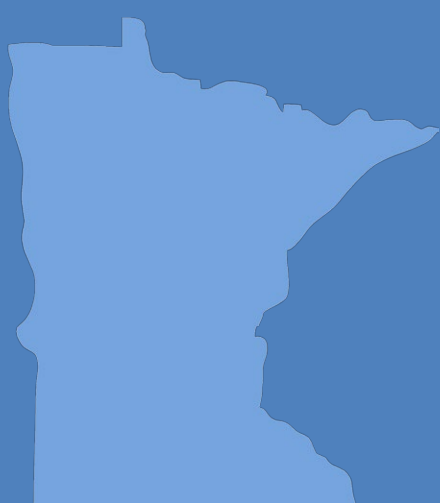
Field Guidance Manual for the Minnesota Pollution Control Agency's Ambient Groundwater Monitoring Network



MINNESOTA POLLUTION CONTROL AGENCY

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1. Introduction

The purpose of this guidance manual is to ensure that field personnel for the Minnesota Pollution Control Agency's Ambient Groundwater Monitoring Network are: 1) conducting fieldwork in a consistent and safe manner and 2) the ground water-quality data collected are representative of the conditions in the aquifer of interest. This document is a reference for all field and data management personnel. Instructions for equipment maintenance and calibration are consistent with the manufacturer's recommendations. For trouble-shooting instructions, please refer to the manufacturer's operation manuals available at the agency's Field Operation Center (FOC) and online.

The Minnesota Pollution Control Agency (MPCA) maintains an Ambient Groundwater Monitoring Network to evaluate the occurrence of non-agricultural chemicals in groundwater and quantify how the concentrations of these chemicals change over time. The agency began building this network in 2004 and added over 100 new monitoring wells to it from 2009-2016. The network currently (2017) consists of 266 wells that MPCA staff sample annually.

The water samples collected by the MPCA staff are routinely analyzed for over 100 different chemicals. This includes nutrients, major ions, volatile organic compounds (VOCs), and trace metals, as well as field measurements of water pH, specific conductance, dissolved oxygen (DO) concentrations, and water temperature. Each year the MPCA also samples a subset of the wells to determine the presence of over 100 contaminants of emerging concern (CEC) and pesticides. MPCA staff also collect CEC samples from about 40 of the network wells each year and 20 pesticide samples annually in collaboration with the Minnesota Department of Agriculture (MDA).

These procedures assume there are two people in the field collecting data: a Recorder and an Operator. The Recorder's primary responsibilities include: 1) operation of the field computer, 2) completion of the field notes, 3) determination that the well is sufficiently purged prior to sample collection, and 4) determination that all samples collected are stored in properly labeled and preserved bottles. The Operator's primary responsibilities are: 1) set up and calibrate the field equipment, 2) ensure all equipment is functioning properly, 3) observe all measurements, 4) collect samples, and 5) pack up the equipment.

2. Safety guidelines

The safety of field personnel is of paramount importance. There usually will be two staff present at the time of sampling. If you ever feel that your safety is at risk, vacate the field site and immediately call your supervisor. A cellular phone will accompany the field team. If this is a state-issued device, field personnel are responsible for understanding the agency procedures regarding state cell phone use. Please use the guidelines below and common sense to reschedule or cease sampling due to weather-related conditions. **Do not** take any unnecessary risks.

Water sample collection is not required when:

1. Threatening weather is developing, such as lightning or thunderstorms.
2. The Minnesota Department of Transportation classifies roads in “Poor” condition.
3. Adverse weather conditions (i.e. storms, floods, or freezing rain).

Following the guidelines in this section is necessary to ensure the safety of field personnel. Report all accidents to: 1) your supervisor, and 2) Ryan Ricci, MPCA Safety Officer (651-757-2560).

2.1 Field safety

The safety of a field site is dependent on its surroundings. It is your responsibility to assess the safety of all field sites. Be aware of the conditions present at each location. Field personnel are not required to sample at any locations where threatening situations are present. Leave the site if your safety may be in question.

All MPCA personnel are required to wear a hardhat and steel-toed boots when observing any drilling operations. All observers must remain approximately 50 feet away from the drill rig.

2.2 Chemical safety

MPCA staff routinely use chemicals during fieldwork, including organic solvents and acid preservatives. Some of these chemicals are used to calibrate field equipment, and others are used to decontaminate sampling equipment and preserve water samples. All chemicals used for the MPCA Ambient Groundwater Monitoring Network are stored at the MPCA’s FOC, which is located at 855 Eighth Street, about two blocks away from the MPCA main office in St. Paul.

The Ambient Groundwater Monitoring Network’s chemical inventory and all associated Material Safety Data Sheets (MSDS) are located in the network’s area at the FOC. The Field Coordinator for the network maintains the chemical inventory. The network uses the following chemicals:

- Hydrochloric acid (HCl) – preservative for VOC samples; the sample vials come from the laboratory pre-preserved with 0.5 milliliters (mL) of HCl.
- Methanol (HPLC grade) – used to decontaminate equipment used for trace organics sampling such as pharmaceuticals.
- Nitric Acid (HNO_3) - preservative for cation and trace metals samples; the preservative is a 20% HNO_3 solution contained in a 5mL vial.
- Potassium Chloride (KCl) salt solutions - conductivity calibration standard, and pH probe storage
- Sulfuric acid (H_2SO_4) – preservative for nutrient samples; the preservative is a 10% H_2SO_4 solution contained in a 5 mL vial.

Any unknown substance encountered in the laboratory or field must be handled as if it is a hazardous material. If you have any questions about chemical handling, storage or disposal, contact Ryan Ricci, MPCA Safety Officer (651-757-2650), or the Employee Hazardous Materials Information Hotline (1-800-673-7466).

2.2.1 Chemical labeling

All bottles (including those containing just water) used for fieldwork must be labeled describing the contents. The label should include the: 1) name of the solution in the bottle, 2) concentration, 3) preparation date, and 4) initials of the employee who prepared the solution.

2.2.2 Protective gloves

MPCA staff must wear protective gloves, usually powder-free nitrile, during all field and laboratory operations to prevent contamination of water samples and protect personnel from any chemicals used during the sample collection process. The MPCA FOC maintains a supply of several types and sizes of gloves.

2.2.3 Eye/Face protection

Eye protection is required when handling acids, bases, or solvents in the field or laboratory. Common procedures requiring eye protection include alkalinity titrations, water sample preservation, and equipment decontamination. Safety goggles should be worn when performing these tasks. Eyeglasses designed for ordinary wear cannot be worn in lieu of safety goggles. These do not provide sufficient protection against chemical hazards. Safety goggles are available that fit comfortably over eyeglasses. It is inadvisable to wear contact lenses when handling chemicals, even under safety goggles, because they interfere with quickly and properly rinsing the eyes in the event of a chemical accident. The Occupational Safety and Health Administration (OSHA) recommends that staff carry an extra pair of contacts or eyeglasses in case of contact lens failure or loss.

2.2.4 Field/Laboratory clothing

Appropriate clothing should be worn during field and laboratory work. T-shirts, jeans, and closed-toe shoes offer adequate protection. Sandals and tank tops are not appropriate in the field or laboratory. These clothes do not offer an adequate amount of protection against the hazards of field and laboratory work such as sun exposure, chemical hazards, or falling objects. In addition, any long hair should be pulled back and secured so it does not interfere with the groundwater sampling.

3. Field trip preparations

Advance preparations need to be made for field sampling trips. Do not fall into the common trap of putting off this planning until the last minute.

3.1 Field trip review

The Ambient Groundwater Monitoring Network's senior hydrologists prepare a sampling plan for the network's 250 plus wells at the beginning of each field season. This plan groups the network wells into sets of field trips that usually are sampled using a two-person crew.

The sampling plan also specifies what kinds of samples will be collected from each individual well and where these will be sent for laboratory analysis. At each well, the field crew collects well water samples that are analyzed for a routine set of chemicals including VOCs, metals, nitrate and other nutrients, and common ions such as chloride and sulfate. These all are analyzed at the Minnesota Department of Health (MDH) Environmental Laboratory. Analyses conducted at other laboratories include CECs, pesticides, and age-dating chemicals like tritium and sulfur hexafluoride.

There is a field folder for each network well that contains detailed information about the sampling site. This includes the sampling point, well log, a site sketch showing the location of the well, property owner contact information, number of the key for the lock installed on the well, and any other special instructions about the site. The field folder associated with each well site should be reviewed prior to the sampling trip. Be sure to note the description and access to each site. At some sites, it is preferable to access the well using a four-wheel drive vehicle. At other sites, the well cannot be accessed using any type of vehicle during the winter or extremely wet conditions.

3.2 Well owner/Property owner notification

The well or property owner(s) must be notified before many of the Ambient Groundwater Monitoring Network wells are sampled. The access agreements for a number of the wells in the network stipulate that the MPCA notify the well or property owner several days prior to conducting any field work at the site. In addition, all owners of the sampled domestic wells must be notified prior to conducting any fieldwork on their property. The site access details for all of the wells in the network is contained in the field folder for the well and should be reviewed prior to the sampling event.

3.3 Vehicle check out

Two dedicated vehicles are available for field activities for the Ambient Groundwater Monitoring Network. The checkout of these vehicles should be coordinated with the network's senior hydrologists. One of these vehicles is a four-wheel drive truck, and the other is a Sprinter van. The mileage driven, fuel purchases, and general maintenance must be recorded using the log books present in each vehicle on a daily basis, per agency policy.

3.4 Sampling equipment and supplies

The field crew should inventory the sampling equipment and supplies prior to each field trip to ensure that everything is stocked in the sampling vehicle to complete the scheduled sampling events. A considerable amount of time is lost if a field crew must drive back to the office to retrieve additional equipment and supplies. A checklist of all of the equipment and supplies required for the network well sampling as well as some tasks that must be completed beforehand is given on the next page. It is a good idea to bring along extra supplies, especially extra batteries and sample bottles. Always carry all the VOCs in a set together and make sure to bring a fresh VOC trip blank.

Before leaving the office, it also is important to ensure that the selected equipment is in proper working condition and appropriate for the sampling event. It is especially important to choose a sampling pump that is suitable to collect the samples that are scheduled for analysis and can be set at an appropriate flow rate for purging and sampling the well. The instruments used to obtain field measurements also should be calibrated according to the procedures described in Appendix 2. Other common equipment problems include power supplies that are not sufficiently charged and malfunctioning water-quality probes. If there is a problem with a piece of equipment and a substitute is needed, inform the network's senior staff.

Checklist for ambient groundwater monitoring well sampling:

Site logistics

___ Contacted well owner on the proposed sampling date for the well
___ Obtained field folder for the site
___ Reviewed field folder for directions to the site and well keys

Sampling documentation and reference materials

___ Field Guidance Manual for the Ambient Groundwater Monitoring Network
___ Field notebook and waterproof pens
___ Laptop computer for electronic data collection
___ Chain of Custody (COC) Forms

Sampling Equipment and Supplies

___ Battery and power inverter (if using the four-wheel drive truck for sampling)
___ Water level indicator
___ Submersible or peristaltic pump and power supply (for monitoring wells)
___ Hose reel (for domestic wells)
___ Calibrated sonde for field measurements, spare batteries
___ Flow-through chamber (for field measurements)
___ New polyethylene pump tubing, ¼ inch inside diameter x 3/8 inch outside diameter
___ Silicone tubing
___ Nitrile gloves (size dependent)
___ Capsule filters and associated hose barb fittings
___ Sample bottles (check expiration dates)

- Pre-preserved VOC vials (3 freshly-prepared vials per well)
- 250-mL metals bottle
- 250-mL nutrients bottle
- 125-mL general chemistry bottle
- 1-L general chemistry bottle (for alkalinity sample)

___ Sample preservatives (check expiration dates)

- H_2SO_4
- HNO_3

___ Cooler(s) with ice for sample transport

Contaminants of emerging concern sampling equipment

___ Aluminum plate filter (clean)
___ Glass fiber filters (for CEC sample collection)
___ Wash bottles with tap water and dilute soap (liquinox) solution
___ Teflon wash bottles with methanol and HPLC-grade organic-free water
___ Cooler of sample bottles from contract laboratory

- 4 1-L HDPE bottles
- 4 1-L amber glass bottles
- 2 500-mL plastic bottles (for perfluorochemical samples, if needed)

___ Bottle labels (from laboratory)

Pesticide sampling equipment (obtained from the MDA monitoring program staff)

___ Two 1-L wide mouth amber glass bottles
___ Plastic vials (for glyphosate samples, if needed)
___ Bottle labels
___ Chain of Custody forms

Age-dating sampling equipment

___ Advanced diffusion sampler (from laboratory)
___ Polyethylene tubing (1/4 inch outside diameter x 0.17 inch inside diameter)
___ Swagelok front and back ferrule set 
___ Bicycle pump with appropriate tubing fittings (from laboratory)
___ Long socket
___ Crescent wrench/Wrench set
___ 2 – 500 mL plastic bottles
___ 2 – 1 L plastic-coated amber glass bottle with cap.

Miscellaneous equipment

___ Well lock keys

- MPCA locks: key 3438
- DNR locks : key 0536
- USGS locks: key 2640

___ Scissors or box cutter
___ Extra MPCA locks
___ Bolt cutters
___ Pens

3.4.1 Sampling pumps

There are several different types of pumps that are available for the MPCA staff to use in the field to collect water samples. The following sections list the advantages and limitations for each of these pumps.

3.4.1.1 Peristaltic pump

Peristaltic pumps are used to sample very shallow wells. These create a suction that draws the water up through a tube and can only lift water from approximately 25 feet deep. This limits its ability to sample deep monitoring wells. These pumps have a variable speed controller to control flow. Depending on the model, an internal or external 12-volt battery can power these pumps. The major disadvantage of using a peristaltic pump is that the suction generates a pressure differential that causes gases to come out of solution. This makes these pumps inappropriate to collect VOC samples.

Since no part of the pump is in contact with the sample water, decontamination of the pump is not necessary. However, new pump tubing should be used at each sampling location.

3.4.1.2 Geosub pump

The Geosub is a submersible pump that can withdraw water from wells as deep as 200 feet. The pump housing is 1.75 inches in diameter and can be used to withdraw water from two-inch diameter monitoring wells. The pump is powered using a 120-volt AC power source or with a DC power source. The pump's flowrate ranges from 10 mL/min to about 2.5 gal/min and is controlled using a variable-speed controller.

3.4.1.3 Keck pump

The Keck pump can operate to a maximum depth of 150 feet. The pump features a 1.5-inch pump head that fits down two-inch monitoring wells, a variable flow rate and an internal 12-volt battery. The pump also can be powered with an external 12-volt battery source. The internal battery is rechargeable and lasts approximately six hours (continuously operating) on a single charge. Flow rate can be controlled anywhere from 0.1 to 4 L/min.

The Keck pumps tend be cumbersome to use and do not pump extremely turbid water very well. They also can be a little harder to decontaminate than some other pumps and are difficult to start at the beginning of sampling due to the O-ring swelling slowly over time. Overcome this problem by loosening the pumping mechanism and immersing it in cold or ice water.

3.4.1.4 Grundfos Redi-Flo2 and Redi-Flo3 pumps

These two Grundfos pump can operate at deeper depths and pump at a greater flow rate compared to the others listed in the document. The Redi-Flo 2 pump is outfitted with 300 feet of Teflon tubing, and the Redi-Flo3 is outfitted with 225 feet of polyethylene tubing. Both pumps can operate at a maximum depth of about 300 feet. The Redi-Flo2 pump can be used in small 2-inch diameter wells, while the Redi-Flo3 only can be used in larger diameter wells. The Redi-Flo3 pump only will fit in wells with diameters that are 3-inch or greater. The Redi-Flo2 can pump at a flow rates ranging from 100 mL/minute to 10 gal/min, and the Redi-Flo3 pumps up to 22 gal/min.

The Grundfos pumps are very sensitive to the voltages emitted from the portable gasoline-powered generator used to power the pumps. Test both the pump and generator prior to fieldwork.

4. Sampling protocols

The procedures below assume that there are two people conducting the fieldwork: the Recorder and the Operator. The Recorder's primary responsibilities include: 1) operation of the field laptop computer, 2) completion of any necessary field forms and entries into the field book, 3) verification that the field parameters in the well water have stabilized prior to sample collection, and 4) collection of all samples in properly labeled and preserved bottles. The Operator's primary responsibilities are to: 1) set up the sampling equipment, 2) ensure the pump and field meter are functioning properly, 3) observe all measurements, 4) collect samples, and 5) pack up the equipment.

4.1 Site review/Well owner introduction

Upon arrival at a site, first verify it is the correct one by reviewing the number listed on the well identification tag (if present), site photographs, and site sketch. Introduce yourselves to the resident or well owner if they are present. Provide them with your proper state employee identification and answer any questions they might have. Let them know that you are going to be on-site long enough to purge and sample the well (estimate an approximate time of 45 to 60 minutes). Verify the sampling point selected is the closest, untreated source to the wellhead.

Gather any information about any water supply well. Ask the property owner if there are any: 1) problems with the well, 2) previous well testing, and 3) previous well testing results. Collect the majority of this information during a phone conversation prior to arriving on site.

4.2 Field notes

Field notes primarily are recorded on a laptop computer using commercial software called the EQuIS Data Gathering Engine (EDGE). The MPCA's water-quality database team has placed detailed instructions for the use of this program online at https://www.pca.state.mn.us/sites/default/files/wq-s5-80.pdf. It is essential to record as much information about the sampling event as possible. This includes weather conditions and possible sources of contamination. For example, if a sample comes back from the lab with a high nitrate concentration the data analysts can examine the field notes to determine whether contamination sources were nearby, such as a feedlot or septic system.

Record all reasons for deviations from standard protocol in the field notes. For example, the staff may not collect field readings if the equipment malfunctions, there are turbid waters, or insufficient flow rates.

4.2.1 Field notebooks

MPCA staff also use field notebooks to supplement the data recorded using the EDGE software. The well identification number (usually the Minnesota Unique Well Number), sampler names, deviations from the standard protocols, detailed weather conditions, changes in site conditions, and geologic investigations must be included in the field book.

Below is a suggested format that represents the minimum amount of information to record within the field book.

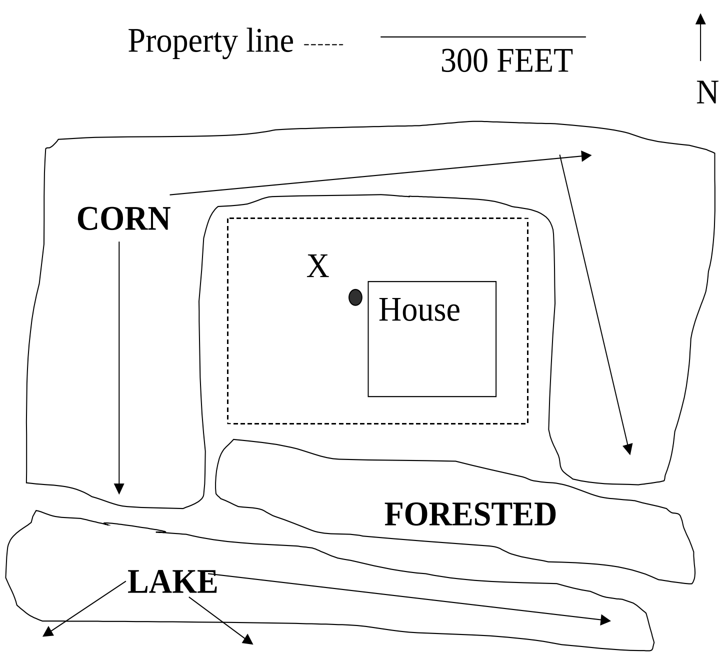
Date: *2/19/98* **Event**: *Sampling* **Time**: *1:45*
Well identifier: *987541* **Samplers:** *JS, EE* **Name**: *O'Donnell*
Weather condition: *warm and sunny, 75 degrees Fahrenheit*
Depth to water: *13 ft.*
Site information/Landuse: *unsewered area with corn field 500 ft. to north*
Sampling procedure: *bailed, appx. 5 gals of water and sampled*
Sample bottles collected:

VOCs
Metals (filtered)
Nutrients (filtered)
General chemistry (filtered)
Alkalinity (filtered)

Comments:

0.45-micron capsule filter used for filtration
Field readings collected before sampling using a sonde and flow through chamber
Water initially was extremely turbid but cleared up during purge

If necessary, include a site map, which shows land use around the sampling location and other activities that may affect water quality. The figure below illustrates a site map for a domestic well sampled in a rural area.



4.3 Water level measurement

Water levels are measured from monitoring wells prior to well purging and sample collection. This is done for two reasons. First, the most accurate reading is obtained before any water is removed from the well. Second, the water level also is used to calculate well volume and determine purge time and/or volume. MPCA staff typically do not obtain water level measurements from water-supply wells since this would require removing the well cap and could inadvertently damage the well pump or introduce contamination in it.

4.3.1 Measurement procedure

1. Water levels typically will be measured using an electronic water level indicator. Upon arrival on site, unlock the well and open the well protective casing. If the well has other equipment in it installed by the MPCA or another agency, take a water level measurement before removing the equipment from the well.

   Do not remove another agency's equipment without their prior permission.
2. First test the water level indicator to ensure the instrument is functioning properly by pressing the Battery Test Button on the side. The Indicator Light should illuminate red and emit a "beep." Lower the probe down the well until the water column is reached (a "beep" will be heard and the light will be lit).

   The water level indicator only should emit a "beep" when it encounters water in the well. The equipment is malfunctioning if it emits a "beep" when it is not in water and the Test Button was not pressed.
3. Take at least three water level measurements and ensure that these agree within a hundredth of a foot. Take readings from the measuring point denoted on the well casing. In the absence of a denoted measuring point, measure from the north edge of the well casing. If equipment, such as a transducer, was extracted from the well, take approximately three water level readings to ensure there is no change in water level before taking a water level measurement.
4. Record the reading in the "depth of water" field in the Initial Water Level & Purge tab in the EQuIS EDGE program to the nearest hundredth of a foot.

4.4 Domestic well equipment setup

4.4.1 Sample point selection

The sampling point should be as close to the wellhead as possible, usually this is an outside faucet. Well water sampled at this point must not be treated by a device such as a filter, chlorinator, or water softener (outside faucets usually by-pass these systems). If these systems are in place, see if they can be by-passed or turned off for 72 hours prior to sampling. If they cannot, do not collect the sample from this residence.

4.4.2 Equipment setup

1. Select the sampling point (usually this is the one indicated in the field folder for the site).
2. Remove any hoses and/or attachments from the faucet (these attachments may cause aeration or contamination and may interfere with the sample).
3. Take the extension hose attached to the hose reel and connect it to the faucet.
4. On the other end of the hose, make certain the valve to the discharge side of the Y-connector that is connected to the extension hose is fully open and the other side of the valve is closed.
5. Turn on the faucet to allow discharge of any air and excess water from the hose. After the discharge is complete (when the discharge stream flows consistently), the valve on the Y-connector leading to the YSI flow cell can be opened enough to allow approximately 1 gallon per minute of water to flow through the flow cell.

4.5 Monitoring well equipment setup

It is recommended to use a variable-speed submersible pump to purge and sample monitoring wells. The pump should be operated in a manner that minimizes turbidity.

4.5.1 Bailer setup

Use a bailer when the monitoring wells do not recover rapidly enough to sample with a pump. The sampler must be very cautious to minimize turbulence and aeration and keep the bailer and bailer line clean.

1. Use a new bailer, if possible.
2. Use a gloved hand to touch the bailer and/or the bailer line, and never allow the bailer to touch the ground.
3. Slowly lower and raise the bailer into the well to minimize disturbing any sediment present at the bottom of the well.

4.5.2 Submersible pump setup

1. Install new tubing (preferably clear) on the pump.
2. Lower the pump slowly and smoothly into the well to minimize stirring up any particulates into the water.
3. Install the pump approximately three feet below the static water level.
4. Adjust the pump's flowrate so it does not substantially lower the water level when pumping. The water pumped should be a smooth, solid stream of water that contains no air or gas bubbles.

5. Well purging

The well must be purged to remove any stagnant water in the well casing prior to sampling. Well purging is required because the water stored in the well casing and filter pack does not always represent the chemistry of the water in the aquifer. In some cases, the water in the casing and filter pack takes on the signature of the materials used to construct the well. In some instances, this water can have an unusually high pH because it was in contact with cement used to construct the well.

Field staff must purge a total of three well volumes of water from the well, and field parameter readings must have stabilized to ensure fresh aquifer water is drawn into the sampling containers.

5.1 Purge volume calculation

Calculating the volume of water in a well is necessary to determine the purge time. Three pieces of information about the well are required in order to make this calculation: water level, well depth, and well diameter. The EQuIS EDGE software used by the network staff for field data entry performs this calculation. The calculation also can be done manually by multiplying the length of the water column by the area of the well, assuming that the area of the well is circular (which usually is the case). This gives the volume of water contained within the well casing or one well volume. Appendix I (*Well Casing Volume Conversions)* contains a chart with this calculation complete for common well diameters.

5.2 Stability readings

The stability of the field readings is checked after three volumes of water are removed from the well. Take a minimum of five measurements at regular intervals (at least 3-5 minutes apart) that meet the following criteria:

Dissolved oxygen	+/- 0.2 mg/L
Temperature	+/- 0.1 degrees C
pH	+/- 0.1 standard unit
Specific conductance	+/- 5%

The EQuIS EDGE software can be used in the field to see if these criteria are met. This software automatically highlights measurements in blue that meet these criteria.

5.3 Modifications to the standard procedure

The well purging requirements may be relaxed in some instances. Any deviations to the standard well purging procedure should be documented using the EDGE software or in the paper field notes. A smaller purge volume may be used in these instances:

1. Domestic and other water supply wells. These usually are pumped frequently and often do not contain as much stagnant water compared to a monitoring well. For domestic and other water supply wells, purge the volume of water present in the pressure tank (usually 10 to 20 gallons) prior to sampling and ensure that the pump is actively drawing water from the well.
2. Low-yielding wells. The water levels in these wells do not recover to the original level within a reasonable timeframe.

6. Sample collection and processing

After the well purging is complete, the field staff begin to collect the well water samples. Two suites of samples typically are collected: 1) the basic suite of VOCs, nutrients, trace metals, and general chemistry constituents and 2) CECs such as DEET, bisphenol A, or prescription and nonprescription medicines.

6.1 Sample identification

The sampling bottles should be labelled prior to sample collection using permanent ink. Label each bottle with the well's Minnesota Unique Well number as well as the sample date, time, and sample type. The sampler also should verify that the identical information were entered into the EDGE software and/or paper field notes.

6.2 Sample collection

This section describes the procedure used to collect the samples for the network. This includes the procedures for the collecting the basic suite of nutrients, metals, chloride, and VOCs as well as the procedures for collecting the specialized CEC and age-dating samples.

6.2.1 Routine network samples

The basic suite of VOC, major ion, nutrient, and metals samples are collected according to the following procedures. If bailing the well, collect samples from the sampling nipple that comes with the bailer. Wear sampling gloves during sample collection.

6.2.1.1 VOC samples

VOC samples are very susceptible to contamination; utilize this procedure to ensure the sample quality.

1. Use three fresh VOC vials to collect these samples. Old vials can pick up any contamination that may be present in the FOC, such as vehicle emissions or refrigerant leaks.
2. First, remove the sample tubing from the flow cell. Slow the flow to reduce splash, but DO NOT turn off the pump or spigot.
3. Slow the flow of the pump. Tilt the vial and fill it smoothly with water. Any aeration of the water at this point can cause the loss of volatiles.
4. Attain a positive meniscus and cap the vial with no air bubbles. **Do not filter the sample.**
5. Invert the vial, tap gently on the bottom of the vial and check for the appearance of air bubbles; if any appear, repeat sample collection using a new pre-preserved vial until three filled vials exist without visible air bubbles. The MDH laboratory pre-preserves VOC vials, so they are only for a single time use.

***Note**: Never touch the inside of the any of the bottle caps, even with gloved fingers. If the cap is touched or dropped, do NOT use it. Instead, use a new bottle. If you recently were exposed to diesel or gasoline, do not take VOC samples until you have thoroughly washed your hands.*

6.2.1.2 Major ion, nutrient, organic carbon, and metals samples

All of these samples are filtered before they are sent to the laboratory using a new 0.45-micron capsule filter using the following procedure:

1. Attach new barbed fittings to a new capsule filter.
2. Attach the capsule filter and hose barb to the tubing that was used to collect the VOC samples in section 6.2.1.1 and invert the capsule filter to allow water to fill it and the air bubble to be forced out. Once the water flow has started from the exit nozzle of the filter, increase the flow rate if desired.
3. Rinse the capsule filter using at least one liter of groundwater.
4. Collect samples in the following order with a slow, steady controlled flow, taking caution to not overfill the sample bottles. Rinse the sample bottles prior to collecting the water samples.
    a) Metals/cations
    b) Nutrients and dissolved organic carbon
    c) General chemistry/major anions
    d) Alkalinity
5. Preserve the metals/cations sample using one vial of HNO_3 preservative.
6. Preserve the nutrient/dissolved organic carbon sample using one vial of H_2SO_4 preservative.

6.2.2 Contaminants of emerging concern

CEC samples are collected at selected wells each year. The concentrations of these samples are extremely low (measured in the nanogram per liter range), and they are very prone to contamination. Collect these samples using the following procedure:

1. Set up a decontaminated aluminum plate filter holder on a clean, flat surface.
2. Open the plate filter holder and place a new glass fiber filter on it. Handle the glass fiber filters carefully using a tweezers.
3. Pre-wet the glass fiber filter using a small amount of HPLC-grade organic-free water.
4. Close the plate filter and open the pressure relief valve on top of the filter.
5. Attach the sample tubing to the barbed fitting on top of the filter plate holder.
6. Allow the filter plate holder to fill with groundwater. Close the pressure relief valve after water flows from it.
7. Let approximately 500 mL of water flow through the filter plate holder to rinse any of the organic-free water from it.
8. Place the labeled sample bottles under the filter plate holder to collect the water samples.

Note*: Very turbid groundwater samples occasionally will cause the glass fiber filters to clog. In this instance, replace the glass fiber filter and continue to filter the sample following steps 2) through 8).*

6.2.3 Age-dating samples

Samples are collected at about 20 wells each year to determine the age of the young fraction of the groundwater. These samples currently are analyzed using the tritium-helium and sulfur hexafluoride methods. The age-dating analysis usually compares the concentrations of the chemicals in the groundwater to those found in the atmospheric air. Because of this, the age-dating samples can easily be contaminated, and extreme care must be taken when collecting these samples.

One of the sampling apparatuses used to collect these samples must be deployed at least 48 hours before sample collection. This is the dissolved gas sample that is collected in a tube connected to a diffusion sampler. Deploy the diffusion sampler using the following procedure:

1. Ensure that the sample tip is tightly screwed onto the diffusion sampler body. This connection must be leak-tight.
2. Ensure the sampler is set in the load position.
3. Label the sample tube with the well's Minnesota Unique Number using a permanent marking pen.
4. Attach an air hose to the top of the diffusion sampler using ¼-inch polyethylene tubing and a front and back ferrule set. The nut should be ¼ to ½ of a turn past finger tight.
5. Lower the sampler into the well so it is located within the screened interval.

The diffusion sampler should be allowed to equilibrate for 48 hours. After this period is complete, retrieve the sampler according to this procedure:

1. Attach the Schraeder valve adapter connected to the hand pump to the free end of the ¼-inch tubing using a front and back ferrule set.
2. Using the hand pump, pressurize the tubing to 60 psi. This will close the sampler and isolate the sample tube from the rest of the diffusion sampler.
3. Retrieve the diffusion sampler from the well.
4. Place the sampler in the stabilizing rack sent by the laboratory and cold weld the sampler tip (where it is pre-crimped) using a socket.
5. Ensure that clamps are tightened so that there is no space between them. Even a piece of paper should not fit between them.

The low-level tritium sample used for age-dating is collected unfiltered along with the other environmental samples following this procedure:

1. Label two 500-mL plastic bottles with the well's Minnesota Unique Number and the date and time of sample collection.
2. Rinse out the bottles several times.
3. Fill the bottles all the way to the top and screw the cap shut.
4. Wrap the cap with electrical tape to prevent it from coming unscrewed during shipment to the laboratory.

The sulfur hexafluoride samples also are collected unfiltered. It is very important to ensure that all of the atmospheric air is purged from the sample bottle. These samples should be collected according to this procedure:

1. Label two 1-L plastic coated amber glass bottles with the well's Minnesota Unique Number and the date and time of sample collection.
2. Place the pump tubing in the bottom of the bottle and allow it to overflow from the neck. Allow three liters of water to overflow from the bottle.
3. Slowly remove the tubing from the bottle while the water still is flowing from it.
4. Cap the bottles tightly using a polyseal cone cap. There should be no headspace in the bottle.
5. Wrap the cap with electrical tape to prevent it from coming unscrewed during shipment to the laboratory.
6. Keep the bottles in a cooler and out of the sun. If the bottles warm excessively, the gases in the sample may expand and crack the bottle.

6.3 Sample transport

Place the collected and preserved samples in a cooler with plenty of ice. The interior temperature of the cooler should be approximately 4ºC. Check that all bottles are capped tightly before placing them in a cooler. The bottles may be placed in a clean zip-top bag to prevent them from getting wet. Pack the bottles securely to prevent breakage. Place the VOC vials in the supplied trays to prevent breakage.

7. Quality assurance/Quality control procedures

7.1 Field decontamination procedures

Equipment used on multiple wells must be decontaminated using the following procedures. A clean standpipe should be used for circulating water through the submersible pumps; these tubes help minimize the amount of water needed during decontamination.

7.1.1 Routine samples

1. Prepare a dilute (0.2%) *Liquinox* solution by mixing approximately one tablespoon of *Liquinox* soap to a gallon of water.
2. Using a coarse bristle brush, scrub and rinse the equipment with tap water. This will remove any excess dirt and debris.
3. After removing the excess dirt, scrub (with a second set of coarse bristle brushes) the equipment using the cleaning solution. If decontaminating a pump, allow the cleaning solution to circulate through the pump and tubing several times.
4. After thoroughly scrubbing the equipment with the cleaning solution, rinse the equipment using copious amounts of tap water to remove all soap residue.
5. Rinse the equipment using copious amounts of deionized (DI) water, circulating the DI water through the pump and tubing.
6. Allow the decontaminated equipment to dry and place in new zip-top plastic bags.

7.1.2 Contaminants of emerging concern

1. First prepare the cleaning solutions and decontaminate the equipment following the procedure listed for routine samples in Section 7.1.1.
2. Using a Teflon wash bottle or standpipe, rinse the equipment using HPLC-grade methanol. Set the cleaned equipment on a new piece of aluminum foil.

Note: *Do not dispose of used methanol in the sink. Capture the used methanol and place it in the appropriate storage container at the FOC for proper disposal.*

3. Using another Teflon wash bottle, rinse the equipment with HPLC-grade organic free water. Set the cleaned equipment on another new piece of aluminum foil and allow to dry.
4. Wrap the decontaminated equipment in aluminum foil and place in a clean zip-top bag until they are used.

Do not use methanol-rinsed equipment to collect VOC samples!

7.2 Quality control sample collection

7.2.1 Trip blanks

Trip blank samples are used to measure any possible contamination that diffused into an environmental sample during sample handling and storage. These samples typically only are collected in association with VOC samples. Each VOC trip blank sample consists of three vials that contain water that is known to be free of the target analytes.

A newly prepared trip blank sample should accompany each set of well water VOC samples. The trip blank samples are prepared by the MDH Environmental Laboratory and come sealed and labeled. **Trip**

blank samples are never opened in the field. The trip blank and the associated samples must always stay together from the time the samples are obtained from the lab. Use a freshly prepared set of VOC vials and trip blank for each sampling trip. Vehicle emissions or refrigerants may contaminate VOC vials stored for long periods at the FOC. If a sampling event is multiple days in length without returning to the FOC, only one trip blank is required for the entire sampling event. However, if a sampling event is multiple days in length, and the field crew returns daily to the FOC, a new trip blank for each day (trip) of that event is required.

7.2.2 Field and equipment blanks

Field and equipment blank samples measure the amount of contamination that is contributed by the sampling equipment, sampling method, sample holding and transport, and laboratory analysis. Equipment blank samples typically are collected at the FOC. Field blank samples are prepared at the field site and also measure any contamination contributed by the local sampling environment.

Field and equipment blank samples are prepared using water that is known to be free of the analytes of interest. The water used to prepare the field blanks that are analyzed for nutrients, cations, anions, and trace metals is obtained from the MDH Environmental Laboratory. The water used to prepare the field blanks that are analyzed for CECs is purchased directly from AXYS Analytical Laboratory.

Collect this sample by pumping the blank water through all of the sampling equipment as if processing a regular environmental sample as listed in section 6.2. Be sure to preserve and transport the blank samples in the same manner as the environmental samples.

7.2.3 Field replicate samples

Field replicate samples are collected to quantify the variability associated with the field and laboratory procedures. Collect these samples immediately after the environmental samples and preserve and transport them as described in Section 6 of this document.

7.3 Field data review

7.3.1 pH range

The water pH should range from approximately 6.3-8.0.

- A pH > 8.0 may occur in some buried carbonate aquifers, sodium-dominated systems, or silica-rich aquifers. Sodium-dominated systems are rare in Minnesota but there is the potential to see some in the Red River Valley. An additional sign of a sodium-dominated system would be a conductivity reading > 2,500 uS/cm.
- A pH < 6.3 can occur in aquifers rich in dissolved organic material. Peaty or sandy-forested areas consisting of primarily oak and evergreen trees have a tendency to increase the acidity of the soil, therefore lowering the pH of the shallow groundwater.

8. Post sampling procedures

Complete the following procedures after returning from a sampling event. Well water samples are stored using the procedures outlined below from the collection date until transported to the laboratory.

8.1 Sample storage and shipping

Upon returning to the FOC, the samples are transferred from the coolers to a refrigerator dedicated to the Ambient Groundwater Monitoring Network. The FOC staff measure the refrigerator temperature weekly during the field season.

The samples are delivered to the laboratory by the FOC staff or a commercial courier. The FOC staff transport the routine water samples to the MDH Environmental Laboratory after they have received a completed MPCA Chain of Custody Form. A commercial courier is used to transport any samples to other laboratories. Samples sent to laboratories outside of the U.S. require additional paperwork. This includes the commercial courier's waybill and three copies of the commercial invoice form. MPCA staff typically ship samples to non-state laboratories using standard coolers received from the laboratory. The sample bottles typically are packed in a foam insert supplied by the laboratory to minimize breakage and laboratory-certified blue ice packs typically are used to keep the samples at the appropriate temperature.

8.2 Holding times

The holding time is the maximum length of time allowed between sample collection and laboratory analysis. The holding times associated with the basic suite of chemicals collected for the network are listed below. Send all samples to the laboratory at the earliest possible time to allow sufficient time for laboratory processing and analysis to occur. However, the laboratory recommends only shipping the CEC samples from Monday through Wednesday. The VOC samples should be delivered to the laboratory within one week of collection to ensure the laboratory staff have sufficient time to process and analyze the samples.

Holding times for the Minnesota Department of Health Laboratory	
VOC (preserved)	14 days
Chloride/Sulfate/Bromide	28 days
Nutrients/Organic Carbon	28 days
Trace elements/Major Cations	180 days
Alkalinity	180 days

8.3 Equipment decontamination and stocking

Upon returning from a sampling event, all equipment must be decontaminated. The pumps must go through a thorough decontamination procedure similar to the one detailed in Section 7.1 *(Field Decontamination Procedure).* Wash the face of the pumps to remove dirt. Recharge any batteries, both internal and external.

Clean and restock all field boxes and field kits with the appropriate supplies. Perform a quick inventory to ensure that supplies are adequate for several sampling events. If supplies are low, order more supplies by informing the network's senior staff of the situation.

Appendix 1. Well casing conversion factors

Diameter of casing	Gallons per foot depth	Diameter of casing	Gallons per foot depth
1	.041	10	4.080
1 1/2	.092	11	4.937
2	.163	12	5.875
2 1/2	.255	14	8.000
3	.367	16	10.44
3 1/2	.500	18	13.22
4	.633	20	16.32
4 1/2	.826	22	19.75
5	1.020	24	23.50
5 1/2	1.234	26	27.58
6	1.469	28	32.00
7	2.000	30	36.72
8	2.611	32	41.78
9	3.305	34	47.16

1 Gallon = 3.785 Liters
1 Meter = 3.281 Feet
1 Gallon of Water Weights 8.33 lb. = 3.785 Kilograms
1 Gallon per Foot of Depth = 12.419 Liters per Foot Depth
1 Gallon per Meter of Depth = 12.419 x 10^{-3} Cubic Meters per Meter Depth

Appendix 2. YSI EX01 sonde operation

Field personnel must be familiar with the proper maintenance and operation of the YSI EXO1 series sondes, which routinely are used during fieldwork. The instructions for equipment operation and maintenance given in this section are consistent with the manufacturer's recommendations and guidelines. For further information about the EXO1 sondes and troubleshooting, please refer to the manufacturer's website at www.ysi.com for the applicable manual, or call YSI at 1-800-765-4974. For further information concerning how this equipment is used to obtain field measurements, please refer to Section 4 and 5 (*Sampling Protocols and Well Purging)* in this document.

1. General information

YSI EXO1 Sondes are multi-parameter instruments used to measure a wide variety of field parameters including water temperature, specific conductance, DO concentration, and pH. The field monitoring system consists of three basic components: 1) the sonde, 2) a displayer, and 3) the field cable. The sonde is the component that houses the probes and contacts the water. The displayer is a hand-held microcomputer used to: 1) display sonde readings, 2) configure and calibrate the sonde, 3) store data, and 4) upload data from the sonde and transfer the information to other computers for analysis and plotting. The field cable connects the sonde to the displayer.

1.1 Installing and removing probes

The YSI EXO1 series sondes used by the Ambient Groundwater Monitoring Network staff are equipped with three detachable probes: 1) conductivity/temperature, 2) pH, and 3) rapid-pulse optical DO probe. When the probes are not installed, a protective plug goes into any vacant probe ports to prevent water leakage into the sonde and avoid damage to the instrument. When installing or removing probes from the sonde, take extra care to ensure the sonde and the probes are completely dry and the installation does not result in cross threading the ports.

Probe removal/Installation procedure

1. To remove a protective plug or probe, insert the probe installation tool provided in the maintenance kit into one of the holes in the slip nut or plug head and turn counter-clockwise.
2. To install a protective plug, insert the plug into the port and gently rotate the plug until the two connectors align. Insert the probe installation tool and turn plug clockwise to tighten.
3. To install a probe, follow this procedure:
    - 3.1. Locate the port with the connector corresponding to the probe you wish to install:
        - 3.1.1. Rapid-Pulse DO = optical port
        - 3.1.2. Conductivity/Temperature = six pin connector
        - 3.1.3. pH = four pin connector
    - 3.2. Apply a thin coat of O-ring lubricant to the O-rings on the connector side of the probe. Insert the probe into the port and gently rotate the probe until the two connectors align. Using the probe installation tool, turn the slip nut clockwise to tighten, being careful not to cross thread the nut or over-tighten.

**** Note**: Before installing a probe to the sonde, be sure the probe and the port are free of moisture.*

1.2 Calibration, maintenance and storage

1.2.1 General calibration tips

The probes on the sonde require periodic calibration to ensure accurate readings. Weekly calibration is required on the DO, conductivity, and pH probes. Field staff must use fresh (not expired) standards when calibrating these probes. The thermistor used to measure water temperature cannot be calibrated. This probe only can be checked using NIST-certified or traceable equipment. If the probe reads outside of the allowable range, it must be immediately replaced because all other measurements are temperature compensated.

Field staff must maintain complete records of sonde calibration. When calibration is performed using the KOR software installed on field laptops, this information is stored automatically. The calibration record is essential to verify the quality of all field measurements. The sonde calibration documentation must include the time and date of calibration and the initials or name of the person performing the work. The staff also should record measurements such as water temperature and barometric pressure because the proper calibration for some probes is dependent on them. All recorded measurements also should have an associated manufacturer, lot number, and expiration date for all standards. Refer to the EXO User Manual for additional guidelines for using the sonde (available on the internet and in hard copy at the MPCA FOC).

1.2.2 Conductivity/Temperature probe

Calibration of the conductivity probe is required weekly or when the expected specific conductance is outside the calibration range. Commercially available standards (available at the FOC) are used to calibrate the instrument.

1.2.2.1 Calibration

1. Select two or three calibration standards to bracket the expected range of specific conductance to measure in the field. Calibrate using the standard closest to the expected specific conductance. The other standard(s) are check standards and document the calibration range.
2. Record standard manufacturer, lot number, and expiration date in calibration notes.
3. Rinse the probes and calibration cup two times with approximately 50 mL of specific conductance standard.
4. Fill the calibration cup with a sufficient amount of standard solution completely submerging the temperature/specific conductance probe. Verify no air bubbles are present on the conductance probe.
5. Allow at least one minute for the temperature to equilibrate.
6. From the *Calibration Mode* menu, select *Conductivity* and then *SpCond.*
7. Enter the calibration value for the standard being used (in mS/cm) at 25^{o}C and press enter. **Many conductance standards are in units of uS/cm, be sure to enter the standard value in mS/cm.**
8. Observe the readings under Specific Conductivity (SpC), and Temperature (TMP). When they show no significant change for approximately 1 to 2 minutes press <Y>. If the calibration value is accepted, press any key to return to the *Calibration Mode* menu.
9. Rinse the probes and calibration cup with approximately 50 mL of deionized water three times.

1.2.2.2 Calibration check(s)

1. Place the sonde in *Run Mode*.
2. Using the lowest check standard, rinse the probes and calibration cup two times with approximately 50 mL of specific conductance standard.
3. Record the standard manufacturer, lot number, and expiration date in calibration notes.
4. Fill the calibration cup with sufficient standard completely submerging the temperature/specific conductance probe. Verify no air bubbles are present on the conductance probe.
5. Allow at least one minute for the temperature to equilibrate.
6. Observe the readings under Specific Conductivity (SpC) and Temperature (TMP). When they show no significant change for approximately 1 to 2 minutes, record the measured specific conductance value in the calibration notes.
7. Verify the measured and expected specific conductance values are within 5%. If the difference is greater than 5%, the probe requires recalibration. The probe will lose its ability to hold calibration over a longer range as it ages. A substantial loss of calibration range indicates the probe needs replacement.
8. Repeat the procedure with another calibration check standard, if necessary.

   ***Note**: The calibration standard values on the bottles are in uS/cm; convert these values to mS/cm by dividing the values in uS/cm by 1000.*

1.2.3 Dissolved oxygen

The network uses an optical DO probe that should be calibrated once a week or when the expected DO falls outside of the calibration range. Follow the procedure listed below to calibrate the probe.

1.2.3.1 Optical probe calibration

1. Place the sensor into a calibration cup containing approximately 1/8 inch of water. Vent it by loosening the threads on the cup.
2. From the *Calibration Mode* menu, select *ODOsat %* and then *1-Point* to access the calibration procedure.
3. Enter the current barometric pressure in mm of Hg (to convert inches of Hg to mm of Hg, multiply the inches of Hg value by 25.4) and select *Enter*.
4. Record the current barometric pressure, air temperature, and initial DO concentration on the calibration notes sheet.
5. Observe the ODOsat % readings. When no significant change has occurred for approximately 30 seconds press *Enter*.
6. Record the calibrated and expected DO concentrations on the calibration notes sheet. Obtain the expected DO concentration from a DO chart using the air temperature and current barometric pressure.
7. Compare the calibrated and expected DO concentrations to verify the accuracy of sonde calibration. The difference between these values should be no greater than 0.2 milligrams per liter.

1.2.4 pH

Calibrate the pH probe at least weekly or when the expected water pH falls outside of the calibration range. A two-point calibration is required when the expected water pH is within the range of the two calibration buffers, 7 (yellow) and 10 (blue). A three-point calibration is required when anticipating the water pH in the field to be between 4 (red) and 10. The pH of the buffers, especially the pH 10 buffer, varies with water temperature. Be sure to calibrate the probe to the pH value associated with the temperature of the buffer.

1.2.4.1 Calibration

1. Rinse the pH probe and calibration cup with approximately 50 mL of pH 7 buffer.
2. Place approximately 200 mL of pH 7 buffer in the rinsed calibration cup and immerse the sonde into the solution. (Be sure there is enough calibration solution to submerge both the pH and temperature probes).
3. Record standard manufacturer, lot number, and expiration date in calibration notes.
4. Allow at least 1 minute for the temperature to equilibrate.
5. From the *Calibration Mode* menu, select *ISE1 pH.* Select *2 point* to perform a two-point calibration. Enter the value for the pH 7 buffer associated with the temperature of the standard recorded in step 3.
6. Observe the temperature (TMP) and pH readings; when the readings have stabilized, press <Y> and then any key to view the calibration value and press enter to proceed.
7. Triple rinse the sonde in distilled or deionized water before proceeding to the second point of the calibration procedure.
8. Repeat steps 1-7 with the second pH buffer (pH 10).
9. Repeat steps 1-7 with the third pH buffer (pH 4) if performing a three-point calibration.

Note*: The values for the pH buffers vary with water temperature, especially for the pH 10 buffer. Be sure to enter the correct pH value associated with a given temperature.*

1.2.4.2 Resetting the sonde to the default calibration

The YSI EXO1-series sondes occasionally must be returned to the default calibration settings from the factory. This usually occurs when the calibration of an instrument is outside of the standard range, which typically happens when a sensor is failing. Follow the settings below to set the instrument back to the default factory settings:

1. Activate any calibration screen (1-point, 2-point, or 3-point) where a numerical entry is required.
2. Instead of entering a numerical value, type the word “uncal” and press *Enter*.
3. An “uncal” entry at any calibration point will reset both the slope and offset for this parameter to the factory default settings.

1.2.5 Care and maintenance

Routine maintenance is required to keep the YSI EXO1-series sondes functioning properly. Record any maintenance activity in the calibration record associated with the instrument.

1.2.5.1 O-rings

The YSI EXO1 Series sondes use O-rings as seals to prevent water from entering the sensor ports. Improperly maintaining the O-rings and sealing surfaces will result in damage because water will reach the internal components of the sonde. Inspect the O-rings for dirt, debris, or damage when extracting probes or protective plugs from the sonde. Any dirt or debris adhering to the O-ring needs to be removed using water, a mild detergent, and a lens cleaning tissue or equivalent lint-free cloth. The O-ring requires a light greasing before replacement. If there is any indication of damage to the O-ring, it requires replacement as well.

- *Note: Do not use alcohol to clean the O-rings. Alcohol may cause a loss of elasticity and may promote cracking.*
- *Note: Do not over-grease the O-rings. The excess grease may cause the waterproofing capabilities to diminish, potentially causing water leaks into the sonde.*

1.2.5.2 Sonde probe ports

Prior to removal of a probe or protective plug, the sonde and all probes require desiccation to prevent water from entering the sonde. When extracting the probe or protective plug from the sonde, examine the connector inside the sonde probe port. If any moisture is present, use compressed air to desiccate the connector.

1.2.5.3 Conductivity/Temperature probe

The opening on the conductivity electrodes must be cleaned weekly or when sediment deposits are present on the probes, whichever occurs soonest. A small brush is included with the maintenance kit for this purpose. Dip the brush in clean water and insert it into the opening 15 to 20 times. If deposits are still noticeable in the opening, use a mild detergent and brush to remove the debris.

1.2.5.4 Optical dissolved oxygen probe

The DO sensor contains a sensing membrane and a sensor cap, which require routine maintenance to achieve the highest accuracy. The sensing membrane is the sapphire-colored disc on the probe. Try to prevent scratches, damage to the sensing membrane, and avoid getting fingerprints on it. If necessary, use a moistened lens tissue (with **water** and dish soap) to clean the sensor membrane. Alcohol and organic solvents must not be used for cleaning. Alcohol likely will dissolve the outer layer of paint on the membrane assembly, and other organic solvents likely will dissolve the dye itself.

The sensor cap covers the sensing membrane and should be replaced every year according to the manufacturer's instructions. The sensor cap is removed by rotating it with your finger counterclockwise. Replace the O-ring underneath the sensor cap at this time. The O-ring on the sensor can be removed without tools. Install the new O-ring without twisting it and apply a thin coat of lubricant to it. Clean the sapphire-colored sensing membrane with a lint-free cloth, and dry the inside cavity of the new sensor cap with a lint-free cloth. Install the new, clean sensor cap by threading it clockwise. The newly installed O-ring should be compressed and not pinched. A new O-ring must be installed if it is pinched during this process. **The sonde must be reconfigured according to the manufacturer's instructions each time the sensor cap is replaced.**

The sensing membrane and sensor cap must be kept moist for the best performance. Store the probe in water, a water-saturated environment, or in a moist environment when not in use to prevent drift. If the sensor is left in dry air for more than eight hours, it must be rehydrated by soaking it in room temperature tap water for 24 hours.

1.2.5.5 pH probe

Inspect the glass bulb on the end of the probe for breakage or any deposits of foreign material. The probe will not work and must be replaced if the glass bulb is cracked or broken. Cleaning is required whenever deposits or contaminants appear on the glass bulb or reference electrode or if the probe response diminishes. The glass bulb on the end of the probe is very prone to breakage. Take extreme care when cleaning the glass bulb, following the guidelines below.

1. Remove probe from the sonde.
2. Use clean water to remove all foreign material from the glass bulb and platinum button.
3. Dry the probe port probe connection with compressed air, and apply a very thin coat of O-ring lubricant before re-installing.
4. Consult the YSI EXO1-Series Sonde Operations Manual for additional cleaning procedures to increase probe response in event the above cleaning procedure is not successful.

1.2.5.6 Pressure transducer

The pressure transducer (if present) includes a circular protective cap with two small holes in it that is factory installed. This can be found between the bulkhead and the sonde tube. To clean the sensor, use a syringe (supplied with the maintenance kit) filled with clean water. Place the tip of the syringe into one of the holes and gently force the water through the sensor. Water should come out the other hole. Continue to flush water through the sensor until the water comes out clean.

1.2.6 Short-term storage

For short-term (weekly or biweekly) storage of the meter, the probes must stay moist within the calibration cup. Pour approximately ½ inch of tap water into the calibration cup supplied with the instrument and thread this onto the sonde (with the probes installed). If a ½ inch of water is unavailable, a water soaked sponge may be placed in the calibration cup.

1.2.7 Long-term storage

For long term storage (monthly or yearly) follow the guidelines below. Each probe has its own storage guidelines.

1.2.7.1 Conductivity/Temperature probe

This probe may be stored wet or dry as long as solutions in contact with the probe are not corrosive (for example, chlorine bleach). If the probe is placed into long-term storage, the probe must be cleaned with the supplied brush in order to keep it in its best condition.

1.2.7.2 Optical dissolved oxygen probe

The optical DO probe **must be stored in a moist environment**, either in water or in water-saturated air. It is preferable to store the probe in water. If the sensor membrane dries out from exposure to air, it is likely to drift slightly at the beginning of your next use unless it is rehydrated. For long-term storage, follow one the procedures below:

1. The easiest storage method is to use the protective plastic cap (and enclosed sponge) which was on the probe when it was new. Simply soak the sponge in water and replace the cap on the probe tip. Inspect the sponge every 30 days to make sure it is still moist.
2. An alternative storage method is to remove the probe from the sonde and place it directly in water (making sure the water does not evaporate over time). Alternatively, leave the probe on the sonde and make certain the calibration cup has a water-saturated atmosphere by placing approximately ½-inch of water in the bottom of the calibration cup and ensuring it is sealed snugly to the sonde.

1.2.7.3 pH probe

Remove the pH probe from the sonde and place a protective plug into the vacant port. Place the probe into a storage vessel filled with 2 M KCl solution or pH 4 buffer. Have the storage vessel sealed to prevent evaporation and check the solution level periodically.

Make sure the reference electrode does not dry out. If the electrode does happen to dry out, rehydrate it by soaking it in two molar KCl solution for 12 to 24 hours.

- *Warning: DO NOT store the pH probe in distilled or deionized water. This will result in irreparable damage to the probe.*

1.3 Flow cell maintenance

Follow this procedure to clean the flow cell:

1. Remove the sonde from the flow cell.
2. Disassemble the flow cell and clean all parts with a brush and mild detergent. **Do not** use harsh solvents to clean the flow cell.
3. Inspect the O-rings and the O-ring seats for damage that may prevent sealing. Replace them as needed. Reassemble the flow cell.

1.4 Power supply

The YSI EXO1 sondes used by the Ambient Groundwater Monitoring Network staff are powered internally using batteries or externally using the EXO displayer. The sonde may be powered internally with two alkaline D batteries. The YSI EXO displayer is powered using C-cell alkaline batteries or an internal rechargeable lithium ion battery pack. The displayer has separate lids for the alkaline C-cell battery and lithium ion battery pack power sources; both should accompany samplers into the field.

1.4.1 Alkaline batteries

THE YSI EXO1 batteries are located in the center of the sonde. To replace the batteries, remove the battery cover (located in the upper portion of the sonde) by turning counterclockwise and sliding it off. The YSI EXO displayer can be powered using four alkaline C-cell batteries. With this configuration, the displayer will last for approximately 45 hours of continuous operation.

1.4.1.1 Internal battery (In the EXO displayer)

The internal lithium ion battery pack powers the EXO displayer and a typical YSI EXO1-series sonde for approximately 15 hours of continuous use. For maximum operational time from the lithium ion battery pack, follow the subsequent procedures.

Do not charge the batteries for more than 48 hours. This can cause irreparable damage to the batteries.

- To obtain an 80-90% regeneration of battery capacity, place the EXO displayer on charge for approximately 2 hours
- To obtain a full charge, place the EXO displayer on charge for approximately 6 hours.
- Do not charge the batteries at temperatures below 0°C or greater than 40°C.
- The lithium ion batteries do not have a memory effect. This means that the batteries are rechargeable before completely discharging.
- The lithium ion batteries do not hold their full charge when stored. They will require a full charge within 24 hours of the next use.

1.4.2 Charging power supplies

Adapters (110-volt) are available to recharge the lithium ion internal battery. A vehicle cigarette lighter adapter is also available to recharge the lithium ion internal battery pack.

The lithium ion internal battery will discharge during storage. It is important to recharge this battery within one day of use. Always remember to take the charger and cigarette lighter adapter when traveling and sampling overnight.

Appendix 3. Converting quarters

When converting quarters to the A, B, C, D method, a reversed order of listing from largest to smallest unit is used.

Example: At point X the legal description would read:

> NE1/4 NW1/4 NW1/4 of Section # Range# Township #
>
> Using the A, B, C, D method the legal description would read in the reverse order
>
> Township # Range # Section # B B A

Identify 2 – 6 quarters when using this method at least 2.

NE 1/4 = A, NW 1/4 = B, SW 1/4 = C, SE 1/4 = D