STANDARD OPERATING PROCEDURE FOR THE STANDARD/WELL-VOLUME METHOD FOR COLLECTING A GROUND-WATER SAMPLE FROM MONITORING WELLS FOR SITE CHARACTERIZATION

INTRODUCTION

The collection of "representative" water samples from wells is neither straightforward nor easily accomplished. Ground-water sample collection can be a source of variability through differences in sampling personnel and their individual sampling procedures, the equipment used, and ambient temporal variability in subsurface and environmental conditions. Many site inspections and remedial investigations require the sampling at ground-water monitoring wells within a defined criterion of data confidence or data quality, which necessitates that the personnel collecting the samples are trained and aware of proper sample-collection procedures.

The objectives of the sampling procedures described in this document are to minimize changes in ground-water chemistry during sample collection and transport to the laboratory and to maximize the probability of obtaining a representative, reproducible ground-water sample. Sampling personnel may benefit from a working knowledge of the chemical processes that can influence the concentration of dissolved chemical species.

The well-volume purging method described in this standard operating procedure (SOP) provides a reproducible sampling technique with the goal that the samples obtained will represent water quality over an entire open interval of a short-screened (ten feet or less) well. This technique is appropriate for long-term and detection monitoring of formation water quality. The resulting sample generally represents a composite of the well-screened interval, and thus integrates small-scale vertical heterogeneities of ground-water chemistry. This sampling technique also is useful for screening purposes for detection monitoring of contaminants in the subsurface. However, the detection of a low-concentration of contaminant in a thin contaminated zone, or with long well screens may be difficult, and should be determined using detailed vertical profiling techniques.

This method may not be applicable for all ground-water-sampling wells, such as wells with very low yields, fractured rock, and some wells with turbidity problems. As always, site-specific conditions and objectives should be considered prior to the selection of this method for sampling.

SCOPE AND APPLICATION

The objective of a good sampling program should be the collection of a “representative” sample of the current ground-water conditions over a known or specified volume of aquifer. To meet this objective, the sampling equipment, the sampling method, the monitoring well construction, monitoring well operation and maintenance, and sample-handling procedures should not alter the chemistry of the sample.

An example of how a site’s Data Quality Objectives (DQO’s) for a characterization sampling effort might vary from those of a remediation monitoring sampling effort could be a difference of how much of the screened interval or aquifer should be sampled. A site characterization objective may be to collect a sample that represents a composite of the entire (or as close as is possible) screened interval of the monitoring well.

Additionally, the site characterization may require a large suite of contaminants to be sampled and analyzed, whereas, the remediation monitoring program may require fewer contaminants sampled and analyzed. These differences may dictate the type of sampling equipment used, the type of information collected, and the sampling protocol.

This sampling method described is for monitoring wells. However, this method should not be used for water-supply wells with a water-supply pump, with long-screened wells in complex hydrogeologic environments (such as fractured rock), or wells with separate phases of liquids (such as a Dense or Light Non-Aqueous Phase Liquids) present within the screened interval.

EQUIPMENT

- Depth-to-water measuring device - An electronic water-level indicator or steel tape and chalk, with marked intervals of 0.01 foot. Interface probe for measuring separate phase liquids, if needed. Pressure transducer and data logger optional for frequent depth-to-water measuring in same well.

- Steel tape and weight - Used for measuring total depth of well. Lead weights should not be used.
- Sampling pump - Submersible or bladder pumps with adjustable rate controls are preferred. Pumps are to be constructed of inert materials, such as stainless steel and teflon. Pump types that are acceptable include gear and helical driven, centrifugal (low-flow type) and air-activated piston. Adjustable rate, peristaltic pumps can be used when the depth to water is 20 feet or less.
- Tubing - Inert tubing should be chosen based on the types and concentrations of contaminants present, or expected to be present in the monitoring well. Generally, Teflon® based tubing are recommended when sampling for organic compounds. Polyethylene or Teflon® tubing can be used when sampling for inorganic constituents.
- Power source - If a combustion type (gasoline or diesel-driven) device is used, it must be located downwind of the point of sample collection. If possible, it should also be transported to the site and sampling location in a different vehicle from the sampling equipment.
- Flow-measurement equipment - Graduated cylinder or bucket and a stop watch, or a flow meter that can be disconnected prior to sampling.
- Multi-parameter meter with flow-through cell - This can be one instrument (such as a Hydrolab® or YSI® downhole sonde with a flow-through-cell) or multiple probes/instruments contained in a flow-through-cell. The water-quality-indicator parameters that are measured in the field are pH, oxidation/reduction potential (ORP, redox or Eh), dissolved oxygen (DO), turbidity, specific electrical conductance (SEC) and temperature. Calibration standards for all instruments should be NIST-traceable, within expiration dates of the solutions, and sufficient for daily calibration throughout the sampling collection.
- Decontamination supplies - A reliable and documented source of distilled water and any solvents (if used). Pressure sprayers, buckets or decontamination tubes for pumps, brushes and non-phosphate soap also will be needed.
- Sample bottles, sample preservation supplies and laboratory paperwork. Also, several coolers, sample packing supplies (absorbing packing material, baggies, etc.).
- Approved plans and background documents - Approved Field Sampling Plan, Quality Assurance Project Plan, well construction data, field and water-quality data from the previous sampling collection.

- Site Access/Permission documentation for site entry.
- Well keys and map showing locations of wells.
- Field notebook, field data sheets and calculator. A suggested field data sheet is provided as a figure.
- Filtration equipment - If needed, this equipment should be an in-line disposable filter used for the collection of samples for analysis of dissolved constituents.
- Polyethylene sheeting - Used for decontamination stations and during sampling to keep equipment clean.
- Site Health and Safety Plan and required equipment - The health and safety plan along with site sign-in sheet should be on site and be presented by the site health and safety officer. Personnel-protective and air-monitoring equipment specified in the Site Health and Safety Plan should be demonstrated, present and in good working order on site at all times.
- Tool box - All needed tools for all site equipment used.
- A 55-gallon drum or container to contain the purged water.

Materials of construction of the sampling equipment (bladders, pump, bailers, tubing, etc.) should be limited to stainless steel, Teflon®, glass and other inert materials when concentrations of the site contaminants are expected within the detection limit range. The sample tubing thickness and diameter should be maximized and the tubing length should be minimized so that the loss of contaminants absorbed to and through the tubing walls may be reduced and the rate of stabilization of ground-water parameters is maximized. The tendency of organics to sorb into and out of many materials makes the appropriate selection of sample tubing materials critical for these trace analyses (Pohlmann and Alduino, 1992; Parker and Ranney, 1998).

Generally, wells should be purged and sampled using the same positive-pressure pump and/or a low-flow submersible pump with variable controlled flow rates and constructed of chemically inert materials. If a pump cannot be used because the recovery rate to the well is so low (less than 100 to 200 ml/min) and the volume of the water to be removed is minimal (less than 5 feet of water in a small-diameter well), then a Teflon® bailer, with a double check valve and bottom-emptying device with a control-flow check valve may be used to obtain the samples. Otherwise, a bailer should not be used when sampling for volatile organics because of the potential bias introduced during sampling (Yeskis, et al., 1988; Pohlmann, et al., 1990; Tai, et al., 1991). Bailers also should be avoided when sampling for metals because repeated bailer deployment has the potential to increase turbidity, which biases concentrations of inorganic constituents. Dedicated sampling pumps are recommended for metals sampling (Puls, et al., 1992).

In addition, for wells with long riser pipes above the well screen, the purge volumes may be reduced by using packers above the pumps. The packer materials should be compatible with the parameters to be analyzed. These packers should be used only on wells screened in highly permeable materials, because of the lack of ability to monitor water levels in the packed interval. Otherwise, if pumping rates exceed the natural aquifer recovery rates into the packed zone, a vacuum or negative pressure zone may develop. This may result in a failure of the seal by the packer and/or a gaseous phase may develop, that may bias any sample taken.

PURGING AND SAMPLING PROCEDURE

WATER-LEVEL MEASUREMENTS

The field measurements should include total well depth and depth to water from a permanently-marked reference point.

TOTAL WELL DEPTH

The depth of each well should be measured to the nearest one-tenth of a foot when using a steel tape with a weight attached and should be properly recorded. The steel tape should be decontaminated before use in another well according to the site specific protocols. A concern is that when the steel tape and weight hit the bottom of the well, sediment present on the bottom of a well is stirred up, thus increasing turbidity which will affect the sampling results. In these cases, as much time as possible should be allowed prior to sampling, such as a minimum of 24 hours. If possible, total well depth measurements can be completed after sampling (Puls and Barcelona, 1996). The weight of electric tapes is generally too light to determine accurate total well depth. If depth of well is greater than 200 feet, stretching of the tape must be taken into consideration.

DEPTH TO WATER

All water levels should be measured from the reference point by use of a weighted steel tape and chalk or an electronic water-level indicator (a detailed discussion of the pros and cons of the different water level devices is provided in Thornhill, 1989). The steel tape is a more accurate method to take water levels, and is recommended where shallow flow gradients (less than 0.05 feet/feet) or deep wells are encountered. However, in those cases where large flow gradients or large fluctuations in water levels are expected, a calibrated electric tape is acceptable. The water level is calculated using the well's surveyed reference point minus the measured depth-to-water and should be measured to the nearest one-hundredth of a foot.

The depth-to-water measurement must be made in each well to be sampled prior to any other activities at the well (such as bailing, pumping, and hydraulic testing) to avoid bias to the depth-to-water measurement. All readings are to be recorded to the nearest one-hundredth of a foot. When possible, depth-to-water and total well depth measurements should be completed at the beginning of a ground-water sampling program, which will allow any turbidity to settle and allow a more synoptic water-level evaluation. However, if outside influences (such as: tidal cycles, nearby pumping effects, major barometric changes) that may result in significant water-level changes in the time between measurement and sampling, a water-level measurement should be completed immediately prior to sampling. In addition, the depth-to-water measurement during purging should be recorded, with the use of a pressure transducer and data logger sometimes more efficient (Barcelona et al., 1985, Wilde et al., 1998).

The time and date of the measurement, point of reference, measurement method, depth-to-water measurement, and any calculations should be properly recorded in field notebook or sampling sheet.

STATIC WATER VOLUME

From the information obtained for casing diameter, total well depth and depth-to-water measurements, the volume of water in the well is calculated. This value is one criteria that may be used to determine the volume of water to be purged from the well before the sample is collected.

The static water volume may be calculated using the following formula:

$V = r^2h(0.163)$

Where:

V = static volume of water in well (in gallons)
r = inner radius of well casing (in inches)
h = length of water column (in feet) which is equal to the total well depth minus depth to water.
0.163 = a constant conversion factor that compensates for the conversion of the casing radius from inches to feet for 2-inch diameter wells and the conversion of cubic feet to gallons, and pi (A). This factor would change for different diameter wells.

Static water volumes also may be obtained from various sources, such as Appendix 11.L in Driscoll (1986).

WELL PURGING

PURGE VOLUMES

In most cases, the standing water in the well casing can be of a different chemical composition than that contained in the aquifer to be sampled. Solutes may be adsorbed or desorbed from the casing material, oxidation may occur, and biological activity is possible. Therefore, the stagnant water within the well must be purged so that water that is representative of the aquifer may enter the well.

The removal of at least 3 well volumes is suggested (USEPA, 1986; Wilde et al., 1998). The amount of water removed may be determined by collecting it in a graduated pail of known volume to determine pumping rate and time of pumping. A flow meter may also be used, as well as capturing all purged water in a container of known volume.

The actual number of well volumes to be removed is based on the stabilization of water-quality-indicator parameters of pH, oxidation-reduction potential (ORP), specific electrical conductance (SEC), dissolved oxygen (DO), and turbidity. The water initially pumped is commonly turbid. In order to keep the turbidity and other probes from being clogged with the sediment from the turbid water, the flow-through cell should be bypassed initially for the first well volume. These measurements should be taken and recorded every 1/2 well volume after the removal of 1 to 1 ½ well volume(s). Once three successive readings of the water-quality-indicator parameters provided in the table have stabilized, the sampling may begin. The water-quality-indicator parameters which are recommended include pH and temperature, but these are generally insensitive to indicate completion of purging since they tend to stabilize rapidly (Puls and Barcelona, 1996). Oxidation-reduction potential may not always be an appropriate stabilization parameter, and will depend on site-specific conditions. However, readings should be recorded because of its value as a double check for oxidizing conditions, and for some fate and transport issues. When possible, especially when sampling for contaminants that may be biased by the presence of turbidity, the turbidity reading is desired to stabilize at a value below 10 Nephelometric Turbidity Units (NTU's). For final dissolved oxygen measurements, if the readings are less than 1 milligram per liter, they should be collected with the spectrophotometric method (Wilde et al., 1998, Wilkin et al., 2001), colorimetric or Winkler titration (Wilkin et al., 2001). All of these water-quality-indicator parameters should be evaluated against the specifications of the accuracy and resolution of the instruments used. No more than 6 well volumes should be purged, to minimize the over pumping effects described by Gibs and Imbrigiotta (1990).

Table of Stabilization Criteria with References for Water-Quality-Indicator Parameters

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

Purging Methods

In a well that is not being pumped, there will be little or no vertical mixing in the water column between sampling events, and stratification may occur. The water in the screened section may mix with the ground water due to normal flow patterns, but the water above the screened section will remain isolated and become stagnant. Persons sampling should realize that stagnant water may contain foreign material inadvertently or deliberately introduced from the surface, resulting in unrepresentative water quality. To safeguard against collecting nonrepresentative stagnant water in a sample, the following guidelines and techniques should be adhered to during sample collection:

1. As a general rule, monitoring wells should be pumped or bailed (bailed is to be strongly avoided) prior to collecting a sample. Evacuation of a minimum of three volumes of water in the well casing is recommended for a representative sample. In a high-yielding ground-water formation where there is no stagnant water in the well above the screened section (commonly referred to as a water-table well), evacuation prior to sample withdrawal is not as critical but serves to field rinse and condition sampling equipment. The purge criteria has been described previously and will be again in the SAMPLING PROCEDURES section. The rate of purging should be at a rate and by a method that does not cause aeration of the water column and should not exceed the rate at which well development was completed.

2. For wells that can be pumped or bailed to dryness with the sampling equipment being used, the well should be evacuated to just above the well screen interval and allowed to recover prior to sample withdrawal. (Note: it is important not to completely de-water the zone being sampled, as this may allow air into that zone which could result in negative bias in organic and metal constituents.) If the recovery rate is fairly rapid and time allows, evacuation of more than one volume of water is preferred.

3. A non-representative sample also can result from excessive prepumping of the monitoring well. Stratification of the contaminant concentrations in the ground-water formation may occur or heavier-than-water compounds may sink to the lower portions of the aquifer. Excessive pumping can decrease or increase the contaminant concentrations from what is representative of the sampling point of interest, as well as increase turbidity and create large quantities of waste water.

The method used to purge a well depends on the inner diameter, depth-to-water level, volume of water in the well, recovery rate of the aquifer, and accessibility of the well to be sampled. The types of equipment available for well evacuation include hand-operated or motor-driven suction pumps, peristaltic pumps, submersible pumps, and bailers made of various materials, such as stainless steel and Teflon®. Whenever possible, the same device used for purging the well, should be left in the well and used for sampling, generally in a continual manner from purging directly to sampling without altering position of the sampling device or turning off the device.

When purging/sampling equipment must be reused in other wells, it should be decontaminated consistent with the Decontamination Procedures outlined in this document. Purged water should be collected and screened with air-monitoring equipment as outlined in the site health and safety plan, as well as water-quality field instruments. If these parameters and/or the facility background data suggest that the water is hazardous, it should be contained and disposed of properly as determined on a site-specific basis.

During purging, water-level measurements should be recorded regularly for shallow wells, typically at 15- to 30-second intervals. These data may be useful in computing aquifer transmissivity and other hydraulic characteristics, and for adjusting purging rates. In addition, these data will assure that the water level doesn’t fall below the pump intake level

SAMPLING PROCEDURES

Ground-water sample collection should take place immediately following well purging. Preferably, the same device should be used for sample collection as was used for well purging, minimize further disturbance of the water column, and reduce volatilization and turbidity. In addition, this will save time and avoid possible contamination from the introduction of additional equipment into the well, as well as using equipment materials already equilibrated to the ground water. Sampling should occur in a progression from the least to most contaminated well, if known, when the same sampling device is used.

The sampling procedure is as follows:

1) Remove locking well cap, note location, time of day, and date in field notebook or on an appropriate log form.
2) Note wind direction. Stand up wind from the well to avoid

contact with gases/vapors emanating from the well.

3) Remove well casing cap.
4) If required by site-specific conditions, monitor headspace of well with appropriate air-monitoring equipment to determine presence of volatile organic compounds or other compounds of concern and record in field logbook.
5) If not already completed, measure water level from reference measuring point on well casing or protective outer casing (if inner casing not installed or inaccessible) and record in field notebook. Alternatively, if no reference point, note that water level measurement is from top of outer protective casing, top of inside riser pipe, ground surface, or some other position on the well head. Have permanent reference point established as soon as possible after sampling. Measure at least twice to confirm measurement; measurement should agree within 0.01 feet or re-measure. Decontaminate water-level-measuring device.
6) If not already completed, measure total depth of well (at least twice to confirm measurement; measurement should agree within 0.01 feet or re-measure) and record in field notebook or on log form. Decontaminate device used to measure total depth. If the total depth of well has been measured recently (in the past year), then measure at the conclusion of sampling.
7) Calculate the volume of water in the well and the volume to be purged using the formula previously provided.
8) Lay plastic sheeting around the well to minimize the likelihood of contamination of equipment from soil adjacent to the well.
9) Rinse outside of sampling pump with distilled water and then, while lowering the pump, dry with disposable paper towels.
10) Lower the pump (or bailer) and tubing down the well. The sampling equipment should never be dropped into the well, because this will cause degassing of the water upon impact. This may also increase turbidity, that may bias the metals analysis. The lowering of the equipment should be slowly and smoothly!
11) The pump should be lowered to a point just below the water level. If the water level is above the screened interval, the pump should be above the screened interval for the reasons provided in the purging section.
12) Turn the pump on. The submersible pumps should be operated in a continuous, low-flow manner so that they do not produce pulsating flows that cause aeration in the discharge tubing,

aeration upon discharge, or resuspension of sediments at the bottom of the well. The sampling pump flow rates should be lower than or the same as the purging rates. The purging and sampling rates should not be any greater than well development rates.

13) Water levels should be monitored during pumping to ensure that air does not enter the pump and to help in the determination of an appropriate purging rate.

14) After approximately one to two well volumes are removed, a flow-through cell will be hooked-up to the discharge tubing of the pump. If the well discharge water is not expected to be highly turbid, encounter separate liquid phases, or minimal bacterial activity that may coat or clog the electrodes within the flow-through cell, then the cell can be immediately hooked-up to the discharge tubing. This cell will allow measurements of water-quality-indicator parameters without allowing contact with the atmosphere prior to recording the readings for temperature, pH, ORP, SEC, DO and turbidity.

15) Measurements for temperature, pH, ORP, SEC, DO and turbidity will at each one-half well volume removed. Purging may cease when measurements for all five parameters have stabilized (provided in the earlier table) for three consecutive readings.

16) If the water level is lowered to the pump level before three volumes have been removed, the water level will be allowed to recovery for 15 minutes and then pumping can begin at a lower flow rate. If the pump again lowers the water level to below the pump intake, the pump will be turned off and the water level allowed to recover for a longer period of time. This will continue until a minimum of two well volumes are removed prior to taking the ground-water sample.

17) If the water-quality-indicator parameters have stabilized, sample the well. Samples will be collected by lowering the flow rate to a rate which minimizes aeration of the sample while filling the bottles (approximately 300 ml/min). Then a final set of water-quality-indicator parameters is recorded. The pump discharge line is rapidly disconnected from the flow-through cell to allow filling of bottles from the pump discharge line. The bottles should be filled in the order of volatile organic compounds bottles first, semi-volatile organic compound's/pesticides, the inorganics, and other unfiltered samples. Once the last set of samples are taken, if filtering is necessary, an in-line, appropriately chosen filter size, disposable filter will be added to the

discharge hose of the pump. Then the filtered samples will be taken. If a bailer is used for obtaining the samples, the filtering will occur at the sampling location, immediately after the sample is obtained from the bailer by using a suction filter. The first one-half to one liter of sample taken through the filter will not be collected, in order to assure the filter media is acclimated to the sample. If filtered samples are collected, WITHOUT EXCEPTION, filtering should be performed in the field as soon as possible after collection, and not later in a laboratory.

18) All appropriate samples that are to be cooled, are to be put into a cooler with ice immediately. All of the samples should not be exposed to sunlight after collection. Keep the samples from freezing in the winter when outside temperatures are below freezing. The samples, especially organics, cyanide, nutrients and other analytes with short holding times, are recommended be shipped or delivered to the laboratory daily. Ensure that the appropriate samples that are to be cooled remain at 4°C, but do not allow any of the samples to freeze.

19) If a pump cannot be used because the recovery rate is so slow and the volume of the water to be removed is minimal (less than 5 feet of water), then a Teflon® bailer, with a double check valve and bottom-emptying device with a control-flow check valve will be used to obtain the samples. The polypropylene rope used with the bailer will be disposed of following the completion of sampling at each well.

20) The pump is removed from the well and decontaminated for the next sampling location.

Additional precautions that can be made to ensure accurate and representative sample collection are as follows:

- Check valves on bailers (if used, which should be designed and inspected to ensure that fouling problems do not reduce delivery capabilities or result in aeration of the sample.
- The water should be transferred to a sample container in a way that will minimize agitation and aeration.
- If the sample bottle contains no preservatives, the bottle should be rinsed with sample water that is discarded before sampling. Bottles for sample analysis which require preservation should be prepared before they are taken to the well. Care should be taken to avoid overfilling bottles so that the preservative is not lost. The pH should be checked

and more preservatives added to inorganic sample bottles, if needed. VOA bottles would need to be discarded and new sample bottles immediately prepared.

- Clean sampling equipment should not be placed directly on the ground or other contaminated surfaces either prior to sampling or during storage and transport.

Special Consideration For Volatile Organic Compound Sampling

The proper collection of a sample for dissolved volatile organics requires minimal disturbance of the sample to limit volatilization and therefore a loss of volatiles from the samples. Sample retrieval systems preferred for the collection of un-biased volatile organic samples are: positive displacement pumps, low-flow centrifugal pumps and some in-situ sampling devices. Field conditions and other constraints will limit the choice of appropriate systems. The principal objective is to provide a valid sample for analysis, one that has been subjected to the least amount of turbulence possible.

1) Fill each vial to just overflowing. Do not rinse the vial, nor excessively overflow it, as this will effect the pH by diluting the acid preservative previously placed in the bottle. Another option is to add the acid at the well, after the sample has been collected. There should be a convex meniscus on the top of the vial.
2) Do not overtighten and break the cap.
3) Invert the vial and tap gently. Observe vial closely. If an air bubble appears, discard the sample and collect another. It is imperative that no entrapped air remains in the sample vial. Bottles with bubbles should be discarded, unless a new sample cannot be collected, and then the presence of the bubble should be noted in the field notes or field data sheet. If an open sample bottle is dropped, the bottle is to be discarded.
4) Place the volatile organic compound vial in the cooler, oriented so that it is lying on its side, not straight up.
5) The holding time for volatile organic compounds is 14 days. It is recommended that samples be shipped or delivered to the laboratory daily. Ensure that the samples remain at 4°C, but do not allow the samples to freeze.

Turbid Samples-Field Filtration

The USEPA recognizes that in some hydrogeologic environments, even with proper well design, installation and development, in combination with the low-flow rate purging and sampling techniques, sample turbidity cannot be reduced to ambient levels. The well construction, development and sampling information should be reviewed by the regional geologists or hydrologists to see if the source of the turbidity problems can be resolved or if alternative sampling methodologies should be employed. If the water sample is excessively turbid, the collection of both filtered and unfiltered samples, in combination with turbidity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), pumping rate and drawdown data is recommended. The filter size used to determine TSS and TDS should be the same as used in the field filtration. An in-line filter should be used to minimize contact with air to avoid precipitation of metals. The typical filter media size used is 0.45 µm because this is commonly accepted as the demarcation between dissolved and non-dissolved species. Other filter sizes may be appropriate but their use should be determined based on site-specific criteria (examples include grain-size distribution, ground-water-flow velocities, mineralogy) and project DQO's. Filter sizes up to 10.0 µm may be warranted because larger size filters may allow particulates that are mobile in ground water to pass through (Puls and Powell, 1992). The changing of filter media size may limit the comparability of the data obtained with other data sets and may affect their use in some geochemical models. Filter media size used on previous data sets from a site, region or aquifer and the data quality objectives should be taken into consideration. The filter media used during the ground-water sampling program should be collected in a suitable container and archived because potential analysis of the media may be helpful for the determination of particulate size, mineralogy, etc.

The first 500 to 1000 milliliters of sample, depending on sample turbidity, taken through the filter will not be collected for a sample, in order to ensure that the filter media has equilibrated to the sample (manufacture's recommendations also should be consulted). Because bailers have been shown to increase turbidity while purging and sampling, bailers should be avoided when sampling for trace element, metal, PCB and pesticide constituents. If portable sampling pumps are used, the pumps should be gently lowered to the sampling depth desired, carefully avoiding being lowered to the bottom of the well, and allowed to sit in order to allow any particles mobilized by pump placement to settle. Dedicated sampling equipment installed in the well prior to the commencement of the sampling activities is one of the recommended methods to reduce turbidity artifacts (Puls and Powell, 1992; Kearl, et al., 1992; Puls et al., 1992; Puls and Barcelona, 1996).

DECONTAMINATION PROCEDURES

Once removed from the well, the purging and sampling pumps should be decontaminated with a non-phosphate soapy-water wash and scrubbed with a brush, a water rinse, and a distilled-water rinse, to help ensure that there is no cross-contamination between wells. The step-by-step procedure is:

1) Pull pump out of previously-sampled well (or out of vehicle) and use three pressure sprayers filled with soapy water, tap water and distilled water. Spray outside of tubing and pump until water is flowing off of tubing after each rinse. Use bristle brush to help remove visible dirt, contaminants, etc.
2) Have three long-PVC tubes with caps or buckets filled with soapy water, tap water and distilled water. Run pump in each until approximately 2 to 3 gallons of each decon solution is pumped through tubing. Pump at low rate to increase contact time between the decon solutions and the tubing.
3) Try to pump decon solutions out of tubing prior to next well. If this cannot be done, compressed air may be used to purge lines. Another option is to install a check valve in the pump line (usually just above the pump head) so that the decon solutions do not run back down the well as the pump is lowered down the next well.
4) Prior to lowering the pump down the next well, spray the outside of the pump and tubing with distilled water. Use disposable paper towels and dry the pump and tubing.
5) If a hydrophobic contaminant is present (such as separate phase, high levels of PCB’s, etc.) an additional decon step, or steps, may be added. For example, an organic solvent, such as reagent-grade isopropanol alcohol may be added as a first spraying/bucket prior to the soapy water rinse/bucket.

If the well has been sampled with a bailer and the bailer is not disposable, the bailer should be cleaned by washing with soapy water, rinsing with tap water, and finally rinsing with distilled water. Bailers are most easily cleaned using a long-handled bottle brush.

It is especially important to clean thoroughly that portion of the equipment that will be in contact with sample water. In addition, a clean plastic sheet should be placed adjacent to or around the well to prevent surface soils from coming in contact with the purging equipment. The effects of cross-contamination also can be minimized by sampling the least contaminated well first and progressing to the more contaminated ones. The bailer cable/rope (if a bailer is used) and plastic sheet should be properly discarded, as provided in the site health and safety plan, and new materials provided for the next well.

FIELD QUALITY CONTROL

The quality assurance (QA) targets for precision and accuracy of sampling programs are based on average accuracy and precision guidelines established by the USEPA. When setting targets, keep in mind that all measurements must be made so that the results are representative of the sample water and site-specific conditions. Various types of blanks are used to check the cleanliness of the field-handling methods. These are known as field blanks, and include field equipment blanks and transport blanks. Other QA samples include spike samples and duplicates.

There are five primary areas of concern for QA in the collection of representative ground-water samples:

1. Obtaining a sample that is representative of water in the aquifer or targeted zone of the aquifer. Verify log documentation that the well was purged of the required volume or that the following parameters (temperature, pH, ORP, SEC, DO and turbidity) stabilized before samples were extracted.
2. Ensuring that the purging and sampling devices are made of materials and utilized in a manner that will not interact with or alter the analyses.
3. Results generated by these procedures are reproducible; therefore, the sampling scheme should incorporate co-located samples (duplicates).
4. Cross-contamination is prevented. Sampling should proceed from least to most contaminated wells, if known. Field-equipment blanks should be incorporated for all sampling and purging equipment, and decontamination of the equipment is

therefore required.
5. Samples are properly preserved, packaged, and shipped.

FIELD EQUIPMENT BLANKS

To ensure QA and quality control, a field equipment blank must be included in each sampling run, or for every twenty samples taken with the sampling device. These allow for a cross check and, in some cases, quantitative correction for imprecision that could arise due to handling, preservation, or improper cleaning procedures.

Equipment blanks should be taken for each sample bottle type that is filled. Distilled water is run through the sampling equipment and placed in a sample bottle (the blank), and the contents are analyzed in the lab like any other sample. Following the collection of each set of twenty samples, a field equipment blank will be obtained. It is generally desirable to collect this field equipment blank after sampling a relatively highly contaminated well. These blanks may be obtained through the following procedure:

a) Following the sampling event, decontaminate all sampling equipment according to the site decontamination procedures and before collecting the blank.
b) VOA field blanks should be collected first, prior to water collected for other TAL/TCL analyses. A field blank must be taken for all analyses.
c) Be sure that there is enough distilled water in the pump so that the field equipment blank can be collected for each analyses.
d) The water used for the field equipment blank should be from a reliable source, documented in the field notebooks, and analyzed as a separate water-quality sample.

TRIP BLANKS

A trip blank should be included in each sample shipment and at a minimum, one per 20 samples. Bottles, identical to those used in the field, are filled with reagent-grade water. The source of the reagent-grade water should be documented in the field notebooks, including lot number and manufacture. This sample is labeled and stored as though it is a sample. The sample is shipped back to the laboratory with the other samples and analysis is carried out for all the same constituents.

DUPLICATE SAMPLES

Duplicate samples are collected by taking separate samples as close to each other in time and space as practical, and should be taken for every 20 samples collected. Duplicate samples are used to develop criteria for acceptable variations in the physical and chemical composition of samples that could result from the sampling procedure. Duplicate results are utilized by the QA officer and the project manager to give an indication of the precision of the sampling and analytical methods.

HEALTH AND SAFETY CONSIDERATIONS

Depending on the site-specific contaminants, various protective programs must be implemented prior to sampling the first well. The site health and safety plan should be reviewed with specific emphasis placed on the protection program planned for the sampling tasks. Standard safe operating practices should be followed, such as minimizing contact with potential contaminants in both the liquid and vapor phase through the use of appropriate personal protective equipment.

Depending on the type of contaminant expected or determined in previous sampling efforts, the following safe work practices will be employed:

Particulate or metals contaminants

1. Avoid skin contact with, and accidental ingestion of, purge water.
2. Wear protective gloves and splash protection.

Volatile organic contaminants

1. Avoid breathing constituents venting from well.
2. Pre-survey the well head space with an appropriate device as specified in the Site Health and Safety Plan.
3. If air-monitoring results indicate elevated organic constituents, sampling activities may be conducted in Level C protection. At a minimum, skin protection will be afforded by disposable protective clothing, such as Tyvek®.

General, common practices should include avoiding skin contact with water from preserved sample bottles, as this water will have pH less than 2 or greater than 10. Also, when filling, pre-preserved VOA bottles, hydrochloric acid fumes may be released and should not be inhaled.

POST-SAMPLING ACTIVITIES

Several activities need to be completed and documented once ground-water sampling has been completed. These activities include, but are not limited to:

- Ensure that all field equipment has been decontaminated and returned to proper storage location. Once the individual field equipment has been decontaminated, tag it with date of cleaning, site name, and name of individual responsible.
- All sample paperwork should be processed, including copies provided to Central Regional Laboratory, Sample Management Office, or other appropriate sample handling and tracking facility.
- All field data should be compiled for site records.
- All analytical data when processed by the analytical laboratory, should be verified against field sheets to ensure all data has been returned to sampler.

REFERENCES

Barcelona, M.J., J.P. Gibb, J.A. Hellfrich and E.E. Garske, 1985, Practical Guide for Ground-Water Sampling; U.S. Environmental Protection Agency, EPA/600/2-85/104, 169 pp.

Driscoll, F.G., 1986, Groundwater and Wells, 2nd Ed.; Johnson Division, St. Paul, Minnesota, 1089 pp.

Gibs, J. and T.E. Imbrigiotta, 1990, Well-Purging Criteria for Sampling Purgeable Organic Compounds; Ground Water, Vol. 28, No. 1, pp 68-78.

Herzog, B.L., S.J. Chou, J.R. Valkenburg and R.A. Griffin, 1988, Changes in Volatile Organic Chemical Concentrations After Purging Slowly Recovering Wells; Ground Water Monitoring Review, Vol. 8, No. 4, pp. 93-99.

Kearl, P.M., N.E. Korte, and T.A. Cronk, 1992, Suggested

Modifications to Ground Water Sampling Procedures Based on Observations from the Colloid Borescope; Ground Water Monitoring Review, Vol. 12, No. 2, pp. 155-161.

Keely, J.F. and K.Boateng, 1987, Monitoring well installation, purging, and sampling techniques - part 1: conceptualizations; Ground Water, Vol.25,No.4 pp. 427-439.

McAlary, T.A. and J.F. Barker, 1987, Volatilization Losses of Organics During Ground Water Sampling from Low Permeability Materials; Ground Water Monitoring Review, Vol. 7, No. 4, pp. 63-68.

Nielson, D.M., 1991, Practical Handbook of Ground-Water Monitoring; Lewis Publishers, 717 pp.

Parker, L.V. and T.A. Ranney, 1998, Sampling Trace-Level Organic Solutes with Polymeric Tubing: Part 2, Dynamic Studies; Ground Water Monitoring and Remediation, Vol. 18, No. 1, pp. 148-155.

Pohlmann, K.F., R.P. Blegen and J.W. Hess, 1990, Field Comparison of Ground-Water Sampling Devices for Hazardous Waste Sites: An Evaluation using Volatile Organic Compounds; EPA/600/4-90/028, 102 pp.

Pohlmann, K.F. and A.J. Alduino, 1992, GROUND-WATER ISSUE PAPER: Potential Sources of Error in Ground-Water Sampling at Hazardous Waste Sites; EPA/540/S-92/019.

Puls, R.W. and R.M. Powell, 1992, Acquisition of Representative Ground Water Quality Samples for Metals; Ground Water Monitoring Review, Vol. 12, No. 3, pp. 167-176.

Puls, R.W., D.A. Clark, B. Bledsoe, R.M. Powell and C.J. Paul, 1992, Metals in Ground Water: Sampling Artifacts and Reproducibility; Hazardous Waste and Hazardous Materials, Vol. 9, No. 2, pp. 149-162.

Puls, R.W. and M.J. Barcelona, 1996, GROUND-WATER ISSUE PAPER: Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures; U.S. Environmental Protection Agency Ground Water Issue, EPA/540/S-95/504, 12 pp.

Tai, D.Y., K.S. Turner, and L.A. Garcia, 1991, The Use of a Standpipe to Evaluate Ground Water Samples; Ground Water

Monitoring Review, Vol. 11, No. 1, pp. 125-132.

Thornhill, J.T., 1989, Accuracy of Depth to Water Measurements; Superfund Ground Water Issue, EPA/540/4-89/002, 3 pp.

U.S. Environmental Protection Agency, 1986, RCRA Ground-Water Monitoring Technical Enforcement Guidance Document; OSWER-9950.1, U.S. Government Printing Office, Washington, D.C., 208 pp., appendices.

U.S. Environmental Protection Agency, 1995, Ground Water Sampling-A Workshop Summary, Dallas, Texas, November 30-December 2, 1993, EPA/600/R-94/025, 146 pp.

Wilde, F.D., D.B. Radtke, J.Gibs and R.T. Iwatsubo, eds., 1998, National Field Manual for the Collection of Water-Quality Data; U.S. Geological Survey Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations, variously paginated.

Wilkin, R.T., M.S. McNeil, C.J. Adair and J.T. Wilson, 2001, Field Measurement of Dissolved Oxygen: A Comparison of Methods, Ground Water Monitoring and Remediation, Vol. 21, No. 4, pp. 124-132.

Yeskis, D., K. Chiu, S. Meyers, J. Weiss and T. Bloom, 1988, A Field Study of Various Sampling Devices and Their Effects on Volatile Organic Contaminants; Proceedings of the Second National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, National Water Well Association, May, 1988.

GROUND-WATER SAMPLING RECORD

Well ID:________________

Station #:________________

Facility Name:__________ Date:____/____/____

Well Depth:__________ Depth to Water:__________ Well Diameter:___________

Casing Material.:__________ Volume Of Water per Well Volume:______________

Sampling Crew:__________________,____________________,___________________,_____________________

Type of Pump:____________________ Tubing Material:__________________ Pump set at ________________ ft.

Weather Conditions:__________________________________ NOTES:___________________________________

____

GROUND-WATER SAMPLING PARAMETERS

Time	Water Level	Volume Pumped	Pumping Rate	DO (mg/l)	Temp. (^{O}C)	SEC (µS/cm)	pH	ORP (mV)	Turbidity (NTU)
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________
_______	_______	_______	_______	_______	_______	_______	_______	_______	________

Other Parameters: ___________________

Sampled at:_______________ Parameters taken with :____

Sample delivered to _______________________________ by _____________________________ at___________.

Sample CRL #:______________ OTR #:______________ ITR #:______________ SAS #:__________________

Parameters Collected	Number of Bottles	Bottle Lot Number
VOA’s	_________	_______________
THF/1,4-Dioxane	_________	_______________
SVOC’s/PCB’s	_________	_______________
Metals	_________	_______________