FIGURE 3
Zone 1 Aquifer Testing Locations
FIGURE 4
Soil boring permeability testing locations
FIGURE 5
Material property zones for the Dilco Coal and adjacent unconsolidated material
Zonation and hydraulic properties derived from calibrated groundwater flow model (Chester Engineers, Oct. 2012)
Material property zones for upper Zone 3 (to 20 ft above base) and adjacent unconsolidated material
Zonation and hydraulic properties derived from calibrated groundwater flow model (Chester Engineers, Oct. 2012)
FIGURE 7
Material property zones for lower Zone 3 (bottom 20 ft) and adjacent unconsolidated material
Zonation and hydraulic properties derived from calibrated groundwater flow model (Chester Engineers, Oct. 2012)
FIGURE 8
Material property zones for Zone 2 and adjacent unconsolidated material
Zonation and hydraulic properties derived from calibrated groundwater flow model (Chester Engineers, Oct. 2012)
Material property zones for Zone 1 and adjacent unconsolidated material. Zonation and hydraulic properties derived from calibrated groundwater flow model (Chester Engineers, Oct. 2012).
APPENDIX B.3

GEOCHEMICAL PROPERTIES OF ALLUVIUM AND SANDSTONE UNITS
Geochemical properties of the alluvium and sandstone were tabulated by Canonie (1987, see Tables 4.4 and 4.5, attached) and attenuation capabilities of the alluvium and sandstone have been demonstrated by historical water quality results. As acidic seepage, comprised in large part by strong sulfuric acid migrated from the tailings ponds, the water chemistry of the seepage changed in response to geochemical attenuation mechanisms, the most important of which was pH neutralization. Generally, neutralization of the acidity by soil and rock results in a reduction of dissolved solids, heavy metals, and radionuclides present in the seepage. The magnitude of these changes depended on whether the seepage percolated through the alluvium or migrated directly into the Upper Gallup Sandstone because the geochemical properties and attenuation capacities of the alluvium and Upper Gallup Sandstone are very different (Canonie, 1987).

The alluvium is characterized by favorable geochemical properties which can neutralize acidic seepage. These properties include the presence of calcium carbonate (CaCO₃, up to 12.6 percent), iron hydroxide, organic carbon, and clay with cation exchange capacity (up to 31.03 meq/100 g) (Canonie, 1987, Table 4.4). In comparison, the sandstones of Zone 3 and Zone 1 show a relatively inert geochemistry (Canonie, 1987, Table 4.5). The sandstones have lower cation exchange capacity (up to 3.26 meq/100 g) likely due to low reactive clay mineral content and have low percentages of acid-neutralizing carbonate minerals (up to 0.03 percent (Canonie, 1987)). The following sections further describe the geochemical attenuation processes and characteristics in the three hydrostratigraphic units (i.e., the Southwest Alluvium, and Zone 3 and Zone 1 of the Upper Gallup Sandstone).

**Southwest Alluvium**

Most of the tailings disposal area is underlain by thick sequences of alluvium and the water quality data from wells completed in the alluvium generally indicated that acidic seepage has been neutralized via reaction with the alluvium (Canonie, 1987).
Geochemical Properties of Alluvium and Sandstone Units
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(1987, Table 4.4 attached) reported measured alluvium CaCO₃ fractions of 2.58 percent in a sample collected during drilling of Well EPA 23; 0.28 to 0.77 percent near the Pipeline Arroyo Nickpoint; and up to 12.6 percent in Borehole 663. The alluvium (as well as Zone 1 and Zone 3 sandstones) also contains high concentrations of sulfate-bearing minerals, principally gypsum, which through dissolution are the source of elevated sulfate concentrations in background water.

Additional data reported by Canonie (1987) indicates that tailings seepage was neutralized within several feet of the tailings deposits. Analyses of alluvium recovered from borings beneath the South and Central tailings cells demonstrated that although the tailings have a pH of 3, the underlying alluvium very quickly neutralizes the seepage so that within six feet beneath the tailings the pH is near neutral. Acid neutralization results principally from the following reaction (Earth Tech, 2000b):

$$\text{CaCO}_3 + \text{H}^+ \leftrightarrow \text{Ca}^{2+} + \text{HCO}_3^-$$

Where:
- CaCO₃ = calcite
- H⁺ = acidity
- Ca²⁺ = calcium
- HCO₃⁻ = bicarbonate

The result of the reaction is an increase in calcium and bicarbonate concentrations. However, geochemical calculations indicate that seepage-impacted water in the alluvium is in equilibrium with calcite and gypsum (Earth Tech, 2002). Sulfate concentrations are in equilibrium with gypsum everywhere in the Southwest Alluvium as well as the other two hydrostratigraphic units (Earth Tech, 2000b). Equilibrium with gypsum throughout the alluvium has resulted from gypsum precipitation from tailings-impacted water and dissolution of natural gypsum into groundwater as it is recharged. Because the calcium concentration is more or less fixed by the presence of two calcium bearing phases (calcite and gypsum), the following reaction summarizes the evolution of seepage-impacted water chemistry in the Southwest Alluvium (Earth Tech, 2002):

$$\text{CaCO}_3 + \text{H}^+ + \text{SO}_4^{2-} + 2\text{H}_2\text{O} \leftrightarrow \text{CaSO}_4\cdot2(\text{H}_2\text{O}) + \text{HCO}_3^-$$

Where:
- CaCO₃ = calcite
- H⁺ = acidity
- SO₄²⁻ = sulfate
- 2H₂O = water
- CaSO₄·2(H₂O) = gypsum
- HCO₃⁻ = bicarbonate

In summary, tailings seepage with low pH and high sulfate concentration results in the dissolution of calcite, decreasing sulfate concentrations as gypsum precipitates and...
increasing bicarbonate concentrations relative to the fixed aqueous component, calcium (Earth Tech, 2002). As described in the 2012 Annual Report (Chester Engineers, 2013) and in the first natural attenuation evaluation (Earth Tech, 2002), bicarbonate concentration is the main attribute by which the presence and extent of seepage-impacts can be evaluated. The neutralization capacity results in a near neutral pH in the Southwest Alluvium groundwater and has also prevented the migration of metals from the former tailings impoundments (Chester Engineers, 2013). Metals and radionuclides in seepage-impacted water are expected to meet groundwater standards and/or natural background concentrations through attenuation by neutralization and adsorption to clays and minerals (such as iron hydroxide).

**Upper Gallup Sandstone**

Acidic seepage directly affected the background water quality in Zone 1 and Zone 3 of the Upper Gallup Sandstone in limited areas where tailings or acidic tailings solutions were placed over thin sequences of alluvium or directly over sandstone outcrops (Canonie, 1987). Although neutralization processes in Zone 1 and Zone 3 are the same as in the Southwest Alluvium, the pH buffering was quickly exhausted and seepage entering the sandstones began to migrate as an acidic plume. Extensive review of the water quality data from Zone 3 and Zone 1 wells confirmed that the best indicator of seepage is acidic pH. As pH approaches neutral, TDS, radionuclides, heavy metals and ammonia are reduced.

**Zone 1**

Background water in Zone 1 was impacted by acidic seepage from Borrow Pit No. 2 on the eastern side of the central tailings impoundment. Acidic seepage contained elevated concentrations of metals, radionuclides, and major ions such as sulfate and chloride. Acid neutralization by reaction with the Zone 1 bedrock (which has a calcite fraction of 0.03 percent (Canonie, 1987, Table 4.5, attached) in Zone 1 is accompanied by the precipitation of stable solids and an increased affinity for metals adsorption to minerals.

The geochemical fate of several contaminants that exceeded groundwater standards was evaluated by Earth Tech (May 2000), who indicated that source remediation, (neutralization and later dewatering the Borrow Pit) plus neutralization of the seepage by natural attenuation and mixing with the background water, reduced the concentrations of most of the constituents to below the cleanup standards established for the Site (Earth Tech, 2000a). The predicted geochemical performance of the Zone 1 natural attenuation system (revised from Earth Tech, 2002) indicates that sulfate and TDS concentrations are not expected to meet Site standards because gypsum equilibrium in the groundwater prevents any further reduction in sulfate concentration. Manganese may meet the Site standards if sufficient bicarbonate is available for attenuation.

The remaining metals and radionuclides are expected to meet the standards through attenuation by neutralization and adsorption. For example, Earth Tech (2000a) cites
Murray et al. (1968) in stating that cobalt and nickel are removed from groundwater at sub-neutral or near-neutral pH values by adsorption, where cobalt is adsorbed strongly by manganese oxides. Earth Tech (2000a, citing Murray, 1975) also states that nickel and barium (and probably radium) are also adsorbed, but have lesser affinities for manganese oxides. Cobalt and nickel are also adsorbed by ferric oxyhydroxides; this is most effective between pHs of approximately 5.5 to 8 for cobalt and 5 to 7 for nickel, depending on conditions (Earth Tech, 2000a, citing Dzombak, 1986). Radium requires a pH of about 6 to attenuate concentrations below applicable standards. Unlike cobalt and nickel, radium adsorption by ferric oxyhydroxides may be minor due to large concentrations of calcium and magnesium in Zone 1 (Earth Tech, 2000a, citing Ames et al. 1983a). Radium may be removed by adsorption onto clay minerals (Earth Tech, 2000a, citing Ames et al., 1983b) and by precipitation.

Analysis of water quality data in Zone 1 indicates that natural processes are attenuating pH, metals, and other seepage constituents and that outside the UNC property boundary in Section 1, the post-pumping groundwater quality continues to improve overall. Zone 1 seepage impacts have been delineated (Figure 48 of Chester Engineers, 2013) by chloride concentrations greater than 50 mg/L (Earth Tech, 2000a) and indicate that the degree of seepage impact is diminishing.

**Zone 3**

The Zone 3 natural attenuation system comprises the hydro-geochemical interactions between the bedrock matrix, the anthropogenic background waters (derived from former groundwater discharge associated with historical mining operations that ceased in 1986), and the tailings fluids. The natural system is attenuating the seepage impacts by the processes of neutralization, precipitation, and adsorption. Furthermore, data obtained as part of a pilot study indicated that the mineral feldspar in the Zone 3 arkosic sandstone had been altered by the acidic tailings liquids, generating kaolinitic clay that significantly clogged pore spaces and reduced hydraulic conductivity (Arcadis BBL, 2007). Arcadis BBL (2007) also concluded that the conversion of the arkosic sandstone to kaolinite will consume hydrogen ions, which will promote a pH increase, along with increasing concentrations of dissolved potassium and silica.

Natural geochemical processes slow the migration of constituents associated with the acidic seepage in Zone 3 (as in the Southwest Alluvium and Zone 1). These processes neutralize the acidic seepage, which causes the precipitation and adsorption of metals and radionuclides. Zone 3 has comparatively less buffering capacity than the Southwest Alluvium or Zone 1 of the Upper Gallup (BBL, 2006). BBL (2006) describes the attenuation process as a relatively gradual increase of the bicarbonate ion concentration, indicative of dissolution of carbonate minerals, followed by a rapid decrease in bicarbonate and pH as the buffering capacity of the formation is exhausted. Historic groundwater quality data (see Chester Engineers, 2013, Appendix B) from fully seepage-impacted wells indicate that it takes from one to three years, from the onset of
geochemical changes associated with the arrival of seepage-impacted groundwater, for full seepage-impact to develop (unless the constituent transport is effected by pumping). Once the buffering capacity of the formation is exhausted, acidic conditions remain without some type of natural or human-induced neutralizing process. The low pH associated with the migrating front will tend to maintain elevated concentrations of target COCs, unless processes act to change the acidic conditions. The depletion of neutralization capacity has stabilized the concentrations of metals at higher levels in some wells.

As in the Southwest Alluvium, sulfate concentrations are controlled by geochemical equilibrium with gypsum (or anhydrite) and calcite. Although very high sulfate concentrations were present in the tailings fluids, such sulfate concentrations attenuate rapidly downgradient. Over the entire monitoring history since 1989, sulfate concentrations overall have remained steady. Moreover, there is a complete overlap between the range of sulfate concentrations in seepage-impacted and background water (except for Well 613). The marked stability of sulfate in all wells, throughout the duration of remedial pumping and in the absence of such pumping, demonstrates that sulfate concentrations are determined exclusively by the geochemical equilibria between natural minerals and waters rather than remedial operations (Chester Engineers, 2013).

It necessarily follows that neither natural attenuation nor active remediation will reduce sulfate concentrations below the Site standard because the concentrations are controlled by groundwater equilibrium with the mineral gypsum (i.e., gypsum can dissolve as well as precipitate to maintain the equilibrium concentrations). TDS also will continue to exceed the Site standard because sulfate comprises most of the TDS (as in the Southwest Alluvium and Zone 1).

References


Geochemical Properties of Alluvium and Sandstone Units
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### TABLE 4.4

Geochemical Properties of Alluvium

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<tr>
<th>Depth (ft)</th>
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1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) describes the procedure for hollow stem auger (HSA) drilling and collecting geotechnical soil samples, as well as cone penetration testing (CPT). The borings and test locations will be conducted at locations specified in the Work Plans. The sample intervals and test parameters are specified in the Work Plans. The procedures presented here are intended to be general in nature to allow various methods to be used based on variable site specific conditions.
2.0 PROCEDURES

2.1 BOREHOLE AND TEST LOCATIONS

Borehole locations will be initially located by a surveyor or by field staff using hand-held GPS coordinates provided in the Work Plans. Locations may be adjusted as needed in any direction from the preliminary location to facilitate drill rig access or to obstacles. Actual (adjusted) locations based on GPS coordinates will be noted on the field logs at time of drilling.

On completion of backfilling of each borehole, the location will be marked with a survey stake, noting the borehole number as provided in the Work Plans. On completion of backfilling and marking by survey stakes of all boreholes, ground surveys will be completed to locate the boreholes according to the marked locations.

2.2 CONE PENETRATION TESTING

A CPT(u) rig capable of measuring pore pressures in-situ and performing seismic CPTs will be used to advance the cone penetrometer through the tailings and native site soils (as applicable) according to the procedures outlined in ASTM D5778 (ASTM, 2012). If necessary, waste rock or other stiff surficial soils that cannot be penetrated without damaging CPT equipment will be penetrated using hydro-punch or auger drilling method to provide a pilot hole through such layers prior to CPT sounding.

The cone penetrometer will be advanced into the tailings at a constant rate to provide a continuous profile of the material. The cone penetrometer will be advanced until refusal. Should refusal occur at a significantly shallower depth than expected, the rig will be moved five feet and the penetrometer will again be advanced until the anticipated depth at that location is reached.

If perched water is encountered, pore pressure dissipation tests will be performed, once per sounding location, where positive pore pressure conditions exist, or as directed by the supervising field engineer or geologist. In order to properly measure pore pressures, the operator will saturate the porous stones within the probe before each test is started.

2.3 HOLLOW STEM AUGER DRILLING

The boreholes will be drilled with hollow stem augers (HSA) of various sizes. Soil sampling may include continuous core, California barrel samples, standard split spoon samples, and Shelby tube samples. Drill cuttings will be placed on the ground adjacent to the boreholes. In areas of concern, the cuttings will be placed on plastic sheeting, until they can be returned to the borehole.

2.4 SOIL SAMPLING

The types and frequencies of soil samples will be provided in the Work Plans. Descriptions of the proposed sample types are included in the following sections.
2.4.1 Continuous Core Samples

Continuous core samples will be collected with a five-foot long continuous sampler barrel advanced inside the HSA as the HSA are advanced. Acrylic sample sleeves (30 or 60-inches long) may be used within the continuous core sampler to collect samples of sensitive materials. The continuous sampler barrel will be retrieved, opened, and the recovery measured/recorded. Out of place soils (slough) at the top of the sampler will be discarded. The soil core will be transferred intact to a core-logging table or truck bed, and core depth intervals marked with legible labels. Samples may be either removed from the core barrels prior to logging, or may be retained in transparent liners.

Photos of the labeled soil core will be taken. The samples will be logged and classified as specified in under Sample Descriptions and in SOP-17 Soil Logging. After logging and photographing the core, samples may be retained by one of two procedures at the discretion of the field geologist or geotechnical engineer, as follows:

1. Bulk samples: zones of similarly classified materials greater than 1-foot thick may be placed in bulk sample containers and handled as specified in Section 2.4.5. Adjacent core materials from the subsequent run or runs having similar classifications may be combined (compositied) with the previously collected bulk samples. Subsamples of minor strata (less than 1 foot thick) having distinctly different field classifications than adjacent major strata, and samples for moisture testing will be placed in 1 gallon resealable bags and placed inside the sample buckets on top of the associated bulk composite samples.

2. Liner samples: Samples collected in transparent plastic liners may be retained in the liners. Liner caps will be sealed with plastic tape. Sample orientation will be indicated by an arrow pointing up or a “T” on the top cap.

Sample buckets, bags, and retained liners will be marked with the boring number and depth interval in accordance with SOP-14.

2.4.2 Split-spoon Samples

Split-spoon samples will be collected by driving the split spoon ahead of the HSA with a 140-lb hammer falling 30 inches. The sampler will be driven 18 inches and blow counts will be recorded for 6-inch intervals. Various diameters of split-spoon samplers may be used. The HSA will be advanced into the soils as necessary to provide discrete sample intervals. When retrieved, the split-spoon sampler will be opened, the recovery will be measured/recorded, and the soil described as specified in Section 2.4.6.

Split-spoon samples will be collected on a maximum of five feet vertical intervals. The sampled interval will be placed in gallon resealable bags. Out of place soils (slough) at the top of the sampler will not be sampled. Samples will be labeled and handled as specified in SOPs-06, 14, and 17. Sample depth will be the starting depth of the sample.
2.4.3 California Split-barrel Samples

California split-barrel samples will be collected by driving the California split barrel ahead of the HSA with a 140-lb hammer falling 30 inches. The California split-barrel sampler will be driven 18 inches and blow counts will be recorded for 6-inch intervals. California split-barrel samples will be collected utilizing a 2.5-inch outside diameter (OD) California split barrel sampler lined with three 2-inch diameter by 4-inch long brass liners, plus additional brass liners as necessary to fill the California split barrel sampler. Alternate sampler diameters may be considered for use, depending on the application.

The sample recovery will be measured/recorded and the soil described as specified in Section 2.4.6. The bottom two, 4-inch long, brass liners will be retained and capped; other recovered soils will be discarded. The brass liners will be labeled with the project number, borehole, sample depth, liner identification, sample date, and orientation. Sample depth is defined as the starting depth of the sample drive. Brass liner identification is “A” for the bottom brass liner and “B” for the brass liner above the “A” brass liner. Sample orientation is an arrow pointing up, a “T” on the top cap, or the orientation of the sample labeling.

2.4.4 Shelby Tube Samples

Shelby tube samples will be collected at locations and intervals specified in the Work Plans. Shelby tube samples will be collected by hydraulically advancing a 3-inch diameter (or other approved diameter), 30-inch long, Shelby tube sampler two feet or to refusal. The recovery will be measured and the soils described as specified in Section 2.4.6 by inspecting the soils at the top and bottom of the Shelby tube.

The Shelby tubes will be sealed before transport. The bottom cap will be secured with plastic tape. Melted wax (paraffin or paraffin with beeswax) will be poured into the top of the Shelby tube to stabilize and seal the top of the sample and be used to seal the end tape and caps. Spacers may also be used to stabilize the samples within the tubes. The top cap will then be secured with plastic tape (see SOP-06).

Both the Shelby tube and the top cap will be labeled with the job number, borehole, sample interval, orientation, and sample date. Shelby tubes must be handled, transported, and stored vertically and cushioned against shock and vibration.

2.4.5 Bulk Samples

Bulk samples will be collected at intervals specified in the Work Plans. Bulk samples may be collected from continuous core samples (Section 2.4.1), or auger cuttings as indicated in the Work Plans and placed in plastic buckets (3.5 or 5 gallon) for geotechnical testing and classification.

The sealed buckets will be labeled and handled as specified in the SOP-14.
2.4.6 Sample Descriptions

Soils will be described and classified in general accordance with SOP-17 (Soil Logging) and ASTM D2488 - Standard Practice for Description and Identification of Soils (Visual-Manual Procedure) (ASTM, 2009). Sample descriptions will include soil type, moisture content, color (Munsell Color), density or consistency, plasticity, grain-size and shape, and other descriptors, as applicable.

Boreholes will be logged on MWH Borehole Log forms. An example MWH Borehole Log form for recording field information is attached to this SOP as Appendix A. Sample intervals, recovery, blow counts (if performed), soil descriptions, and sample time will be recorded.

2.4.7 Field QA/QC Samples

Field duplicate and equipment blank samples for geotechnical samples will not be collected. Equipment blanks of geotechnical sampling equipment will not be collected.

2.5 DECONTAMINATION

HSA and CPT equipment will be decontaminated by removing visible material with a scraper or brush between test holes. Geotechnical sampling equipment will be decontaminated by removing visible material with a scraper or brush between samples. Equipment will be decontaminated at the drill sites. See also SOP-31 for additional details.

2.5.1 Borehole and CPT Abandonment

Abandonment specifics will be described in the Work Plans and may vary depending on the sampling location at the site. HSA boreholes and CPT holes will be abandoned with bentonite grout and/or soil cuttings. Bentonite grout, when used, will be placed to within about 1 to 2 feet from the ground surface, or to the top of the radon barrier, then the top of the borehole will be backfilled with drill cuttings, or cover material.
3.0 DOCUMENTATION AND RECORDS MANAGEMENT

Field data will be recorded in bound field books or on MWH Borehole Log forms (Appendix A). Documentation and records procedures are specified in SOP-14. Field data collected during CPT will be recorded in bound field books and by the instruments associated with the cone penetrometer. Data recorded by the cone penetrometer instrumentation will be provided, by the operator, to MWH within seven days of completion of CPT activities.
4.0 REFERENCES


APPENDIX A

SAMPLE BOREHOLE LOG
### Soil Boring Log Form

- **Loc. ID:**
- **Elevation:**
- **Datum:**
- **Project Name:**
- **Drill Date:**
- **Inclination:**
- **Azimuth:**
- **Hammer Weight:**
- **Date Finished:**
- **Samples:**
  - **Depth Units:**
  - **Soil Description:**
  - **Graphic Log:**
  - **Soil Profile:**
  - **Logged By:**
  - **Checked By:**

**Additional Comments**

---

**SOIL BORING LOG FORM**

---

**MWH**
<table>
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<th>Boring #:</th>
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<td>Revision: 0</td>
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<td>CHURCH ROCK MINE AND MILL SITE</td>
<td>Date: July 2013</td>
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<td>SAMPLE MANAGEMENT AND SHIPPING</td>
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SOP-6, Rev. 0
1.0 SCOPE AND APPLICABILITY

This standard operating procedure (SOP) describes the requirements for sample identification, handling, storage, chain-of-custody (COC) documentation, and shipping. The purpose of this SOP is to define sample management activities as performed from the time of sample collection to the time they are received by the laboratory.

These procedures apply to all work conducted for MWH clients, by MWH, or under direction of MWH at the Church Rock Mine and Mill sites during Pre-Design studies. The information in this SOP may be used by direct reference or incorporated into project-specific plans. Deviations or modifications to procedures addressed herein must be brought to the attention of, and approved by, the Project Manager.
2.0 SAMPLE MANAGEMENT PROCEDURES

2.1 SAMPLE CONTAINERS

Samples will be placed in containers that are appropriate for the type of sample collected and the analyses that will be performed.

2.1.1 Chemical Samples

Samples to be submitted for chemical analysis will be placed in contaminant-free containers. Containers will be stored in cool, dry, clean areas to prevent exposure to fuels, solvents, and other non-site related impacts. Sample containers with preservatives added by the laboratory will not be used if held for an extended period on the job site or exposed to extreme heat conditions.

The sample containers to be used will be dependent on the sample matrix and analyses desired. Sample containers will be filled with adequate headspace if necessary (approximately 90 percent) for safe handling upon opening, except containers for volatile organic compound (VOC) analyses, which will be filled completely with no headspace. The no-headspace requirement applies to both soil and groundwater samples.

Once opened, the containers will be used immediately. If the container is used for any reason in the field (e.g., screening) and not sent to the laboratory for analysis, it will be discarded. Prior to discarding the contents of the used container and/or the container, disposal requirements will be evaluated to assess whether the contents or the container require disposal as a hazardous material. The containers will be stored (before and after sampling) remain separate from solvents and other volatile organic materials.

2.1.2 Geotechnical Samples

Samples to be submitted for geotechnical analysis will be collected in brass or plastic sleeves, or Shelby tubes as undisturbed samples, or in plastic bags or buckets as bulk samples. Undisturbed tube samples will be capped with plastic end caps and taped at both ends and/or sealed in re-sealable plastic bags to maintain sample moisture content. For Shelby tube samples, spacers will be used to stabilize the samples along with cheesecloth and wax. Wax will then be used in addition to plastic caps to seal both ends of each sample prior to prevent moisture loss.

2.2 FIELD SAMPLE IDENTIFICATION AND LABELING

2.2.1 Field Sample Identification

A protocol for field sample identification will be clearly defined at the beginning of the project based on client requirements and will be carried forward throughout the duration of the project. A coding system will be used to uniquely identify each sample collected.
The sample identifier should include sufficient information to allow for quick data retrieval and tracking throughout the project. This information could include the company name, date of sample collection, area of sample collection (such as Central Cell, East Borrow, etc.), test pit or boring identification, and depth of sample collection. As an example, the sample identifier “MWH-31JUL2013-EB-TP-1 @ 4-5” would designate a sample collected by MWH on July 31, 2013 from Test Pit #1 in the East Borrow area from a depth of 4 to 5 inches. Regardless of the specific format used, it should be defined at the beginning of the project and carried forward through the duration of the project.

2.2.2 Sample Label

A sample label similar to that shown in Attachment 1 will be affixed to all sample containers. The sample label, at a minimum, will be completed with the following information:

- Client name, project title, or project location
- Sample location
- Sample identification number
- Date and time of sample collection
- Type of sample (grab or composite)
- Initials of sampler
- Preservative used (if applicable)
- Label number (if applicable)

Alternatively, the above information may be written directly on the sample containers with permanent, waterproof ink.

If a sample is split with another party, identical labels will be attached to each sample container.

2.3 SAMPLE HANDLING AND STORAGE

After labeling, each aqueous sample will be refrigerated or placed upright in a cooler. Wet ice, in double re-sealable bags (to prevent leakage), will be placed around, among, and on top of the sample bottles. Enough ice will be used so that the samples will be chilled and maintained at 4 degrees Celsius (°C) ± 2 °C prior to and during transport to the laboratory.

Geotechnical samples will be stored in a sturdy box, cooler, plastic bucket, or similar container. Care should be taken to store the samples out of direct sunlight. Shelby tubes and similar undisturbed samples will be stored upright and will be protected from excessive vibration and disturbance. If samples will be stored for several days prior to transport to the laboratory, they should be stored in a secure location rather than in a vehicle to protect them from vibration and disturbance.
Some sample types require specific handling procedures, including:

- Compressed gas cylinders
- Radioactive substances
- Biological hazards
- Chemical warfare agents
- Drugs (controlled substances)
- Explosive ordnance
- Explosives (as per the Department of Transportation [DOT])
- Shock-sensitive materials

If any of these materials are associated with a project, the field personnel must follow the health and safety procedures defined in the project-specific plans.

2.4 SAMPLE PRESERVATION

The requirements for sample preservation are dependent on the desired analyses and the sample matrix. Sample preservation requirements outlined in the project-specific work plan will be followed. When an acid or base is used as preservative, pH paper will be used to determine if an adequate amount of preservative is being used to preserve analytical samples. When testing pH for VOC samples, a third VOC sample will be collected, tested with pH paper, and then disposed of properly.

2.5 QUALITY CONTROL SAMPLES

The number and types of quality control (QC) samples to be collected for a project will be defined in the project-specific plans. The following briefly describes field QC samples that may be collected during a field program.

2.5.1 Trip Blanks

Trip blanks are used to assess cross-contamination of samples for VOC analysis from sample containers or during sample transport and storage at the laboratory. Trip blanks consist of 40 milliliter (ml) amber glass vials filled by the laboratories with acidified reagent-grade water, then sealed by the laboratories prior to shipment. Trip blank vials accompany the empty bottles to the site and remain with the samples throughout sample collection and shipment.

2.5.2 Equipment Rinseate Blanks

Equipment rinseate blanks are used to evaluate sample equipment decontamination procedures and are prepared in the field (after decontamination of sampling equipment is complete). These samples are prepared by collecting the final equipment decontamination rinse water into the appropriate sample container.
2.5.3 Filter Blanks

If water samples are collected for dissolved metals analysis, a filter blank (for each lot of filters) should be collected prior to sample collection to evaluate whether the filter is a source of metals to the samples. This sample is collected in the field by passing the source water through the same filter type that will be used to filter water media for dissolved metals analysis.

2.5.4 Duplicate Samples

Duplicate field samples (water samples) are used to assess variability in the sample media and to assess sampling and analytical precision. A duplicate sample pair is a single aqueous grab sample that is split into two samples during collection. If the field duplicate is being submitted blind to the laboratory, one of the samples is labeled with the correct sample identification and the other is labeled with fictitious sample identification. Regardless of whether the samples are submitted blind to the laboratory or not, the field duplicate and parent sample are submitted to the same laboratory as two separate samples.

2.5.5 Replicate Samples

Replicate field samples (air, soil, or sediment) are used to assess variability in the sample media and to assess sampling and analytical precision. A replicate sample pair is a single soil grab sample that is split into two samples during collection. If the field replicate is being submitted blind to the laboratory one of the samples is labeled with the correct sample identification and the other is labeled with a fictitious sample name. Regardless of whether the samples are submitted blind to the laboratory or not, the field replicate and parent sample are submitted to the same laboratory as two separate samples.

2.6 SAMPLE HOLDING TIMES

The holding times for samples will depend on the analysis and the sample matrix. Unless otherwise specified, holding times listed in project-specific work plans will be followed. For geotechnical samples, holding times do not apply. However, samples will be shipped as soon as possible and kept cool to prevent drying and mold growth.

2.7 CHAIN-OF-CUSTODY (COC)

Chain-of-custody procedures require a written record of the possession of individual samples from the time of collection through laboratory analyses. A sample is considered to be in custody if it is:

- In a person’s possession
- In view after being in physical possession
- In a secured condition after having been in physical custody
- In a designated secure area, restricted to authorized personnel
2.7.1 COC Record

The COC record, similar to the example shown in Attachment 2, will be used to document the samples collected and the required analyses. Information recorded by field personnel on the COC record will include the following:

- Client name
- Project name
- Project location
- Sampling location
- Signature of sampler(s)
- Sample identification number
- Date and time of collection
- Sample designation (grab or composite)
- Sample matrix
- Signature of individuals involved in custody transfer (including date and time of transfer)
- Airbill number (if appropriate)
- Number and type of samples collected for each analysis
- Type of analysis and laboratory method number
- Any comments regarding individual samples (e.g., organic vapor meter readings, special instructions)

All COC entries will be made using indelible ink and will be legible. Any errors will be corrected by drawing a single line through the incorrect entry, entering the correct information, and then initialing and dating the change. Unused portions of the COC form will be crossed out with a single strike through and initialed and dated by the field sampler.

If the samples are transferred directly from the field sampler to the laboratory, both the receiving and relinquishing individuals will sign the COC. If samples are transported to the laboratory by a commercial carrier, signed airbills or other applicable bills of lading will serve as evidence of custody transfer between the field sampler and carrier as well as carrier and laboratory.

The sampler will retain copies of the COC record and airbills, or bills of lading. If the COC records are sequentially numbered the record number and airbill number will be cross-referenced in the field logbook or appropriate field form.

2.7.2 Custody Seals

Custody seals, similar to the label shown in Attachment 3, will be used on each sample (if required) and/or shipping container to ensure custody. Custody seals used during the course of the project will consist of security tape with the date and initials of the sampler. As a minimum, custody seals will be placed in two locations (the front right and back left of the cooler) across the cooler closure to ensure that any tampering is
detected. If required by the client, a seal will be placed on each sample container so that it must be broken to gain access to the contents. Because VOC samples may be subject to contamination by the tape, VOC sample containers will first be secured in a re-sealable plastic bag. The plastic bag will then be sealed with a completed custody seal. If the seals are serially numbered, these numbers will be cross-referenced in both the field logbook and the COC form.

2.7.3 Sample Register/Sample Tracking

The sample register maybe electronic or a bound logbook with sequentially numbered pages. The sample register is used to document which samples were collected each day. The sample register is also used as the key to correlate field samples with duplicate samples. Information that will be recorded in the sample register includes the following:

- Client name
- Project name and location
- Job number
- Date and time of collection
- Sample identification number
- Sample designation (e.g., grab or composite, etc.)
- Sample matrix (e.g., soil, groundwater, etc.)
- Number and type of bottles
- Type of analysis
- Sample destination
- Sampler's initials

If the sample register is electronic, a hard copy of each day's sampling activities will be maintained in the field logbook.

2.8 SAMPLE SHIPPING

Geotechnical samples will be preserved and transported in general accordance with ASTM D4220. Shelby tube samples and brass liners will be transported vertically in the orientation in which they were obtained. If the samples will be driven to the laboratory by field staff, they will be secured for transport against excessive vibration inside the cab of the vehicle on the seats. If the samples will be shipped by a commercial carrier, shipping containers designed to maintain orientation and minimize disturbance will be used.

Procedures for packaging and transporting samples to the laboratory are based on the actual chemical, physical, and hazard properties of the material. The procedures may also be based on an estimation of contaminant concentrations/properties in the samples to be shipped. Samples will be identified as environmental samples, excepted quantities samples, limited quantities samples, or standard hazardous materials.
Environmental samples are defined as solid or liquid samples collected for chemical or geotechnical analysis.

Excepted quantities involve the shipment of a few milliliters of either an acid or base preservative in an otherwise empty sample container.

Limited quantities are restricted amounts of hazardous materials that may be shipped in generic, sturdy containers (this includes geotechnical samples of mill tailings).

Standard hazardous material shipments require the use of stamped/certified containers.

Samples other than those listed above (refer to Section 2.3) must be shipped according to the requirements of 49 CFR 173.24 and other applicable Federal, state, and local regulations. Prior to the collection and shipment of these samples, shipment requirements will be researched, a written description of shipment procedures will be prepared, and the description reviewed and approved by a MWH certified industrial hygienist prior to sample collection. These shipment procedures will be included in the project-specific plans. Examples of such samples include materials that potentially contain asbestos, radioactive materials, explosives, and chemical warfare agents, and transformer fluids (refer to Section 2.3).

The following paragraphs describe standard sample shipping procedures for different types of samples. Any exceptions to these procedures will be defined in the project-specific work plan. If the samples to be collected are potentially limited quantity or standard hazardous materials the most current DOT regulations must be reviewed to ensure that the most current shipping procedures are used. The carrier service selected for transport may also be able to provide information needed for sample shipping procedures. It is the responsibility of the sampler to understand Department of Transportation requirements and limitations associated with the shipment of all types of samples.

No samples, other than geotechnical samples, will be held on site for more than 24 hours, except during weekend field activities. Samples collected on the weekend will be stored under refrigeration and shipped the following Monday. Sampling activities for analytes with extremely short holding times, such as 24 hours, will not be scheduled for weekend collection.

Occasionally, multiple coolers or packages will be sent in one shipment to the laboratory. One cooler will have the original COC Record and the other coolers will have copies. The plastic bag in which the COC Records are placed will be marked appropriately “ORIGINAL” or “COPY.” In addition, the outside of the coolers will be marked to indicate how many coolers are in the shipment (i.e. “1 of 2” or “2 of 2”).
2.8.1 Environmental Samples

Hand-Delivered Samples: For aqueous or solid samples that will be hand carried to the Contract Laboratory the following procedures apply:

- Sample labels will be completed and attached to sample containers as described in Section 2.2.
- The samples will be placed upright in a waterproof metal (or equivalent strength plastic) ice chest or cooler.
- Wet ice in double re-sealable bags (to prevent leakage) will be placed around, among, and on top of the sample bottles. Enough ice will be used so that the samples will be chilled during transport to the laboratory.
- To prevent the sample containers from shifting inside the cooler, the remaining space in cooler will be filled with inert cushioning material, such as shipping peanuts, additional bubble pack, or cardboard dividers.
- The original copy of the completed COC Record will accompany the samples to the laboratory.
- A copy of the COC Record will be retained for the project files.

Commercial Carrier: For aqueous or non-geotechnical solid samples that are shipped to the Contract Laboratory via a commercial carrier the following procedures apply:

- Sample labels will be completed and attached to sample containers as described in Section 2.2.
- The samples will be placed upright in a waterproof metal (or equivalent strength plastic) ice chest or cooler. If the container has a drain, the drain will be taped shut and a large plastic bag used as a liner for the cooler. Each sample will be placed in a separate re-sealable or bubble-wrap bag. As much air as possible will be squeezed from the bag before sealing. Bags may be sealed with a custody seal if required by the client.
- Wet ice in double re-sealable bags (to prevent leakage) will be placed around, among, and on top of the sample bottles. Enough ice will be used so that the samples will be chilled and maintained at 4°C ± 2°C during transport to the laboratory. Dry ice will not be used. In addition, experience has shown that blue ice is inadequate to maintain sample temperature and it will not be used for sample preservation.
- To prevent the sample containers from shifting inside the cooler, the remaining space in the cooler will be filled with inert cushioning material, such as shipping peanuts, additional bubble pack, or cardboard dividers.
- The original copy of the completed COC Record will be placed in a waterproof plastic bag and taped to the inside of the cooler lid.
- The lid will be secured by wrapping strapping tape completely around the cooler in two locations.
As a minimum, custody seals similar to those shown in Attachment 3 will be placed in two locations (the front right and back left of the cooler) across the cooler closure to ensure that any tampering is detected.

The airbill will be filled out before the samples are handed over to the carrier. The laboratory will be notified if MWH personnel suspect that the sample contains any substance for which the laboratory personnel should take safety precautions.

A copy of the COC Record and the signed air bill will be retained for the project files.

Geotechnical Samples: Geotechnical samples may be hand-delivered or shipped in a sturdy box or other container. No ice is necessary. Enough packing material will be added so that samples remain undisturbed. COC procedures as described previously will be followed to generate defensible data. Any hazardous nature of the samples, including any organic vapor measurements, name of suspected contaminants present, and the approximate range of concentrations, if know, should be noted on the COC Record.

2.8.2 Excepted Quantities

Usually, corrosive preservatives (e.g., hydrochloric acid, sulfuric acid, nitric acid, or sodium hydroxide) are added to otherwise empty sample bottles by the analytical laboratory prior to shipment to field sites. However, if there is an occasion whereby personnel are required to ship bottles with these undiluted acids or bases, the containers will be shipped in the following manner:

- Each individual sample container will have not more than 30 milliliters of preservative.
- Collectively, these individual containers will not exceed 500 milliliters in the same outer box or package.
- Despite the small quantities, only chemically compatible material may be placed in the same outer box, i.e., sodium hydroxide, a base, must be packaged separately from the acids.
- Federal Express will transport nitric acid only in concentrations of 40 percent or less.
- A "Dangerous Goods in Excepted Quantities" Label will be affixed to the outside of the outer box or container. Information required on the label includes:
  - Signature of Shipper
  - Title of Shipper
  - Date
  - Name and Address of Shipper
  - Check of Applicable Hazard Class
  - Listing of UN Numbers for Materials in Hazard Classes.
2.8.3 Limited Quantities

Occasionally, it may become necessary to ship known hazardous materials, such as pure product (e.g., light or dense non-aqueous phase liquids, geotechnical samples of uranium mill tailings). DOT regulations still permit the shipment of many hazardous materials in "sturdy" packages, such as an ice chest or cardboard box (not a specially constructed and certified container), provided the following conditions are met:

- Each sample bottle of liquid is placed in a plastic bag, and the bag is sealed. Each VOC vial is wrapped in a paper towel, and the two vials are placed in one bag. As much air as possible is squeezed from the bag before sealing. Bags may be sealed with evidence tape for additional security.

- Each bottle of liquid is placed in a separate paint can, the paint can is filled with vermiculite, and the lid is affixed to the can. The lid must be sealed with metal clips, filament, or evidence tape. If clips are used, the manufacturer typically recommends six clips.

- The outside of each can will contain the proper DOT shipping name and identification number for the sample. The information may be placed on stickers or printed legibly. A liquid sample of an uncertain nature will be shipped as a flammable liquid with the shipping name "FLAMMABLE Liquid N.O.S." and the identification number "UN1993." If the nature of the sample is known, Title 49, Code of Federal Regulations, Parts 171 to 177 (49 CFR 171-177) will be consulted to determine the proper labeling and packaging requirements. The carrier should be contacted to ensure that the information provided is correct.

- The cans are placed upright in a cooler that has had the drain plug taped shut inside and outside and lined with a large plastic bag. Approximately 1 inch of packing material, such as vermiculite or other type adsorbent sufficient to retain any liquid that may be spilled, is placed in the bottom of the liner. Three sizes of paint cans may be used: pint, half-gallon, and gallon. The pint or half-gallon paint cans may be stored on top of each other; however, the gallon cans are too high to stack. The cooler will be filled with additional packing material, and the liner will be taped shut. Only containers having chemically compatible material may be packaged in each cooler or other outer container.

- The COC Record will be placed inside a sealed plastic bag and attached to the inside of the cooler lid. The sampler retains one copy of the COC Record. The laboratory will be notified if the sample is suspected of containing any substance for which laboratory personnel should take safety precautions.

- The lid will be secured by wrapping strapping tape completely around the cooler in two locations. As a minimum, custody seals similar to those shown in Attachment 3 will be placed in two locations (the front right and back left of the cooler) across the cooler closure to ensure that any tampering is detected.
The following markings are placed on the side of the cooler:
- Proper Shipping Name (Column B, List of Dangerous Goods, Section 4, IATA Dangerous Goods Regulations [DGR])
- UN Number (Column A, List of Dangerous Goods, Section 4, IATA DGR)
- Shipper's name and address
- Consignee's name and address
- The words "LIMITED QUANTITY"
- Hazard Labels (Column E, List of Dangerous Goods, Section 4, IATA DGR)
- "Cargo Aircraft Only" (if applicable as identified in 49 CFR 172.101).
- Two Orientation (Arrow) labels (indicating "This End Up") placed on opposite sides of the cooler.

The Airbill/Declaration of Dangerous Goods form will be completed as follows:
- Shipper's name and address
- Consignee's name and address
- Services, Delivery & Special Handling Instructions
- Passenger or Cargo Aircraft (cross off the non-applicable items. Up to 25 pounds of flammable solid per cooler can be shipped on a passenger aircraft. Up to 1 quart of flammable liquid per cooler can be shipped on a passenger aircraft and up to 10 gallons of flammable liquid can be shipped on a cargo aircraft).
- Cross out "Radioactive" under Shipment Type
- Nature and Quantity of Dangerous Goods
- Proper Shipping Name (Column B, List of Dangerous Goods, Section 4, IATA DGR)
- Class or Division (Column C, List of Dangerous Goods, Section 4, IATA DGR)
- UN Number (Column A, List of Dangerous Goods, Section 4, IATA DGR)
- Packing Group (Column F, List of Dangerous Goods, Section 4, IATA DGR)
- Subsidiary Risk, if any (Column D, List of Dangerous Goods, Section 4, IATA DGR)
- Quantity and type of packing (number and type of containers: for example, "3 plastic boxes", and the quantity per container, "2 L", is noted as "3 Plastic boxes X 2 L". This refers to 3 plastic boxes (coolers are referred to as plastic boxes) with 2 liters in each box.
- Packing Instructions (Column G, List of Dangerous Goods, Section 4, IATA DGR). Note: Only those Packing Instructions in Column G that begin with the letter "Y" may be used. These refer specifically to the Limited Quantity provisions.
- Authorization (Write in the words Limited Quantity)
- Emergency Telephone Number (List 800-535-5053. This is the number for INFOTRAC.)
2.8.4 Standard Hazardous Materials

Shipment of hazardous materials using this option presents the most difficulty and expense. However, there may be occasion whereby a hazardous material cannot be shipped under the Limited Quantity provisions, e.g., where there is no Packing Instruction in Column G, List of Dangerous Goods, IATA Dangerous Goods Regulations, that is preceded by the letter "Y."

In such cases, the general instructions noted above but for non-Limited Quantity materials will apply, but with one important difference: standard hazardous materials shipment requires the use of certified outer shipping containers. These containers have undergone rigid testing and are, therefore, designated by a "UN" stamp on the outside, usually along the bottom of a container's side. The UN stamp is also accompanied by codes specifying container type, packing group rating, gross mass, density, test pressure, year of manufacturer, state of manufacturer, and manufacturer code name. The transport of lithium batteries in Hermit Data Loggers is an example of a standard hazardous material, and where only a designated outer shipping container may be used. Contact the DOT for the most current shipping regulations.

2.9 TRAINING

The U.S. Department of Transportation requires that all employees involved in any aspect of hazardous materials transport (shipping, transport, receipt, preparing documents) receive training at least bi-annually. Project Managers have the overall responsibility for ensuring all sampling staff have appropriate training.
3.0 REFERENCES

# ATTACHMENT 1
SAMPLE LABEL

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<tr>
<th>MWH</th>
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</table>

**Project Name/Location**

**Field ID Number**

**Analysis**