrub brush, where practical
 - rinse three times with clean control water
 - inspect for remaining particles or surface film and repeat cleaning and rinse procedures if necessary
2. **Equipment that contacts sample water or the inside of the well**
 - clean inside and the outside where possible with a phosphate-free detergent/clean-water solution - applied with a scrub brush made of inert materials.
 - rinse three times with clean control water
 - inspect for remaining particles or surface film and repeat cleaning and rinse procedures if necessary
3. **For sites that require sampling of volatile or semi-volatile organics**
 - rinse with an inorganic desorbing agent in the laboratory
 - rinse with clean control water
 - rinse with an organic desorbing agent: for example, hexane
 - rinse thoroughly with laboratory controlled deionized water
 - shake off remaining water and allow to air dry
 - do NOT reuse equipment such as bailers and tubing when testing for organics

Thoroughly clean equipment used during purging or sampling (including the water elevation meter) prior to use in each individual well. Decontaminate pump bladders by circulating decontamination fluids through the pump after working at each sampling point. After cleaning, inspect the equipment visually to detect sticky residues or other substances that may survive normal cleaning. If inspection reveals that decontamination was insufficient, implement additional measures as necessary and document that activity.

Clean the internal surfaces of pumps and tubing that cannot be adequately cleaned by the above methods alone by circulating decontamination fluids through them. Exercise special care to ensure that the rinse fluids are circulated in sufficient quantities to completely flush out contaminants, detergents and desorbing agents.

Use new pump tubing the first time each well is sampled and then discard. Alternatively, pump tubing may be dedicated to a single well for subsequent sampling events. Between sampling events, decontaminate dedicated tubing in a laboratory setting and store in a sealed, chemically inert plastic bag. Label the bag with the well name and store in a secure, clean location. Sampling pumps and tubing that are permanently installed and dedicated to individual wells are exempt from field decontamination. Handle all equipment in a manner that shall minimize cross-contamination between wells and avoid introducing surface or ambient air contamination into a well.

When transporting or storing equipment after cleaning, protect the equipment in a manner that minimizes the potential for contamination. Enclose sampling pumps totally in a clean case. If used pumps are transported in the case, decontaminate the case as described above before using again. Place tubing in a clean, inert plastic bag. Wrap bailers in inert plastic or aluminum foil.

Field Blanks and Replicates

Field blanks and replicates are used to ensure the accuracy of analytical results and to identify field contamination problems. These are a critical part of the Quality Assurance/Quality Control (QA/QC) for the sampling event.

{One "set" of samples refers to all of the samples collected at a single well in one sampling event.}

Assign all QA/QC samples identification aliases on the sample bottle label to avoid alerting laboratories that the sample is a blank or replicate sample.

Record the true identity of the QA/QC samples in the field sampling log.

All facilities are required to take one set of QA/QC samples. When a permitted facility has more than ten wells, take one set of QA/QC samples for every ten wells. The following schedule applies:

Collection Schedule and Analysis of QA/QC Samples:

⇒ one field methods (equipment) blank for every sampling event, plus one for every additional group of ten wells.

⇒ one replicate (duplicate) sample set for every ten sets of samples collected. Replicates shall be collected and analyzed for each parameter required by the facility's permit.

⇒ one trip blank for every sampling event where VOCs are monitored.

Field methods (equipment) blank: These blanks should reflect all of the potential exposures to background contamination and cross-contamination. Collect blanks in the field at the same time the primary samples are collected. Use the same type of container for each blank as for the actual sample.

In the field, clean, organic-free deionized water should be run through all of the same tubes, sample collection devices, filters, etc., that actual samples encounter. All containers shall be pre-cleaned within the laboratory's QA/QC program in the same manner as primary sample bottles. Fill the blank containers in the field.

Use laboratory-controlled, deionized water to fill all organic blank samples. Fill trace metals blanks with laboratory-prepared, triple deionized water. Add the same preservatives to both the methods blank and the primary samples. The field blank water shall contact all the equipment surfaces that the sample water shall contact.

Replicate (duplicate) sample: Replicate samples are collected to evaluate variability in analytical methods. Collect field replicate samples of actual ground water for each parameter in the facility's monitoring requirements. Fill the replicate sample bottles as closely as possible to the time the actual samples are taken. All containers shall be filled as close together in time as practical with a sampling stream that is steady and continuous.

Do not sample all replicates together. Collect each replicate sample after the primary sample from each parameter group is collected. For example, after the primary trace metal sample is collected, the replicate trace metal sample is collected, then the VOCs, and so on. All of the replicate samples should be acquired at one well; essentially, two sample sets shall be collected at one of the wells during the sampling event. *{If you are required to sample more than ten wells at your facility, one replicate sample set shall be collected at one in every ten wells.}*

Trip blank: A trip blank is used to detect contaminants that might leak into sample containers during transportation, on-site storage, or storage in the laboratory. Clean, organic-free deionized water should be placed in a sample container in the field, and then be treated as a sample during storage and transport. Trip blanks are most important for facilities that monitor trace metals and/or organics.

2.4 Sampling Containers And Preservatives

In most cases, laboratories shall supply containers and preservatives needed for sampling. The correct sampling containers and preservatives to be used for each parameter group are identified in Appendix 1. Coordination with the laboratory conducting analyses is necessary to determine whether preservatives are added to bottles in the field or in the laboratory.

2.5 Field Water-Quality Measurements

Measure specific conductance, pH, and temperature in the field during purging to determine well stabilization (Section 3.4). When trace metals are monitored, reduction/oxidation potential (Eh) must also be measured. Record the calibration information and all measurements on the Well Purging - Field Water-Quality Measurements Form or approved equivalent form. Note measurement conditions and the steady-state value for each field water-quality parameter on the Sampling Form (forms described in Section 3.1).

Water Quality Measurements with a Flow Cell

{For the definition of a flow cell, see Appendix 2.}

When a pump is used, we recommend that all measurements be taken within a closed flow cell designed to allow measurement of these parameters while minimizing changes in temperature, pressure, and dissolved gases from the in-situ aquifer environment. If a flow cell is not available, steps should be taken to minimize exposure to air and direct sunlight, and measurements should be taken as quickly as possible.

- Maintain a continuous and steady flow of sample water through the flow cell, as practical, throughout the measurement period.
- Keep discharge velocities through the flow cell low to prevent problems of streaming potential with probes.
- Fully immerse all probes without touching the sides of the air tight, non-metallic flow cell.
- Allow all probes to equilibrate with fresh aquifer water for five minutes before beginning to record measurements.

Allow all probes to equilibrate with fresh aquifer water for five minutes before beginning to record measurements

Water Quality Measurements without a Flow Cell

When a bailer is used, or a flow cell is not available, carefully pour sample water from the bailer (or pump discharge line) into a clean container which minimizes exposure to sunlight and the atmosphere. Probes shall be allowed to equilibrate with fresh aquifer water. When the readings are reasonably stable, measurements shall be recorded. Specific procedural details for measurement of individual field water quality parameters are discussed below. Follow general care, maintenance, calibration procedures, and operation instructions as specified in the instruction/owner's manual for each measurement device.

Specific Conductance: Store the conductivity probe according to manufacturer specifications, and inspect it to be sure it is in good condition with no chips in the coating. Calibrate the conductivity meter each day before taking measurements at the first site. Record the reading taken in the calibration standard. Compare this reading with the chart value for the standard reference solution at the temperature of the solution. Follow the measurement procedures in the manufacturer's instructions. Measure and record the specific conductance to the nearest 10 $\mu\text{mhos/cm}$. The specific conductance, rather than the electrical conductance, shall be used to determine when the well is stabilized.

Temperature: At the beginning of each day of field operations, inspect the temperature probe. To ensure that the temperature probe is in good operating condition, immerse the probe and a mercury thermometer capable of being read to the nearest 0.1 degrees Celsius in a water bath, and compare the readings. Measure and record ground water temperature readings to the nearest 0.1 degrees Celsius.

pH: Personnel using pH measuring equipment shall read the manufacturer's instruction manual carefully before recording any measurements. This equipment must be handled carefully, including all steps from taking the cap off the electrode to keeping the electrode tip moist between sampling points. Take special care to protect the fragile glass bulb on the end of the pH electrode. Do not touch the electrode, or allow it to freeze.

Before beginning sampling for the day, calibrate the pH meter using a two-point calibration method or according to the manufacturer's specifications (if using manufacturer's specifications disregard the following instructions). If the meter holds its slope well over time, routine calibration later in the day can be accomplished by calibrating the meter with only one buffer. The single buffer calibration shall normally be accomplished using a pH = 7 buffer for natural waters. At a minimum, calibrate the pH meter

using a single-point calibration method before taking measurements at each new sampling point or every two hours, whichever comes first.

For the two-point calibration method, use two buffers with pH values representative of the range of values expected in the field to check the slope of the meter. Typically, a pair of buffers with pH = 4 and 7 or, alternately, of pH = 7 and 10 shall be used for the two-point calibration. Refer to the manufacturer's instructions regarding the variability of the buffers due to temperature, and make adjustments accordingly. Under extreme or variable temperature conditions, place the buffers in a water bath from the well discharge to minimize temperature-correction errors.

Use only fresh buffer solutions. Take precautions to prevent dilution or contamination of the buffer solutions. Discard buffer solutions after the tenth calibration or four weeks after the first use of the solution, whichever occurs first. Measure and record pH to the nearest 0.1 units.

Reduction/Oxidation Potential (Eh): Measure the Eh (also called redox potential) only at sites where trace metal samples are taken. The most common way of measuring Eh is to use a pH meter with redox probes attached to it. Carefully pre-treat platinum electrodes according to the manufacturer's instructions, and store them in an oxygen-scavenging solution of 0.2 M sodium sulfide because the probes are sensitive to the presence of oxygen.

Replace the redox probes after each sampling day after exposure to water containing oxygen, as variations of several hundred mV have been observed between used and fresh electrodes. Follow manufacturer recommendations when calibrating the redox probe. During calibration, gently stir the solution. Measure and record Eh to the nearest millivolt (mV).

2.6 Purging And Sampling Equipment

Selection of equipment for purging and sampling depends on your sampling objectives and the parameters to be analyzed. For assistance with selection of appropriate equipment for your project, please contact the MPCA hydrogeologist assigned to your facility.

The most common types of well purging and sampling equipment include the following:

- Pumps: for instance, two-inch nominal diameter stainless-steel positive-displacement submersible bladder pumps or low flow variable-speed electric submersible pumps with Teflon[®] bladder
- Pump discharge lines: new or dedicated Teflon[®] tubing
- Regulators and compressed nitrogen or air tanks

- Bailers
- Flow through cells
- Miscellaneous equipment: rope, generators, air compressors with air filter, etc.

Equipment description and specification details, and equipment inspection and maintenance schedules must be available at the facility upon request.

2.7 Order Of Sampling

Where water quality data are available, purge and sample the least contaminated wells first, and proceed to increasingly contaminated wells. Where the distribution of contaminants is not known, begin with wells considered to be upgradient from likely sources of contamination and finish with the downgradient wells closest to the suspected contamination. Where application of the term "upgradient" may not be applicable and previous water quality data are not available, purge and sample wells considered to be background wells first. Collect the ground water sample immediately after purging. Complete purging and sample collection at each well before moving on to the next. Keep records of the order in which wells are sampled, and make them available to the Agency upon request.

2.8 Selection of Purging Rate

The purpose of purging wells is to remove stagnant water from within the well casing so that samples collected are representative of the ground water at the sampling location. To purge the well, pump or bail to remove this stagnant water. Once the well contains fresh ground water, the well is considered to be stabilized and ready for sample collection.

Because wells recharge with water at different rates, the pumping rate and purging method must be adjusted to avoid conditions in the well which changes the ground water characteristics (for example, aeration). In order to determine the rate of purging which should be used, characterization of the formation recharge rate is needed. This information can be obtained from a variety of sources. If information to determine the recharge rate is not available, the appropriate pumping rate can be determined in the field. The Pumping and Sampling Rate Test Form in Appendix 5 can be used to determine the correct pumping rate. Instructions for completing this test are included on the back of the form.

This document contains methods for purging medium to high yield wells (wells which can be purged at rates between 100 - 200 ml/min) and Low Yield Wells (wells which cannot be purged at rates between 100 - 200 ml/min). See Section 3.4 for information on how to purge these two categories of wells.

2.9 Alternatives for Sample Collection

Ground water samples can be collected using pumps or bailers. Pumps **must** be used to collect samples when testing for volatile organic compounds, and are highly recommended for monitoring other parameters as well. This is because there is less chance for sample contamination when using pumps than there is when using bailers. If pumps are not available, Teflon or stainless steel bailers may be used. The use of any other devices for sample collection must be approved by the MPCA hydrogeologist prior to sampling. Note the type of pump or bailer that was used to sample each well on the Sampling Form.

Sample Collection with a Pump

A two-inch submersible bladder or low flow variable speed submersible pump (e.g. Well Wizard or Grundfos Rediflo) shall be used as the default device for sample collection. Peristaltic pumps are also acceptable, except where trace metals and VOCs are monitored. In most cases, the pump intake setting should be approximately two feet from the top of the static water elevation. Record the approximate depth of the pump intake setting. Pump continuously, and sample immediately following purging using the same pump and the same purging rate for both procedures. If pumping is not continuous, note it on the Sampling Form.

Sample Collection with a Bailer

Use a thoroughly decontaminated stainless steel or PTFE-coated bailer retrieval line when sampling for metals and semi-volatile organics. If rope is used for the bailer retrieval line, evaluate its potential to interfere with sample integrity. Do not reuse the rope. Follow these guidelines for optimal sample collection:

- Do not allow either the bailer or the retrieval line to touch dirty hands or gloves, the ground, a dirty ground cloth, or any other potentially contaminated surface during the purging or sampling process.
- Keep track of where the top of the water column is and make sure that the bailer enters the water column gently during both purging and sampling.
- Withdraw the bailer gently from the water column.
- Keep check valves clear of sediment and inspect to make sure they are operating effectively to minimize the amount of water that drips back into the well.
- Use the same device for purging and sampling. If this is not possible, regard at least the first two bails of sample water as rinse water and discard.
- When collecting a sample, raise the sample to the surface immediately. After surfacing from the water column, continue to raise the sample slowly and carefully.
- Transfer the sample from the bailer to the sample

vessel quickly while minimizing turbulence and exposure to the atmosphere.

- Use a bottom-emptying device that delivers water from the bottom of the bailer at an appropriately low rate that results in a controlled, non-turbulent flow.

3.0 FIELD PROTOCOL

This section describes procedures for sampling of monitoring wells in the field. Field decisions to make minor changes to this protocol can be made by the field crew leader. The project manager shall review field decisions at the end of the day to decide whether or not any wells need to be re-sampled. The project manager shall review any changes to the protocol that may adversely affect results.

Exceptions to this protocol shall be noted on the Ground Water Sampling Information Form and detailed in a report included with the Discharge Monitoring Report (DMR).

The report shall include:

- the reason for the exception
- the identification of all samples and individual parameters that may have been impacted either in terms of the quantitative or legal integrity of their reported values
- the significance of the potential impacts to the integrity of each parameter for each sample
- Significant changes to this protocol require approval obtained in advance from a MPCA hydrogeologist.

3.1 Sample Documentation

For each step in this section, one or more of the forms from Appendix 5:

- Ground Water Sampling Information Form (Sampling Form)
- Water-level Data Form
- Well Purging/Field Water Quality Measurements Form
- Purging and Sampling Rate Test Form

The Sampling Form, or another form containing the same information, shall be completed at each sampling point in the field. The other forms may be used as needed. All of the completed forms should be kept at the facility. Monitoring data required by the MPCA should be submitted on pre-printed forms supplied to each facility by the MPCA (for instance, DMRs). Monitoring data may also be submitted via Electronic Data Transfer.

each laboratory

- 6) an alias cross-reference list for QA/QC samples if needed

Sample Identification

All primary and QA/QC samples collected at a given sampling point over a discrete interval of time shall be assigned the same sample event ID. This ID is used to link that set of containers together and associate them with all of the information contained on the Sampling Form or approved equivalent.

Label each sample container with the following information using a waterproof marker on firmly affixed, water-resistant labels:

- ⇒ site name
- ⇒ unique container ID #
- ⇒ sample collection date
- ⇒ sample collection time
- ⇒ initials of person collecting sample
- ⇒ parameter names/groups to be analyzed
- ⇒ preservation method

Label containers at the sampling location and at the time of sample collection, with the following exceptions:

- Containers receiving preservatives in advance, “parameter names” and “preservation method” shall be entered onto labels by laboratory staff.
- Containers receiving preservatives in the field, “preservation method” shall be entered onto labels at the time individual containers are filled.

Field Sampling Log

The leader of the field sampling crew shall keep a daily field log of sampling activities. This record or log shall supplement information entered on the Sampling Form. At a minimum, the log shall contain a record of the following items:

- 1) a list of field personnel present
- 2) field conditions as described below in Section 3.2, “Field Inspection”
- 3) a summary of how samples were transferred/transported to laboratories
- 4) a description of exceptions to this protocol, identifying which samples may have been impacted by the exceptions
- 5) for each well sampled:
 - the unique identifier used to label samples
 - the well name and Minnesota unique well number
 - the date and time of sampling
 - a list of primary and QA/QC samples sent to

3.2 STEP 1: Field Inspection

FORMS NEEDED: Ground Water Sampling Information Form

Upon arrival at each monitoring well, inspect the well to verify that the annular seal is intact at the surface. Note missing parts, missing labels, missing locks, well damage, or signs of tampering. Note any relevant information regarding the general physical condition of the well, the surrounding soil and vegetation, or other objects in the immediate vicinity of the well. If you discover any condition that may interfere with obtaining representative analytical results, note the condition and rectify the situation if possible before sampling. Record any unusual condition, including the presence of wind-blown dust or odor in the ambient air.

The sampling summary must include information about any unusual field conditions that had a significant impact on the integrity of results. The field conditions report must include:

- air temperature
- wind speed and direction
- precipitation/moisture
- ambient odors
- airborne dust

Record field conditions on the Ground Water Sampling Information Form. Unlock the well and remove the inner riser cap to a clean storage spot.

3.3 STEP 2: Depth and Elevation Measurements

FORMS NEEDED: Water Level Data Form (optional) Ground Water Sampling Information Form

Prior to any well evacuation or sampling, measure initial static water levels to the nearest 0.01 feet and record. This is done to facilitate selection of the proper pump intake depths for purging and sampling, and calculation of the ground water flow direction. We recommend use of an electronic water-level sensor that indicates, with a light or tone, when the sensor contacts water.

The depth to water shall be referenced to the measuring point marked at the top of the innermost well casing. Where a measuring point has not been marked at the top of the innermost casing, the measuring point shall be assumed

to be at the top of the north side of the innermost casing.

When reporting, the absolute water level elevation, not the depth to ground water must be submitted. This can be determined by subtracting the depth to ground water from the surveyed elevation of the inner most casing. Record the water level elevation on the Sampling Form. You may also use the Water Level Data Form to record these measurements.

During initial static water level measurement, measure the water level twice at each well. If there is poor agreement between the first and second static water level measurements (i.e., a difference of more than 0.01 feet), evaluate the data for measurement errors, unsuspected pumping that may have caused transient changes in gradient, or other factors that might have impacted the accuracy of the measurement. If the disagreement cannot be reconciled, take a third static water level measurement at the sampling point in question to assess the water level and verify non-steady state conditions.

Decontaminate water level probes with phosphate-free detergent and rinse twice with deionized water. Begin calibrating field water quality instruments according to manufacturer's instructions.

3.4 STEP 3: Well Purging And Stabilization

*FORMS NEEDED: Well Purging - Field Water Quality Measurements Form (optional)
Ground Water Sampling Information Form
Purging and Sampling Rate Test Form (optional)*

The first step in purging wells is determining one water column volume. Well depth information is necessary for this calculation. See Appendix 3 for procedures for calculating this value. The instructions on the back of the Well Purging and Sampling Rate Test Form describe how to select the correct purging rate for monitoring wells. Once you have determined whether you have a medium to high yield well, or a low yield well, select the correct purging method below. While the well is being purged, water quality parameters described above in Section 2.5 shall be monitored in a flow cell or container.

If previous sampling indicates the need, or if directed by an MPCA hydrogeologist, collect purge water from contaminated wells for disposal in accordance with Minnesota Rules 7048 and 7060.

METHOD A. Medium to High Yield Wells (>100-200 ml/min.)

Wells that have recharge rates within this category shall be purged and sampled as described below. If you are sampling for volatile organics, you must use the Purging and Sampling Rate Test Form in Appendix 5 to determine an appropriate pumping rate. If you are not sampling for volatile organics, you may approximate the recharge rate of the aquifer and use that as your purging rate; that is, the well should NOT be "pumped dry". Purging must be conducted in a manner that removes "old" water in the well so it is replaced by fresh formation water.

Set equipment to remove water from a depth approximately two feet below the water surface.

Once pumping begins, vertical adjustment of the purging equipment intake should not be necessary because the pumping rate should approximate the aquifer yield. Collect samples for laboratory analysis only after:

(1) a minimum of three water column volumes has been purged, and (2) stabilization of field water-quality parameters has been demonstrated by meeting the target criteria defined below. If, after five or more water column volumes have been purged, field measurements have not stabilized, you may begin sample collection. Clearly document that stabilization has not been achieved on the Well Purging - Field Water Quality Measurements Form and in a report included with the DMR form.

Following is the purging and stabilization procedure for medium to high yield wells:

- 1) Determine the volume of water in one water column (see Appendix 3).
- 2) Set pump at approximately two feet below the water surface.
- 3) Begin purging. Remove one water column volume. Water should be pumped through a flow cell or placed in a clean container. Record the purging rate used. Avoid any significant amount of cascading or turbulence in the well.
- 4) Measure and record field water quality parameters after purging each water column volume or each partial water column volume, as applicable, to determine stabilization. The following target criteria for three consecutive measurements shall be used to define stabilization:
 - temperature +/- 0.1 degrees Celsius
 - specific conductance +/- 5%
 - pH +/- 0.1 units
- 5) Repeat steps 3 and 4 until the field water quality parameters are stable within the above tolerance limits. If field parameters do not stabilize after approximately five water column volumes, check operator procedures, equipment, and well construction information for potential problems.

- 6) The well is now ready for sampling. Sample immediately after purging. Well evacuation should be continuous between purging and sampling.

METHOD B. Low Yield Wells with Recovery (Wells that cannot be stabilized at purge rates of 100-200 ml/min.)

Normal purging may be impractical for a well installed in tight formation materials with an extremely slow recharge rate. In such a case, purge the well until it is nearly dry and allow it to partially recover one time before sampling. This may take up to a few hours. Sample the well as soon as possible after the evacuation. The pump intake setting may require adjustments during sampling in low recovery wells. Note the data and procedures clearly on the Sampling Form.

3.5 STEP 4: Sample Collection

FORMS NEEDED:

Ground water Sampling Information Form

Don protective gloves before collection of samples. Remember that field blanks, trip blanks and replicate samples are required for all sampling events, as described in Section 2.3.

Sample Filtration

Appendix 1 identifies which sample containers shall be filled with sample water that has been filtered in the field. Sample filtration shall be completed as follows:

- Flush the new filters with fresh sample water before collecting samples
- Connect the filter directly to the well sampling pump discharge line using positive pressure to force the sample through the filter. If a bailer is used, discharge the sample directly from the bailer into the filter apparatus
- From the filter, route the flow directly into the sample collection container
- Use a 0.45 micron pore size filter unless otherwise specified
- The flow rate shall not exceed 500 ml per minute.
- Minimize agitation and aeration of the sample
- Use Teflon tubing for the pump and filter discharge lines

Filling Sample Containers

Appendix 1 summarizes the sample container type, filling method, preservation method and holding time for each analytical parameter set. To clarify and supplement the

summary in Appendix 1, the manner in which containers shall be filled is described in Appendix 4.

Do not open individually prepared bottles until they are to be filled with water samples. Ensure that the sources of contamination listed in Section 2.3 are eliminated. Sampling personnel shall not touch the inside of sampling containers, bottle caps, or rim of sample containers. If contact occurs, replace sample containers.

At the well, field personnel shall label the bottles according to procedures described in Section 3.1. Use laboratory-prepared bottles to ensure quality control. Fill bottles with water to be analyzed in the following order (consult your permit for the parameters which are required for your facility):

- 1 major and minor ions
- 2 nitrogen (nitrate/nitrite, ammonia, Kjeldahl)
- 3 trace metals
- 4 volatile organics
- 5 semi-volatile organics
- 6 coliform bacteria
- 7 total organic carbon
- 8 total phosphorus
- 9 sulfide

Hold the sample water discharge point at the end of the tube as close to the sample container as possible without allowing the sample tubing to contact the container. At a minimum, sampling personnel should use their bodies to shield the sampling container from wind and airborne dust while filling. When strong winds, heavy rain, or dusty conditions are present, take additional precautions to avoid background interference, such as using a portable shelter at the well head.

At wells used for collecting QA/QC samples, those samples should be taken at this time. Refer to Section 2.3 for proper timing and filling of field method blanks, trip blanks, and replicate samples.

Do not rinse any sample bottles in the field or overfill sample bottles. Minimize turbulence during filling.

3.6 STEP 5: Sample Preservation, Handling and Transport

This section describes procedures that shall be followed between the time samples are collected and the time they are either shipped or delivered to an analytical laboratory.

Sample Preservation

Samples shall be preserved as described in Appendix 1. All chemical preservatives, added to containers in the

laboratory or field shall be produced and controlled within the laboratory's QA/QC program. Field supplies of preservatives and sample containers with pre-dosed preservatives shall be discarded and replaced according to the laboratory's schedule.

Keep all samples cool in the field by placing the samples in an insulated ice chest containing uncontaminated ice immediately after sample collection. Place the ice inside leak-proof plastic containers. Check the ice chest containing volatile organic compound samples for temperature and record. Record the temperature just before transporting samples and upon receipt at the laboratory to verify the sample temperatures.

Sample Handling And Transport

All ice chests shipped shall be labeled, both inside and outside, with a complete address and return address. Keep the samples at approximately 4 degrees C during transport to laboratories. Before transporting samples, field personnel shall perform the following tasks:

- Verify that laboratory personnel shall be present to receive samples when they arrive.
- Check labeling and documentation to ensure sample identity shall be clear to laboratory personnel.
- Hand deliver or ship samples in a manner that ensures samples shall remain cool, about 4 degrees Celsius, until received by laboratory personnel.

3.7 STEP 6: Closing the Well

After field record documentation is completed, the inner riser cap shall be replaced and the well shall be locked.

3.8 Reporting Sample Results to the MPCA

Ground water sampling data shall be submitted to the Minnesota Pollution Control Agency on a DMR or other form provided by the Agency by the 21 st day of the month following sampling, unless otherwise specified in the MPCA permit. Include copies of the following with the form:

- Data sheets completed by the laboratory after analysis of the samples.
- If there are any deviations from this Sampling Protocol, any unusual conditions at the well (such

as odor or free matter in the water), or if stabilization of the well was not reached, then this information should be detailed in a report and included with (NOT attached to) the DMR.

In the future, electronic submission of data may be possible.

All other forms completed during sampling shall remain at the facility for a minimum of five years and made available upon request.

4.0 SUMMARY OF SAMPLING PROTOCOL

This section is a general outline of the chain of events in the field. This section is for general reference only; samples must be taken in accordance with the detailed sampling protocol.

- 1) Inspect the well for damage, missing parts, labeling, and for evidence of tampering; document field conditions
- 2) Review equipment list; prepare area around well for sampling
- 3) Unlock well and remove inner riser cap to clean storage
- 4) Measure static water elevation; calculate water column volume
- 5) Calibrate equipment within specified operating limits; document
- 6) Document field work in the field log book and other appropriate forms such as the well purging form
- 7) Measure field parameters while simultaneously purging the well based on predetermined rates
- 8) Consult parameter list; adequately label sampling containers; don protective gloves
- 9) Collect the sample and field filter as appropriate, add preservatives as specified
- 10) Place the samples in a chilled shipment cooler
- 11) Prepare quality control samples, where applicable
- 12) Perform additional field analyses, if specified
- 13) Complete documentation for the well on sampling form
- 14) Replace inner riser cap and lock well
- 15) Decontaminate any reusable equipment and proceed to the next well
- 16) Initiate chain-of-custody controls, as requested by the individual laboratory
- 17) Ship the samples to the laboratory for analysis

**APPENDIX 1:
Sample Containers, Filling Method, Preservation and Holding Times**

<i>PARAMETER GROUP¹</i>	<i>BOTTLE² VOLUME/TY PE</i>	<i>FILL METHOD³</i>	<i>PRESERVATION</i>	<i>HOLDING TIME</i>
MAJOR & MINOR IONS	1L P	No head space	Cool	28 days
NITROGEN SERIES	250 ml P	Leave head space	H ₂ SO ₄ /pH<2 Lab, Cool	28 days
CYANIDE	500 ml P	Leave head space	NaOH/pH>12 Lab, Cool	14 days
TRACE METALS (unfiltered) (mercury)	500 ml P	Leave head space	HNO ₃ /pH<2 Lab, Cool	6 months 28 days
TRACE METALS (filtered) (mercury)	500 ml P	Filter 0.45 micron No head space	HNO ₃ /pH<2 Lab, Cool	6 months 28 days
CHROMIUM VI (unfiltered)	125 ml P	No head space	Cool	24 hours
CHROMIUM VI (filtered)	125 ml P	Filter 0.45 micron No head space	Cool	24 hours
MISCELLANEOUS	1 L P	No head space	Cool	
TDS and TSS				7 days
specific conductance-lab				28 days
VOLATILE ORGANICS	3 x 40 ml P & T	Positive meniscus	HCl/pH<2 Field, Cool	14 days to analysis
purgeable halocarbons purgeable aromatics non- halogenated volatiles				
NON-VOLATILE ORGANICS	2 x 1L AG	No head space	Cool	7 days/extraction 40 days/analysis
base-neutral/acid extractable organics phthalate esters phenols polynuclear aromatic hydrocarbons chlorinated herbicides organochlorinated pesticides & PCBs organophosphorus pesticide acid herbicides carbamate pesticides				
DIOXINS AND DIBENZO FURANS	1L AG	No head space	Cool	7 days/extraction 40 days/analysis

Table 1: Sample Containers, Filling Method, Preservation and Holding Times
(continued)

<i>PARAMETER¹</i>	<i>BOTTLE² VOLUME/TYPE</i>	<i>FILL METHOD³ Leave head space</i>	<i>PRESERVATION Cool</i>	<i>HOLDING TIME 6 hours</i>
TOTAL COLIFORM BACTERIA	125 ml P			
TOTAL ORGANIC CARBON	1 L G	Leave head space	H ₂ SO ₄ /pH<2 Lab, Cool	48 hours
TOTAL PHOSPHORUS	125 ml P	Leave head space	H ₂ SO ₄ /pH<2 Lab, Cool	28 days
SULFIDE	250 ml P	Leave head space	Zn(C ₂ H ₃ O ₂) ₂ *2H ₂ O & NaOH/pH>9 Lab, Cool	7 days
RADIUM, GROSS ALPHA, GROSS BETA	1 Gallon P	Leave head space	HNO ₃ /pH<2 Lab	6 months

(1) PARAMETER NAMES/GROUPS

Some of these parameter names actually represent groups of individual analytes.

(2) BOTTLE TYPE

L: liters;
 ml: milliliters;
 P: polyethylene;
 P & T: 40 ml purge and trap vial fitted with a Teflon® septum;
 G: glass bottle fitted with Teflon®-lined cap
 GG: glass bottle fitted with glass stopper
 AG: amber glass bottle fitted with Teflon®-lined cap

(3) FILL METHOD

Positive meniscus: fill container completely with zero head space resulting in a positive meniscus with no air bubbles in container, add acid and cap container quickly;
 No head space: fill container completely; container shall not be rinsed; overfilling shall be minimized.
 Leave head space: fill container about 90 to 95 % full - do not allow preservative (if present) to be diluted by overfilling container
 Fill from bottom : fill container completely from the bottom of container using tubing; allow several bottle-volumes of water to overflow before sealing bottle
 Filter 0.45 micron: filter in-line with positive pressure through a filter with 0.45 micron pore size.

(4) PRESERVATION

Cool: place container inside sealed Zip-Lock bag; place in cooler with sufficient ice to quickly bring temperature down to 4 degrees C and hold at approximately 4 degrees C until received by laboratory personnel
 HNO₃/pH<2: add a predetermined amount of high-purity HNO₃ to sample to bring the sample pH down to 2 or less;
 HCl/pH<2: add a predetermined amount of high-purity HCl to sample to bring the sample pH down to 2 or below;
 NaOH/pH>12: add a predetermined amount of high-purity NaOH to sample to bring the sample pH up to 12 or above;
 (for Cyanide, use 50% NaOH solution and add ascorbic acid if oxidizing agents are present)
 Zn(C₂H₃O₂)₂*2H₂O: predetermined amount added by laboratory staff to prevent oxidation of sulfide
 Field: preservative added in the field by field personnel
 Lab: preservative added to container in laboratory before going into the field

APPENDIX 2: FLOW CELLS

A flow cell has the following characteristics:

- Air tight fittings for installation of all probes.
- Intake is connected directly to the pump discharge line.
- Resides in a water bath kept at a temperature close to the in-situ ground water temperature.
- A discharge line approximately 3 feet long that is connected to the flow cell with an air tight connection.
- A maximum volume of no greater than five times the per minute volumetric rate of inflow to the cell to maintain measurement sensitivity to temporal changes in water quality.
- A minimum volume of 500 ml to provide enough thermal mass to minimize external temperature effects.
- The flow cell and lines shall be shielded from strong winds and from direct sunlight.

APPENDIX 3: CALCULATING THE WATER COLUMN VOLUME

One water column volume is defined as the amount of water in the well initially, prior to purging. This is equal to the volume of a cylinder with a height (h) inside the well and a diameter (d) equal to the diameter of the well casing and can be calculated as follows:

$$\text{Volume} = \pi \cdot (d/2)^2 \cdot h \cdot 7.48$$

Where:

$$\pi = 3.14$$

d = diameter of well in feet

h = height of water column from bottom of well in feet

7.48 = gallons/cubic foot

Volume = one water column volume in gallons

APPENDIX 4: PROPER FILLING OF SAMPLE CONTAINERS

Major and Minor Ions: Sample containers used for analysis of major and minor ions shall be filled completely with unfiltered sample water.

Nitrogen Series: Sample containers for nitrate/nitrite, ammonia and Kjeldahl analyses shall be prepared in advance by the laboratories with H₂SO₄ as a preservative, if required. [Consult your specific laboratory for its preferred method of nitrogen sample collection.] The containers shall be filled approximately 95% full (up to the neck) with unfiltered water.

Trace Metals: Sample containers for general ions and metals analysis shall be prepared in advance by the laboratories with HNO₃ as a preservative. This shall insure that samples shall be acidified as soon as they are collected. Containers shall be filled approximately 95% full.

The sample bottles for dissolved metals analysis shall be clearly labeled as “filtered.” Sample water shall be filtered through a 0.45 micron pore size filter unit before filling the laboratory prepared bottle. New filters shall be used for each sample. Samples shall be collected in a manner that minimizes turbulence and aeration, and then acidified immediately as described above. Plastic containers shall be used for sample collection. The acid shall be produced/controlled within the applicable QA/QC program to ensure that it is pure enough (e.g. Ultrex, or pure acid diluted with triply distilled water) with regard to metals to avoid a false positive analytical result.

Volatile Organics: The use of bailers for VOC sampling is strongly discouraged. The 40-ml purge and trap vials shall be filled in a manner that minimizes turbulence, entrapment of air and overfilling. They shall not be rinsed in the field but shall be completely filled in a manner that leaves a positive meniscus at the top of the vial

Hydrochloric acid prepared specifically for volatile organics analysis by the laboratory shall be used to preserve samples. The acid may be added to vials at the laboratory in advance of sampling, with extra caution exercised to minimize overfilling in the field. Alternatively, the acid may be added immediately after filling the vials in the field. Field personnel shall add the number of drops specified by the laboratory to bring the pH to less than or equal to pH = 2, and immediately cap the vials.

Semi-Volatile Organics: As defined here, semi-volatile organics include the following sets of parameters: base- neutral/acid extractable organics, phthalate esters, polychlorinated biphenyls (PCBs), phenols, polynuclear aromatic hydrocarbons, chlorinated herbicides, organochlorinated pesticides and PCBs, and organophosphorus pesticides. Containers shall be filled completely.

General Parameters: The sample containers for laboratory analysis of general parameters: anions, total dissolved solids, total suspended solids and alkalinity. The containers shall be filled completely and capped promptly.

Coliform Bacteria: Unfiltered sample water for coliform bacteria shall be collected in laboratory-supplied sterilized and pre-treated plastic containers. The containers shall be partially filled, leaving a one-inch head space. Nothing but atmospheric air and sample water should touch the inside and rim of the container or the inside and rim of the cap.

Total Organic Carbon and Total Phosphorus: Sample containers for TOC analyses are prepared with H₂SO₄ by the laboratory and shall be filled to about 95% capacity.

APPENDIX 5: EXAMPLE FORMS

Forms listed below are available at

<http://www.pca.state.mn.us/water/groundwater/sampleguide.html#part1>

- 1) **Ground Water Sampling Information Form (also referred to as “Sampling Form”)**. This form shall be used to record all field activities, including:
 - General Information
 - Sampling Station (Well) Details
 - Purging Information
 - Field Water-Quality Measurements and Observations
 - Sample Collection Information
- 2) **Water Level Data Form**. This form shall be used to record the water level in the well before purging, as detailed in Section 3.3 of this document.
- 3) **Well Purging - Field Water Quality Measurements Form**. This form shall be used to record the field water quality measurements during purging, as detailed in Section 2.5 and 3.4 of this document.
- 4) **Purging and Sampling Rate Test Form**. This form *may* be used during tests to determine what is an appropriate purging rate for a given well. The object of testing is to find a pumping rate that is:
 - high enough to complete purging and sampling in a reasonable length of time
 - low enough to not bring the water level below the top of the open (screened) interval
 - low enough to not cause so much drawdown that significant cascading (and associated aeration and turbulence) occurs

GROUND WATER SAMPLING INFORMATION FORM*

Sheet _____ of _____
Side 1 of 2*

General Information

Location (Site/Facility Name) _____ Sampling Point (common name) _____
 Project Name/# _____ Type (mon. well, spring, etc.) _____
 Field Personnel _____ Field Sample (Event) ID#* _____
 Sampling Organization _____ Facility ID (for IGWIS data entry) _____
 Weather ☀️ ? _____ Station ID (for IGWIS data entry) _____

Sampling Station (Well) Details

Read from left to right top -- bottom
 Well Depth (ft. below MP) _____ Casing Diameter (inches) _____ Open Interval (depth below GS) _____
 Static Depth to Water (below MP) _____ Static DTW (ft. below GS) _____ Date _____ Time _____
(0.01 ft.) (0.1 ft.) (0.1 ft.)
 Water Column Length (L) (ft.) _____ One WC Volume (cu. ft.) _____ One WC Volume (gals) _____
 Condition: Securely Locked? Y or N Station (Well) Damaged? Y or N Surface Contamination (visible)? Y or N

Purging

Read from left to right
 PID/FID Reading @ Wellhead* _____ Concentration _____ ppm Background Conc. _____ ppm
 Free Product (circle: LNAPL or DNAPL)* _____ Detected/Sampled? Y or N / Y or N Appearance _____
 Well Purging Equipment _____ Pump, bailer? _____ Type* _____
 Purging Date/Time _____ Start _____ / _____ Finish _____ / _____
 Pump/Bailer Intake Set at _____ Feet below MP _____ Avg. Purge Rate _____ gpm
 Amt. Purged before Sampling _____ Gals./WC Volumes _____ / _____ Purge Protocol of _____ WCV's met? Y or N

Field Water-Quality Measurements and Observations

Date/Time Measurements Began _____ / _____ Purge Rate for Measurements (gpm) _____
 Submersible Pump with direct line to Flow Cell used for all Field Water Quality Measurements? Y or N
 All Field Measurement Instruments Calibrated according to Protocol? Y or N
 All Field Water Quality Parameters Stabilized according to Protocol Criteria just before filling sample containers? Y or N
 The Measurements below Represent: (1) stabilization, (2) sample water collected, (3) both 1 and 2, (4) other*: _____
 Sample Appearance: _____ Odor: _____

Field Measurement	Value	Time (24 hour)	Comments*
Temperature	° C		
Electrical Conductivity	µMhos/cm		= meter reading x magnitude x k
Specific Conductance	µMhos/cm		EC corrected to 25 ° C
pH	Standard Units		
Dissolved Oxygen	mg/l		
Eh	mV		
Turbidity	NTU		

Sample Collection

Sampling Device (type of pump/bailer)* _____ Sample Medium (well water, LNAPL, etc.)* _____
 Permanently Installed Pump? Y or N Dedicated Equipment? Y or N Used Same Equip. for Purge? Y or N
 Pump Intake/Bailer Set at (ft. below MP) _____ Interval Samples Represent (ft. below GS) Top = _____ / Bottom = _____
 Date/Time Sampling Began _____ Date/Time Sampling Finished _____
 Depth to Water (ft. below MP) _____ Depth to Water (ft. below MP) _____
 QC Samples Collected? Y or N (see reverse*) Sample Withdrawal Rate _____ gpm

All Field Protocols were followed with no exceptions (Y, N); Enter Protocol Codes* 1. _____ 2. _____
 Remarks (1)* (include protocol exceptions) _____

Form Completed by _____ (sign in ink) Date _____

* Side 2 of this form contains definitions of abbreviations, protocol codes, additional room for equipment specification, QC sample description and other comments Form GWS #4
Revised 1-12-95

GROUND WATER SAMPLING INFORMATION FORM*
(Reverse side)

Sheet _____ of _____
Side 2 of 2

ABBREVIATIONS

ft.	feet	MP	Measuring Point	GS	Ground Surface
DTW	Depth to Water	WC	Water Column	cu. ft.	cubic feet
Y	Yes (circle if appropriate)	N	No (circle if appropriate)	gals	gallons
PID	Photo Ionization detector	FID	Flame Ionization detector	ppm	parts per million
gpm	gallons per minute	Amt.	amount	k	cell constant
EC	Electrical Conductivity	LNAPL	light non-aqueous phase liquid (floater)	DNAPL	dense non-aqueous phase liquid (sinker)

GENERAL INFORMATION

The "Field Sample (Event) ID#" should be constructed from the date and time that the first sample container of a purposefully associated set of sample containers is filled. This set of samples would normally be collected very closely together in time and include containers for a number of analytical parameters and QC samples. QC samples are normally assigned temporary aliases (see below) For example, if the first of a set of containers is filled at 1:30 PM on December 19, 1992, the Field Sample Event ID# for all containers in the set should be 9212191330.

WELL INFORMATION

The water column length (L) is calculated by subtracting the depth to water (DTW) from the well depth. $L = \text{well depth} - \text{DTW}$. However, both of these distances must be referenced to the same datum: either from the measuring point (MP) or from ground surface (GS). This form was designed with the assumption that both the well depth and static water level values are referenced to the MP.

For convenience, a blank was included to also enter depth to water below GS in case the well depth referenced to the MP is unknown or cannot be measured directly. In addition, this value will indicate where the static water level is relative to the open (screened) interval which is referenced to GS. For the calculation of L in this case, the "stick up", the distance from the MP to GS, needs to be looked up or measured in the field. If the MP is above GS, then the stick up is a positive number for this calculation. Enter the stick up distance here _____ ft. (to the nearest 0.1 ft.). $\text{DTW (from GS)} = \text{DTW (from MP)} - \text{stick up}$; $L = \text{well depth (from GS)} - \text{DTW (from GS)}$.

One water column volume = $\pi r^2 L$. The units conversion from cubic feet to gallons is as follows: $\pi r^2 [\text{ft.}^2] L [\text{ft.}] [7.48 \text{ gallons/ft}^3]$. $r = \text{well radius in feet}$ (since well specifications are normally given as diameter in inches, the diameter must be converted from inches to feet and then divided by one-half to yield r , in feet). Examples of well diameter/gallons per ft. of WC: 1"/0.041 gals; 2"/0.163; 4"/0.653; 6"/1.47; 8"/2.61.

PURGING

Measure the concentration of organic vapors inside the well immediately after removing the wellhead cap. On the front side of this form, circle whether a PID or a FID was used, then enter wellhead and ambient background readings. Here specify the calibration gas _____, lamp voltage _____ make & model # of the instrument here _____. If free product was detected, describe appearance, thickness, etc. (free product samples collected? { Y , N }): _____. Supplemental description of purging equipment: _____.

FIELD WATER QUALITY MEASUREMENTS AND OBSERVATIONS

If a flow cell was not used, describe how measurements were taken (note whether or not measurements were taken down hole): _____
Other Comments and Observations _____.

SAMPLE COLLECTION

Sampling equipment details (Mfgr., Model#, tubing, etc.): _____.

Quality Control Samples

Fictional sampling point name(s) and field sample event ID#(s) (aliases) can be used for QC samples on sample labels and chain of custody sheets to distinguish them from primary samples without tipping off laboratories. List aliases here to document their association with primary sample identifiers on front side of sheet. Name(s)/ID#(s) _____.
Indicate total # of QC samples collected: Replicates _____ Splits _____ Trip blanks _____ Field ambient air blanks _____ Field methods blanks _____.

Protocol codes: 1.

Indicate the type of sampling protocol followed by selecting from codes (A-F) below and entering it on the front of this form. Specify the name of the agency _____ and the name of the agency program _____ that approved the protocol. If none, write "none."
A) A slightly modified agency program standard sampling protocol, approved as a site-specific protocol
B) An unmodified or slightly modified agency program standard sampling protocol, approved as a non site-specific protocol
C) A non site-specific protocol approved by an agency
D) A detailed but non agency-approved, site-specific sampling protocol with adequate QA/QC procedures was followed;
E) A detailed but non agency-approved sampling protocol without adequate QA/QC procedures was followed;
F) None of the above protocol conditions were known to be met (comment): _____.

Protocol codes: 2

A) Sampling observed by _____ (agency) to meet all field protocols except as noted below: (agency signature) _____;
B) Sampling observed by "neutral" observer (signature) _____ approved by _____ (agency) to meet all field protocols except as noted below; (list the agency that approved observer)
C) Neither A or B applies (comment): _____.

PROTOCOL EXCEPTIONS

List/discuss protocol exceptions for sampling-related field work (attach additional sheets if necessary): _____

OTHER REMARKS(2)

Form GWS #4R

* Other forms normally used to support this form include GWS #1 for Purging & WQ Measurements, GWS #3 for Sample ID/Chain of Custody, GWS#4 for Water Levels. Revised 09-07-94

WATER LEVEL DATA FORM*

Project Name/# _____ Date(s) of Measurements _____
 Location (Site/Facility Name) _____ Facility ID (for IGWIS data entry only) _____
 Personnel (include affiliation) _____
 Water-Level Measurement Equipment (type., mfg., model #, serial #, etc.) _____

Station ID <small>(for IGWIS data entry)</small>	Well Name	Hold <small>(0.01 ft.)</small>	Cut <small>(0.01 ft.)</small>	DTW below MP <small>(0.01 ft.)</small>	User-Defined Field (optional)	Time <small>(24 hour)</small>	Measurement Qualifiers <small>(Use IGWIS codes from reverse side of form)</small>			Measurement by <small>(Initials)</small>	Comments <small>(for listing measurement device serial # when using more than one device of the same type, time well was last pumped, nearby pumping activity, recent recharge events, barometric pressure, MP information, MP elev. & WL elev. etc.)</small>
							Static Water Level? (Y, N)	Method/ Device	Measuring Point Verification		

WEATHER		CALIBRATION	
Yesterday Date	Last night Date	This morning Date	Date
Temp. Range			
Precipitation			
Wind			
		Device/Serial #	
		Date Last Calibrated	Calibrated to ? ft (target = 0.1 ft.)

WATER LEVEL DATA FORM

(reverse side)

Abbreviations: DTW = Depth to Water, MP = Measuring Point, IGWIS = Integrated Ground Water Information System

Guidance

Use the codes listed below for data entry in the applicable columns on the front side of this form.

Note that this form is designed for field data entry only. Furthermore, it is designed for a single 24-hour period. It is not intended for calculation of water level elevations, use as a historical water level data base, etc. Therefore, it has been assumed that information such as measuring point description, measuring point elevation and historical data is recorded elsewhere (e.g., an historical water level data base). However, this form can be customized to your needs by making use of the "user defined field" column, and using the comment column for entry of one or more additional custom fields.

The column headings "hold" and "cut" are intended to receive the two measurements required to determine the depth to water below the MP. These terms come from the metal tape measuring technique. The same terms can also work for other techniques. For example, for an electric sounder, "hold" could be the value of the first demarcation label on the sounding wire above the measuring point. "Cut" could be the distance along the wire from the actual measurement point to the "hold" point (label). The distance from the MP to the top of the water column would then be hold minus cut. The user may want to write in different column headings or take the measurement differently, but caution is in order to ensure that the subtraction is done correctly.

Measurement Qualifiers

<u>Parameter Fields</u>	<u>Code</u>	<u>Code Description</u>	
Static Water Level	Y	Assumed to be static	
	N	Known to not be static	
	U	Status unknown	
Conditions (up to 2 codes can be entered)	A	Artesian	
	D	Dry	
	F	Free Product	
	Z	Frozen	
	B	Obstruction	
	P	Pumped	
	S	Surface Water Effect	
	O	Other (specify in Station Remarks)	
	Method/Device	A	Airline
		C	Calibrated Airline
D		Pressure (Electrical) Transducer	
E		Estimated	
G		Pressure Gauge	
H		Calibrated Pressure Gauge	
L		Geophysical Log	
M		Manometer	
P		Popper	
S		Steel Tape (chalk)	
T		Electric Tape	
U		Acoustic Water Level Sounder	
V		Calibrated Electric Tape	
Measuring Point Verification	O	Other (specify in Station Remarks)	
	U	Unknown	
	G	From Ground Surface	
	S	From Measuring Point Scribed	
	P	From Measuring Point - Top of Protective Casing (outer casing)	
	W	From Measuring Point - Top of Well Casing (inner casing)	

Discussion of Protocol Exceptions: _____

Other Comments: _____

WELL PURGING - FIELD WATER QUALITY MEASUREMENTS FORM*

Location (Site/Facility Name) _____ Sampling Point (common name) _____
 Project Name/# _____ Date _____ Facility ID (for IGWIS data entry only) _____
 Field Personnel _____ Station ID (for IGWIS data entry only) _____
 Sampling Organization _____ Purging Device (type of pump, bailer, etc):* _____
 Submersible pump with direct line to Flow Cell used for all measurements? (Y, N)* _____ Pump Intake or Bailer set at (ft. below MP) _____

Time (24-hour clock)	DTW below MP (ft.)	Purge Rate (specify units below) ()	Cumulative Volume Purged (specify units below) ()	Water Column Volumes Purged	Temp. (°C)	Electrical Conductivity (µMhos/cm)	Specific Conductance (µMhos/cm)	pH	Eh (mv)	DO (mg/l)	Turbidity (NTU)	Comments <small>(At appropriate time enter "static water level", "purging began", describe sample appearance, odor) (alternately, list sampling point when recording data for multiple sampling points)</small>

CALIBRATION

Date			
Time (24 hour clock)			
Calibration: Summary	1 or 2 pt.	k =	Type
Comments*			

Field Measurements protocol followed with no exceptions (Y, N)* Form completed by _____ Date _____

* Side 2 of this form contains room for supporting documentation including protocol exceptions

Form GWS #3
Revised 1-12-95

WELL PURGING - FIELD WATER QUALITY MEASUREMENTS FORM

(Reverse Side)

Location (Site/Facility Name) _____
 Project Name/# _____
 Sampling Point (common name) _____

CALIBRATION	Temp. (°C)	Electrical Conductivity (µMhos/cm)	Specific Conductance (µMhos/cm)	pH	Eh (mv)	DO (mg/l)	Turbidity (NTU)	GUIDANCE REMARKS	Comments
DATE									
TIME (24 hour clock)									
TYPE OF CALIBRATION								e.g., standard KCL solution, Zobels solution, in air/water, etc.	
LIST 1ST STANDARD								e.g., pH = 7.02 @ 25 °C KCL solution = 1000 µMhos/cm	
INSTRUMENT READING								actual reading from instrument	
CALIBRATED TO +/-?								difference between calibrated instrument display and standard	
LIST 2ND STANDARD								e.g., repeat calibration with 2nd buffer or by alternate method	
INSTRUMENT READING								"	
CALIBRATED TO +/-?									
CORRECTION FACTOR								e.g., cell constant, "k"	
CALIB. SUCCESSFUL?								Enter YES or NO	
SATISFIES PROTOCOL?								Did calibration meet criteria in the sampling protocol? (Y or N)	
CALIBRATION BY								Signature or Initials	
INSTRUMENT ID#								serial # or other ID #	
LOCATION								specify "field", "lab", "office", etc.	

Well Purging Equipment (more details): _____

List/Describe Field Instruments: _____

Discussion of Protocol Exceptions: _____

Other Comments: _____

Form completed by _____ Date _____

PURGING AND SAMPLING RATE TEST FORM*

Location (Site/Facility Name) _____ (MN Unique Well #) _____
 Project Name/# _____ Date of Measurements _____
 Personnel (include affiliation) _____
 Well Pumping Equipment (type of pump, bailer, etc.) _____
 Water Column Length (L) Calculation*: Well depth, _____ (ft.) - Static Water Level, _____ (ft.) = _____ ft.
 Sampling Point (common well name) _____
 Casing Diameter _____ feet _____ inches
 Well Depth (ft. below MP/GS) _____
 Depth of screened interval (ft. below MP/GS) _____
 Volume of (One) Water Column (gals.)* _____

Trial #	Pumping Rate (Q) (gpm)	Water Level Measurement	Correction or Conversion	Depth to Water below MP (ft.)	Water Level Change (ft.) <small>Drawdown</small> s <small>Residual Drawdown</small> s_r	Specific Capacity (Q/s)	Clock Time (24 hour)	Elapsed Time (minutes)		Cumulative Volume Pumped (gals.)	Water Column Volumes Pumped	Comments <small>(At appropriate time enter "static water level", "pumping began", "pumping ended", etc.)</small>
								Since pump started t	Since pump stopped t_s optional			

Based on the above data and plots on the reverse side of this form, the following pumping rates have been selected:

Pumping rate selected for purging _____
 Associated draw down after 5th WC Volume _____
 Pumping rate selected for sampling _____
 Associated draw down after 10th WC Volume _____

- (1) Is Static Water Level above top of screened interval? _____ Y, N
- Assuming 10 Water Column Volumes are pumped at selected rates: _____ ft.
- (2) What is the estimated maximum drawdown? _____ Y, N
- (3) If (1) = yes, will the water level fall below the top of well screen? _____ Y, N
- (4) If (1) = no, will the well be pumped dry? _____ Y, N
- (5) Estimated free fall distance from top of screen to pumping water level _____ ft.

* See reverse side of form for guidance, abbreviations, calculations, etc.

PURGING AND SAMPLING RATE TEST FORM

(reverse side)

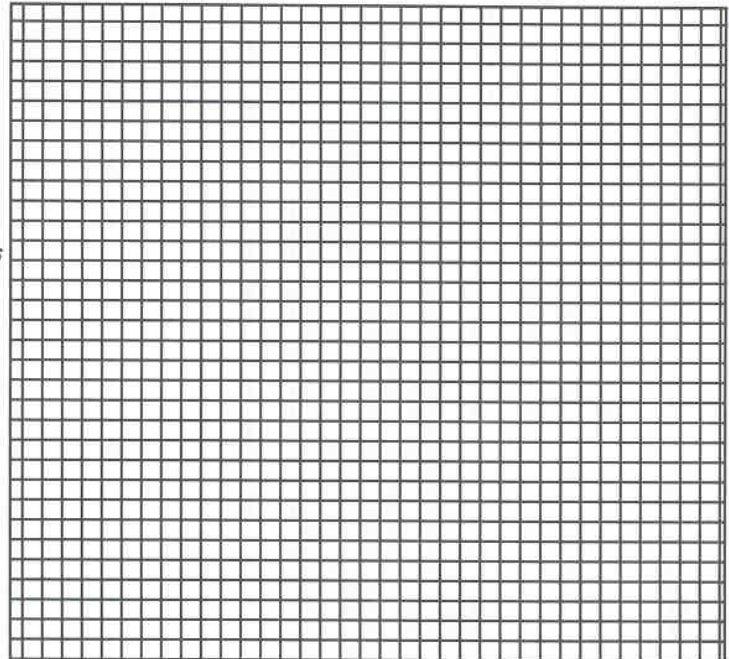
ABBREVIATIONS

MP = Measuring Point
GS = Ground Surface
DTW = Depth to Water
 s = drawdown
 s^1 = residual drawdown
gals. = gallons
WC = water column
Q = Pumping Rate

WATER COLUMN VOLUME

Well Diameter	Gallons per ft. of WC
1"	0.041
2"	0.163
4"	0.653
6"	1.47
8"	2.61

Q/s



s

OBJECT OF EQUILIBRIUM PUMPING RATE TEST

The object of the test is to find a pumping rate that is

- (1) high enough to complete purging and sampling in a reasonable length of time; and
- (2)a. low enough to not bring the water level below the top of the open (screened) interval if applicable; or
- (2)b. low enough to not cause so much drawdown that significant cascading (and associated aeration and turbulence) occurs

note: sampling protocol criteria may specify a maximum pumping and sampling rate lower than that determined in (2).

Q (gpm)

HOW TO PERFORM THE TEST

The following procedure is based on the assumption that the typical sampling event can be completed by purging about 5 water column volumes and then filling sample containers while pumping no more than 5 additional water-column volumes.

Several trial pumping rates should be tested. Start with a very low rate. Pump at this rate until ten water-column volumes have been pumped and then record the maximum drawdown for the trial. In addition to the final drawdown for each trial, it may be useful to record intermediary drawdown values such as at 3, 5, and 7 water-column volumes. These data will help in understanding the well's response to pumping. On side 1 of this sheet, fill in all of the columns that have a "√" at the top. Ideally, you will wait for nearly full recovery to static water level between trials. Increase the pumping rate for each consecutive trial and plot the data (using the above graph) until an informed choice can be made regarding purging and sampling rates. Guidance is given below.

$$\text{One Water Column Volume} = \pi r^2 L: \pi r^2 [\text{ft.}^2] L [\text{ft.}] [7.48 \text{ gallons/ft.}^3] = \text{gallons per water column volume}$$

L = height of water column = depth of well minus depth to static water level measured from the same datum; r = well radius in feet.

GUIDANCE

For your convenience, the form on the front side of this sheet is designed to allow recording of more information than needed for the objectives given above (see "Other Uses", below). Note that the balance of current researchers and guidance documents recommend that both purging and sampling rates should be very low when sampling for sensitive parameters such as volatile organics or trace metals. According to some authors, the "ideal" rate is 100 to 500 ml/minute when sampling for sensitive parameters. Although these rates may seem impractical for various scenarios, the negative impacts of higher pumping rates on data quality should be considered before exceeding the 500 ml/min. value. In any case, it is recommended that cascading be minimized by not exceeding rates determined by this test.

For each trial, enter a point for Q/s vs. Q and one for s vs. Q. (using two different symbol types) on the above graph. The plot of specific capacity (Q/s) versus Q may show a decreasing specific capacity with greater Q values. A sharp decrease in Q/s probably indicates that turbulent flow to the well has increased significantly compared to lower pumping rates. This is a key indicator to stay below that rate while purging or sampling. On the s versus Q graph, draw a horizontal line that represents the top of the screen or whatever depth you preliminarily choose to keep the pumping level above. As you plot the s and Q data, it will then be immediately apparent when you reach a pumping rate that will exceed the ideal maximum drawdown. After plotting data from an adequate number of trials, fill in the blanks in the two large rectangles at the bottom of side 1 of this sheet.

OTHER USES OF THIS FORM

Note the columns that are labeled "optional" in the first (very narrow) row. These columns can be used along with the other columns for a short-term, single well constant-rate pumping (and/or recovery) test. Alternatively, they can be used for a slug test. Note that a true static water level is needed to begin these tests as residual drawdown from earlier testing is difficult to factor into the analysis. Slug tests are most appropriate for roughly estimating permeability in the immediate vicinity of the tested well. They are not generally considered reliable for assessing transmissivity or storativity. Single well pumping tests also have significant limitations, especially where storativity values are needed. It is essential to know factors such as % of aquifer thickness screened and whether the aquifer is confined, unconfined, leaky, etc., to determine what type of analytical method is appropriate. The reader is encouraged to consult reference materials on these subjects.