**SPRING MEADOW LAKE SITE**
**HELENA, MONTANA**

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## ATTACHMENTS

# 4.0 RECLAMATION WORK PLAN

The Montana DEQ/MWCB has requested that Tetra Tech EM Inc. prepare a reclamation work plan that includes a field sampling plan (FSP), a quality assurance protocol plan (QAPP), a laboratory analytical plan (LAP), and a health and safety plan. This reclamation work plan has been prepared as a functional guide for conducting full-scale reclamation at the Spring Meadow Lake site. The four supporting plans are presented in Sections 4.2 through 4.5. The references cited in Section 4.0 are presented in Section 4.6.

## 4.1 PRELIMINARY RECLAMATION OBJECTIVES AND GOALS

The preliminary reclamation objectives and goals for the Spring Meadow Lake site are discussed in the following sections.

### 4.1.1 Preliminary Reclamation Objectives

The overall objective of the Spring Meadow Lake site reclamation project is to protect human health and the environment in accordance with the guidelines set forth by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Specifically, site reclamation must limit human and ecological exposure to mineral processing-related contaminants and reduce the mobility of those contaminants through associated solid media, sediment, groundwater, and surface water exposure pathways. The final reclamation objectives, including the specific amount of contaminant exposure and mobility reduction required, will be determined after site characterization, risk assessment, and analysis of the applicable or relevant and appropriate requirements are completed.

### 4.1.2 Preliminary Reclamation Goals

Preliminary remediation goals (PRG) are contaminant-specific and media-specific numbers that reflect potential cleanup levels at the Spring Meadow Lake site. PRGs have been established for the Spring Meadow Lake site to guide investigation activities and to identify areas and media that may require reclamation. Water and solid matrix (soil and sediment) PRGs for the Spring Meadow Lake site are shown in Table 4-1 and Table 4-2, respectively. PRGs may be based on Federal and State water quality standards, sediment quality screening values, or on risk-based concentration values. Federal and State water quality standards used to evaluate surface water and groundwater data include maximum contaminant levels (MCL), non-zero maximum contaminant level goals (MCLG), freshwater chronic aquatic life standards (CALS), and Montana human health standards (HHS) for water. Sediment quality values are derived from the probable apparent effects thresholds (PEAT) from bioassay studies in Oregon and Washington State (Washington State Dept. of Ecology). Risk-based PRGs or cleanup guidelines have been developed by the U.S. Environmental Protection Agency (EPA) Region 9 and by Montana DEQ. The risk-based numbers are calculated for different contaminants and the recreational visitor exposure pathway using standard EPA risk assessment methodology. The following sections present the water quality standards for surface water, the freshwater sediment quality values from Washington State, and the risk-based concentrations for soil.

**Surface Water**

Surface water in Spring Meadow Lake originates primarily from groundwater inflow. The lake water level does fluctuate seasonally with the irrigation of cropland near the site and with the surface water flows in nearby Tenmile Creek. Surface water runoff from the Montana Wildlife Center property and surrounding areas of Spring Meadow Lake also flows into the lake. Seasonal overflows from Spring Meadow Lake are discharged from the northeast corner of the lake and flow northerly into wetland areas associated with the Green Meadow Country Club and Crystal Springs Creek.

Previous analyses of the surface water indicated elevated arsenic and manganese concentrations. Arsenic is a human health contaminant of concern and manganese may affect the beneficial uses of the water. The historical surface water sampling results are presented in Section 3.2.1. Table 4-1 presents the surface water PRGs for metals of concern.

**Solid Matrix Materials**

Analysis of solid matrix samples (which include soils, mineral processing wastes, and sediments) collected during the site inspection and hazardous materials inventory (DEQ-MWCB 2004) indicates that the soils and mineral processing wastes contain concentrations of arsenic, manganese, and lead above background concentrations and at levels of potential concern. Analytical results from other solid matrix samples collected by the Montana DEQ and by a student at Carroll College indicate similar contaminants and concentrations above background. The historical solid matrix sampling results are presented in Section 3.2.1.

**TABLE 4-1**

**PRELIMINARY RECLAMATION GOALS FOR SURFACE WATER (µg/L)**
**SPRING MEADOW LAKE SITE**

| **Contaminant** | **CALS [a]** | **HHS [b]** |
|---|---|---|
| Arsenic | 150 | 18 |
| Cadmium | 1.429 [c] | 5 |
| Copper | 5.2 [c] | 1,300 |
| Iron | 1,000 | 300 |
| Lead | 3.2 [c] | 15 |
| Manganese | None | 50 |
| Zinc | 67 [c] | 2100 |

Notes:

[a] CALS - Freshwater Chronic Aquatic Life Standards, Circular WQB-7, Montana Numeric Water Quality Standards (DEQ 2004)

[b] HHS - Human Health Standards for Water, Circular WQB-7, Montana Numeric Water Quality Standards (DEQ 2004)

[c] CALS assume water hardness of 50 mg/L for cadmium, copper, and zinc, and 100 mg/L for lead

Sediment samples collected during the site inspection and hazardous materials inventory (DEQ-MWCB 2004) indicate that concentrations of arsenic, manganese, lead, and zinc may be above sediment quality values (Washington State Dept. of Ecology 1997) and at levels of potential concern. There are currently no promulgated standards for metal concentrations in soil or sediment in Montana. To assist in investigation planning and reclamation option selection and development, EPA Region 9 has developed risk-based PRGs for metals in soil. In addition, the Montana DEQ has developed a conservative set of risk-based guidelines that are calculated for different contaminants using a recreational visitor exposure scenario. The guidelines take into account the possibility of exposure through multiple exposures. The PRGs are intended to help investigators plan reclamation actions but should not be used to determine site risks.

At other sites in Montana, the Montana DEQ has recommended the use of the freshwater sediment quality values published by the Washington State Dept. of Ecology (1997) for ecological screening levels. Action levels for soils and sediments at the Spring Meadow Lake site will be determined based on the results from the human health and ecological risk assessments completed during the RI. The PRGs for the metals of concern in soils and sediments are listed in Table 4-2.

**TABLE 4-2**

**PRELIMINARY RECLAMATION GOALS
FOR SOIL AND SEDIMENT (mg/kg)
SPRING MEADOW LAKE SITE**

| Contaminant | EPA Region 9 Residential PRGs | Washington State Dept. of Ecology Freshwater Sediment Quality PAET Values [a] |
|---|---|---|
| Arsenic | 0.39 (40) [b] | 19 |
| Manganese | 1800 | 1400 |
| Lead | 400 | 240 |
| Zinc | 23,000 | 500 |

Notes:
mg/kg milligrams per kilogram
[a] Probable Apparent Effects Threshold (PAET) Values; (Washington State Dept. of Ecology 1997)
[b] 0.39 is the arsenic Region 9 Residential PRG for the carcinogenic endpoint. Montana DEQ uses a soil screening value of 40 mg/kg for arsenic based on background arsenic values for Montana soils.

## 4.2 FIELD SAMPLING PLAN

This FSP has been prepared as a guide for conducting the RI of the Spring Meadow Lake site. The FSP presents sampling objectives and procedures, field analytical procedures, sample documentation and custody procedures, sample preservation and handling requirements, and decontamination procedures.

The purpose of the RI is to collect the information necessary to perform the risk assessments, to complete an expanded engineering evaluation and cost analysis (EEE/CA), and to select a reclamation alternative. Once the reclamation alternative has been selected, site- and alternative-specific engineering data may need to be collected to support design efforts.

Data collected to support the human health and ecological risk assessments will include:

- the magnitude and extent of surface and subsurface soil contamination
- the magnitude and extent of sediment contamination
- the magnitude of surface water contamination
- metals concentration in background soil

Data collected to complete the EEE/CA will include:

- accurate estimates of the area and volume of solid waste material requiring reclamation
- data to determine if waste material is classified as a Resource Conservation and Recovery Act (RCRA) hazardous waste
- data to determine reclamation requirements for disturbed areas including soil texture and grain size, liming requirements, fertilizer requirements, percent organic matter, and identification of native species
- location and characterization of potential repository sites
- location of potential cover soil borrow area

### 4.2.1 Sampling Objectives

Surface soil, subsurface soil, and sediments with elevated metal concentrations are present at the Spring Meadow Lake site. Table 4-3 lists the sample type, analysis, approximate number of samples that will be required to fulfill the sampling objectives, and number of contingency samples. Figure 4-1 shows the approximate sampling locations. The sampling objectives for the Spring Meadow Lake site are:

- Determine the nature and extent of surface soil contamination. Samples will be collected to further define the approximate locations of the contaminated materials that were identified during the site inspection and hazardous materials inventory (DEQ-MWCB 2004). Up to 10 opportunistic surface soil grab samples will be collected within or near visually identified edges of the tailings and mineral processing waste areas. All samples will be sent to the laboratory for total metals analysis.
- Determine the nature and extent of subsurface soil contamination. The thickness of contaminated materials and waste sources was approximately defined during the site inspection and hazardous materials inventory (DEQ-MWCB 2004). To provide more accurate calculations of the volume of materials that may require removal, 24 additional backhoe pits will be completed in and around the identified waste source areas. Assuming that an average of 2 samples are collected at each backhoe pit, 48 subsurface soil samples will be collected and analyzed for total metals at an offsite laboratory.
- Determine the location and distribution of metal-contaminated sediments in the east arm and south end of Spring Meadow Lake site area. Eight sediment samples will be collected from the central areas of the east arm and from approximately 25 feet from the footbridge. Grab samples will be collected from a boat using a standard sediment sampling device (Ponar or coring tube). The sediment sampler will be lowered to the surface of the bottom sediment and opened up or rotated into the sediment. The sediment grab sampler is relatively easy to handle and operate, and generally provides high sample integrity. The sediment sampler can collect sediments to a depth of about 6 inches which should provide sufficient sample volume

for analysis. All sediment samples will be decanted and sent to an offsite laboratory for total metals and total organic carbon analysis.

- Determine the quality of surface water in the east arm of Spring Meadow Lake and at a representative background area within the Lake. Three surface water samples will be collected and sent to an offsite laboratory for analysis.

- Determine the quality of groundwater (metals) downgradient of the former mineral processing location and below the contaminated sediments near the east arm of Spring Meadow Lake to determine if metals have migrated from surface and subsurface soils to the groundwater at this site. Install two monitoring wells, develop wells, and collect groundwater samples for total metals analysis at an offsite laboratory.

### 4.2.2 Soil Sampling Procedures

**Surface Soil**

Up to 10 opportunistic surface soil grab samples will be collected within or near visually identified edges of the tailings and mineral processing waste areas. The method used to select the sample locations will be different for samples intended to characterize the mineral processing wastes (visual) compared to samples intended to characterize the extent of surface soil contamination (soil located a short distance away from a visual waste). Sample locations used to characterize the waste materials will be selected based on visible characteristics including soil texture, staining, topography, and lack of vegetative cover. Additional sampling locations may be identified during the RI field effort.

All surface soil samples will be analyzed for 13 target analyte list (TAL) metals including: antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc. All samples will be sent to an offsite laboratory for total metals analysis (ICP-AES methods). A subset of samples (4 samples) will also be analyzed for particle size (texture), cation exchange capacity (CEC) and complete agricultural (includes pH; conductivity; nitrogen-phosphorus-potassium; organic matter; lime recommendation; and fertilizer recommendation). The 4 samples selected for the additional analysis will be selected based on the probability that the soil may be reclaimed in place and not have total metals concentrations above the PRG values.

Table 4-3 lists the approximate number of samples that will be collected to characterize the extent of soil contamination. The soil sampling locations will be identified during the initial phase of the RI. All surface soil samples will be collected from 0 to 3 inches below ground surface with a trowel.

## TABLE 4-3

## PROPOSED SOIL, SEDIMENT, SURFACE WATER, AND GROUNDWATER SAMPLES SPRING MEADOW LAKE SITE

| Sample Type | Analysis | Number of Samples | Number of Contingency Samples |
|---|---|---|---|
| Soil (0-3") | TAL Metals | 10 | 2 |
| | Particle size (texture) | 4 | 2 |
| | CEC | 4 | 2 |
| | Complete Agricultural (pH; conductivity; N-P-K; OM; lime and fertilizer requirement) | 4 | 2 |
| Subsurface Soil (24 backhoe pits, 2 samples collected in each pit) | TAL Metals | 48 | 5 |
| | Particle size (texture) | 8 | 5 |
| | CEC | 8 | 5 |
| | Partial Agricultural (pH; N-P-K; texture; and lime requirement) | 8 | 5 |
| Background Soil (0-3") | TAL Metals | 3 | 1 |
| | Particle size (texture) | 2 | 1 |
| | CEC | 2 | 1 |
| | Complete Agricultural (pH; conductivity; N-P-K; OM; lime and fertilizer requirement) | 2 | 1 |
| Sediment (0-1") | TAL Metals | 8 | 1 |
| | TOC | 8 | 1 |
| Surface Water | TAL Metals | 3 | 1 |
| | Field Parameters (pH, conductivity, hardness, chloride, sulfate) | 3 | 1 |
| Groundwater | TAL Metals | 2 | 0 |
| | Field Parameters (pH, conductivity, hardness, chloride, sulfate) | 2 | 0 |

Notes:

TAL Target analyte list (antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc)
CEC Cation exchange capacity
TOC Total organic carbon

## Subsurface Soil

Subsurface soil samples will be collected to characterize the tailings and mineral processing wastes and to verify the depth of contamination and the thickness of the waste sources. Subsurface soil samples will be collected from 24 backhoe pits completed in and around the waste source areas at the Spring Meadow Lake site. Proposed backhoe pit locations are shown on Figure 4-1. Forty-eight soil samples will be collected from within and below the waste material in each backhoe pit and analyzed for total metals using an offsite laboratory. The locations of the backhoe pits have been preliminarily identified based on the results from the site inspection and hazardous materials inventory (DEQ-MWCB 2004) and to provide additional coverage for areas not yet characterized. The results from the subsurface soil sampling will increase the accuracy of the waste volume calculations.

Up to 8 samples will also be analyzed for particle size (texture), CEC, and partial agricultural parameters. The samples submitted for these additional analyses will be selected as typical of the wastes and of the buried soils below the wastes. The samples submitted for partial agricultural parameters will be collected from the soil immediately below the wastes to assess the potential for metals leaching from the wastes and to determine the recommended lime and fertilizer requirements for these buried soils. Samples from within 3 feet of the surface will be collected from the trench walls by using a trowel to fill the sample containers. Samples from depths greater than 3 feet below ground surface will be collected from the backhoe bucket by using a trowel to fill the sample container. The locations of the backhoe pits will be surveyed using a handheld global positioning survey (GPS) instrument.

All soil sampling equipment will be decontaminated using the procedures described in Section 4.2.9 before collecting the next sample.

## Background Soil Samples

Three soil samples will be collected outside of the impacted area to establish background metals concentrations. All surface soil samples will be collected from 0 to 3 inches below ground surface using the same methods used to collect the other surface soil samples. The background sampling locations will be identified during the initial phase of the RI.

### 4.2.3 Sediment Sampling Procedures

The potential environmental/health risks and reclamation alternatives associated with sediment contamination in Spring Meadow Lake will be evaluated by collecting grab samples at various locations in the east arm and south end of Spring Meadow Lake. Eight sediment samples will be collected from the central areas of the east arm and from approximately 25 feet from the footbridge. Grab samples will be collected from a boat using a standard sediment sampling device (Ponar or coring tube). The sediment sampler will be lowered to the surface of the bottom sediments and opened up or rotated into the sediment. The sediment grab sampler is relatively easy to handle and operate, and generally provides high sample integrity. The sediment sampler can collect sediments to a depth of about 6 inches (15 centimeters) which should provide sufficient sample volume for analysis. All sediment samples will be decanted of excess water and sent to an offsite laboratory for total metals analysis. Sediment samples will also be analyzed for organic matter content to help evaluate the solubility and bio-availability of the metals. The proposed sediment sampling locations are shown on Figure 4-1.

### 4.2.4 Surface Water Sampling Procedures

The risk to potential receptors from surface water contamination will be evaluated during the RI. Twelve surface water samples were collected during the site inspection and hazardous wastes inventory (DEQ-MWCB 2004) and analyzed for total metals at an offsite laboratory. Three water samples (SW-109, SW-110, and SW-112) had arsenic concentrations above the human health surface water standard of 0.018 milligrams per liter (mg/L) (Montana DEQ 2004). In addition, two water samples (SW-110 and SW-112) had manganese concentrations above the Montana manganese standard of 0.050 mg/L (Montana DEQ 2004). In order to complete the ecological risk assessment during the RI, some additional water quality data (hardness, Cl, sulfate) are needed. Three additional surface water samples are proposed to be collected for the RI. The risk to potential receptors will be evaluated using the previous surface water data and the additional RI water quality data. The surface water samples will be analyzed for the parameters listed in Table 4-3. The proposed surface water sampling locations are shown on Figure 4-1.

Surface water samples will be collected from a boat by dipping the sample container into the lake water with the mouth pointed upward. After the container is full, the required preservative (if any) will be added to the bottle. The samples will not be filtered.

### 4.2.5 Groundwater Installation and Sampling Procedures

Two groundwater monitoring wells are proposed for installation and sampling at the Spring Meadow Lake site. The proposed monitoring wells will be constructed in accordance with State of Montana monitoring well standards. Proposed monitoring well locations are shown on Figure 4-1 but the final selection will be made in consultation with the Montana DEQ project manager and the Montana FWP personnel.

**Monitoring Well Installation**

Monitoring well installations will follow Tetra Tech EM Inc. Standard Operation Procedure (SOP) No. 020 (Attachment 1), with the top of casing flush mounted or with the casing stick-up, as appropriate. The monitoring wells will be constructed using two-inch ID Schedule 40 PVC riser with flush threaded joints and Schedule 40 PVC screen with 0.02-inch machined slots. The riser and screen lengths will be determined in the field based on total boring depth and depth to the water table. Material specifications and completion depths will be recorded during well construction and documented on a well completion log.

The monitoring well filter pack will consist of 10-20 mesh silica sand placed from the bottom of the borehole to two feet above the top of the screen. The annular seal placed above the filter pack will consist of approximately two feet of hydrated bentonite pellets. A grout mixture of 95 percent cement and five percent bentonite will be poured from the top of the annular seal to approximately two feet below the ground surface. Concrete will then be poured in the space above the grout to form a surface seal and set the protective casing. The concrete surface seal will be sloped to allow for drainage of surface water away from the well. The volume of material placed in the borehole to form the filter pack, annular seal, and surface seal will be calculated and recorded on the well completion log.

The monitoring well screen and riser material will be assembled and lowered by hand through the augers to the desired depth. The 10-20 mesh silica sand will be poured or tremied through the augers to form the filter pack. The auger will be removed from the borehole as the filter pack is poured. Bentonite pellets will then be poured or tremied through the augers to a minimum thickness of 2 feet and hydrated with potable water to form the annular seal. Grout will be poured or tremied through the augers on top of the bentonite seal to within approximately two feet below ground surface. Grout will be continuously added as the remaining auger is removed from the borehole.

**Monitoring Well Development and Purging**

Monitoring well development activities will be performed in accordance with Tetra Tech EM Inc. SOP No. 021 (Attachment 2). The monitoring well will be allowed to stabilize for a minimum of 24 hours after completion to allow for adequate curing of the grout. Prior to well development, the depth to water will be measured using a water level probe. These measurement will be used to determine the well casing volume and minimum purge volume. Before purging, the well will be surged by manually raising and lowering a surge block through the water column for a minimum of 10 minutes.

After the well has been surged, a portable pump will be used to evacuate a maximum of 10 casing volumes of water from the well. A new piece of disposable tubing will be attached to the pump and lowered to variable depths below the water table to evacuate the water from the well and introduce groundwater into the well from the aquifer. Water quality parameters including pH, specific conductance, and temperature will be measured upon the removal of each casing volume of water to provide baseline information. Prior to use, all water quality meters will be calibrated in accordance with the manufacturer's specifications. Monitoring well development will continue until two consecutive sets of water quality parameter measurements have stabilized to within 10 percent and the purge water is reasonably free of sediment, or until 10 casing volumes have been removed. Monitoring well development activities will be documented on a well development form.

Observations of water level, flow rate, and the quantity and clarity of the water withdrawn will be monitored during this process and recorded on water quality sheets during well development and while purging for sampling. During purging of the monitoring well using the submersible or peristaltic pump, field parameters will be measured using a closed flow-through cell system. Field parameters measured will include temperature, pH, conductivity, Eh, and turbidity. Parameters are considered stabilized when three or more sequential measurements are within ±0.2 °C for temperature, ±3 percent for conductivity, and ±0.1 unit for pH (EPA 1996). Purging will continue until temperature, conductivity, pH, and water clarity have stabilized. A groundwater sample will then be collected. If the stabilization parameters do not fall within the specified ranges after three well volumes have been purged, then a comment will be recorded on the data sheet that sample collection began after three well casing volumes were purged. If the well runs dry before the specified amount of purge water has been withdrawn, the well will be allowed to recharge. After the well has recharged, one set of stabilization parameters will be measured and the well will be sampled.

**Groundwater Sample Collection**

The groundwater samples will be collected using the traditional bailing sampling method as described in Tetra Tech EM Inc. SOP No. 010 (Attachment 3). Disposable polypropylene bottom-weighted bailers with be used. Because volatile compounds and organic chemicals are not expected chemicals of concerns in groundwater at this site, some minimal aeration of the water column will not affect the quality of the water samples. Groundwater samples will be collected from monitoring wells following well development and purging. All groundwater samples will be filtered at the laboratory prior to analysis. The need for additional groundwater sampling will be evaluated and performed after the completion of this RI.

### 4.2.6 Field Analytical Procedures

Field analysis will be collected within Spring Meadow Lake and the east arm at the sediment and surface water sampling locations. Field measurements will be recorded at a water depth approximately half way between the lake surface and the bottom of the lake immediately prior to collecting the samples. The water quality parameters that will be measured in the field include pH, Eh, dissolved oxygen, specific conductance, and temperature. The pH, Eh, dissolved oxygen, specific conductance, and temperature will be measured with field portable meters. The instrument will be calibrated using the manufacturer's recommended procedures. The probes will be inserted into the water and the pH, Eh, dissolved oxygen, specific conductance, and temperature readings will be recorded. Before every sample, a check standard will be measured to verify instrument calibration. Before every second sample, a series of three measurements will be made to check instrument response and precision.

### 4.2.7 Sample Documentation and Custody

The possession and handling of each sample will be properly documented to promote timely, correct, and complete analysis for all required parameters. To promote sample integrity, each sample will be traceable from the point of collection through analysis and final disposition.

The field records and documentation control measures to be used during sample collection, identification, handling, and shipping include the following:

- Sample labels

- Custody seals
- Field sample data and chain-of-custody record

The Tetra Tech EM Inc. field team leader is responsible for obtaining these items and distributing them to field personnel. All paperwork will be completed using indelible ink.

**Sample Designation**

A sample numbering scheme has been developed that allows each sample to be uniquely identified and provides a means of tracking the sample from collection through analysis. The numbering scheme indicates the sample type, location, and depth (or interval depth). The unique sample number will be entered on sample labels, field tracking sheets, chain-of-custody forms, and other records documenting sampling activities. The following sample numbering system will be used for this investigation:

X-Y-Z

where:

X = Sample Type (BG = background soil sample; BP = backhoe pit subsurface soil sample; MW = monitoring well; SD = sediment sample; SS = surface soil sample; and SW = surface water sample)

Y = Sample Location (for example, test pit number)

Z = Depth only for subsurface soil samples (test pit)

for example: BP-01-10 would be a subsurface soil sample from test pit 01 collected at a depth of approximately 10 feet below ground surface.

A matrix spike/matrix spike duplicate (MS/MSD) will also be submitted to the subcontractor laboratory for analysis for each sample matrix. Surface water MS/MSD samples require triplicate volumes for each analyte. The sample designation for the MS/MSD surface water samples is identical to the normal sample; however, one suite of the triplicate volume will be labeled MS and the other volume MSD. Soil samples selected for MS/MSD analysis will be designated in a similar manner.

**Field Logbook**

Daily field activities will be documented through journal entries in a bound field logbook, dedicated to the Spring Meadow Lake site. Logbook entry and custody procedures will follow National Enforcement

Investigation Center policies and procedures (EPA 1986). The logbook will be water-resistant, and all entries will be made in indelible ink. The logbook contains all pertinent information about sampling activities, site conditions, field methods used, general observations, and other pertinent technical information. Examples of typical logbook entries include the following:

- Personnel present
- Daily temperature and other climatic conditions
- Field measurements, activities, and observations
- Referenced sampling location description (in relation to a stationary landmark) and map
- Media sampled
- Sample collection methods and equipment
- Date and time of sample collection
- Types of sample containers used
- Sample identification and cross-referencing
- Sample types and preservatives used
- Analytical parameters
- Sampling personnel, distribution, and transporters
- Site sketches
- Instrument calibration procedures and frequency
- Visitors to the site

The Tetra Tech EM Inc. field team leader or designee will be responsible for the daily maintenance of all field records. Each page of the logbook will be numbered, dated, and signed by the person making the entry. Corrections to the logbook will be made by using a single strike mark through the entry to be corrected, then recording and initialing the correct entry. For corrections made at a later date, the date of the correction will be noted.

Color photographs taken during the sampling activities will be numbered to correspond to logbook entries. The name of the photographer, date, time, site location, and photograph description will be entered sequentially in the logbook as photographs are taken. Adequate logbook notations and receipts will be retained to account for custody during film processing.

**Chain-Of-Custody Record**

A chain-of-custody record establishes the documentation necessary to trace sample possession from time of collection through sample analysis and disposition. A sample is in the custody of a person if any of the following criteria are met:

- The sample is in a person's physical possession.
- The sample is in a person's view after being in his or her physical possession.
- The sample was in a person's physical possession and was then locked up or sealed to prevent tampering.
- The sample is kept in a secured area.

The sample collector will complete a chain-of-custody record to accompany each sample delivery container (cooler) and will be responsible for shipping samples to the laboratory. The sample collector will provide the project number and the sample collector's signature as header information on the chain-of-custody record. For each station number, the sample collector will indicate the date, time, station location, number of containers, analytical parameters, and designated sample numbers. When shipping the samples, the sample collector will sign the bottom of the form and enter the date and time (military) that the samples were relinquished. The sample collector will enter the carrier name and air bill number on the form. The original signature copy of the chain-of-custody record will be enclosed in a plastic bag and secured to the inside of the cooler lid. A copy of the chain-of-custody record will be retained for Tetra Tech EM Inc. files.

Each shipping cooler will be secured for shipment by placing custody seals across two sides of the cooler lid. Commercial carriers are not required to sign the chain-of-custody form, provided that the form is sealed inside the shipping cooler and the custody seals remain intact. The subcontractor laboratories will carry out the chemical analyses and are responsible for storing the samples in a secure location and following all chain-of-custody procedures.

**Sample Shipment**

All samples will be packaged and labeled for shipment in compliance with current regulations. Only metal or plastic ice chests will be used for shipping samples. The samples will be placed in the cooler and padded with bubble wrap to absorb shock. The chain-of-custody form will then be placed in a sealed plastic bag and taped to the inside of the cooler lid. The ice chest will be securely taped shut and the custody seals and shipping airbill will be attached.

### 4.2.8 Sample Preservation and Handling

The preservation and holding time requirements for the samples and analysis described in Sections 4.2.1 through 4.2.5 are listed in Table 4-4.

## TABLE 4-4
## SAMPLE COLLECTION, PRESERVATION, AND HOLDING TIME REQUIREMENTS
## SPRING MEADOW LAKE SITE

| Matrix | Analyte | Preservation | Holding Time | Sample Size | Bottle |
|---|---|---|---|---|---|
| Soil | EPA 6010 TAL Metals | Cool to 4°C | 180 days; Hg 28 days | 8 ounce | 8-ounce polyethylene |
| Water | EPA 6010 TAL Metals | Cool to 4°C, $HNO_3$ to pH <2 | 180 days; Hg 28 days | 1 liter | 1-liter polyethylene |
| Soil | Particle Size | None | None | 4 ounce | 4-ounce polyethylene |
| Soil | Cation Exchange Capacity | None | None | 4 ounce | 4-ounce polyethylene |
| Water | Total Dissolved Solids[b] | Cool to 4°C | 7 days | 1 liter | 1-liter polyethylene |
| Water | Hardness[b] | | 28 days | | |
| Water | Alkalinity/Acidity[b] | | 7 days | | |
| Water | Sulfate[b] | | 28 days | | |
| Water | Chloride[b] | | 28 days | | |
| Water | Nitrate/Nitrite | Cool to 4°C $H_2SO_4$ to pH < 2 | 28 days | 250 milliliter | 250-milliliter polyethylene |

Notes:

[a] Analytes can be analyzed from the same 1-liter sample bottle

TAL Target analyte list (antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc)
$HNO_3$ Nitric acid
EPA Environmental Protection Agency
$H_2SO_4$ Sulfuric acid
°C Degree Celsius

### 4.2.9 Decontamination Procedures

Decontamination will be required for all sampling equipment, personal protective gear, and field monitoring equipment used during field activities. Sampling equipment will be decontaminated between collection of each sample. Liquinox or Alconox cleaning solutions and distilled water rinses will be used for all sampling equipment and tools. Decontamination procedures for specific equipment used in association with field activities are described in the following sections.

**Excavation Equipment**

All excavation equipment will be decontaminated at designated locations within the Spring Meadow Lake site. The decontamination locations will be identified before fieldwork begins. Decontamination will be performed before excavation operations begin and between excavation pit locations. Decontamination will consist of examining the backhoe bucket and removing residual soil.

**Sampling Equipment**

All non-disposable sampling equipment will be decontaminated before and after use. Sampling equipment may include shovels, sediment sampler, and hand trowels. Laboratory-supplied sample containers are provided precleaned and will not require decontamination.

In general, the following procedures will be used for sampling equipment decontamination:

- Scrub the sampling equipment in a bucket using a stiff brush and Liquinox or Alconox solution with potable water.
- Triple-rinse the sampling equipment with potable water.
- Final rinse the sampling equipment with distilled water and allow to air dry in a clean dust-controlled area.
- Store the equipment in clean plastic bags until the next sampling event.

## 4.3 QUALITY ASSURANCE PROTOCOL PLAN

This QAPP has been prepared to support the reclamation work plan and field sampling plan and describes the quality assurance (QA) for the RI of the Spring Meadow Lake site. This QAPP presents the data quality objectives; QA objectives; QA sample collection procedures; sample documentation and custody;

equipment operation, maintenance, and calibration; analytical procedures; data reduction, validation, and reporting; and corrective action procedures.

### 4.3.1 Data Quality

Data quality objectives (DQO) are qualitative and quantitative statements that specify the quality of the data required to support the RI activities. The data quality objectives for the project and the type, analytical level, and use of the data are presented below.

**Data Quality Objectives**

DQOs were prepared using EPA guidance for the data quality objectives process (EPA 1994). The EPA guidance (1994) presents the DQOs as a seven-step process:

**Step 1 - State the Problem.** Concisely describe the problem to be studied.

**Step 2 - Identify the Decision.** Identify what questions the study will attempt to resolve and what actions may result.

**Step 3 - Identify the Inputs to the Decision.** Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.

**Step 4 - Define the Study Boundaries.** Specify the time periods and spatial area to which the decisions will apply.

**Step 5 - Develop a Decision Rule.** Define the statistical parameter of interest, specify the action level, and integrate the previous DQO outputs into a single statement that describes the logical basis for choosing among alternative actions.

**Step 6 - Specify Tolerable Limits on Decision Errors.** Define the decision maker's tolerable decision error rates based on a consideration of the consequences of making an incorrect decision.

**Step 7 - Optimize the Design.** Evaluate information from the previous steps and generate alternative data collection designs.

The following paragraphs describe each step, as listed above, and how it pertains to the investigation of the Spring Meadow Lake site.

**Step 1: Stating the Problem**

The Spring Meadow Lake site is a State park and Montana Wildlife Center located in Helena, Montana. Tailings and mineral processing wastes have been disposed of at this site and contain elevated concentrations of arsenic, manganese, lead, and zinc. Preliminary evaluation of site risks using the abandoned inactive mine scoring system (AIMSS) suggests that the tailings and mineral processing wastes may pose an unacceptable risk to ecological receptors and human recreational users. The objective for the project is to protect human health and the environment in accordance with the guidelines set forth by the NCP.

**Step 2: Identify the Decision**

Previous data and inspection of the site reveal that mineral process tailings with levels of arsenic and lead are found at a depth greater than eighteen feet below ground surface. In addition, mineral processing wastes containing elevated levels of manganese are found on the surface of the site and in shallow sediments of the east arm of Spring Meadow Lake. These materials may cause adverse impacts to human health and the environmental. The following decisions will be made: What reclamation action is necessary at the site to protect human health and the environment? What is the areal extent and volume of tailings, mineral processing wastes, and metal contaminated soil and sediment? How will the characteristics of the mineral processing wastes and underlying soil impact revegetation of the site? How will the physiography of the site affect reclamation alternatives? Are there suitable repository sites and soil borrow areas near the site?

**Step 3: Identify the Inputs to the Decision**

The areal extent of tailings, mineral processing wastes, and metal contaminated soil and sediments, and the characteristics of soil underlying the wastes will be determined by analyzing soil, sediment, surface water, and groundwater samples for metals and reclamation parameters. The volume of wastes and the physiography of the site will be determined by completing a survey of site topography and site features. Potential repository sites and soil borrow areas will be identified and the site characteristics will be determined through the excavation of test pits and the collection of soil samples for agronomic analyses.

**Step 4: Define the Study Boundaries**

The disturbed area at the Spring Meadow Lake site covers approximately 2 acres in the NE1/4 of the SW1/4 of Section 23, Township 10 North, Range 4 West, in Lewis and Clark County, Montana.

**Step 5: Develop a Decision Rule**

The potential receptors at the site include recreational users, terrestrial wildlife, vegetation, and aquatic life. Reclamation of the site will be necessary if levels of contaminants in surface and subsurface soil samples exceed the recreational cleanup levels and pose unacceptable risks to human health and the environment. Reclamation may include, but is not limited to, mine waste removal and reclamation-in-place actions.

**Step 6: Specify Tolerable Limits on Decision Errors**

In general, environmental data may be strongly indicative of site conditions, but data are not absolutely definitive; therefore, decisions based upon the data could be in error. This is known as the decision error. This section discusses the limits on decision errors for this investigation.

Sampling error and measurement error are associated with environmental data collection and may lead to decision error. Sampling error occurs because it is impossible for a sampling effort to measure conditions at every point of a site or at every point in time. Sampling error occurs when the sample is not representative of the true state of the environment at a site. Measurement error occurs because of random and systematic errors associated with sample collection, handling, preparation, analysis, data reduction, and data handling. The two types of errors may lead to incorrect decisions or recommendations. In general, decision errors are controlled by adopting a scientific approach that uses hypothesis testing to minimize the potential for decision errors. EPA guidance (1994) suggests the following steps to identify and control decision errors:

- Define the possible range of the parameter of interest,
- Define both types of decision errors and the consequences of each, and
- Specify a range of parameter values for which the consequences of decision errors are relatively minor.

Decision errors are evaluated through hypothesis testing. The reclamation may result in members of the public coming into contact with site wastes. Therefore, the null hypothesis for recreational use is that the site waste contains concentrations of contaminants above the risk-based recreation cleanup levels. The site may also have terrestrial wildlife, vegetation, and aquatic life that are exposed to site wastes and contaminated sediments and surface water runoff. Therefore, the null hypothesis for vegetation, terrestrial wildlife, and aquatic receptors is that site wastes materials, sediments, and surface water runoff are contaminated.

There are two types of decision errors:

> **False Negative Error.** A false negative decision error occurs when the hypothesis is rejected although it is true. In the case of this project, the decision-maker would determine that the site does not contain mineral processing wastes, soil, surface water, sediment, or groundwater that require additional reclamation although concentration levels do require additional reclamation. The consequences of a false negative error would be that contaminated soil and groundwater are left in place instead of being reclaimed.
>
> **False Positive Error.** A false positive decision error occurs when the hypothesis is not rejected although it is false. In the case of this project, the decision-maker would determine that the site contains mineral processing wastes, soil, surface water, sediment, and groundwater that require reclamation (based on the results of the analytical data), although the concentrations of contaminants in the wastes, soil, surface water, sediment, or groundwater do not require reclamation. The consequences of a false positive error would be that unnecessary resources may be spent to perform additional reclamation to address contamination that does not exist at levels exceeding action levels or acceptable risk levels.

Limits on decision errors due to sampling error will be minimized by using the analytical results from the site inspection and hazardous materials inventory (DEQ-MWCB 2004), other previously collected and reported data from the site (Montana DEQ, Carroll College, Montana FWP) and visual observations to identify contaminated areas. The sampling approach will be to collect enough data to define the areal and vertical extent of contamination.

**Step 7: Optimize the Design**

The collection of surface soil and subsurface soil samples should be adequate to accept or reject the null hypothesis for recreational exposure. Visual examination of the site together with incorporation of previous site analytical date will be used to bias the collection of samples. The analytical results will be used to locate and characterize the extent of contamination, risk assessment, and reclamation design.

The collection of surface water and sediment samples should be sufficient to accept or reject the null hypothesis for exposure of aquatic organisms. Representative areas within the south end and east arm of Spring Meadow Lake will be sampled to characterize potential impacts.

**Data Type, Analytical Level, and Use**

Table 4-5 presents data quality objectives, including data analysis or measurement, location of that measurement, analytical method, analytical support level, sample media, and the data use.

The analytical support levels are the analytical options available to support data collection activities. There are five general levels that are distinguished by the types of technology, documentation use, and degree of sophistication, which are:

- Level V - Nonstandard methods. Analyses that may require method modification and development. Analyses performed by the EPA Contract Laboratory Program (CLP) under a Special Analytical Service (SAS) request are considered Level V.
- Level IV - EPA CLP Routine Analytical Service (RAS). This level is characterized by rigorous QA protocols and documentation and provides qualitative and quantitative analytical data. Some commercial laboratories provide this level of data.
- Level III - Laboratory analysis using methods other than EPA CLP RAS methods. This level is used primarily in support of engineering studies using standard EPA-approved procedures. Some procedures may be equivalent to CLP RAS without the CLP requirements for documentation.
- Level II - Field analysis. This level is characterized by the use of portable analytical instruments on site or in mobile laboratories stationed near the site.
- Level I - Field screening. This level is characterized by the use of portable instruments that can provide real-time data to assist in optimizing sampling point locations and for health and safety support.

Analytical levels to be implemented during the Spring Meadow Lake site activities are Levels II, III, and IV.

## TABLE 4-5

## SUMMARY OF DATA QUALITY OBJECTIVES
## SPRING MEADOW LAKE SITE

| Analysis | Location | Analysis Method | Analytical Support Level | Media | Data Use |
|---|---|---|---|---|---|
| TAL Metals | Laboratory | EPA 6010b | IV | SS, SW, GW | SC, RA, RA, ED |
| Particle Size | Laboratory | Method D421 ASTM | III | SS | SC |
| Cation Exchange Capacity | Laboratory | Method 9080 SW-846 | III | SS | SC |
| Complete and Partial Agricultural Analysis | Laboratory | MSA, Second Edition | III | SS | SC |
| Total Dissolved Solids | Laboratory | Method 160.1 (EPA 1999) | III | SW, GW | SC, RA, EA, ED |
| Hardness | Laboratory | SM 2340B | III | SW, GW | SC, RA, EA, ED |
| Alkalinity | Laboratory | EPA 310.1 | III | SW, GW | SC |
| Sulfate | Laboratory | Method 9038 SW-846 | III | SW, GW | SC, RA, EA, ED |
| Acidity | Laboratory | EPA 305.1 | III | SW, GW | SC |
| Chloride | Laboratory | Method 325.3 (EPA 1999) | III | SW, GW | SC, RA, EA, ED |
| Specific Conductivity, Temperature | Field | Manufacturer's Instructions | II | SW, GW | SC |
| pH, Eh, Dissolved Oxygen | Field | Manufacturer's Instructions | II | SW, GW | SC |

Notes:

| | |
|---|---|
| ASTM | American Society of Testing and Materials (ASTM 1985) |
| EA | Evaluation of alternatives |
| ED | Engineering design |
| EPA | Environmental Protection Agency |
| EPA 1999 | Methods and Guidance for the Analysis of Water, Version 2 |
| GW | Groundwater |
| MSA | Methods of Soil Analysis Part 3: Chemical Methods (ASA 1996) |
| RA | Risk assessment |
| SC | Site characterization |
| SM | Standard Method |
| SS | Soil or sediment |
| SW | Surface water |
| SW-846 | Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, SW-846 (EPA 1996) |
| TAL | Target analyte list includes: antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc |

### 4.3.2 Quality Assurance Objectives

The overall QA objective for the Spring Meadow Lake site RI is to produce well-documented data of known quality. Meeting this objective involves establishing and meeting goals for precision, accuracy, completeness, representativeness, comparability, and target reporting limits for the analytical methods. The quantitative and qualitative QA objectives are presented below.

If analytical data fail to meet the QA objectives described in this section, Tetra Tech EM Inc. will explain in the RI report why the data failed to meet the objectives (for example, because of matrix interferences), and will describe the limitations and usability of the data. The following corrective actions may be taken for data that do not meet QA objectives: (1) verify that the analytical measurement system was in control, (2) thoroughly check all calculations, (3) use data qualifiers, and (4) assuming a sufficient quantity of sample is available, reanalyze the affected samples, if authorized by the Montana DEQ Spring Meadow Lake site project manager. Corrective actions for internal QA and quality control (QC) are presented in detail in Section 4.3.7.

The data precision, accuracy, and completeness requirements are listed in Table 4-6; Table 4-7 lists the target reporting limits (TRL) for all analytes of concern by each analytical method. Table 4-5 presents the specific analytical methods selected for determining the concentration of components in the identified matrices.

**Quantitative QA Objectives**

Quantitative QA objectives that will be evaluated for both the field and laboratory data include completeness, accuracy, precision, and method detection limits. The following sections discuss the calculation of each QA objective.

**Precision and Accuracy**

Precision and accuracy are indicators of data quality. Generally, precision is a measure of the variability of a group of measurements compared to their mean value. Laboratory analytical precision is estimated by calculating the relative percent difference (RPD) between the analytical results from the matrix spike (MS) and matrix spike duplicate (MSD) samples for low-level samples and laboratory duplicate samples for high-level samples.

## TABLE 4-6

## PRECISION, ACCURACY, AND COMPLETENESS REQUIREMENTS
## SPRING MEADOW LAKE SITE

| Analyte | Matrix | Precision | Accuracy | Completeness |
|---|---|---|---|---|
| Metals | Soil<br>Sediment | <35% RPD between homogenized sample aliquots | Calibration, LCS to CLP data validation functional guideline criteria<br>Matrix Spike Recovery 75% to 125% | 90% |
| | Water | <20% RPD between duplicate samples | Calibration, LCS to CLP data validation functional guideline criteria<br>Matrix Spike Recovery 75% to 125% | 90% |
| Particle Size | Soil | <35% RPD between homogenized sample aliquots | Method-specified calibration | 90% |
| Cation Exchange Capacity | Soil | <35% RPD between homogenized sample aliquots | Method-specified calibration | 90% |
| Total Dissolved Solids | Water | <20% RPD between duplicate samples | Method-specified calibration | 90% |
| Hardness | Water | <20% RPD between duplicate samples | Method-specified calibration | 90% |
| Sulfate | Water | <20% RPD between duplicate samples | Method-specified calibration | 90% |
| Alkalinity/Acidity | Water | <20% RPD between duplicate samples | Method-specified calibration | 90% |
| Chloride | Water | <20% RPD between duplicate samples | Method-specified calibration | 90% |
| Field Parameters | Water | <10% RPD between replicate measurements | Method-specified calibration | 90% |

Notes:

RPD Relative percent difference
< Less than
MSD Matrix spike duplicate
LCS Laboratory check sample
CLP Contract Laboratory Program
% Percent
MS Matrix spike

## TABLE 4-7

## TARGET REPORTING LIMITS FOR SOIL, SEDIMENT, AND WATER METAL ANALYSIS SPRING MEADOW LAKE SITE

| Analyte Type | Method | Analyte | Reporting Limit Soil and Sediment (mg/kg) | Reporting Limit Water (µg/L) |
|---|---|---|---|---|
| TAL Metals | SW-846 6010B, 6020, and 7471 | Antimony | 5 | 50 |
| | | Arsenic | 5 | 5 |
| | | Barium | 5 | 100 |
| | | Cadmium | 1 | 1 |
| | | Chromium | 5 | 10 |
| | | Copper | 5 | 10 |
| | | Iron | 5 | 30 |
| | | Lead | 5 | 10 |
| | | Manganese | 5 | 10 |
| | | Mercury | 1 | 1 |
| | | Nickel | 5 | 10 |
| | | Silver | 5 | 5 |
| | | Zinc | 5 | 10 |

Notes:

| | |
|---|---|
| µg/L | Micrograms per liter |
| mg/kg | Milligrams per kilogram |
| TAL | Target analyte list (antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc) |
| SW-846 | Test Methods for Evaluating Solid Waste - Physical/Chemical Methods, SW-846 (EPA 1996) |

The RPD between the analyte levels measured in the MS sample and MSD sample (or sample duplicates) will be calculated using the following equation.

$$RPD = \frac{|MS - MSD|}{0.5\,(MS + MSD)} \times 100\%$$

Where:

RPD = Relative percent difference
MS = Matrix spike
MSD = Matrix spike duplicate

Accuracy is a measure of the bias in a measurement system. Sampling accuracy is assessed by analyzing field and equipment blanks. The blanks are used to determine if the ambient air, sample containers, or sample preservatives are contaminating the sample. Analytical accuracy for laboratory data is assessed by evaluating matrix spike sample percent recovery, instrument calibration data, and laboratory control sample results.

Accuracy will be estimated by calculating the percent recovery of laboratory MS samples using the following equation.

$$\%R = \frac{(C_j - C_o)}{C_t} \times 100\%$$

Where:

%R = Percent recovery
$C_j$ = Measured concentration in spiked sample aliquot
$C_o$ = Measured concentration in unspiked sample aliquot
$C_t$ = Actual concentration of spike added

Precision and accuracy goals depend on the types of samples and analysis to be performed and the ultimate use of the analytical data.

**Completeness**

Completeness is defined as an assessment of the amount of valid analytical data obtained from a measurement system compared to the amount of analytical data needed to achieve a particular statistical level of confidence. The percent completeness is calculated by dividing the number of samples with acceptable data by the total number of samples planned to be collected, and multiplying the result by 100. For this project, the QA objective for degree of completeness for the laboratory is 90 percent. If completeness is less than 90 percent, Tetra Tech EM Inc. will provide documentation explaining why this objective was not met, and the impact, if any, of a lower percentage on the project. Completeness will be reported as the percentage of all measurements judged valid. The following equation will be used to determine completeness:

$$\%C = (V/T) \times 100\%$$

Where:

| | | |
|---|---|---|
| %C | = | Percent completeness |
| V | = | Number of measurements judged valid |
| T | = | Total number of measurements |

The completeness target for this project is 90 percent.

**Target Reporting Limits**

The analytical measurements are listed in Table 4-5. The target reporting limits (TRL) for soil and water metals analyses are listed in Table 4-7. The target reporting limit is defined as the lowest concentration that needs to be reported for undiluted samples to obtain project objectives. The laboratory will try to achieve the lowest reporting limits possible for all measurements and will notify the Tetra Tech EM Inc. project manager if the detection limits for the samples exceed the TRLs. If samples are diluted to qualify constituents present at high concentration levels or to reduce matrix interferences, the reporting limit will be calculated as the reporting limit for the particular matrix multiplied by the dilution factor. The actual matrix reporting limits for each sample will vary depending on the concentration of analytes present and the presence of any interference.

## Qualitative QA Objectives

Qualitative QA objectives that will be evaluated include sample representativeness and comparability. The following sections present an analysis of the representativeness and comparability for each matrix to be sampled.

**Representativeness**

Representativeness is the degree to which sample data represent characteristics of a population, variation at a sample point, or an environmental condition. Sampling locations will be selected to obtain representative soil and groundwater samples. Representative data will also be obtained through the proper collection and handling of samples. The QA objective is to obtain a statistically adequate number of samples that represent the various process matrices at the time samples are collected. The FSP contains a discussion of the representativeness of samples from each environmental matrix.

**Comparability**

Comparability expresses the confidence with which one data set can be compared to another. Comparability will be maximized by using standard EPA methods and standard sampling techniques. Tetra Tech EM Inc. will document all sample locations, conditions, and field sampling methods. All results will be reported in standard units or, for field parameters, as defined in the method. All laboratory calibrations will be performed with standards traceable to the National Institute for Standards and Technology or to EPA-approved sources.

### 4.3.3 QA Sample Collection Procedures

Various types of QA/QC samples will be collected during the field investigation activities: MS, MSD, and laboratory sample duplicates.

**<u>MS, MSD, and Duplicate Samples</u>**

The RI field team will collect MS, MSD, and duplicate samples at a rate of 1 for every 20 samples collected. If fewer than 20 samples are collected in one day, then a minimum of one set of field duplicate samples will be collected. For water samples requiring MS/MSD analyses, three times the amount of sample required for routine analysis will be collected. Soil samples do not require the collection of additional sample volume. In the laboratory, two (for MS/MSD) aliquots of this sample will be spiked to allow determination of percent recoveries and RPD for the MS compounds. MS/MSD samples will be collected for each matrix and each analytical method at a rate of 1 per 20 samples.

### 4.3.4 Sample Documentation and Custody

The possession and handling of each sample will be properly documented to promote timely, correct, and complete analysis for all required parameters. To promote sample integrity, each sample will be traceable from the point of collection through analysis and final disposition. Sample documentation and custody procedures are presented in Section 4.2.7.

### 4.3.5 Equipment Operation, Maintenance, Calibration, and Standardization

The procedures and frequency for field instrument operation, initial and continuing calibration verification, and maintenance requirements are described in the analytical methods or instrument manufacturer's calibration procedures. Calibration data will be recorded in the field logbook as will the source and method of preparation of the standard solutions used. Tetra Tech EM Inc. will calibrate all field analytical equipment before it is shipped to the field, and daily, before and after use. All calibration standards will be prepared from commercially available (Supelco or equivalent) NIST, EPA-traceable, or EPA-certified standards. The laboratory instrument operation, calibration, and maintenance procedures are described in the analytical method.

### 4.3.6 Analytical Procedures

The field and laboratory analytical methods that will be used are listed in Table 4-5. Laboratory analysis of samples collected during the RI will be completed by laboratories that have established QA protocols that meet or exceed EPA guidelines. EPA methods will be used whenever they are available for the target analyte.

### 4.3.7 Data Reduction, Validation, and Reporting

Procedures must be used to ensure that all laboratory data generated and processed are scientifically valid, defensible, and comparable. The following sections describe the data reduction, validation, and reporting procedures that will be used in this RI.

**Data Reduction**

The results will be reported in milligrams per kilogram (mg/kg) for soil and sediment analysis and micrograms per liter (µg/L) for water analysis or using the procedures described in the analytical methods. In accordance with standard document control procedures, the laboratories will maintain on file the original copies of all data sheets and logbooks containing raw data, signed and dated by the responsible analyst. Separate instrument logs will also be maintained by the laboratories to enable a reconstruction of the run sequences for individual instruments. The laboratories will maintain all data on file in a secure archive warehouse accessible only to designated laboratory personnel. After three years, the laboratories will send all data on file to the Montana DEQ. The data will be disposed of only upon receipt of instructions to do so from Montana DEQ.

The laboratories will store all residual samples until disposal is authorized by the Montana DEQ. The laboratories will be notified within six months from the time of analysis of the disposition of residual samples. For the first 60 days after the laboratory receives the samples, samples and sample extracts will be stored in a refrigerator at 4°C. After that time, they may be stored at room temperature.

**Data Validation**

Individual analysts will verify that the appropriate data forms have been completed and the completeness and correctness of data acquisition and reduction. The laboratory group leader will review calculations daily and inspect laboratory notebooks and data sheets weekly to verify accuracy, completeness, and adherence to the specified analytical method protocols. Calibration and QC data will be examined daily by the individual analysts and the laboratory supervisor. The group leader and QA manager or designee will verify that all instrument systems are in control and that QA objectives for precision, accuracy, completeness, and TRLs are being met.

Analytical outlier data are defined as QC data lying outside a specific QA objective range for precision or accuracy for a given analytical method. If QC data are outside control limits, corrective action procedures will be applied to determine the probable causes of the problem. If necessary, the sample will be reanalyzed, and only the reanalyzed results reported. If the problem is with the matrix, both initial and reanalyzed results will be reported and identified in the laboratory report. If reanalysis is not feasible, the initial analysis results will be reported and the results will be flagged and identified in the laboratory report.

Project outlier data are defined as sample data that are outside specified acceptance limits established around the central tendency estimator (the arithmetic mean) of the entire data set for the project. For data that are known or assumed to be normally distributed, the specified acceptance limits will be the 90 percent confidence limits defined by the Student one-tailed t-test distribution. Tetra Tech EM Inc. will identify project outlier data, which will be reported in the final laboratory report.

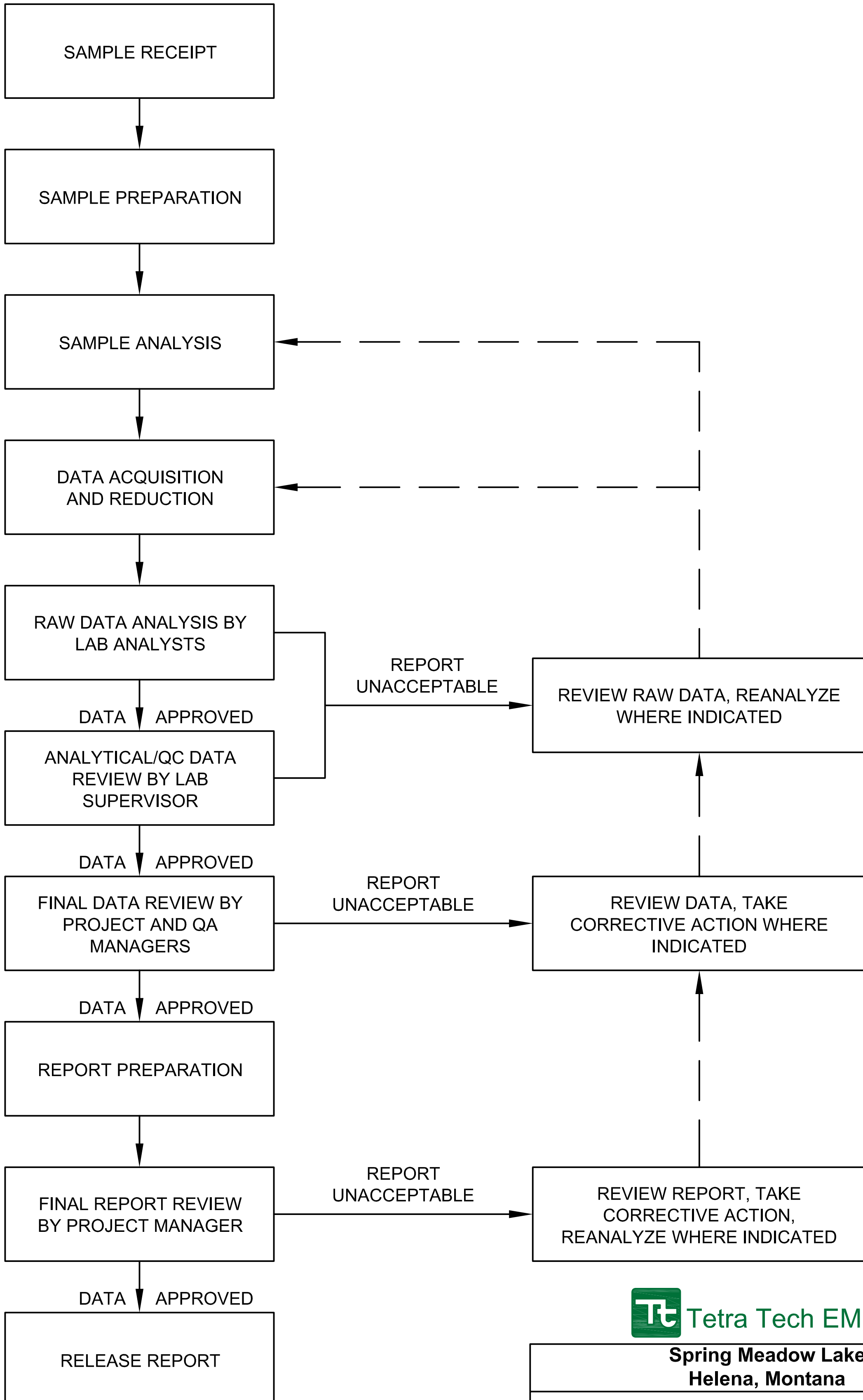
The laboratory project manager and QA coordinator will be responsible for laboratory data validation. The Tetra Tech EM Inc. project manager and Tetra Tech EM Inc. QA manager will be responsible for post-laboratory data validation of all data generated by the selected laboratories. The soil, sediment, and water metal data will be validated using the procedures described in Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analysis (EPA 1988).

**Reporting**

A flow chart depicting the overall data handling and reporting scheme is given in Figure 4-2. Data will be reported in standard units as described in the analytical methods.

The laboratory project manager will be responsible for reviewing the laboratory report. The completed laboratory report will be approved by the laboratory project manager. The laboratory will provide all raw data necessary to fully validate the data. Each data package will include the following items:

- Case narrative including a statement of samples received, description of any deviation from standard procedures, explanation of any data qualifiers used, and any problems encountered during analysis
- A QC summary report including applicable surrogate recoveries, MS/MSD, recoveries, method blank results, and laboratory control sample recoveries. This report must identify all QC outliers and describe their impact on data quality and useability
- Chain-of-custody records
- Reporting limits
- Analytical instrument run logs
- Analytical instrument raw data for samples, blanks, and standards
- Initial calibration information
- Continuing calibration information
- Laboratory accuracy and precision limits
- All values below reporting limits and above method detection limits
- Date of analysis




Tetra Tech EM Inc.

**Spring Meadow Lake**
**Helena, Montana**

**FIGURE 4-2**
**DATA REDUCTION, VALIDATION, AND REPORTING SCHEME**

The final report will contain a QA/QC summary that discusses whether the final data meet the original project QA objectives. If the QA objectives are not met, the report will contain an explanation of the impact on the evaluation of the project objectives.

### 4.3.8 Corrective Action Procedures

Corrective actions will be taken when any problems are identified in the program that affects product quality. The laboratory project manager and the Tetra Tech EM Inc. project manager, or their designees, are responsible for identifying the causes of the problems and developing a solution.

The cause of the problem must first be determined so that the effect of the problem on the overall program can be identified. The field team (and if necessary, the Montana DEQ project manager) will then develop a plausible corrective action. The effects of the action will be examined to determine whether the problem is addressed.

If the corrective action is initially successful, the laboratory project manager, or designee, will prepare a corrective action memorandum describing the corrective action, how and when it will be implemented, and the expected results. A copy of the memorandum will be sent to the Tetra Tech EM Inc. project manager and QA manager and then to the Montana DEQ project manager. The laboratory project manager, or designee, will be responsible for implementing the corrective action and assessing its effectiveness. Procedures are presented below for correcting (1) problems detected during audits, (2) laboratory problems, and (3) data outside control limits.

**Performance and System Audits**

The Tetra Tech EM Inc. program manager and QA manager will perform an internal QA audit of field procedures. If problems are detected during any field audit, the following procedures will be followed:

- The field team leader will immediately notify the field or laboratory personnel responsible, the Tetra Tech EM Inc. project manager, the Tetra Tech EM Inc. QA manager, and all other appropriate personnel of the problem and any corrective action to be taken.
- Personnel will then correct the problem according to the procedures outlined above.

**Laboratory Corrective Actions**

The laboratory QA manager will review laboratory procedures to identify conditions or procedures that may have an adverse impact on data quality. The QA manager will then assess the impact on the quality of the associated data, and then identify the corrective actions to be implemented. All conditions or procedures that may have an adverse impact on data quality will be included in the laboratory reports.

**Data Outside Control Limits**

The manner in which data outside of control limits are handled will depend on where the nonconformance is discovered. During data review in the laboratory, if QC checks fail to meet acceptance criteria, either the data will be flagged in accordance with standard EPA-defined data flags, or the nonconformance will be discussed in the case narrative. During the post-laboratory data validation, the data will be reviewed and assigned to one of the following three categories:

1. **Valid-unqualified** - This category is used for all data that meet all QC criteria without any qualifier. These data are useful for any purpose, and are not flagged.

2. **Valid-qualified** - Data placed in this category are valid, but their usefulness may be limited in certain situations. These data may be qualified as "estimated," which is indicated by use of a "J" flag, or by the use of a specific flag that conveys information about the limitations of the data.

3. **Invalid or Rejected** - Data are considered to be invalid in cases such as failure to properly ice samples that require storage at $4^{o}C$ during shipment. These data are flagged with an "R" and are considered to be unusable for any purpose.

Data will be validated using EPA guidance documents and the specific requirements of this QAPP. If certain data appear to be borderline between two categories, the data validator may seek the advice of the individuals cited in Section 1.3.1 as having a QA function.

## 4.4 LABORATORY ANALYTICAL PLAN

This LAP describes laboratory requirements for conducting the RI at the Spring Meadow Lake site. Analysis of the solid matrix samples (surface soils, subsurface soils, and sediments), surface water, and groundwater samples will be conducted during the RI. All analytical work is to follow the requirements listed in this LAP for the duration of the project. This LAP contains four sections including sample collection requirements, laboratory requirements, quality assurance requirements, and analytical methods.

### 4.4.1 Sample Collection Requirements

Samples will be collected from surface soils, subsurface soils, sediments, surface water, and groundwater at the Spring Meadow Lake site. The number and type of samples are specified in Table 4-3 (Section 4.2.1).

The matrix, analyte, required preservation, holding time, sample size, and containers to be used during the Spring Meadow Lake site RI are specified in Table 4-5 (Section 4.2.8 of the FSP). Whenever possible, standard EPA protocols will be used.

### 4.4.2 Laboratory Requirements

The primary laboratory will be subcontracted by Montana DEQ for all total metals, particle size (texture), CEC, and agricultural analyses. The primary laboratory may use a separate laboratory for certain physical and chemical analyses. All laboratories for the project will be supplied with this document and will be required to meet the baseline data quality requirements for the project. All analyses performed by the project laboratories should follow the analytical methods listed in Table 4-8, which includes the applicable reference for each method.

## TABLE 4-8

## SUMMARY OF ANALYSES AND ANALYTICAL METHODS
## SPRING MEADOW LAKE SITE

| Analysis | Analytical Method | Media |
|---|---|---|
| TAL Metals | EPA 6010b | SS, SW, GW |
| Particle Size | Method D421 ASTM | SS |
| Cation Exchange Capacity | Method 9080 SW-846 | SS |
| Complete and Partial Agricultural Analysis | MSA, Second Edition | SS |
| Total Dissolved Solids | Method 160.1 (EPA 1999) | SW, GW |
| Hardness | SM 2340B | SW, GW |
| Alkalinity/Acidity | EPA 310.1/305.1 | SW, GW |
| Sulfate | Method 9038 SW-846 | SW, GW |
| Chloride | Method 325.3 (EPA 1999) | SW, GW |
| Specific Conductivity, Temperature | Manufacturer's Instructions | SW, GW |
| pH, Eh, Dissolved Oxygen | Manufacturer's Instructions | SW, GW |

Notes:

| | |
|---|---|
| SS | Soil or sediment |
| SW | Surface water |
| GW | Groundwater |
| TAL | Target analyte list includes: antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, and zinc |
| EPA 1999 | Methods and Guidance for the Analysis of Water, Version 2 (includes EPA Series 500, 600, 1600 Methods) (EPA 1999) |
| SM | Standard Method |
| SW-846 | Test Methods for Evaluating Solid Waste-Physical/Chemical Methods, SW-846 (EPA 1996) |
| MSA | Methods of Soil Analysis Part 3: Chemical Methods (ASA 1996) |
| CLP | Contract Laboratory Procedures |
| SOW | Statement of Work |
| EPA | Environmental Protection Agency |
| ASTM | American Society of Testing and Materials (ASTM 1985) |

### Qualifications and Experience

The laboratory shall designate and use key personnel meeting the minimum requirements, as specified below, and comply with all terms and conditions of the contract. Experience is defined as more than 50 percent of the person's productive work time in active participation on a given task and includes the following:

1. The Inductively Coupled Plasma (ICP) emission spectroscopist responsible for work under this contract must have at least one year of experience in the operation of the ICP on soil and water samples.

2. The Furnace Atomic Absorption (AA) spectroscopist responsible for the work on this contract must have at least one year of experience in the operation of a furnace AA on soil and water.

3. The Hydride Generation AA and Cold Vapor AA (CVAA) spectroscopist responsible for work on this contract must have specific training in hydride applications and at least one year of experience in the operation of hydride AA and CVAA.

4. The inorganic sample preparation expert performing sample preparation for this contract must have at least three months of experience in the preparation of environmental samples for ICP and AA analysis.

5. The analyst or technician responsible for determining soil pH on the contract must have at least six months of experience in the technique and instrumentation.

6. The sample custodian, who is responsible for receiving, logging, and tracking the samples for the laboratory must have at least three months experience. This requirement is necessary because of the large number of samples and complexity of the project.

The laboratory shall have in place an acceptable QA plan. The plan shall designate key QA individuals by name and shall define their responsibilities. The plan shall detail the mechanisms for checking whether laboratory procedures are within control, and shall detail the corrective actions and responsibilities for out-of-control conditions.

**Subcontracting**

Subcontracting portions of this work by the primary laboratory is acceptable for special analysis, but subcontracting must be approved by the Montana DEQ Spring Meadow Lake site project manager, Mr. John Koerth. All laboratories in this project must abide by the LAP and the QAPP.

**Confidentiality**

Analytical results are to be held in the strictest of confidence and will be discussed with only those individuals approved by the Montana DEQ Spring Meadow Lake site project manager.

**Reporting Times**

Analytical results are to be reported within 30 working days of sample receipt by the laboratory. If at all possible, holding, analysis, and reporting times should be minimized.

**Reporting Format**

The data report package for the target analyte list (TAL) metals will not initially include a standard EPA Contract Laboratory Program (CLP) package, but the laboratory must save all the run data on magnetic media in order to generate a CLP package on request for a period of two years following completion of the analysis. The laboratory should obtain written permission from the Montana DEQ prior to disposing of any archived data support packages.

The data support package provided as a deliverable should include the following:

1. Cover letter documenting analytical protocols used.
2. Copies of completed chain-of-custody forms.
3. Cross-reference table of contractor and laboratory identification numbers.
4. Data summary tables (hard copy and electronic media in format to be negotiated between Tetra Tech EM Inc. and the laboratory.
5. QA/QC summaries including laboratory control samples (LCS), spikes, duplicates, and preparation blank results.

The physical parameters and other specialized chemical analyses, such as particle size, cation exchange capacity (CEC), and fertilizer and lime requirements, should comply with the above five components, when applicable.

**Report Transmittal**

All data reports are to be sent directly to Tetra Tech EM Inc., Power Block Building, 7 West 6th Avenue, Suite 612, Helena, Montana 59601, in care of Mr. J. Edward Surbrugg.

### 4.4.3 Quality Assurance Requirements

The mechanism used to monitor the precision and accuracy of environmental data is the analysis of field and laboratory QC samples. The required field QC types and frequency are provided in the QAPP. The required laboratory QC requirements are specified in this LAP when the CLP statement of work (SOW) for inorganics (EPA 1992), or the analytical method does not define the QC requirement. Laboratory QC includes method blanks, duplicates, matrix spikes, and LCS. These QC requirements are to be performed at a frequency of 1 per 20 samples except for particle size analysis, components of the lime requirement, and CEC. The CEC will only have duplicates performed. The ranges for precision (duplicates) and accuracy (matrix spikes) acceptability are presented in the QAPP. The method blank should have a reported value within the method detection limit of the instrument detection limit.

Calibration procedures and sample preparation procedures are presented in the analytical method references listed in Table 4-8 when appropriate. There will be no referee laboratory or auditing of the main laboratory or the specialized laboratory (if applicable) for this project.

#### 4.4.4 Analytical Methods

Analytical methods are summarized in Table 4-8 with the appropriate reference document(s). The project laboratories should contact Mr. Koerth or Mr. Reynolds for permission to deviate from the listed analytical methods for the project analyses.

**Detection Limits**

The instrumentation used must be sensitive enough to meet the required detection limits. Instruments for target analyte analyses are ICP, AA, and CVAA. The detection limits for the parameters presented in Tables 4-4 (Section 4.2.8) and 4-8 are included in the analytic reference methods.

**Storage Requirements**

The contracted laboratory is required to have a secured sample bank for storage of samples, digestates, and extracts. Original samples will be stored in the sample bank for a standard six month interval. All other forms of the sample to be analyzed will be stored in this area for the standard six month interval after analysis or to the end of the analyte holding time, which ever comes first. This will provide the Montana DEQ and Tetra Tech EM Inc. ample time to review data and request reanalysis if necessary. At the end of six months time, the laboratory will be responsible for sample disposal.

**Chain-Of-Custody**

A sample is physical evidence collected from a facility or from the environment. An essential part of hazardous waste investigations is that samples and data may be used as evidence in legal proceedings.

Laboratories performing analyses will use document control and chain-of-custody procedures as specified in Exhibit F for the CLP SOW for inorganics (EPA 1992).

**Sample Stream**

In accordance with EPA procedures, field QC samples (duplicates, blanks, and equipment rinsates) will be treated in the same manner as the natural samples. This provides external QC checks of laboratory data.

## 4.5 HEALTH AND SAFETY PLAN

The health and safety plan for RI activities at the Spring Meadow Lake site begins on the next page.

# HEALTH AND SAFETY PLAN

| | | |
|---|---|---|
| **Site Name:** SPRING MEADOW LAKE SITE | **Site Contact:** J. Edward Surbrugg, Tetra Tech EM Inc. | **Telephone:** (406) 442-5588 |
| **Location:** On the west side of Helena, Montana | **Client Contact:** John Koerth, MWCB | **Telephone:** (406) 841-5026 |
| **EPA I.D. No.:** Not Applicable | **Prepared By:** Jessica Allewalt, Tetra Tech EM Inc. | **Date:** 03/1/05 |
| **Project No.** S1129-30SMLSRI | **Date of Proposed Activities:** April-May 2005 | |

**Objectives:**
The Spring Meadow Lake site is an abandoned mill and mineral processing facility located on the west side of Helena, MT. Portions of the site are on a State Park and portions are on the Montana Wildlife Center property. The Montana DEQ/MWCB is currently preparing plans for mitigating environmental impacts associated with the tailings, mineral processing wastes, and contaminated soils on this site.

**Site Type:** *Check as many as applicable.*

| | | |
|---|---|---|
| ☐ Active | ☐ Confined space | ☐ Well field |
| ☒ Inactive | ☐ Landfill | ☐ Unknown |
| ☐ Secure | ☒ Uncontrolled | ☐ Underground storage tank |
| ☒ Unsecure | ☐ Industrial | ☒ Other *(specify)* Abandoned mine site |

**Site Description and History:**

The Spring Meadow Lake site is located within the city limits on the west side of Helena, Montana, in Lewis & Clark County, Montana. Milling and mineral processing operations commenced in the early 1900s and ceased in 1920. Gravel mining activities at the site commenced in the 1920s and ceased approximately four decades later. The project site is situated at an elevation between approximately 3,950 feet above mean sea level in Section 23, Township 10 North, Range 4 West, Montana principle meridian (Latitude North 46° 36' 30"; Longitude West 112° 04' 30") The project site includes several old building and lake located within an abandoned gravel mining pit.

Note: A site map is provided on Page 4-50. Definitions and additional information about this form are provided on Page 4-52.

**Waste Management Practices:**

Tetra Tech EM Inc. investigated the Spring Meadow Lake site in 2004 in order to complete a site inspection and hazardous materials inventory (DEQ-MWCB 2004 ). The volume of tailings and other mineral processing wastes associated with the Spring Meadow Lake site was estimated at 10,000 cubic yards. Wet tailings were observed in a subsurface pit or sump during the investigation. The total impacted area at the site is estimated at 20 acres.

Analysis of solid-matrix samples (which included wet tailings) collected during the inventory indicates that the tailings and mineral processing waste materials contain elevated concentrations of arsenic (up to 52,228 milligrams per kilogram [mg/kg]), copper (up to 28,952 mg/kg), lead (up to 25,661mg/kg), manganese (up to 293,133 mg/kg), and zinc (up to 42,657 mg/kg).

**Waste Types:** ☐ Liquid ☒ Solid ☐ Sludge ☐ Gas ☐ Unknown ☐ Tailings

**Waste Characteristics:**

- ☐ Corrosive
- ☒ Toxic
- ☐ Inert
- ☐ Ignitable
- ☐ Flammable
- ☐ Volatile
- ☐ Reactive
- ☐ Radioactive
- ☐ Unknown
- ☐ Other *(specify)* ________________________

**Hazards of Concern:**

- ☒ Heat stress
- ☒ Cold stress
- ☐ Explosion or fire hazard
- ☐ Oxygen deficiency
- ☐ Radiological hazard
- ☐ Underground storage tanks
- ☐ Surface tanks
- ☒ Buried utilities
- ☒ Overhead utilities
- ☐ Biological hazard
- ☐ Noise
- ☒ Inorganic chemicals
- ☐ Organic chemicals
- ☒ Heavy equipment
- ☒ Other *(specify)* <u>Wood and metal debris, steep slopes, and loose rock and soil</u>

**Explosion or Fire Potential:** ☐ High ☐ Medium ☒ Low ☐ Unknown

**Chemical Products Tetra Tech EM Inc. Will Use or Store On Site:** (Attach a Material Safety Data Sheet [MSDS] for each item.)

☒ Alconox® or Liquinox®

☐ Hydrochloric acid (HCl)

☒ Nitric Acid ($HNO_3$)

☐ Sodium hydroxide (NaOH)

☒ Sulfuric Acid ($H_2SO_4$)

☐ Other *(specify)* ________________________________________

☐ Other *(specify)* ________________________________________

☐ Other *(specify)* ________________________________________

☐ Other *(specify)* ________________________________________

☐ Other *(specify)* ________________________________________

☐ Other *(specify)* ________________________________________

☐ Other *(specify)* ________________________________________

☐ Other *(specify)* ________________________________________

| Chemicals Present at Site | Highest Observed Concentration (specify units and media) | PEL/TLV (specify ppm or mg/m$^3$) | IDLH Level (specify ppm or mg/m$^3$) | Symptoms and Effects of Acute Exposure | Photo-ionization Potential (eV) |
|---|---|---|---|---|---|
| Arsenic | 52,228 mg/kg | 0.01 mg/m$^3$ | 5 mg/m$^3$ | Ulceration of nasal septum, dermatitis, gastrointestinal disturbances, peripheral neuropathy, respiratory irritation, hyperpigmentation of skin; potential occupational carcinogen | NA |
| Cadmium | 326 mg/kg | 0.005 mg/m$^3$ | 9 mg/m$^3$ | Pulmonary edema, dyspnea, cough, chest tightness, substernal pain; headache; chills, muscular aches; nausea, vomiting, diarrhea; anosmia, emphysema, proteinuria, mild anemia, potential occupational carcinogen | NA |
| Chromium | 56 mg/kg | 1 mg/m$^3$ | 250 mg/m$^3$ | Irritation of the eyes, skin, and lungs; fibrosis (histologic) | NA |
| Copper | 28,952 mg/kg | 1 mg/m$^3$ | 100 mg/m$^3$ | Irritation of eyes, nose, pharynx; nasal perforation, metallic taste, dermatitis | NA |
| Lead | 25,661 mg/kg | 0.05 mg/m$^3$ | 100 mg/m$^3$ | Weakness, lassitude, insomnia; facial pallor; pal eye, anorexia, low-weight, malnutrition; constipation, abdominal pain, colic; anemia; gingival lead line; tremor; wrist and ankle paralysis; encephalopathy; nephropathy; irritation of eyes; hypotension | NA |
| Manganese | 293,133 mg/kg | 5 mg/m$^3$ | 500 mg/m$^3$ | Parkinson's disease; asthenia, insomnia, mental confusion; metal fume fever; dry throat, cough, chest tightness, dyspnea, rales, flu-like fever; low-back pain; vomiting; malaise; fatigue; kidney damage | NA |
| Mercury | 3.9 mg/kg | 0.1 mg/m$^3$ | 10 mg/m$^3$ | Cough, chest pain, dyspnea, bronchitis pneumonitis; tremor, insomnia; irritability, indecision; headache, fatigue, weakness; stomatitis, salivation, gastrointestinal disturbance, anorexia, low-weight; proteinuria; irritation of eyes and skin | NA |
| Zinc | 42,657 mg/kg | 5 mg/m$^3$ | 500 mg/m$^3$ | Sweet, metallic taste; dry throat, cough; chills, fever; tight chest, dyspnea, rales, reduced pulmonary function; headache; blurred vision; muscle cramps, lower back pain; nausea, vomiting; fatigue, lassitude, malaise | NA |

**Notes:**

| | | | | |
|---|---|---|---|---|
| A = Air | GW = Groundwater | NA = Not available | ppm = Part per million | TLV = Threshold limit value |
| CARC = Carcinogenic | IDLH = Immediately dangerous to life or health | NE = Not established | S = Soil | U = Unknown |
| eV = Electron volt | mg/m$^3$ = Milligram per cubic meter | PEL = Permissible exposure limit | SW = Surface water | |

# HEALTH AND SAFETY PLAN

**Field Activities Covered Under This Plan:**

| Task Description | Type | Level of Protection: Primary | Level of Protection: Contingency | Date of Activities |
|---|---|---|---|---|
| **1** Surface soil, sediment, and surface water sample collection. | ☒ Intrusive<br>☐ Nonintrusive | ☐ C ☒ D<br>☐ Modified | ☐ C ☒ D<br>☒ Modified | March-June 2005 |
| **2** Subsurface soil sample collection (test pits - backhoe). | ☒ Intrusive<br>☐ Nonintrusive | ☐ C ☒ D<br>☐ Modified | ☐ C ☒ D<br>☒ Modified | March-June 2005 |

**Site Personnel and Responsibilities (include subcontractors):**

| Employee Name and Office Code | TASK | Responsibilities |
|---|---|---|
| J. Edward Surbrugg, Tetra Tech EM Inc. (HE) | All | Project Manager: Directs project investigation activities, makes site safety coordinator (SSC) aware of pertinent project developments and plans, and maintains communications with client as necessary. |
| Chris Reynolds, Tetra Tech EM Inc. (HE) | All | Site Safety Coordinator (SSC): Ensures that appropriate personal protective equipment (PPE) is available, enforces proper utilization of PPE by on-site personnel, suspends investigative work if he or she believes that site personnel are or may be exposed to an immediate health hazard, implements the health and safety plan, and reports any observed deviations from anticipated conditions described in the health and safety plan to the health and safety representative. |
| Joe Faubion, Tetra Tech EM Inc. (HE) | All | Field Team Leader, Project Engineer, and Field Personnel: Complete tasks as directed by the project manager, field team leader, and SSC and follow all procedures and guidelines established in the Tetra Tech, EM Inc. Health and Safety Manual. |
| Gary Sturm, Tetra Tech EM Inc. (HE), Project Engineer | All | |
| Laura Newman, Tetra Tech EM Inc. (HE), Field Team Member | All | |
| Matt Hulbert, Tetra Tech EM Inc. (HE), Engineering Design Support | All | |
| Aaron Cade, Tetra Tech EM Inc. (HE), Technical Support, Site Map and Volume Estimates | All | |
| Jessica Allewalt, Tetra Tech EM Inc. (HE), Field Team Member | All | |

# HEALTH AND SAFETY PLAN

**Protective Equipment: (**Indicate type or material as necessary for each task; attach additional sheets as necessary)

Task: ☒ 1 ☒ 2
Level: ☐ C ☒ D ☐ Modified
☒ Primary ☐ Contingency

RESPIRATORY
- ☒ Not needed
- ☐ APR: ____
- ☐ Cartridge: ____
- ☐ Escape mask: ____
- ☐ Other: ____

PROTECTIVE CLOTHING
- ☒ Not needed
- ☐ Tyvek® coveralls: ____
- ☐ Saranex® coveralls: ____
- ☐ Coveralls: ____
- ☐ Other: ____

HEAD AND EYE
- ☐ Not needed
- ☒ Safety glasses: As Required
- ☐ Face shield: ____
- ☐ Goggles: ____
- ☒ Hard hat: As Required
- ☐ Other: ____

GLOVES
- ☐ Not needed
- ☒ Undergloves: Latex
- ☒ Gloves: Leather
- ☐ Overgloves: ____

FIRST AID EQUIPMENT
- ☐ Not needed
- ☒ Standard First Aid kit
- ☐ Portable eyewash

BOOTS
- ☐ Not needed
- ☒ Work boots: Steel-Toe/Steel Shank
- ☐ Overboots: ____

OTHER
- ☐ (specify): ____

Task: ☒ 1 ☒ 2
Level: ☐ C ☒ D ☒ Modified
☐ Primary ☒ Contingency

RESPIRATORY
- ☒ Not needed
- ☐ APR: ____
- ☐ Cartridge: HEPA
- ☐ Escape mask: ____
- ☐ Other: ____

PROTECTIVE CLOTHING
- ☐ Not needed
- ☒ Tyvek® coveralls: ____
- ☐ Saranex® coveralls: ____
- ☐ Coveralls: ____
- ☐ Other: ____

HEAD AND EYE
- ☐ Not needed
- ☒ Safety glasses: ____
- ☐ Face shield: ____
- ☐ Goggles: ____
- ☒ Hard hat: ____
- ☐ Other: ____

GLOVES
- ☐ Not needed
- ☒ Undergloves: Latex
- ☒ Gloves: Nitrile
- ☐ Overgloves: ____

FIRST AID EQUIPMENT
- ☐ Not needed
- ☒ Standard First Aid kit
- ☐ Portable eyewash

BOOTS
- ☐ Not needed
- ☒ Work boots: Steel-Toe/Steel Shank
- ☐ Overboots: ____

OTHER
- ☐ (specify): ____

Note: APR = Air purifying respirator

| **Monitoring Equipment:** (Specify instruments needed for each task; attach additional sheets as necessary) | | | | |
|---|---|---|---|---|
| Instrument | Task | Instrument Reading | Action Guideline | Comments |
| Combustible gas indicator model: | ☐ 1<br>☐ 2 | 0 to 10% LEL<br>10 to 25% LEL<br>> 25% LEL | No explosion hazard<br>Potential explosion hazard; notify SSC<br>Explosion hazard; interrupt task; evacuate site, notify SSC | ☒ Not needed |
| O2 meter model: | ☐ 1<br>☐ 2 | > 23.5% O2<br>23.5 to 19.5% O2<br>< 19.5% O2 | Potential fire hazard; evacuate site<br>Oxygen level normal<br>Oxygen deficiency; interrupt task; evacuate site; notify SSC | ☒ Not needed |
| Radiation survey meter model: | ☐ 1<br>☐ 2 | < 2 mrem per hour<br>Three times background<br>> 2 mrem per hour | Normal background<br>Notify SSC<br>Radiological hazard; interrupt task; evacuate site; notify SSC | Note: Annual exposure not to exceed 1,250 mrem per quarter ☒ Not needed |
| Photoionization detector model:<br>☐ 11.7 eV<br>☐ 10.2 eV<br>☐ 9.8 eV<br>☐ ______________eV | ☐ 1<br>☐ 2 | >0 to 5 ppm above background<br>>5 to 20 ppm above background<br>>20 ppm above background | Level D<br>Level C<br>Evacuate site; notify SSC | ☒ Not needed |
| Flame ionization detector model: | ☐ 1<br>☐ 2 | >0 to 5 ppm above background<br>>5 to 20 ppm above background<br>>20 ppm above background | Level D<br>Level C<br>Evacuate site; notify SSC | ☒ Not needed |
| Detector tubes models: | ☐ 1<br>☐ 2 | Specify: | Specify: | Note: This action level for upgrading the level of protection is one-half of the contaminant's PEL. If the PEL is reached, evacuate the site and notify the SSC. ☒ Not needed |
| Respirable dust monitor model: | ☐ 1<br>☐ 2 | Specify: | Specify: | ☒ Not needed |
| Other: (specify): | ☐ 1<br>☐ 2 | Specify: | Specify: | ☐ Not needed |

Notes: eV = Electron volt LEL = Lower explosive limit mrem = Millirem $O_2$ = Oxygen PEL = Permissible exposure limit ppm = Part per million

# HEALTH AND SAFETY PLAN

**Additional Comments:**

**Emergency Contacts:**

| Emergency Contacts | Telephone |
|---|---|
| U.S. Coast Guard National Response Center | 800/424-8801 |
| InfoTrac | 800/535-5053 |
| Fire department | 911 |
| Police department | 911 |
| Tetra Tech EM Inc. Personnel: | |
| Human Resource Development: Norman Endlich | 703/390-0626 |
| Health & Safety Representative: Judith Wagner | 847/818-7192 |
| Office Health and Safety Coordinator | 442-5588 |
| Project Manager | 442-5588 |
| Site Safety Coordinator | 421-4549 (cell phone) |

**Personnel Decontamination and Disposal Method:**

Personnel will follow the U.S. Environmental Protection Agency's "Standard Operating Safety Guides" for decontamination procedures for Modified Level D personal protection (with Level D contingency). The following decontamination steps should be employed for this project:

- Disposable gloves
- Safety glasses and hard hat
- Hand and face wash and rinse (portable water jugs and paper towels)

If site conditions require upgrading to Level D, Tyvek coveralls, boot covers, and undergloves will be added to the standard PPE.

All disposable equipment, clothing, and wash water will be double-bagged or containerized in an acceptable manner and disposed of in accordance with local regulations.

**Medical Emergency:**

Hospital Name: St. Peters Hospital

Hospital Address: 2475 Broadway, Helena, MT 59601

Hospital Telephone: Emergency - 911<br>General – 442-2480

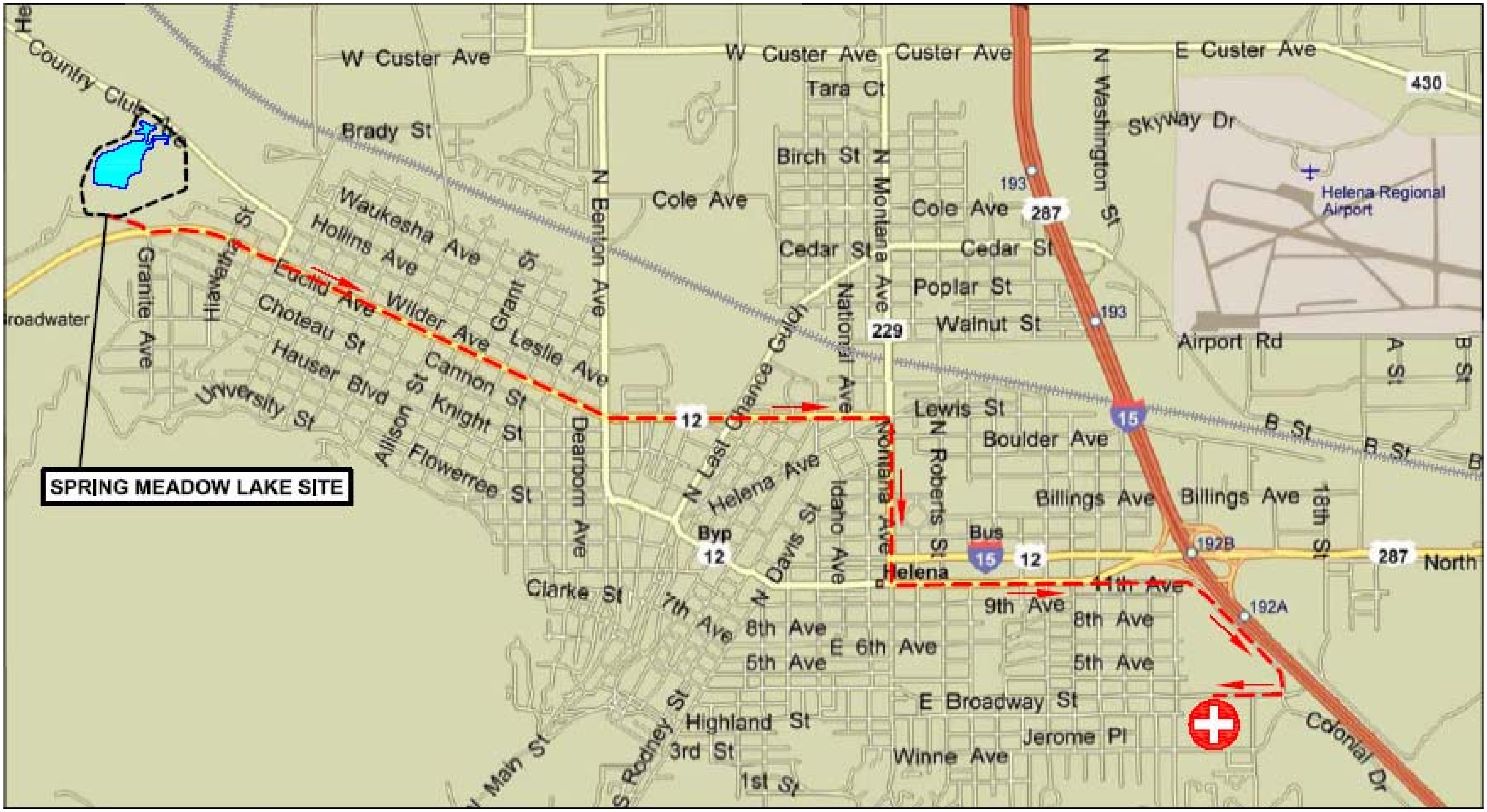
Ambulance Telephone: 911 or 444-2228

Route to Hospital: (see Page 4-50 for route map)

Exit Spring Meadow Lake site and turn east (left) onto Hwy 12 (Euclid Ave.). Follow Hwy 12 east until it becomes Montana Ave. Continue north on Montana Ave. and proceed to 11th Ave. Turn east (left) onto 11th Ave and proceed about 0.75 mile to Colonial Drive exit. Proceed about 0.75 miles on Colonial Drive until it intersects with East Broadway. Turn right (west) onto Broadway and St. Peter's Hospital is located on the left.

Note: This page must be posted on site.

**Hospital Route Map (if available):**



**APPROVAL AND SIGN-OFF FORM**

**Project No. S1129-06BLUERI**

*I have read, understood, and agree with the information set forth in this Health and Safety Plan and will follow the direction of the Site Safety Coordinator as well as procedures and guidelines established in the Tetra Tech, Inc., Health and Safety Manual. I understand the training and medical requirements for conducting field work and have met these requirements.*

| Name | Signature | Date |
|---|---|---|
| | | |
| Name | Signature | Date |
| | | |
| Name | Signature | Date |
| | | |
| Name | Signature | Date |

APPROVALS: (Two Signatures Required)

Site Safety Coordinator — Date

Health and Safety Representative or Designee — Date

**DEFINITIONS**

**Intrusive** - Work involving excavation to any depth, drilling, opening of monitoring wells, most sampling, and Geoprobe® work

**Nonintrusive** - Generally refers to site walk-throughs or field reconnaissance

**Levels of Protection**

**Modified Level D** - Hard hat, safety boots, and glasses
**Level D** - Items listed for modified Level D above, **PLUS** protective clothing such as gloves, boot covers, and Tyvek® or Saranex® coveralls
**Modified Level C** - Hard hat, safety boots, glasses, and air purifying respirators with appropriate cartridges
**Level C** - Items listed for modified Level C above, **PLUS** protective clothing such as gloves, boot covers, and Tyvek® or Saranex® coveralls

**Emergency Contacts**

**InfoTrac** - For issues related to incidents involving the transportation of hazardous chemicals; this hotline provides accident assistance 24 hours per day, 7 days per week
**U.S. Coast Guard National Response Center** - For issues related to spill containment, cleanup, and damage assessment; this hotline will direct spill information to the appropriate state or region

**Health and Safety Plan Short Form**

- Used for field projects of limited duration and with relatively limited activities; may be filled in with handwritten text
- Limitations:
  - No Level B or A work
  - No more than two tasks
  - No confined space entry
  - No unexploded ordnance work

## 4.6 REFERENCES CITED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EPA. 1992. *U.S. EPA Contract Laboratory Program, Statement of Work, Inorganic Analysis, Multimedia, Multiconcentration*. Document ILM02.0.

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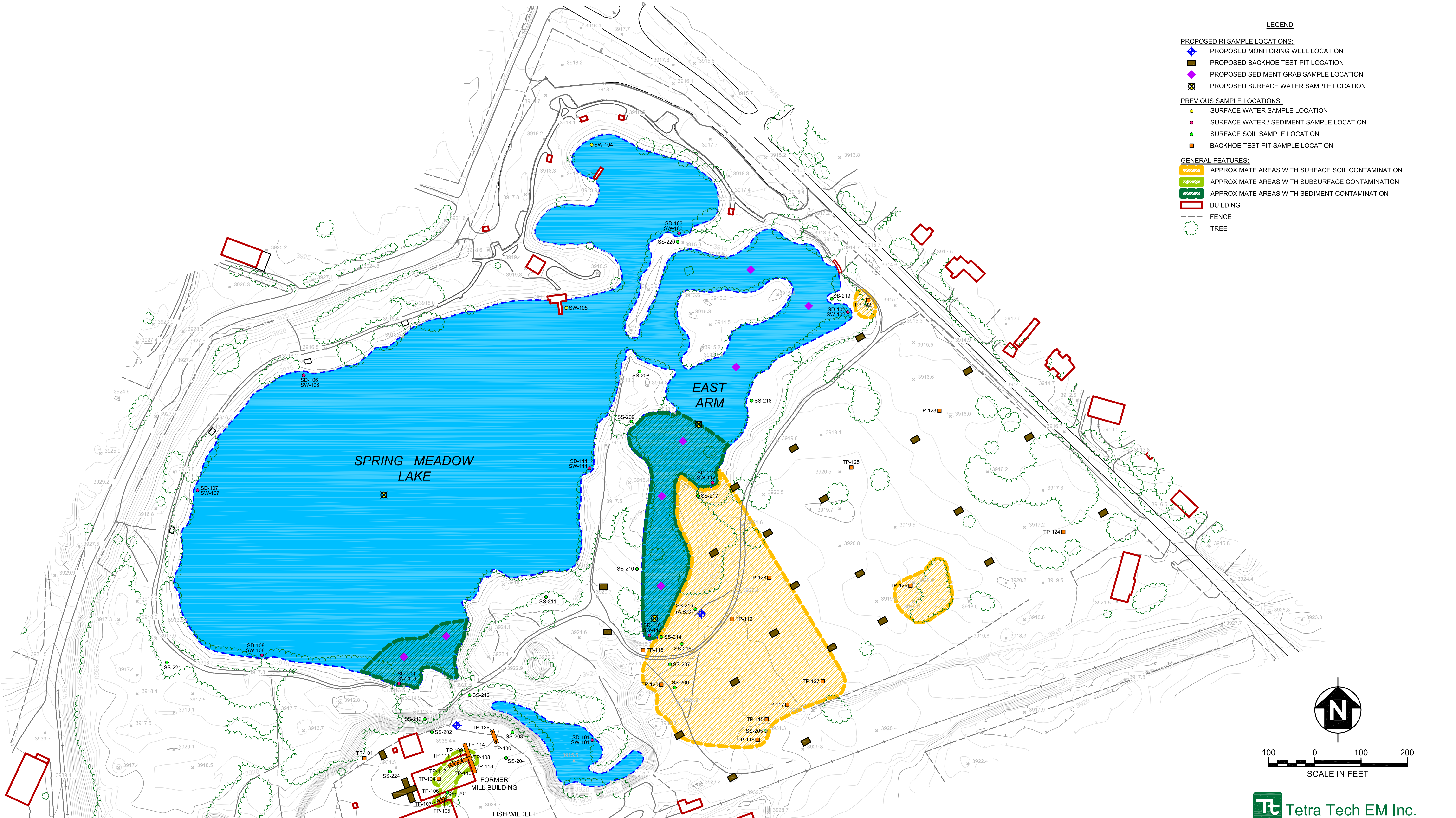
Washington State Department of Ecology. 1997. Creation and Analysis of Freshwater Sediment Quality Values in Washington State. Publication No. 97-323a, Department of Ecology Publications Distributions Office, Olympia, Washington. July.




**Spring Meadow Lake**
**Helena, Montana**

**FIGURE 4-1**
**EXISTING AND PROPOSED**
**SAMPLE LOCATION MAP**

FIG4-1_PROP SAMP LOC MAP.dwg - DWH - 02/25/2005 - S1129.30.SMLSRI

# ATTACHMENT 1

# MONITORING WELL INSTALLATION
# SOP NO. 020

**SOP APPROVAL FORM**

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

**MONITORING WELL INSTALLATION**

**SOP NO. 020**

**REVISION NO. 3**

Last Reviewed: December 2000

| | |
|---|---|
| | *December 19, 2000* |
| Quality Assurance Approved | Date |

## 1.0 BACKGROUND

Groundwater monitoring wells are designed and installed for a variety of reasons including: (1) detecting the presence or absence of contaminants, (2) collecting groundwater samples representative of in situ aquifer chemical characteristics, or (3) measuring water levels for determining groundwater potentiometric head and groundwater flow direction.

Although detailed specifications for well installation may vary in response to site-specific conditions, some elements of well installation are common to most situations. This standard operating procedure (SOP) discusses common methods and minimum standards for monitoring well installation for Tetra Tech EM Inc. (Tetra Tech) projects. The SOP is based on widely recognized methods described by the U.S. Environmental Protection Agency (EPA) and American Society for Testing and Materials (ASTM). However, well type, well construction, and well installation methods will vary with drilling method, intended well use, subsurface characteristics, and other site-specific criteria. In addition, monitoring wells should be constructed and installed in a manner consistent with all local and state regulations. Detailed specifications for well installation should be identified within a site-specific work plan, sampling plan, or quality assurance project plan (QAPP).

General specifications and installation procedures for the following monitoring well components are included in this SOP:

- Monitoring well materials
  - Casing materials
  - Well screen materials
  - Filter pack materials
  - Annular sealant (bentonite pellets or chips)
  - Grouting materials
  - Tremie pipe
  - Surface completion and protective casing materials
  - Concrete surface pad and bumper posts
  - Uncontaminated water
- Monitoring well installation procedures
  - Well screen and riser placement
  - Filter pack placement
  - Temporary casing retrieval

  - Annular seal placement
  - Grouting
  - Surface completion and protective casing (aboveground and flush-mount)
  - Concrete surface pad and bumper posts
  - Permanent and multiple casing well installation

- Recordkeeping procedures

  - Surveying
  - Permits and well construction records
  - Monitoring well identification

Well installation methods will depend to some extent on the boring method. Specific boring or drilling protocols are detailed in other SOPs. The boring method, in turn, will depend on site-specific geology and hydrogeology and project requirements. Boring methods commonly used for well installation include:

- Hollow-stem augering
- Cable tool drilling
- Mud rotary drilling
- Air rotary drilling
- Rock coring

The hollow-stem auger method is preferred in areas where subsurface materials are unconsolidated or loosely consolidated and where the depth of the boring will be less than 100 feet. This maximum effective depth for hollow-stem augering depends on the diameter of the augers, the formation characteristics, and the strength and durability of the drilling equipment. This method is preferred because under the right conditions it is cost effective, addition of water into the subsurface is limited, continuous soil samples can easily be collected, and monitoring wells can easily be constructed within the hollow augers.

Cable tool drilling is a preferred method when the subsurface contains boulders, coarse gravels, or flowing sands, or when the operational depth of the hollow-stem auger is exceeded. However, this method is slow.

Rotary methods are generally used when other methods cannot be used. The use of drilling fluids or large amounts of water to maintain an open borehole, and the difficulty in obtaining representative samples limit the utility of rotary methods. However, rotary methods can be used to quickly and effectively drill deep wells through consolidated or unconsolidated materials. Modifications to this method such as dual-tube drilling procedures, drill-through casing hammers, or eccentric-type drill systems, can reduce the amount of fluids introduced into the well borehole.

Rock coring is an effective method when drilling in competent consolidated rock. Intact, continuous cores can be obtained, and limited amounts of fluid are required if the formations are not fractured.

## 1.1 PURPOSE

This SOP establishes the requirements and procedures for monitoring well installation. Monitoring wells should be designed to function properly throughout the duration of the monitoring program. The performance objectives for monitoring well installation are as follows:

- Ensure that the monitoring well will provide water samples representative of in situ aquifer conditions.
- Ensure that the monitoring well construction will last for duration of the project.
- Ensure that the monitoring well will not serve as a conduit for vertical migration of contaminants, particularly vertical migration between discrete aquifers.
- Ensure that the well diameter is adequate for all anticipated downhole monitoring and sampling equipment.

## 1.2 SCOPE

This SOP applies to the installation of monitoring wells. Although some of the procedures may apply to the installation of water supply wells, this SOP is not intended to cover the design and construction of such wells. The SOP identifies several well drilling methods related to monitoring well installation, but the scope of this SOP does not include drilling methods.

Other relevant SOPs include SOP 002 for decontamination of drilling and well installation equipment, SOP 005 for soil sampling, SOP 021 for monitoring well development, SOPs 010 and 015 for groundwater sampling from monitoring wells, and SOP 014 for measuring static water levels within monitoring wells.

## 1.3 DEFINITIONS

**Annulus:** The space between the monitoring well casing and the wall of the well boring.

**Bentonite seal:** A colloidal clay seal separating the sand pack from the annular grout seal.

**Centralizer:** A stainless-steel or plastic spacer that keeps the well screen and casing centered in the borehole.

**Filter pack:** A clean, uniform sand or gravel placed between the borehole wall and the well screen to prevent formation material from entering the screen.

**Grout seal:** A fluid mixture of (1) bentonite and water, (2) cement, bentonite, and water, or (3) cement and water placed above the bentonite seal between the casing and the borehole wall to secure the casing in place and keep water from entering the borehole.

**Tremie pipe:** A rigid pipe used to place the well filter pack, bentonite seal, or grout seal. The tremie pipe is lowered to the bottom of the well or area to be filled and pulled up ahead of the material being placed.

**Well casing:** A solid piece of pipe, typically polyvinyl chloride (PVC) or stainless steel, used to keep a well open in either unconsolidated material or unstable rock.

**Well screen:** A PVC or stainless steel pipe with openings of a uniform width, orientation, and spacing used to keep materials other than water from entering the well and to stabilize the surrounding formation.

## 1.4 REFERENCES

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## 1.5 REQUIREMENTS AND RESOURCES

Well installation requires a completed boring with stable or supported walls. The type of drilling rig needed to complete the boring and the well construction materials required for monitoring well installation will depend on the drilling method used, the geologic formations present, and chemicals of concern in groundwater. The rig and support equipment used to drill the borehole is usually used to install the well. Under most conditions, the following items are also required for the proper installation of monitoring wells:

- Tremie pipe and funnel
- Bentonite pellets or chips
- Grouting supplies
- Casing materials
- Well screen materials
- Filter pack materials
- Surface completion materials (protective casing, lockable and watertight well cover, padlock)
- Electronic water level sounding device for water level measurement
- Measuring tape with weight for measuring the depth of the well and determining the placement of filter pack materials
- Decontamination equipment and supplies

- Site-specific work plan, field sampling plan, health and safety plan, and QAPP
- Monitoring Well Completion Record (see Figure 1)

## 2.0 MONITORING WELL INSTALLATION PROCEDURES

This section presents standard procedures for monitoring well installation and is divided into three subsections. Section 2.1 addresses monitoring well construction materials, while Section 2.2 describes typical monitoring well installation procedures. Section 2.3 addresses recordkeeping requirements associated with monitoring well installation. Monitoring well installation procedures described in work plans, sampling plans, and QAPPs should be fully consistent with the procedures outlined in this SOP as well as any applicable local and state regulations and guidelines.

### 2.1 MONITORING WELL CONSTRUCTION MATERIALS

Monitoring well construction materials should be specified in the site-specific work plan as well as in the statement of work for any subcontractors assisting in the well installation. Well construction materials that come in contact with groundwater should not measurably alter the chemical quality of groundwater samples with regard to the constituents being examined. The riser, well screen, and filter pack and annular sealant placement equipment should be steam cleaned or high-pressure water cleaned immediately prior to well installation. Alternatively, these materials can be certified by the manufacturer as clean and delivered to the site in protective wrapping. Samples of the filter pack, annular seal, and mixed grout should be retained as a quality control measure until at least one round of groundwater sampling and analysis is completed.

This section discusses material specifications for the following well construction components: casing, well screen, filter pack, annular sealant (bentonite pellets or chips), grout, tremie pipes, surface completion components (protective casing, lockable and water tight cap, and padlock), concrete surface pad, and uncontaminated water. Figure 2 shows the construction details of a typical monitoring well.

### 2.1.1 Casing Materials

The material type and minimum wall thickness of the casing should be adequate to withstand the forces of installation. If the casing has not been certified as clean by the manufacturer or delivered to and maintained in clean condition at the site, the casing should be steam cleaned or high-pressure water cleaned with water from a source of known chemistry immediately prior to installation (see Tetra Tech SOP No. 002). The ends of each casing section should be either flush-threaded or beveled for welding.

Schedule 40 or Schedule 80 PVC casing is typically used for monitoring well installation. Either type of casing is appropriate for monitoring wells with depths less than 100 feet below ground surface (bgs). If the well is deeper than 100 feet bgs, Schedule 80 PVC should be used.

Stainless steel used for well casing is typically Type 304 and is of 11-gauge thickness.

### 2.1.2 Well Screen Materials

Well screens should be new, machine-slotted or continuous wrapped wire-wound, and composed of materials most suited for the monitoring environment based on site characterization findings. Well screens are generally constructed of the same materials used for well casing (PVC or stainless steel). The screen should be plugged at the bottom with the same material as the well screen. Alternatively, a short (1- to 2-foot) section of casing material with a bottom (sump) should be attached below the screen. This assembly must be able to withstand installation and development stresses without becoming dislodged or damaged. The length of the slotted area should reflect the interval to be monitored.

If the well screen has not been certified as clean by the manufacturer or delivered to and maintained in clean condition at the site, the screen should be steam cleaned or high-pressure water cleaned with water from a source of known chemistry immediately prior to installation (see Tetra Tech SOP No. 002).

The minimum internal diameter of the well screen should be chosen based on the particular application. A minimum diameter of 2 inches is usually needed to allow for the introduction and withdrawal of sampling devices. Typical monitoring well screen diameters are 2 inches and 4 inches.

The slot size of the well screen should be determined relative to (1) the grain size of particles in the aquifer to be monitored and (2) the gradation of the filter pack material.

Screen length and monitoring well diameter will depend on site-specific considerations such as intended well use, contaminants of concern, and hydrogeology. Some specific considerations include the following:

- Water table wells should have screens of sufficient length and diameter to monitor the water table and provide sufficient sample volume under high and low water table conditions.
- Wells with low recharge should have screens of sufficient length and diameter so that adequate sample volume can be collected.
- Wells should be screened over sufficiently short intervals to allow for monitoring of discrete migration pathways.
- Where light nonaqueous-phase liquids (LNAPL) or contaminants in the upper portion of a hydraulic unit are being monitored, the screen should be set so that the upper portion of the water-bearing zone is below the top of the screen.
- Where dense nonaqueous-phase liquids (DNAPL) are being monitored, the screen should be set within the lower portion of the water-bearing zone, just above a relatively impermeable lithologic unit.
- The screened interval should not extend across an aquiclude or aquitard.
- If contamination is known to be concentrated within a portion of a saturated zone, the screen should be constructed in a manner that minimizes the potential for cross-contamination within the aquifer.
- If downhole geophysical surveys are to be conducted, the casing and screen must be of sufficient diameter and constructed of the appropriate material to allow for effective use of the geophysical survey tools.
- If aquifer tests are to be conducted in a monitoring well, the slot size must allow sufficient flux to produce the required drawdown and recovery. The diameter of the well must be sufficient to house the pump and monitoring equipment, and allow sufficient water flux (in combination with the screen slot size) to produce the required drawdown or recovery.

### 2.1.3 Filter Pack Materials

The primary filter pack consists of a granular material of known chemistry and selected grain size and gradation. The filter pack is installed in the annulus between the well screen and the borehole wall. The grain size and gradation of the filter pack are selected to stabilize the hydrologic unit adjacent to the screen and to prevent formation material from entering the well during development. After development, a properly filtered monitoring well is relatively free of turbidity.

A secondary filter pack is a layer of material placed in the annulus directly above the primary filter pack and separates the filter pack from the annular sealant. The secondary filter pack should be uniformly graded fine sand, with 100 percent by weight passing through a No. 30 U.S. Standard sieve, and less than 2 percent by weight passing through a No. 200 U.S. Standard sieve.

### 2.1.4 Annular Sealant (Bentonite Pellets or Chips)

The materials used to seal the annulus may be prepared as a slurry or used as dry pellets, granules, or chips. Sealants should be compatible with ambient geologic, hydrogeologic, and climatic conditions and any man-induced conditions anticipated to occur during the life of the well.

Bentonite (sodium montmorillonite) is the most commonly used annular sealant and is furnished in sacks or buckets in powder, granular, pelletized, or chip form. Bentonite should be obtained from a commercial source and should be free of impurities that may adversely impact the water quality in the well. Pellets are compressed bentonite powder in roughly spherical or disk shapes. Chips are large, coarse, irregularly shaped units of bentonite. The diameter of the pellets or chips should be less than one-fifth the width of the annular space into which they will be placed in order to reduce the potential for bridging. Granules consist of coarse particles of unaltered bentonite, typically smaller than 0.2 inch in diameter. Bentonite slurry is prepared by mixing powdered or granular bentonite with water from a source of known chemistry.

### 2.1.5 Grouting Materials

The grout backfill that is placed above the bentonite annular seal is ordinarily liquid slurry consisting of either (1) a bentonite (powder, granules, or both) base and water, (2) a bentonite and Portland cement base and water, or (3) a Portland cement base and water. Often, bentonite-based grouts are used when flexibility is desired during the life of the well installation (for example, to accommodate freeze-thaw cycles). Cement- or bentonite-based grouts are often used when cracks in the surrounding geologic material must be filled or when adherence to rock units, or a rigid setting is desired.

Each type of grout mixture has slightly different characteristics that may be appropriate under various physical and chemical conditions. However, quick-setting cements containing additives are not recommended for use in monitoring well installation because additives may leach from the cement and influence the chemistry of water samples collected from the well.

### 2.1.6 Tremie Pipe

A tremie pipe is used to place the filter pack, annular sealant, and grouting materials into the borehole. The tremie pipe should be rigid, have a minimum internal diameter of 1.0 inch, and be made of PVC or steel. The length of the tremie pipe should be sufficient to extend to the full depth of the monitoring well.

### 2.1.7 Surface Completion and Protective Casing Materials

Protective casings that extend above the ground surface should be made of aluminum, steel, stainless steel, cast iron, or a structural plastic. The protective casing should have a lid with a locking device to prevent vandalism. Sufficient clearance, usually 6 inches, should be maintained between the top of the riser and the top of protective casing. A water-tight well cap should be placed on the top of the riser to seal the well from surface water infiltration in the event of a flood. A weep hole should be drilled in the casing a minimum of 6 inches above the ground surface to enable water to drain out of the annular space.

Flush-mounted monitoring wells (wells that do not extend above ground surface) require a water-tight protective cover of sufficient strength to withstand heavy traffic. The well riser should be fitted with a locking water-tight cap.

### 2.1.8 Concrete Surface Pad and Bumper Posts

A concrete surface pad should be installed around each well when the outer protective casing is installed. The surface pad should be formed around the well casing. Concrete should be placed into the formed pad and into the borehole (on top of the grout), typically to a depth of 1 to 3 feet bgs (depending on state, federal, and local regulations). The protective casing is then installed into the concrete. As a general guideline, if the well casing is 2 inches in diameter, the concrete pad should be 3 feet square and 4 inches thick. If the well casing is 4 inches in diameter, the pad should be 4 feet square and 6 inches thick. Round concrete pads are also acceptable.

The finished pad should be sloped so that drainage flows away from the protective casing and off the pad. The finished pad should extend at least 1 inch below grade. If the monitoring wells are located in high traffic areas, a minimum of three bumper posts should be installed around the pad to protect the well. Bumper posts, consisting of steel pipes 3 to 4 inches in diameter and at least 5 feet long, should be installed in a radial pattern around the protective casing, beyond the edges of the cement pad. The base of the bumper posts should be installed 2 feet bgs in a concrete footing; the top of the post should be capped or filled with concrete.

### 2.1.9 Uncontaminated Water

Water used in the drilling process, to prepare grout mixtures, and to decontaminate the well screen, riser, and annular sealant injection equipment, should be obtained from a source of known chemistry. The water should not contain constituents that could compromise the integrity of the monitoring well installation.

## 2.2 MONITORING WELL INSTALLATION PROCEDURES

This section describes the procedures used to install a single-cased monitoring well, with either temporary casing or hollow-stem augers to support the walls of the boring in unconsolidated formations. The procedures are described in the order in which they are conducted, and include: (1) placement of well screen and riser pipe, (2) placement of filter pack, (3) progressive retrieval of temporary casing, (4) placement of annular seal, (5) grouting, (6) surface completion and installation of protective casing, and (7) installation of concrete pad and bumper posts.

The additional steps necessary to install a well with permanent or multiple casing strings are described at the end of this section.

### 2.2.1 Well Screen and Riser Placement

After the total depth of the boring is confirmed and the well screen depth interval and the height of the aboveground completion are determined, the screen and riser is assembled from the bottom up as it is lowered down the hole. The following procedures should be followed:

1. Measure the total depth of the boring using a weighted tape.
2. Determine the length of screen and casing materials required to construct the well.
3. Assemble the well parts from the bottom up, starting with the well sump or cap, well screen, and then riser pipe. Progressively lower the assembled length of pipe.
4. The length of the assembled pipe should not extend above the top of the installation rig.

The well sump or cap, well screen, and riser should be certified clean by the manufacturer or should be decontaminated before assembly and installation. No grease, oil, or other contaminants should contact any portion of the assembly. Flush joints should be tightened, and welds should be water tight and of good quality. The riser should extend above grade and be capped temporarily to prevent entrance of foreign materials during the remaining well completion procedures.

When the well screen and riser assembly is lowered to the predetermined level, it may float and require a method to hold it in place. For borings drilled using cable tool or air rotary drilling methods, centralizers should be attached to the riser at intervals of between 20 and 40 feet.

### 2.2.2 Filter Pack Placement

The filter pack is placed after the well screen and riser assembly has been lowered into the borehole. The steps below should be followed:

1. Determine the volume of the annular space in the filter pack interval. The filter pack should extend from the bottom of the borehole to at least 2 feet above the top of the well screen.

2. Assemble the required material (sand pack and tremie pipe).

3. Lower a clean or decontaminated tremie pipe down the annulus to within 1 foot of the base of the hole.

4. Pour the sand down the tremie pipe using a funnel; pour only the quantity estimated to fill the first foot.

5. Check the depth of sand in the hole using a weighted tape.

6. Pull the drill casing up ahead of the sand to keep the sand from bridging.

7. Continue with this process (steps 4 through 6) until the filter pack is at the appropriate depth.

If bridging of the filter pack occurs, break out the bridge prior to adding additional filter pack material. For wells less than 30 feet deep installed inside hollow-stem augers, the sand may be poured in 1-foot lifts without a tremie pipe.

Sufficient measurements of the depth to the filter pack material and the depth of the bottom of the temporary casing should be made to ensure that the casing bottom is always above the filter pack. The filter pack should extend 2 feet above the well screen (or more if required by state or local regulations). However, the filter pack should not extend across separate hydrogeologic units. The final depth interval, volume, and type of filter pack should be recorded on the Monitoring Well Completion Record (Figure 1).

A secondary filter pack may be installed above the primary filter pack to prevent the intrusion of the bentonite grout seal into the primary filter pack. A measured volume of secondary filter material should be added to extend 1 to 2 feet above the primary filter pack. As with the primary filter pack, a secondary filter pack must not extend into an overlying hydrologic unit. An on-site geologist should evaluate the need for a secondary filter pack by considering the gradation of the primary filter pack, the hydraulic head difference between adjacent units, and the potential for grout intrusion into the primary filter pack.

The secondary filter material is poured into the annular space through tremie pipe as described above. Water from a source of known chemistry may be added to help place the filter pack into its proper location.

The tremie pipe or a weighed line inserted through the tremie pipe can be used to measure the top of the secondary filter pack as work progresses. The amount and type of secondary filter pack used should be recorded on the Monitoring Well Completion Record (Figure 1).

### 2.2.3 Temporary Casing Retrieval

The temporary casing or hollow-stem auger should be withdrawn in increments. Care should be taken to minimize lifting the well screen and riser assembly during withdrawal of the temporary casing or auger. It may be necessary to place the top head of the rig on the riser to hold it down. To limit borehole collapse in formations consisting of unconsolidated materials, the temporary casing or hollow-stem auger is usually withdrawn until the lowest point of the casing or auger is at least 2 feet, but no more than 5 feet, above the filter pack. When the geologic formation consists of consolidated materials, the lowest point of the casing or auger should be at least 5 feet, but no more than 10 feet, above the filter pack. In highly unstable formations, withdrawal intervals may be much less. After each increment, the depth to the primary filter pack should be measured to check that the borehole has not collapsed or that bridging has not occurred.

### 2.2.4 Annular Seal Placement

A bentonite pellet, chip, or slurry seal should be placed between the borehole and the riser on top of the primary or secondary filter pack. This seal retards the movement of grout into the filter pack. The thickness of the bentonite seal will depend on state and local regulations, but the seal should generally be between 3 and 5 feet thick.

The bentonite seal should be installed using a tremie pipe, lowered to the top of the filter pack and slowly raised as the bentonite pellets or slurry fill the space. Care must be taken so that bentonite pellets or chips do not bridge in the augers or tremie pipe. The depth of the seal should be checked with a weighted tape or the tremie pipe.

If a bentonite pellet or chip seal is installed above the water level, water from a known source should be added to allow proper hydration of the bentonite. Sufficient time should be allowed for the bentonite seal to hydrate. The volume and thickness of the bentonite seal should be recorded on the Monitoring Well Completion Record (Figure 1).

### 2.2.5 Grouting

Grouting procedures vary with the type of well design. The volume of grout needed to backfill the remaining annular space should be calculated and recorded on the Monitoring Well Completion Record (Figure 1). The use of alternate grout materials, including grouts containing gravel, may be necessary to control zones of high grout loss. Bentonite grouts should not be used in arid regions because of their propensity to desiccate. Typical grout mixtures include the following:

- Bentonite grout: about 1 to 1.25 pounds of bentonite mixed with 1 gallon of water
- Cement-bentonite grout: about 5 pounds of bentonite and one 94-pound bag of cement mixed with 7 to 8 gallons of water
- Cement grout: one 94-pound bag of cement mixed with 6 to 7 gallons of water

The grout should be installed by gravity feed through a tremie pipe. The grout should be mixed in batches in accordance with the appropriate requirements and then pumped into the annular space until full-strength grout flows out at the ground surface without evidence of drill cuttings or fluid. The tremie pipe should then be removed to allow the grout to cure.

The riser should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser. For bentonite grouts, curing times are typically around 24 hours; curing times for cement grouts are typically 48 to 72 hours. However, the curing time required will vary with grout content and climatic conditions. The curing time should be documented in the Monitoring Well Completion Record (Figure 1).

### 2.2.6 Surface Completion and Protective Casing

Aboveground completion of the monitoring well should begin once the grout has set (no sooner than 24 hours after the grout was placed). The protective casing is lowered over the riser and set into the cured grout. The protective casing should extend below the ground surface to a depth below the frost line (typically 3 to 5 feet, depending on local conditions). The protective casing is then cemented in place. A minimum of 6 inches of clearance should be maintained between the top of the riser and the protective casing. A 0.5-inch diameter drainage or weep hole should be drilled in the protective casing approximately

6 inches above the ground surface to enable water to drain out of the annular space between the casing and riser. A water-tight cap should be placed on top of the riser to seal the well from surface water infiltration in the event of a flood. A lock should be placed on the protective casing to prevent vandalism.

For flush-mounted monitoring wells, the well cover should be raised above grade and the surrounding concrete pad sloped so that water drains away from the cover. The flush-mount completion should be installed in accordance with applicable state and local regulations.

### 2.2.7 Concrete Surface Pad and Bumper Posts

The concrete pad installed around the monitoring well should be sloped so that the drainage will flow away from the protective casing and off the pad. The finished pad should extend at least 1 inch below grade. If the monitoring wells are located in high traffic areas, a minimum of three bumper posts should be installed in a radial pattern around the protective casing, outside the cement pad. Specifications for concrete surface pads and bumper posts are described in Section 2.1.8.

### 2.2.8 Permanent and Multiple Casing Well Installation

When wells are installed through multiple saturated zones, special well construction methods should be used to assure well integrity and limit the potential for cross-contamination between geologic zones. Generally, these types of wells are necessary if relatively impermeable layers separate hydraulic units. Two procedures that may be used are described below.

In the first procedure, the borehole is advanced to the base of the first saturated zone. Casing is then anchored in the underlying impermeable layer (aquitard) by advancing the casing at least 1 foot into the aquitard and grouting to the surface. After the grout has cured, a smaller diameter borehole is drilled through the grout. This procedure is repeated until the zone of interest is reached. After the zone is reached, a conventional well screen and riser are set. A typical well constructed in this manner is shown on Figure 3.

A second acceptable procedure involves driving a casing through several saturated layers while drilling ahead of the casing. However, this method is not acceptable when the driven casing may structurally damage a competent aquitard or aquiclude and result in cross-contamination of the two saturated layers. This method should also be avoided when highly contaminated groundwater or nonaqueous-phase contamination may be dragged down into underlying uncontaminated hydrologic units.

## 2.3 RECORDKEEPING PROCEDURES

Recordkeeping procedures associated with monitoring well installation are described in the following sections. These include procedures for surveying, obtaining permits, completing well construction records, and identifying monitoring wells.

### 2.3.1 Surveying

Latitude, longitude, and elevation at the top of the riser should be determined for each monitoring well. A permanent notch or black mark should be made on the north side of the riser. The top of the riser and ground surface should be surveyed.

### 2.3.2 Permits and Well Construction Records

Local and state regulations should be reviewed prior to monitoring well installation, and any required well permits should be in-hand before the driller is scheduled.

Monitoring well installation activities should be documented in both the field logbook and on the Monitoring Well Completion Record (Figure 1). Geologic logs should be completed and, if necessary, filed with the appropriate regulatory agency within the appropriate time frame.

### 2.3.3 Monitoring Well Identification

Each monitoring well should have an individual well identification number or name. The well identification may be stamped in the metal surface upon completion or permanently marked by using another method. Current state and local regulations should be checked for identification requirements (such as township, range, section, or other identifiers in the well name).

## FIGURE 1

## MONITORING WELL COMPLETION RECORD

TETRATECH EM INC

### MONITORING WELL COMPLETION RECORD

**MONITORING WELL**

MONITORING WELL NO.: ______
PROJECT: ______
SITE: ______
BOREHOLE NO.: ______
WELL PERMIT NO.: ______
TOC TO BOTTOM OF WELL: ______

**DRILLING INFORMATION**

DRILLING BEGAN:
DATE: ______ TIME: ______
WELL INSTALLATION BEGAN:
DATE: ______ TIME: ______
WELL INSTALLATION FINISHED:
DATE: ______ TIME: ______
DRILLING CO.: ______
DRILLER: ______
LICENSE: ______
DRILL RIG: ______
DRILLING METHOD:
❑ HOLLOW-STEM AUGER
❑ AIR ROTARY
❑ OTHER: ______
DIAMETER OF AUGERS:
ID: ______ OD: ______

**WELL CASING**

❑ SCHEDULE 40 PVC
❑ OTHER: ______
PRODUCT: ______
MFG. BY: ______
CASING DIAMETER:
ID: ______ OD: ______
LENGTH OF CASING: ______

**WELL SCREEN**

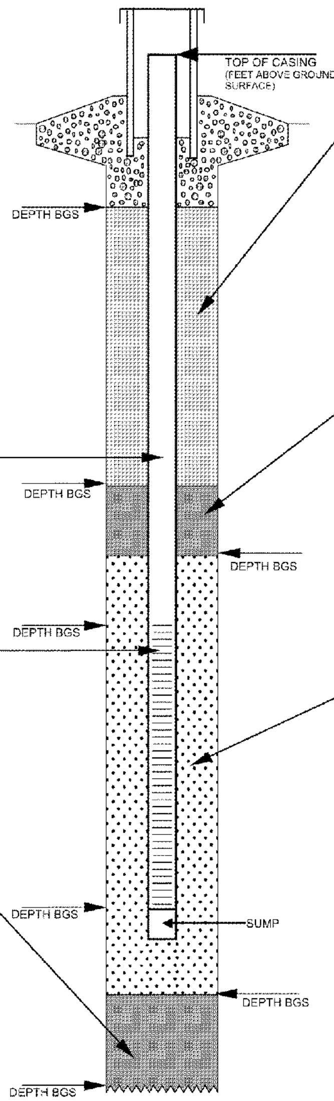
❑ SCHEDULE 40 PVC
❑ OTHER: ______
PRODUCT: ______
MFG. BY: ______
CASING DIAMETER:
ID: ______ OD: ______
SLOT SIZE: ______
LENGTH OF SCREEN: ______

**BOREHOLE BACKFILL**

AMOUNT CALCULATED: ______
AMOUNT USED: ______
❑ BENTONITE CHIPS, SIZE: ______
❑ BENTONITE PELLETS, SIZE: ______
❑ SLURRY: ______
❑ FORMATION COLLAPSE: ______
❑ OTHER: ______
PRODUCT: ______
MFG. BY: ______
METHOD INSTALLED:
❑ POURED ❑ TREMIE
❑ OTHER: ______

**SURFACE COMPLETION**

❑ FLUSH MOUNT
❑ ABOVE GROUND WITH BUMPER POST
❑ CONCRETE ❑ ASPHALT




**SURVEY INFORMATION**

TOC ELEVATION: ______
GROUND SURFACE ELEVATION: ______
NORTHING: ______
EASTING: ______
DATE SURVEYED: ______
SURVEY CO.: ______

**ANNULAR SEAL**

VOLUME CALCULATED: ______
AMOUNT USED: ______
❑ GROUT FORMULA (PERCENTAGES)
PORTLAND CEMENT: ______
BENTONITE: ______
WATER: ______
❑ PREPARED MIX
PRODUCT: ______
MFG. BY: ______
METHOD INSTALLED:
❑ POURED ❑ TREMIE
❑ OTHER: ______

**BENTONITE SEAL**

VOLUME CALCULATED: ______
AMOUNT USED: ______
❑ PELLETS, SIZE: ______
❑ CHIPS, SIZE: ______
❑ OTHER: ______
PRODUCT: ______
MFG. BY: ______
METHOD INSTALLED:
❑ POURED ❑ TREMIE
❑ OTHER: ______
AMOUNT OF WATER USED: ______

**FILTER PACK**

❑ PREPACKED FILTER
VOLUME CALCULATED: ______
AMOUNT USED: ______
❑ SAND, SIZE: ______
PRODUCT: ______
MFG. BY: ______
METHOD INSTALLED:
❑ POURED ❑ TREMIE
❑ OTHER: ______
WATER LEVEL: ______
(BTOC AFTER WELL INSTALLATION)

**CENTRALIZERS USED?**

❑ YES ❑ NO;
CENTRALIZER DEPTHS: ______ ______

**LEGEND**

BGS = BELOW GROUND SURFACE
BTOC = BELOW TOP OF CASING
N/A = NOT APPLICABLE
NR = NOT RECORDED
TOC = TOP OF CASING
ID = INSIDE DIAMETER
OD = OUTSIDE DIAMETER

**FIGURE 2**

**MONITORING WELL CONSTRUCTION DIAGRAM**

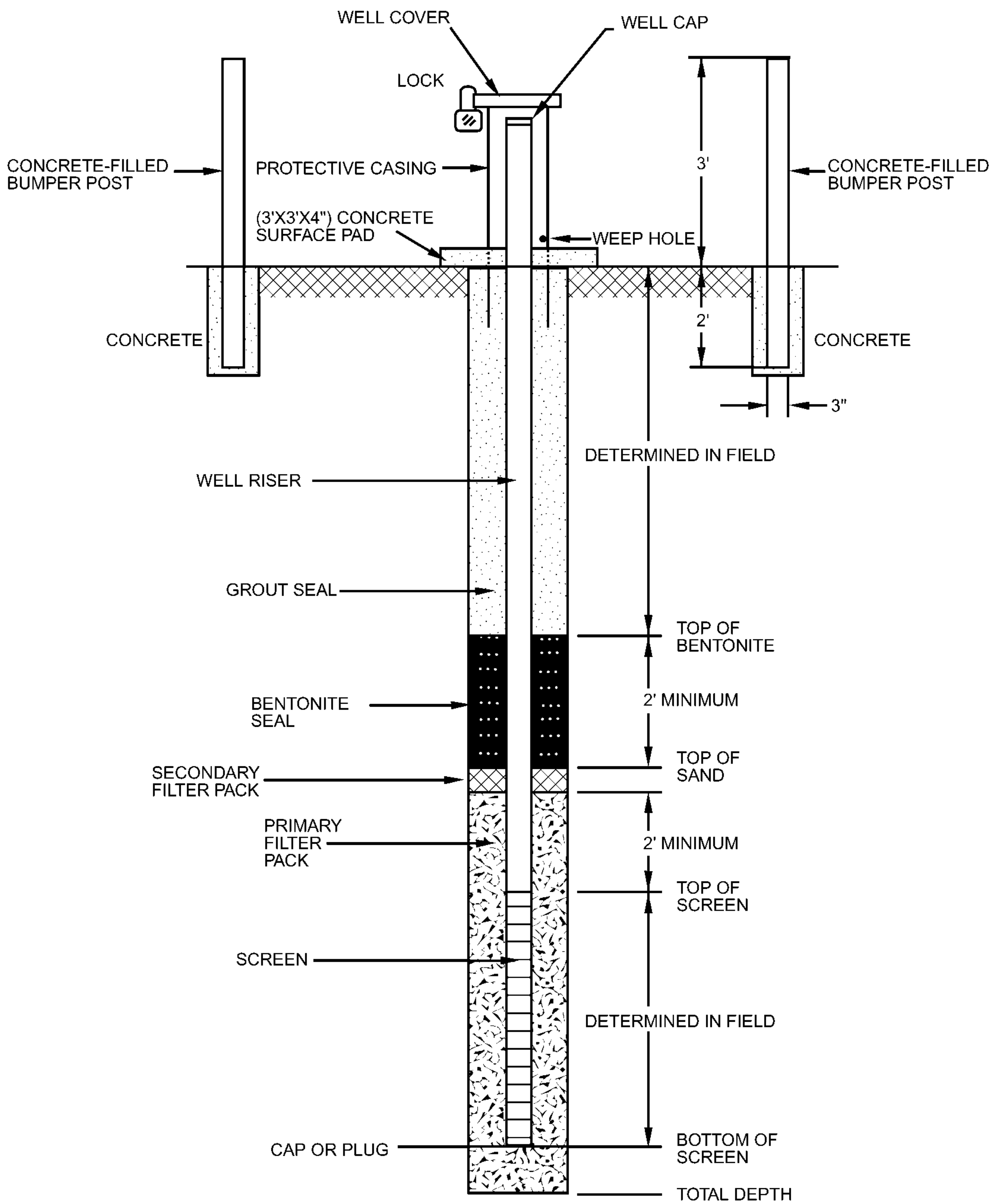
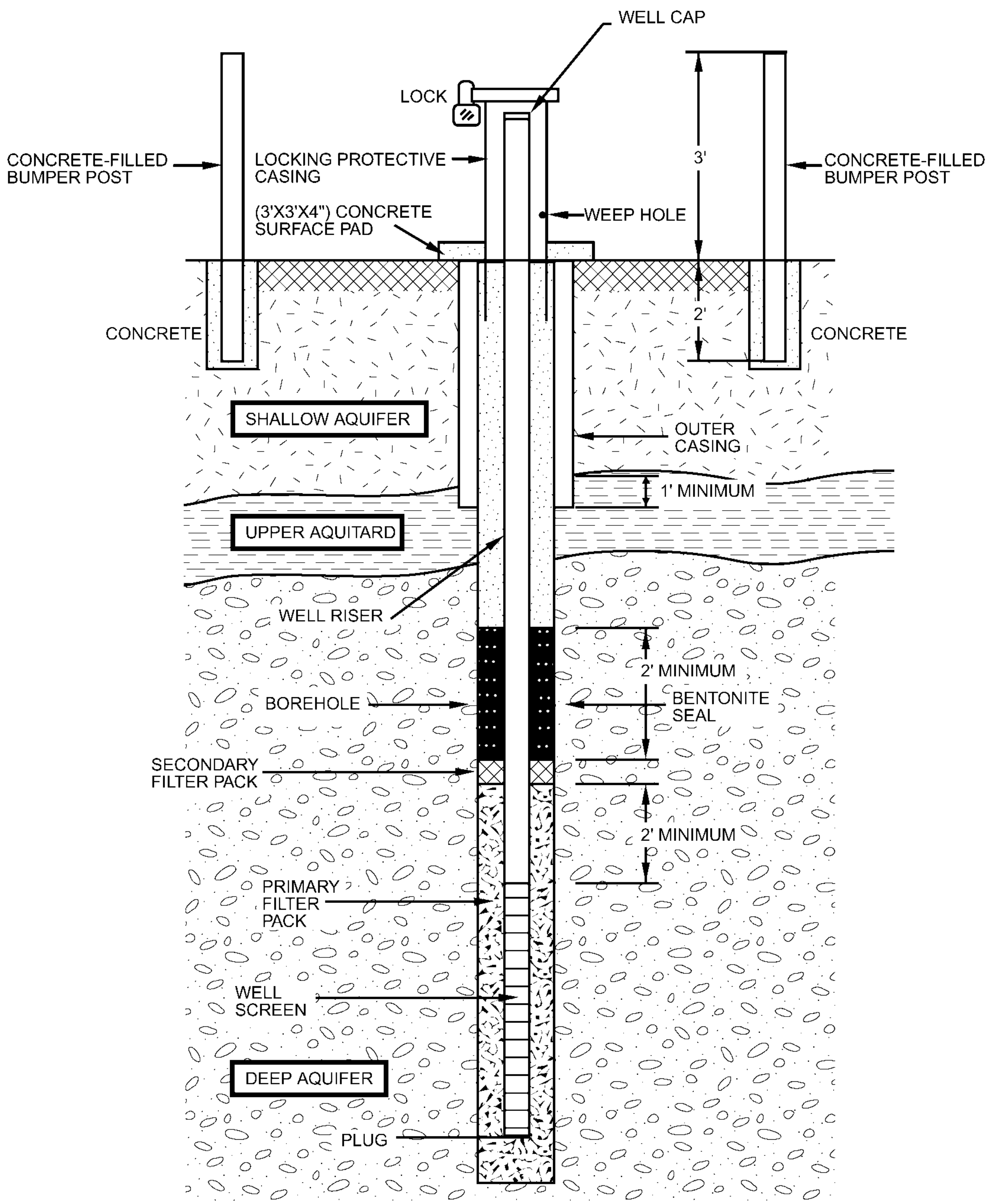


**FIGURE 3**

**MULTIPLE CASING WELL CONSTRUCTION DIAGRAM**



# ATTACHMENT 2

# MONITORING WELL DEVELOPMENT
# SOP NO. 021

**SOP APPROVAL FORM**

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

**MONITORING WELL DEVELOPMENT**

**SOP NO. 021**

**REVISION NO. 3**

Last Reviewed: October 2000

_________________________________ *October 5, 2000*

Quality Assurance Approved Date

## 1.0 BACKGROUND

All drilling methods impair the ability of an aquifer to transmit water to a drilled hole. This impairment is typically a result of disturbance of soil grains (smearing) or the invasion of drilling fluids or solids into the aquifer during the drilling process. The impact to the hydrologic unit surrounding the borehole must be remediated so that the well hydraulics and samples collected from the monitoring well are representative of the aquifer.

Well development should be conducted as an integral step of monitoring well installation to remove the finer-grained material, typically clay and silt, from the geologic formation near the well screen and filter pack. (Monitoring well installation is discussed in standard operating procedure [SOP] No. 020.) The fine-grained particles may interfere with water quality analyses and alter the hydraulic characteristics of the filter pack and the hydraulic unit adjacent to the well screen. Well development improves the hydraulic connection between water in the well and water in the formation. The most common well development methods are surging, jetting, overpumping, and bailing.

The health and safety plan for the site should be followed to avoid exposure to chemicals of concern. Water, sediment, and other waste removed from a monitoring well should be disposed of in accordance with applicable federal, state, and local requirements.

### 1.1 PURPOSE

This SOP establishes the requirements and procedure for monitoring well development. Well development improves the hydraulic characteristics of the filter pack and borehole wall by performing the following functions:

- Reducing the compaction and the intermixing of grain sizes produced during drilling by removing fine material from the pore spaces.
- Removing the filter cake or drilling fluid film that coats the borehole as well as much or all of the drilling fluid and natural formation solids that have invaded the formation.
- Creating a graded zone of sediment around the screen, thereby stabilizing the formation so that the well can yield sediment-free water.

## 1.2 SCOPE

This SOP applies to the development of newly installed monitoring wells. The SOP identifies the most commonly used well development methods; these methods can be used individually or in combination to achieve the most effective well development. Selection of a particular method will depend on site conditions, equipment limitations, and other factors. The method selected and the rationale for selection should be documented in a field logbook or appropriate project reports.

## 1.3 DEFINITIONS

**Aquifer:** A geologic formation, group of formations, or part of a formation that is saturated and capable of storing and transmitting water.

**Aquitard:** a geologic formation, group of formations, or part of a formation through which virtually no water moves.

**Bailer:** A cylindrical sampling device with valves on either end, used to extract water from a well or borehole.

**Bentonite seal:** A colloidal (extremely fine particle that will not settle out of solution) clay seal separating the sand pack from the surface seal.

**Drilling fluid:** A fluid (liquid or gas) that may be used in drilling operations to remove cuttings from the borehole, to clean and cool the drill bit, and to maintain the integrity of the borehole during drilling.

**Filter pack:** A clean, uniform sand or gravel placed between the borehole wall and the well screen to prevent formation material from entering the screen.

**Grout seal:** A fluid mixture of (1) cement and water or (2) cement, bentonite, and water that is placed above the bentonite seal between the casing and the borehole wall to secure the casing in place and keep water from entering the borehole.

**Hydraulic conductivity:** A measure of the ease with which water moves through a geologic formation. Hydraulic conductivity, K, is typically measured in units of distance per time in the direction of groundwater flow.

**Hydrologic units:** Geologic strata that can be distinguished on the basis of capacity to yield and transmit fluids. Aquifers and confining units are types of hydrologic units.

**Oil air filter:** A filter or series of filters placed in the airflow line from an air compressor to reduce the oil content of the air.

**Oil trap:** A device used to remove oil from the compressed air discharged from an air compressor.

**Riser:** The pipe extending from the well screen to or above the ground surface.

**Specific conductance:** A measure of the ability of the water to conduct an electric current. Specific conductance is related to the total concentration of ionizable solids in the water and is inversely proportional to electrical resistance.

**Static water level:** The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumpage.

**Transmissivity:** The volume of water transmitted per unit width of an aquifer over the entire thickness of the aquifer flow, under a unit hydraulic gradient.

**Well screen:** A cylindrical pipe with openings of a uniform width, orientation, and spacing used to keep materials other than water from entering the well and to stabilize the surrounding formation.

**Well screen jetting (hydraulic jetting):** A jetting method used for development; nozzles and a high pressure pump are used to force water outwardly through the screen, the filter pack, and sometimes into the adjacent geologic unit.

## 1.4 REFERENCES

American Society for Testing and Materials. 1990. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. D5092-90. West Conshohocken, Pennsylvania.

California Department of Toxic Substances Control. 1994. Monitoring Well Design and Construction for Hydrogeologic Characterization. Guidance for Groundwater Investigations. August.

Driscoll, F.G. 1986. *Groundwater and Wells (Second Edition).* Johnson Division, UOP, Inc. St. Paul, Minnesota.

U.S. Environmental Protection Agency (EPA). 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. Office of Research and Development, Environmental Monitoring Systems Laboratory. Washington, DC. EPA/600-4-89/034. March. On-Line Address: http://www.epa.gov/swerust1/cat/wwelldct.pdf

EPA. 1994. Well Development. Environmental Response Team SOP #2044 (Rev. #0.0, 10/03/94). On-Line Address: http://www.ert.org/media_resrcs/media_resrcs.asp?Child1=

## 1.5 REQUIREMENTS AND RESOURCES

The type of equipment used for well development will depend on the well development method. Well development methods and the equipment required are discussed in Section 2.1 of this SOP. In general, monitoring wells should be developed shortly after they are installed but no sooner than 24 hours after the placement of the grout seal, depending on the grout cure rate and well development method. Most drilling or well development rigs have pumps, air compressors, bailers, surge blocks, and other equipment that can be used to develop a monitoring well.

All downhole equipment should be properly decontaminated before and after each well is developed. See SOP No. 002 (General Equipment Decontamination) for details.

# 2.0 WELL DEVELOPMENT PROCEDURES

This section describes common well development methods, factors to be considered in selecting a well development method, procedures for initiating well development, well development duration, and calculations typically made during well development. In addition to this, procedures described in any work plans for well development should be fully consistent with local and state regulations and guidelines.

## 2.1 WELL DEVELOPMENT METHODS

Well development methods vary with the physical characterization of hydrologic units in which the monitoring well is screened and the drilling method used. The most common methods include mechanical surging, overpumping, air lift pumping, backwashing, surge bailing, and well jetting. These methods may be effective alone or may need to be combined (for example, overpumping combined with backwashing). Factors such as well design and hydrogeologic conditions will determine which well development method will be most practical and cost-effective. Commonly used well development methods are described in Sections 2.1.1 through 2.1.6.

The use of chemicals for monitoring well development should be avoided as much as possible. Introduction of chemicals may significantly alter groundwater chemistry in and around the well.

### 2.1.1 Mechanical Surging

The mechanical surging method forces water to flow in and out of the well screen by operating a plunger (or surge block) in the casing, similar to a piston in a cylinder. A typical surge block is shown in Figure 1. The surge block should fit snugly in the well casing to increase the surging action. The surge block is attached to a drill rod or drill stem and is of sufficient weight to cause the block to drop rapidly on the down stroke, forcing water contained in the borehole into the aquifer surrounding the well. In the recovery stroke or upstroke, water is lifted by the surge block, allowing water and fine sediments to flow back into the well from the aquifer. Down strokes and recovery strokes are usually 3 to 5 feet in length.

The surge block should be lowered into the water column above the well screen. The water column will effectively transmit the action of the block to the filter pack and hydrologic unit adjacent to the well screen. Development should begin above the screen and move progressively downward to prevent the surge block from becoming sand locked in the well. The initial surging action should be relatively gentle, allowing any material blocking the screen to break up, go into suspension, and then move into the well. As water begins to move easily both in and out of the screen, the surge block is usually lowered in increments to a level just above the screen. As the block is lowered, the force of the surging movement should be increased. In wells equipped with long screens, it may be more effective to operate the surge block in the screen to concentrate its actions at various levels.

A pump or bailer should be used periodically to remove dislodged sediment that may have accumulated at the bottom of the well during the surging process. The pump or bailer should be moved up and down at the bottom of the well to suspend and collect as much sediment as possible.

The accumulation of material developed from a specific screen interval can be measured by sounding the total depth of the well before and after surging. Continue surging until little or no sand accumulates.

#### 2.1.2 Overpumping

Overpumping involves pumping the well at a rate substantially higher than it will be pumped during well purging and groundwater sampling. This method is most effective on coarse-grained formations and is usually conducted in conjunction with mechanical surging or backwashing. Overpumping is commonly implemented using a submersible pump. In cases were the water table is less than 30 feet from the top of the casing, it is possible to overpump the well with a centrifugal pump. The intake pipe is lowered into the water column at a depth sufficient to ensure that the water in the well is not drawn down to the pump intake level. The inflow of water at the well screen is not dependent on the location of the pump intake as long as it remains submerged.

Overpumping will induce a high velocity water flow, resulting in the flow of sand, silt, and clay into the well, opening clogged screen slots and cleaning formation voids and fractures. The movement of these particles at high flow rates should eliminate particle movement at the lower flow rates used during well purging and sampling. The bridging of particles against the screen because of the flow rate and direction created by overpumping may be overcome by using mechanical surging or backwashing in conjunction with this method.

### 2.1.3 Air Lift Pumping

Air lift pumping uses a two-pipe system consisting of an air injection pipe and a discharge pipe. In this well development method, an air lift pump is operated by cycling the air pressure on and off for short periods of time. This operation provides a surging action that can dislodge fine-grained particles in the vicinity of the well screen. Subsequently applying a steady low pressure removes the fines drawn into the well by the surging action.

The bottom of the air lift should be at least 10 feet above the top of the well screen. Air is injected through an inner pipe at sufficient pressure to bubble out directly into the surrounding discharge pipe. The bubbles formed by the injected air cause the column of water in the discharge pipe to be lifted upward and allow water from the aquifer to flow into the well. This arrangement prevents injected air from entering the well screen. Pumping air through the well screen and into the filter pack and adjacent hydrologic unit should be avoided because it can cause air entrainment, inhibiting future sampling efforts and possibly altering groundwater chemistry.

The air injected into the well should be filtered using an oil/air filter and oil trap to remove any compressor lubricant entrained in the air. Air pressures required for this well development method are relatively low; an air pressure of 14.8 pounds per square inch should move a 30-foot column of water. For small-diameter, shallow wells where the amount of development water is likely to be limited, tanks of inert gas (such as nitrogen) can be used as an alternative to compressed air.

### 2.1.4 Backwashing

Effective development procedures should cause flow reversals through the screen openings that will agitate the sediment, remove the finer fraction, and then rearrange the remaining formation particles. Backwashing overcomes the bridging that results from overpumping by allowing the water that is pumped to the top of the well to flow back through the submersible pump and out through the well screen. The backflow portion of the backwashing cycle breaks down bridging, and the inflow then moves the fine material toward the screen and into the well.

Some wells respond satisfactorily to backwashing techniques, but the surging effect is not vigorous enough to obtain maximum results in many cases.

A variation of backwashing may be effective in low-permeability formations. After the filter pack is installed on a monitoring well, clean water is circulated down the well casing, out through the well screen and filter pack, and up through the open borehole before the grout or bentonite seal is placed in the annulus. Flow rates should be controlled to prevent floating the filter pack. Because of the low hydraulic conductivity of the formation, negligible amounts of water will infiltrate into the formation. Immediately after this procedure, the bentonite seal should be installed, and the nonformation water should be pumped out of the well and filter pack.

#### 2.1.5 Surge Bailing

Surge bailing can be an effective well development method in relatively clean, permeable formations where water flows freely into the borehole. A bailer made of stainless steel or polyvinyl chloride and slightly smaller than the well casing diameter is allowed to fall freely through the borehole until it strikes the groundwater surface. The contact of the bailer produces a downward force and causes water to flow outward through the well screen, breaking up bridging that has developed around the screen. As the bailer fills and is rapidly withdrawn from the well, the drawdown created causes fine particles to flow through the well screen and into the well. Subsequent bailing can remove these particles from the well. Lowering the bailer to the bottom of the well and using rapid short strokes to agitate and suspend solids that have settled to the well bottom can enhance removal of sand and fine particles. Bailing should continue until the water is free of suspended particles.

#### 2.1.6 Well Jetting

Well jetting can be used to develop monitoring wells in both unconsolidated and consolidated formations. Water jetting can open fractures and remove drilling mud that has penetrated the aquifer. The discharge force of the jetting tool is concentrated over a small area of the well screen. As a result, the tool must be rotated constantly while it is raised and lowered in a very small increments to be sure that all portions of the screen are exposed to the jetting action.

Jetting is relatively ineffective on the fine screens typically used in monitoring wells (slot sizes from 0.01 to 0.02 inch). In addition, jetting requires the introduction of external water into the well and surrounding formation. This water should be obtained from a source of known chemistry. Water introduced for development should be completely removed from the aquifer immediately after development.

The use of compressed air as a jetting agent should not be employed for development of monitoring wells. Compressed air could entrain air in the formation, introduce oil into the formation, and damage the well screen.

## 2.2 FACTORS TO CONSIDER WHEN SELECTING A WELL DEVELOPMENT METHOD

It is important to check federal, state, and local regulatory requirements for monitoring well development requirements. This SOP may be changed to accommodate applicable regulations, site conditions, or equipment limitations.

The type of geologic material, the design and completion of the well, and the type of drilling method used are all factors to be considered during the development of a monitoring well.

Monitoring well development should usually be started slowly and gently and then performed with increasing vigor as the well is developed. Most well development methods require the application of sufficient energy to disturb the filter pack, thereby freeing fine particles and allowing them to be drawn into the well. The coarser particles then settle around and stabilize the screen.

Development procedures for wells completed in fine sand and silt strata should involve methods that are relatively gentle so that strata material will not be incorporated into the filter pack. Vigorous surging for development can produce mixing of the fine strata and filter pack and produce turbid samples from the formation. In addition, development methods should be carefully selected based upon the potential contaminants present, the quantity of wastewater generated, and requirements for containerization or treatment of wastewater.

For small diameter and small volume wells, a development bailer can be used in place of a submersible pump in the pumping method. Similarly, a bailer can be used in much the same fashion as a surge block in small diameter wells.

Any time an air compressor is used for well development, it should be equipped with an oil air filter or oil trap to minimize the introduction of oil into the screened area. The presence of oil could impact the organic constituent concentrations of the water samples collected from the well.

The presence of light nonaqueous phase liquid (LNAPL) can impact monitoring well development. Water jetting or vacuum-enhanced well development may assist in breaking down the smear zone in the LNAPL. Normal development procedures are conducted in the water-saturated zone and do not affect the LNAPL zone.

## 2.3 INITIATING WELL DEVELOPMENT

Newly completed monitoring wells should be developed as soon as practical, but no sooner than 24 hours after grouting is completed if rigorous well development methods are used. Development may be initiated shortly after well installation if the development method does not interfere with the grout seal. State and local regulations should be checked for guidance. The following general well development steps can be used with any of the methods described in Section 2.1.

1. Assemble the necessary equipment on a plastic sheet around the well. This may include a water level meter (or oil/water interface probe if LNAPL or dense nonaqueous phase liquid is present); personal protective equipment; pH, conductivity, temperature, and turbidity meters; air monitoring equipment; Well Development Data Sheets (see Figure 2); a watch; and a field logbook.

2. Open the well and take air monitoring readings at the top of the well casing and in the breathing zone. See SOP No. 003 (Organic Vapor Air Monitoring) for additional guidance.

3. Measure the depth to water and the total depth of the monitoring well. See SOP No. 014 (Static Water Level, Total Well Depth, and Immiscible Layer Measurement) for additional guidance.

4. Measure the initial pH, temperature, turbidity, and specific conductance of the groundwater from the first groundwater that comes out of the well. Note the time, initial color, clarity, and odor of the water. Record the results on a Well Development Data Sheet (see Figure 2) or in a field logbook. See SOPs No. 011 (Field Measurement of Water Temperature), 012 (Field Measurement of pH), 013 (Field Measurement of Specific Conductance), and 088 (Field Measurement of Water Turbidity) for additional guidance.

5. Develop the well using one or more of the methods described in Section 2.1 until the well is free of sediments and the groundwater turbidity has reached acceptable levels. Record the development method and other pertinent information on a Well Development Data Sheet see Figure 2) or in a field logbook.

6. Containerize any groundwater produced during well development if groundwater contamination is suspected. The containerized water should be sampled and analyzed to determine an appropriate disposal method.

7. Do not add water to assist in well development unless the water is from a source of known chemical quality and the addition has been approved by the project manager. If water is added, five times the amount of water introduced should be removed during development.

8. Continue to develop the well, repeating the water quality measurements for each borehole volume. Development should continue until each water quality parameter is stable to within 10 percent. Development should also continue until all the water added during development (if any) is removed or the water has a turbidity of less than 50 nephelometric turbidity units. This level may only be attainable after allowing the well to settle and testing at low flow sampling rates.

9. At the completion of well development, measure the final pH, temperature, turbidity, and specific conductance of the groundwater. Note the color, clarity, and odor of the water. Record the results on a Well Development Data Sheet (see Figure 2) or in a field logbook. In addition to the final water quality parameters, the following data should be noted on the Well Development Data Sheet: well identification, date(s) of well installation, date(s) and time of well development, static water level before and after development, quantity of water removed and time of removal, type and capacity of pump or bailer used, and well development technique.

All contaminated water produced during development should be containerized in drums or storage vessels properly labeled with the date collected, generating address, well identification, and consultant contact number.

## 2.4 DURATION OF WELL DEVELOPMENT

Well development should continue until representative water, free of the drilling fluids, cuttings, or other materials introduced during well construction is obtained. When pH, temperature, turbidity, and specific conductance readings stabilize and the water is visually clear of suspended solids, the water is representative of formation water. The minimum duration of well development should vary in accordance with the method used to develop the well. For example, surging and pumping the well may provide a stable, sediment free sample in a matter of minutes, whereas bailing the well may require several hours of continuous effort to obtain a clear sample.

An on-site project geologist should make the final decision as to whether well development is complete. This decision should be documented on a Well Development Data Sheet (see Figure 2) or in a field logbook.

## 2.5 CALCULATIONS

It is necessary to calculate the volume of water in the well. Monitoring well diameters are typically 2, 3, 4, or 6 inches. The height of water column (in feet) in the well can be multiplied by the following conversion factors to calculate the volume of water in the well casing.

| Well Diameter (inches) | Volume (gallon per foot) |
|---|---|
| 2 | 0.1631 |
| 3 | 0.3670 |
| 4 | 0.6524 |
| 6 | 1.4680 |

## 3.0 POTENTIAL PROBLEMS

The following potential problems can occur during development of monitoring wells:

- In some wells the pH, temperature, and specific conductance may stabilize but the water remains turbid. When this occurs, the well may still contain construction materials (such as drilling mud in the form of a mud cake) and formation soils that have not been washed out of the borehole. Excessive or thick drilling muds cannot be flushed out of a borehole with one or two well volumes of flushing. Continuous flushing over a period of several days may be necessary to complete well development. If the well is completed in a silty zone, it may be necessary to sample with low flow methods or filtering.

- Mechanical surging and well jetting disturb the formation and filter pack more than other well development methods. In formations with high clay and silt contents, surging and jetting can cause the well screen to become clogged with fines. If an excessive amount of fines is produced, sand locking of the surge block may result. Well development with these methods should be initiated gently to minimize disturbance of the filter pack and to prevent damage to the well screen.

- Effective overpumping may involve the discharge of large amounts of groundwater. This method is not recommended when groundwater extracted during well development is contaminated with hazardous constituents. If the hazardous constituents are organic compounds, this problem can be partially overcome by passing the groundwater through an activated carbon filter.

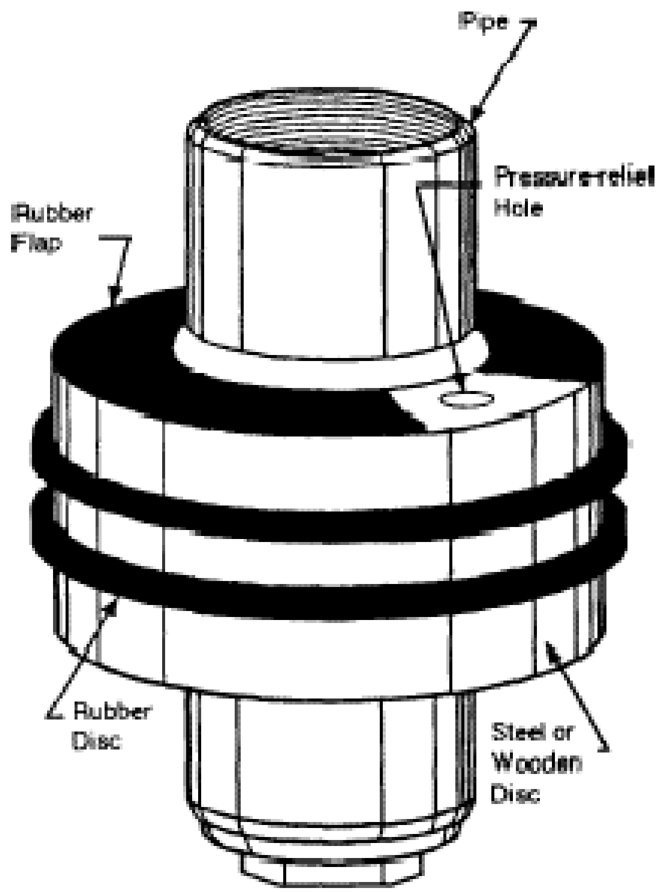
- When a well is developed by mechanical surging or bailing, rapid withdrawal of the surge block or bailer can result in a large external pressure outside of the well. If the withdrawal is too rapid and this pressure is too great, the well casing or screen can collapse.

- A major disadvantage of well jetting is that an external supply of water is needed. The water added during well jetting may alter the hydrochemistry of the aquifer; therefore, the water added in this development procedure should be obtained from a source of known chemistry. In addition, the amount of water added during well development and the amount lost to the formation should be recorded.

- The use of air in well development can chemically alter the groundwater, either directly through chemical reaction or indirectly as a result of impurities introduced through the air stream. In addition, air entrainment within the formation can interfere with the flow of groundwater into the monitoring well. Consequently, air should not be injected in the immediate vicinity of the well screen.

**FIGURE 1**

**SCHEMATIC DRAWING OF A SURGE BLOCK**



# FIGURE 2

# WELL DEVELOPMENT DATA SHEET

Sheet ___ of ___

## WELL DEVELOPMENT DATA SHEET

**BORING NO.** __________ **WELL NO.** __________

Project ____________________
Project No. ____________________
Date(s) of Installation ____________________
Date(s) of Development ____________________
Personnel/Company ____________________
____________________
Type of Rig Used ____________________

Casing Diameter/Type ____________________
Borehole Diameter ____________________
Screened Interval(s) ____________________
Total Length of Well Casing ____________________
Measured Total Depth (TOC) Initial ____________
Final ____________
Initial Depth to Water
(TOC) __________ Date __________ Time __________
Stabilized Depth to Water
(TOC) __________ Date __________ Time __________

DEVELOPMENT TECHNIQUE(S) — EQUIPMENT TYPE/CAPACITY

___ Surging ____________________
___ Overpumping ____________________
___ Air Lift Pumping ____________________
___ Backwashing ____________________
___ Bailing ____________________
___ Well Jetting ____________________

FLUIDS ADDED

Lost Drilling Fluid: __________ Gallons
Lost Purge Water: __________ Gallons
Water During Installation: __________ Gallons
Total Fluids Added: __________ Gallons
Source of Added Water: ____________________
Sample Collected of Added Water: Y N
Sample Designation of Added Water: ____________

PURGE VOLUME CALCULATION

Casing Volume: __________ Ft. of water
x __________ Gallons/Foot
= __________ Gallons per Single Casing Volume
Sand Pack Volume: __________ Ft. of Saturated Sand Pack
x __________ Gallons/Foot (borehole diameter)
= __________ Gallons (in borehole)
- __________ Gallons of Casing Volume
= __________ x 0.3 (Assuming porosity = 30%)
= __________ Gallons Within Sand Pack
Single Purge Volume: __________ Gallons (Casing Vol. + Sand Pack Vol. + Fluids Added)
Minimum Purge Volume: __________ Gallons
Actual Purge Volume: __________ Gallons
Volume Measured by: ____________________
Rate of Development ________ Gallons/Minute (Hour, Day)
Pumping Rate/Depth __________ @ _____ Ft. (Below Grd.)
Immiscible Phases Present: Y N Thickness __________

Development Criteria: ________________________________________

| Total Volume Discharged | Rate of Discharge | Time | Temp | pH | Specific* Conductance | Turbidity (NTU) | D.O., Clarity, Odor, PID Readings, Other: |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

Development Completed at ____________________ Gallons Discharged. Date: __________ Time: __________

Personnel: ________________________________________
____________________

* Specific Conductance readings temperature compensated to 25°C, if not, report temperatures at which reading obtained.

# ATTACHMENT 3

# GROUNDWATER SAMPLING
# SOP NO. 010

**SOP APPROVAL FORM**

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

**GROUNDWATER SAMPLING**

**SOP NO. 010**

**REVISION NO. 3**

Last Reviewed: March 2000

*February 19, 1993*

Quality Assurance Approved

Date

## 1.0 BACKGROUND

Groundwater sampling may be required for a variety of reasons, such as examining potable or industrial water supplies, checking for and tracking contaminant plume movement in the vicinity of a land disposal or spill site, Resource Conservation and Recovery Act (RCRA) compliance monitoring, or examining a site where historical information is minimal or non-existent, but where groundwater may be contaminated.

Groundwater is usually sampled through an in-place well, either temporarily or permanently installed. However, it can also be sampled anywhere groundwater is present, such as a pit or a dug or drilled hole.

Occasionally, a well will not be in the preferred location to obtain the sample needed (for example, to track a contaminant plume). In such a case, a temporary or permanent well will have to be installed. An experienced and knowledgeable person, preferably a hydrogeologist, will need to locate the well and supervise its installation so that the samples ultimately collected will be representative of the groundwater. SOP No. 020 (Monitoring Well Installation) provides guidance for installing new monitoring wells.

### 1.1 PURPOSE

This standard operating procedure (SOP) establishes the requirements and procedures for determining the quality of groundwater entering, leaving, or affected by site activities through groundwater sampling. The samples are obtained by retrieving water from a well screened in the aquifer(s) underlying a site.

### 1.2 SCOPE

This SOP provides general guidance for groundwater sampling activities conducted in the field. SOP No. 015 (Groundwater Sample Collection Using Micropurge Technology) provides additional specific guidance for using low flow methods to collect groundwater samples.

## 1.3 DEFINITIONS

**Bailer:** A cylindrical sampling device with valves on either end used to extract water from a well. Bailers are usually constructed of an inert material such as stainless steel or polytetrafluoroethylene (Teflon). The bailer is lowered and raised by means of a cable that may be cleaned and reused, or by disposable rope.

**Electrical Water Level Indicator:** An electrical device that has a light or sound alarm connected to an open circuit used to determine the depth to liquid. The circuit is closed when the probe intersects a conducting liquid. The wire used to raise and lower the probe is usually graduated.

**Immiscible Phase:** Liquid phases that cannot be uniformly mixed or blended with water. Heavy immiscible phases sink, and light immiscible phases float on water.

**Interface Probe:** An electrical probe that determines the distance from the surface to air/water, air/immiscible, or immiscible/water interfaces.

**Purge Volume:** The volume of water that needs to be removed from the well prior to sampling to ensure that the sample collected is representative of the groundwater.

**Riser Pipe:** The length of well casing above the ground surface.

**Total Well Depth:** The distance from the ground surface to the bottom of the well.

**Water Level:** The level of water in a well, measured as depth to water or as elevation of water, relative to a reference mark or datum.

## 1.4 REFERENCES

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## 1.5 REQUIREMENTS AND RESOURCES

There are various options available to obtain groundwater samples. The procedures are outlined in the following section. The equipment needed to accomplish these procedures includes the following:

- Organic vapor detector with a flame ionization detector (FID) or a photoionization detector (PID)
- Pipe wrench
- Electrical water level indicator or interface probe
- Steel tape with heavy weight
- Purging device (type needed depends on well depth, casing diameter, and type of sample desired; see sampling devices below)
- Sampling device (type needed depends upon depth to water and type of sample desired)
  - Teflon bailer
  - Stainless steel bailer
  - Teflon bladder pump
  - Stainless steel submersible (nonoil-bearing) pump
  - Existing dedicated equipment
  - Peristaltic pump
- Sample containers
- Wastewater containers
- Field logbook
- Stopwatch

Additional equipment is required to complete measurement of field parameters (for example, pH, specific conductance, and temperature) of the groundwater in the well.

## 2.0 PROCEDURE

Prior to sampling, a site-specific sampling plan should be developed. The plan should take into consideration the site characteristics and should include:

- Specific repeatable well measurement techniques and reference points for determining the depth to water and the depth to the bottom of the well
- Specific method of purging and selection of purging equipment
- Specific methods and equipment for measurements of field parameters
- Specific method of sample collection and the sampling equipment that will be used
- Specific parameters for which samples will be analyzed
- Order in which sample bottles will be filled, based on the analytical parameters

The following sections discuss procedures for approaching the well, establishing a sample preparation area, making preliminary well measurements, purging the well, and collecting samples.

### 2.1 APPROACHING THE WELL

In general, all wells should be assumed to pose a health and safety risk until field measurements indicate otherwise. Approach wells from the upwind side. Record well appearance and general condition of the protective casing, surface seal, and surrounding area in the logbook.

Once at the well, the lead person should systematically use the organic vapor detector to survey the immediate area around the well (from the breathing zone to the top of the casing to the ground). If elevated FID and PID meter readings are encountered, retreat to a safe area and instruct the sampling team to put on the appropriate level of personal protective equipment (PPE). See SOP No. 003 (Organic Vapor Air Monitoring) for additional guidance.

Upon opening the well casing, the lead person should systematically survey inside the well casing, above the well casing in the breathing zone and the immediate area around the well. If elevated FID or PID meter readings in the breathing zone are encountered (see health and safety plan for action levels), retreat and put on appropriate PPE. It is important to remember that action levels are based on readings in the breathing zone, not within the well casing. Representative organic vapor detector readings should be recorded in the logbook.

## 2.2 ESTABLISHING A SAMPLE PREPARATION AREA

The sample preparation area is generally located upwind or to either side of the well. If elevated readings are encountered using an organic vapor detector, this area should be taped off and the sample preparation area should be located upwind where ambient readings are found.

## 2.3 MAKING PRELIMINARY WELL MEASUREMENTS

Several preliminary well measurements should be made prior to initiating sampling of the well. These include determining water level and total well depth measurements, determining the presence of immiscible phases, and calculating purge volumes. All preliminary measurements will be recorded in the logbook as they are determined. SOP No. 014 (Static Water Level, Total Well Depth, and Immiscible Layer Measurement) provides additional information concerning these preliminary measurements.

### 2.3.1 Water Level and Total Well Depth Measurements

Tetra Tech typically uses an electric water level indicator for water level measurements. This device sounds an alarm or illuminates a light when the measuring probe touches the water surface, thus closing an electrical circuit. The electric cable supporting the probe is usually graduated in feet and can be read at the well site directly. The remaining fraction is measured with a steel tape graduated to 0.01 foot. The distance between the static water level and the marked or notched location at the top of the riser pipe is measured. The height of the riser pipe above ground surface, as obtained from well location survey data, is then subtracted from the total reading to give the depth to static water. To improve accuracy, three separate readings should be made, and the values averaged. This helps to eliminate any errors due to kinks or bends in the cables, which may change in length when the water level indicator is raised and lowered.

The total well depth can be measured by using a steel tape with a heavy weight attached to the end. The tape is lowered into the well until resistance is met, indicating that the weight has reached the bottom of the well. The total well depth is then read directly from the steel tape to the 0.01-foot fraction. The distance between the bottom of the well and the marked or notched location on the riser pipe is measured. The height of the riser pipe above the ground surface, as obtained from well survey data, is then subtracted from the total reading to give the depth to the bottom of the well. To improve accuracy, three separate readings should be made, and the readings averaged.

### 2.3.2 Determining If Immiscible Phases Are Present

If immiscible phases (organic floaters or sinkers) are present, the following measurement activities should be undertaken. Organic liquids are measured by lowering an interface probe slowly to the surface of the liquid in the well. When the audible alarm sounds, record the depth. If the alarm is continuous, a floating immiscible layer has been detected. To determine the thickness of this layer, continue lowering the probe until the alarm changes to an oscillating signal. The oscillating signal indicates that the probe has detected an aqueous layer. Record this depth as the depth to water and determine the thickness and the volume of the immiscible layer.

Continue lowering the probe into the well to determine if dense immiscible phases (sinkers) are present. If the alarm signal changes from oscillating to a continuous sound, a heavier immiscible layer has been detected; record this depth.

Continue lowering the probe to the bottom of the well and record the total depth. Separate total depth measurements with a steel tape are not necessary when using an interface probe. Calculate and record the sinker phase volume and total water volume in the well. A chart is provided in Table 1 to assist in these calculations. If immiscible phases are present, immediately refer to Section 2.5.3 or 2.5.4 of this SOP.

### 2.3.3 Determination of Purging Volume

If the presence of floaters or sinkers does not need to be determined, determine the depth to water and the total depth of the well as described in Section 2.3.1. Once these measurements have been made and recorded, use Table 1 to calculate the total volume of water in the well. Multiply this volume by the purging factor to determine purging volume. The minimum purging factor is typically three casing volumes but may be superseded by site-specific program requirements, individual well yield characteristics, or stabilization of field parameters measured during purging. Field parameters (for example, pH, specific conductance, and temperature) should be measured prior to purging and after each well volume. All field parameter data should be recorded in the field logbook. SOPs No. 011 (Field Measurement of Water Temperature), 012 (Field Measurement of pH), and 013 (Field Measurement of Specific Conductance) include more detailed procedures for determining these field parameters.

In Table 1, the volume of water in a 1-foot section of a 2-inch-diameter well is 0.163 gallon. This chart can easily be used for any water depth by multiplying all the values in Table 1 by the L value (depth, in feet, of water in the well). The volume of water in the well is based on the following formula:

$$V = \frac{\pi \times D^2}{4} \times L$$

where

V = volume of water in the well (cubic feet)
D = inside diameter of the well (feet)
L = depth of water in the well (feet)

## 2.4 PURGING THE WELL

Currently, Tetra Tech standards allow for six options for purging wells:

1. Teflon bailers
2. Stainless steel bailers
3. Teflon bladder pumps
4. Stainless steel submersible (nonoil-bearing) pumps
5. Existing dedicated equipment
6. Peristaltic pumps (these devices are for shallow wells only)

As previously stated, the minimum purging volume is typically three casing volumes. Exceptions to this standard may be made in the case of low-yield wells. When purging low-yield wells, purge the well once to dryness. Samples should be collected as soon as the well recovers. When the time required for full recovery exceeds 3 hours, samples should be collected as soon as sufficient groundwater volume is available.

The well should be purged until measured field parameters have stabilized. If any field parameter has not stabilized, additional purging should be performed. To be considered stable, field parameters should change by no more than the tolerance levels listed on Table 2 between each well volume purged.

At no time should the purging rate be high enough to cause the groundwater to cascade back into the well, resulting in excessive aeration and potential stripping of volatile constituents.

The actual volume of purged water can be measured using several acceptable methods:

- When bailers are used, the actual volume of each bailer's contents can be measured using a calibrated bucket.
- If a pump is used for purging, the pump rate can be determined by using a bucket of known volume, stopwatch, and the duration of pumping time necessary to purge the known volume.

## 2.5 SAMPLE COLLECTION

This section first describes general groundwater sample collection procedures. This section also describes procedures for collecting groundwater samples for volatile organic analysis (VOA) and for collecting samples when light or heavy immiscible layers are present in a monitoring well. Samples of light and heavy immiscible layers should be collected before the well is purged.

### 2.5.1 General Groundwater Sampling Procedures

The technique used to withdraw a groundwater sample from a well should be selected based on the parameters for which the sample will be analyzed. To ensure that the groundwater samples are representative, it is important to avoid physically altering or chemically contaminating the sample during collection, withdrawal, or containerization. If the samples are to be analyzed for volatile organic compounds, it is critical that air does not become entrained in the water column.

Acceptable sampling devices for all parameters are double check valve stainless steel or Teflon bailers, bladder pumps, low-flow positive displacement pumps, or for shallow wells, peristaltic pumps. Additional measurements of field parameters should be performed at the time of sampling.

In some cases, it may become necessary to use dedicated equipment already in the well to collect samples. This is particularly true of high volume, deep wells (>150 feet) where bladder pumps are ineffective and bailing is impractical. If existing equipment must be used, however, determine the make and model of the pump and obtain information on component construction materials from the manufacturer or facility representatives. If an existing pump is to be used for sampling, make sure the flow volume can be reduced so that a reliable VOA sample can be taken. Record the specific port, tap, or valve from which the sample is collected.

General sampling procedures include the following:

- Clean sampling equipment should not be placed directly on the ground. Use a plastic drop cloth or feed line from clean reels. Never place contaminated lines back on reels.
- Check the operation of the bailer check valve assemblies to confirm free operation.
- If the bailer cable is to be decontaminated and reused, it must be made of Teflon-coated stainless steel.
- Lower sampling equipment slowly into the well to avoid degassing the water and damaging the equipment.
- Pump flow rates should be adjusted to eliminate intermittent or pulsed flow. The settings should be determined during the purging operations.
- A separate sample volume should be collected to measure necessary field parameters. Samples should be collected and containerized in the order of the parameters' volatilization sensitivity. Table 3 lists the preferred collection order for common groundwater parameters.

Intermediate containers should never be used to prepare VOA samples and should be avoided for all parameters in general. All VOA containers should be filled at a single sampling point or from a single bailer volume.

### 2.5.2 Collection of Volatile Organics Samples

This section discusses the collection of samples for VOA using either a bailer or bladder pump in detail. Other pumps (such as positive displacement or peristaltic) can be used. The following factors are critical to the collection of representative samples for VOA: ensuring that no air has become entrained in the water column, low pump flow rates (less than 100 milliliter [mL] per minute, if possible), and avoiding flow surges.

#### 2.5.2.1 Collection with Bailers

Samples for VOA should be collected from the first bailer removed from the well after purging. The most effective means requires two people. One person should retrieve the bailer from the well and pour its contents into the appropriate number of 40-mL VOA vials held by the second person. Cap each vial and invert it. If a bubble exists, unscrew the cap and add more water, or discard and repeat. The sample should be transferred from the bailer to the sample container in a manner that will limit the amount of agitation in order to reduce the loss of volatile organics from the sample.

Always fill VOA vials from a single bailer volume. If the bailer is refilled, samples cannot be considered duplicates or splits.

#### 2.5.2.2 Collection with a Bladder Pump (Well Wizard)

To successfully perform VOA sampling with a Well Wizard bladder pump, the following steps must be completed:

1. Following manufacturer's directions, activate the pump. Full water flow from the discharge tubing will begin after 5 to 15 pumping cycles. These initial pumping cycles are required to purge air from the pump and discharge tubing. The discharge and recharge settings must be manually set and adjusted to pump at optimum flow rates. To activate the bladder, it is best to set the initial cycle at long discharge and recharge rates.

2. Reduce water flow rate for VOA sample collection. To reduce the water flow rate, turn the throttle control valve (located on the left side of the Well Wizard pump control panel) counterclockwise.

3. Collect VOA sample from discharge tubing. VOA vials must be placed beneath the discharge tubing while avoiding direct contact between the vials and the tubing. Never place tubing past the mouth of the VOA vial. The pump throttle control must be turned as necessary to maintain a trickle of water in order to obtain a meniscus in the vial.

4. Continue with non-VOA sampling. Increase pump flow rate by turning the throttle control knob clockwise.

### 2.5.3 Collection of Light Immiscible Floaters

The approach used when collecting floaters depends on the depth to the floating layer and the thickness of that layer. If the thickness of the floater is 2 feet or greater, a bottom-filling valve bailer should be used. Slowly lower the bailer until contact is made with the floater surface, and lower the bailer to a depth less than that of the floater/water interface depth as determined by preliminary measurements with the interface probe.

When the thickness of the floating layer is less than 2 feet, and the depth to the surface of the floating layer is less than 15 feet, a peristaltic pump can be used to extract a sample.

When the thickness of the floating layer, however, is less than 2 feet and the depth to the surface of the floating layer is beyond the effective "lift" of a peristaltic pump (greater than 25 feet), a bailer can be modified to allow filling from the top only (an acceptable alternative is to use a top- loading Teflon or stainless-steel bailer). Disassemble the bailer's bottom check valve and insert a piece of 2-inch diameter Teflon sheet between the ball and ball seat. This will seal off the bottom valve. Remove the ball from the top check valve, thus allowing the sample to enter from the top. To overcome buoyancy when the bailer is lowered into the floater, place a length of one-inch stainless steel pipe on the retrieval line above the bailer (this pipe may have to be notched to allow sample entry if the pipe remains within the top of the bailer). As an alternative, use a top-loading stainless-steel bailer. Lower the device, carefully measuring the depth to the surface of the floating layer, until the top of the bailer is level with the top of the floating layer. Lower the bailer an additional one-half thickness of the floating layer and collect the sample. This technique is the most effective method of collection if the floating layer is only a few inches thick.

#### 2.5.4 Collection of Heavy Immiscible Sinkers

The best method for collection of sinkers is use of a double check valve bailer. The key to collection is controlled, slow lowering and raising of the bailer to and from the bottom of the well. Collection methods are equivalent to those described in Section 2.5.3 above.

**TABLE 1**

**LIQUID VOLUME IN A 1-FOOT SECTION OF WELL CASING**

| Well Casing Inside Diameter (D) (inches) | Volume of Liquid in 1-Foot Well Section (gallons) $V= 0.0408 (D^2)$ |
|---|---|
| 1 | 0.041 |
| 1.5 | 0.092 |
| 2 | 0.163 |
| 3 | 0.367 |
| 4 | 0.653 |

**TABLE 2**

**FIELD MEASUREMENT TOLERANCE LEVELS**

| Field Parameter | Tolerance Level |
|---|---|
| pH | 0.1 pH unit |
| Specific Conductance | 10 percent relative percent difference (RPD)[a] |
| Temperature | 1 °C |

Note:

[a] RPD can be determined as follows:

$$RPD = \frac{(\text{Measurement 1 - Measurement 2}) \times 100}{(\text{Measurement 1 + Measurement 2}) / 2}$$

**TABLE 3**

**ORDER OF PREFERRED SAMPLE COLLECTION**

1. VOA
2. Purgeable organic halogens (POX)
3. Total organic halogens (TOX)
4. Cyanide
5. Extractable organics
6. Purgeable organic carbon (POC)
7. Total metals
8. Dissolved metals
9. Total organic carbon (TOC)
10. Phenols
11. Sulfate and chloride
12. Nitrate and ammonia
13. Radionuclides