Appendix B

Procedures for Conducting Field Investigations and Site Assessments

The objective of the following procedures is to provide general reference information for various field and site investigation activities. These procedures may be varied or changed as necessary, dependent upon site conditions, equipment limitations, or the intent of the investigation. In all instances, the procedures employed should be documented in the site logbook and associated with the final report.

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1.0 Field Screening

The Colorado OIS field screening methodology was developed to generate consistency and reliability of results when using PID/FID instruments. OIS will not accept analytical results for soil samples collected for field soil screening. Separate soil samples must be collected according to the soil sampling procedures presented in this section. The field soil sampling and screening procedures shall include the following:

- Samples collected during drilling procedures must be taken in advance of the drill bit or auger.
- No samples shall be collected from the auger flights.
- When using a PID/FID instrument the following procedure must be used:

1. Half-fill a glass jar, or a sealable plastic bag.

1.1. When using glass jars:

1.1.1. Seal each jar with one (1) or two (2) sheets of aluminum foil with the screw cap applied to secure the aluminum foil.

1.2. When using sealable plastic bag:

1.2.1. Half fill the bag from the split spoon or excavation sample.

1.2.2. Seal the bag.

2. Breakup the sample and briefly shake the sample jars or bags once or twice in a 10-15 minute period to allow for headspace development.

3. If ambient temperatures are below 32° Fahrenheit (0° Celsius) headspace development is to be within a heated vehicle or building.

4. Quickly insert the PID/FID sampling probe through the aluminum foil. If plastic bags are used, unseal a small portion of the bag and insert the probe or insert the probe directly through the plastic. Record the maximum meter response (should be within the first 2-5 seconds). When using a PID, erratic responses should be discounted as a result of high organic vapor concentrations or conditions of elevated headspace moisture.
5. Record headspace screening data from both jars or bags for comparison.

6. PID/FID instruments shall be operated and calibrated to yield "total organic vapors" in parts per million as benzene. PID instruments should be operated with

a 10.2 eV lamp source. Calibration must be checked/adjusted daily. In addition, all manufacturers requirements for instrument calibration must be followed.

- If sample jars are to be re-used in the field, jars must be cleaned according to field decontamination procedures for cleaning of bailers. In addition, headspace readings must be taken to ensure no residual organic vapors exist in the cleaned sample jars. Plastic bags may not be re-used.
- Any deviation(s) from these procedures must be noted and a basis stated for the deviation(s), with consideration of acceptance by the OIS.

2.0 Soil Vapor Sampling

2.1 Field Screening

Prior to the installation of soil vapor sampling points, a field screening survey of all underground utilities, vaults, trenches and other underground structures shall be completed. These structures shall be screened (using either a FID or PID) for chemical(s) of concern vapors to determine if there is the possibility for a preferential pathway for vapor migration (e.g., utility lines, sump pumps).

OIS will not accept analytical results for soil vapor samples collected for field screening. Separate soil vapor samples must be collected according to the soil vapor sampling procedures presented in Section 3.2 below. Field screening protocol is presented in Section 1.0.

2.2 Soil Vapor Sampling

2.2.1 Equipment

- Hand auger, or
- Direct push rig, or
- Drill rig and equipment
- Expendable drive points
- Stainless steel screen or
- Perforated sample tubing
- Sample containers - for chemical analyses
- OVM
- Decontamination equipment (as necessary)
- Indelible pens
- Boring log form, etc.
- Cooler and ice
- Sealable plastic bags
- Plastic sheeting and/or aluminum foil
- Compass
- 200 ft tape measure
- Watch
- Camera and film

2.2.2 Methods

Soil vapor samples are collected by inserting a sampling implant into a borehole, usually with a slide hammer, a direct push system, or a hollow stem auger. Most sampling implants consist of screens or ports that are pushed directly into the ground or inserted through the insides of drill rod or pipe. Once the implant is in place, and the borehole is properly sealed, soil gas is drawn through the port or screen through plastic (polyethylene or Teflon$^{\text{TM}}$) or metal tubing and into a collection vessel using a vacuum device.

2.2.3 Sample Collection Procedures

Both soil gas concentrations for the chemical(s) of concern beneath existing point(s) of exposure and parameters that affect fate and transport of the chemical(s) of concern vapors will be measured. The following are the key parameters that must be determined when evaluating the air exposure pathways:

Table 1 Sample Collection Procedures – Key Parameters.

Measurement	Reason
Soil gas - Chemical(s) of concern	To estimate indoor air concentrations
Soil gas - oxygen concentration	Evidence of natural attenuation
Soil gas - carbon dioxide concentration	Evidence of natural attenuation
Soil - grain-size distribution	For modeling input
Soil - total organic carbon (TOC)	For modeling input
Soil - dry bulk density	For modeling input
Soil - specific gravity	For modeling input
Soil - moisture content	For modeling input
Soil – chemical(s) of concern	For modeling input
Groundwater – concentration of chemicals of concern (directly below each soil vapor implant)	For modeling input and to evaluate volatilization

These soil characteristics should be measured in soil samples collected from each interval that corresponds to the location of each soil gas implant. These measured soil characteristics will be used to calculate the following terms needed to estimate flux to indoor air:

- Total porosity
- Volumetric air content
- Volumetric water content

The initial soil boring at each vapor implant location should be advanced either to the water table (in the case of contaminated groundwater) or to the soil source. Concentration of chemicals of concern in the groundwater located near the vapor implants will also be needed. Groundwater data can be generated using existing wells if located near the soil gas sampling point or can be collected during the installation of the initial soil boring at each vapor implant location.

The oxygen and carbon dioxide measurements are used to evaluate aerobic degradation occurring in the vadose zone. Anaerobic degradation will not be evaluated at this time because of the difficulty in obtaining appropriate indicators.

Once all of these parameters have been collected, the risk to indoor air will be calculated using the most appropriate soil vapor concentration (usually from the closest location to the potential receptor) as the source term. The model used to estimate indoor air concentrations will be Johnson and Ettinger (1991).

2.2.3.1 *Soil Vapor Implants*

Evaluation of the distribution of chemical(s) of concern in the vadose zone requires that soil gas samples be repetitively collected and analyzed. Therefore, a permanent sampling system that is reliable and sufficiently sturdy to be utilized for an extended period of time must be installed. The sampling system will consist of nested soil gas implants capable of generating data that are discrete as a function of depth and time. The nested soil gas implants must be installed in a manner that is as non-disruptive and unobtrusive as possible, and should result in as low a sampler "dead-volume" (volume of air contained within the sampling device) as possible.

The nested soil gas implants shall be installed at a minimum of two locations at the site. One located directly over the source area and a second located as close as possible to the location of an existing point of exposure (e.g., building foundation). If there are multiple sources or points of exposure, then additional soil gas implants will be required.

If contaminated groundwater is present at the site, implants shall be installed at depths very close to the water table. Implants will also be installed at depths associated with existing building foundation depths. Local building practices will be consulted for more specific information on foundation depths when selecting sampling depths.

Unless there is a very shallow water table (i.e., less than 3 feet), a minimum of three (3) vertical implants should be installed at each sampling point. An objective of this investigation is to demonstrate a vertical profile of the concentration of chemical(s) of concern. For chemicals that degrade in the vapor phase the vertical profile is also important to demonstrate an inverse profile of O_2 concentration. The number of vertical implants needed to accomplish this objective shall be based on depth to ground water and degree of heterogeneity at the site.

2.2.3.2 *Laboratory Analyses*

Samples used for VOC analysis must be collected to minimize the potential loss of volatiles. Place VOC soil vapor samples in a suitable container (e.g., Tedlar^{TM} bag, glass bulb, syringe, etc.). Properly label the container and immediately place the sample into coolers packed with ice to maintain a temperature of less than 4ºC. The location of samples submitted for laboratory analysis should be selected to provide the information necessary to evaluate the exposure pathways.

3.0 Soil Sampling

3.1 Surface Soil Sampling

3.1.1 Equipment

- Hand Augers (multiple size stainless steel buckets)
- Power Auger (if required for 2+ foot depth)
- Stainless steel trowels
- Shovels (to remove gravel and debris)
- Plastic sheeting and/or aluminum foil
- Decontamination equipment as required
- Hand tools (for equipment or other needs)
- Camera and film
- Watch
- Labels
- Cooler
- Field log book
- Soils Data form, Daily QC form, etc.
- Site Safety and Health Plan
- Appropriate sample bottles
- Plastic bags (sealable)
- Compass
- 200 ft tape
-

3.1.2 Procedures

Surficial soil samples shall be collected as follows. Vegetation at the sample location is removed by cutting or scraping away with a stainless steel trowel. While drilling the hole, remove gravel or other debris before obtaining the sample. Advance the trowel or auger to a depth of approximately six inches and then remove from the hole. Using pre-cleaned stainless steel equipment, extrude the soil directly into the sampling containers. If dedicated sampling equipment is not used, sampling equipment must be decontaminated before collecting another sample.

Samples for VOC analysis must be collected first. Fill VOC sample containers as full as possible to minimize headspace losses. Fill separate containers with a sufficient quantity of soil for analyses of other required parameters. Immediately place the samples on ice at 4ºC. Enter all data into a permanent field log book.

3.2 Subsurface Soil Sampling

3.2.1 Equipment

- Drill rig and equipment
- Stainless steel split spoon
- Shelby tubes
- Sample containers - chemical and geotechnical analysis
- OVM
- Decontamination equipment (as necessary)
- Indelible pens
- Boring log form, etc.
- Cooler and ice
- Sealable plastic bags
- Plastic sheeting and/or aluminum foil
- Compass
- 200 ft tape measure
- Watch
- Camera and film
-

3.2.2 Methods

Subsurface soil samples can be obtained by several methods depending on the type of samples required and the soil conditions. The usual method is to collect samples using a 2.5 to 3-inch diameter, 2.5 to 5-ft-long, continuous-drive, split-barrel sampler, which is advanced during drilling. This technique has several advantages, the primary one being good sample recovery over a large interval, and accuracy in that cuttings are less likely to be included in the sample than in other methods. Disturbance to the soil is minimal so that subtle structures such as laminations or voids are less likely to be destroyed and geologic contacts are more readily observed and logged. In loose soil and/or where large debris or cobbles impede the progress of the sampler, sample recovery with a continuous sampler may be poor and a different sampling technique may be used.

When continuous drive sampling is not practical, a 24-inch stainless steel split-barrel sampler can be driven a total of 24 inches into the undisturbed materials by dropping a 140-lb weight 30 inches. A 3-inch diameter split spoon may be used to increase the chances of sufficient volume recovery for sampling purposes. Record in 6-inch increments the number of blows required to drive the sampler. Indicate these data along with the amount of sample recovery in the drilling log. In the event of poor sample recovery, the consultant may elect to offset within 10 feet to obtain the missing sample interval. Note on the boring log if the offset boring is unsuccessful.

At times where samples are required from shallow depths (less than 10 feet) it may be more feasible to collect samples using a hand auger. In this case a clean, 4-inch diameter hand auger shall be advanced to the top of the desired sample interval. Collect the sample with a stainless steel trowel or sampling trier and place in a laboratory-cleaned glass container and labeled accordingly. Samples for VOC analysis must be collected first to minimize potential loss of volatiles. To minimize the potential for cross-contamination, use dedicated stainless steel trowels or sampling triers at each location. Between each use, decontaminate sampling equipment.

3.2.3 Sample Collection Procedures

3.2.3.1 *Field Screening Samples*

Soil samples should be collected for field screening every five feet, or at zones of obvious contamination, and at the water table. Perform the field screening in accordance with the procedure described in Section 1.1 above. Note the field screening results on the boring log.

3.2.3.2 *Laboratory Samples*

After collecting the field screening samples, collect soil samples for laboratory analysis. Samples for VOC analysis must be collected first to minimize potential loss of volatiles. Place VOC soil samples in a suitable container. Fill sample containers as full as possible to prevent headspace degradation of VOC. Properly label the container and immediately place the sample into coolers packed with ice to maintain a temperature of less than 4ºC. When the headspace screening is complete for each boring, the laboratory sample that corresponds to the highest headspace sample is selected for laboratory analysis. If field screening showed no elevated headspace readings, the sample collected from at or just above the water table should be submitted for analysis. In some instances, it may be necessary to submit the samples from both the water table and the highest headspace reading. The location of samples submitted for laboratory analysis should be selected to provide the information necessary to evaluate the exposure pathways.

3.3 Lithologic Logging

The lithology of the sample along with any other pertinent information shall be logged by personnel familiar with soil classification procedures. Particular consideration should be given to grain-size distribution (relative percentages of different size materials), presence of lamination or layering and soil consistency. Estimate the mineralogy for coarser grained material. Classify soil samples and enter onto the boring log using the Unified Soil Classification System (USCS), following methods outlined in ASTM Standard D 2488. Prepare the final boring log using observations of the driller and on-site consultant and from laboratory analysis.

3.4 Decontamination of Sampling Equipment

Removing or neutralizing contaminants from equipment which must be reused minimizes the likelihood of sample cross contamination. It also reduces or eliminates the transfer of contaminants to clean areas and prevents the mixing of incompatible substances. Gross contamination can be removed by physical decontamination procedures. These abrasive and nonabrasive methods include the use of brushes, air and water blasting, and high and low pressure water cleaning. Solvents may then be used to remove trace amounts of contaminants which may still remain on the equipment.

A suggested method is to set up a decontamination line that consists of three to four stations where washing or rinsing of the sampling equipment is performed. These stations typically consist of buckets containing wash or rinse water. The first station is used to remove the most of the contamination. Subsequent stations are utilized to remove traces of wash water or contaminants.

After any contaminants are physically removed by scraping or brushing the sampling equipment, the equipment should be submerged in a detergent (nonphosphate) and tap water wash, contained in the first bucket, and scrubbed with a brush, to remove any remaining visible particulate matter and residual oils and grease. This step may be preceded by a steam or high-pressure, hot water wash to facilitate the removal of residuals.

The next step involves a tap water rinse and a distilled/deionized water rinse to remove the detergent.

Finally, a high-purity solvent rinse is performed for the removal of trace-organics. Typical solvents used for removal of organic contaminants include methanol or water. Methanol is typically chosen because it is an excellent solvent, miscible in water, and not a target analyte on the Priority Pollutant List The solvent must be allowed to evaporate completely and then a final distilled/deionized water rinse is performed. This removes any residual traces of the solvent. The equipment is then allowed to air dry.

All rinses should be collected and properly disposed of according to the characteristics of the contaminants. Sample collection and analysis of decontamination waste may be required before beginning proper disposal of decontamination liquids and solids generate at a site. This should be determined prior to initiation of sampling activities.

4.0 Water Sampling

4.1.Groundwater

4.1.1 Scope and Application

The objective of this section is to provide general reference information on sampling of wells. This guideline is primarily concerned with the collection of water samples from the saturated zone at sites that are thought to be contaminated. Every effort must be made to ensure that the sample is representative of the particular zone of water being sampled. The procedures described in this document are designed to be used in conjunction with analyses for the most common types of ground-water contaminants. The procedures may be varied or changed as required, dependent upon site conditions or equipment limitations. In all instances, the procedures employed should be documented in the site logbook and associated with the final report.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

4.1.2 Methods

Monitoring wells can be sampled immediately after initial well installation and development. Prior to sampling a monitor well, the well must be purged to remove water that may have been stagnant in the well, and to introduce fresh groundwater into the well for sampling. This may be achieved with one of a number of instruments. The most common of these are the bailer, submersible pump, noncontact gas bladder pump, suction pump, inertia pump, and air-lift pump. At a minimum, three well volumes should be purged if recharge to the well is sufficient. While the well is being purged, OIS recommends that field parameters (i.e., pH, temperature, and electrical conductivity) be measured and recorded following removal of each well casing volume until the readings stabilize. This is done to assure that fresh groundwater is entering the well. Field parameters are stable when there is less than 0.2 pH unit change and 10% change for conductivity and temperature for three consecutive measurements.

Once purging is completed and the laboratory-cleaned sample containers have been labeled, sampling may proceed. Sampling may be conducted with any of the above instruments and need not be the same as the device used for purging. Only the air-lift pump may not be used for sampling due to aeration of the sample. Care should be taken when choosing the sampling device as some may affect the integrity of the sample.

Sampling should occur in a progression from the least to most contaminated well, if this information is known. Even though the sampling and purging equipment are always decontaminated between wells, the possibility always exists that some contamination may remain on this equipment. By beginning the sampling at the least contaminated, it is hoped that any cross contamination of wells that may occur will be kept to a minimum.

4.1.3 Interferences and Potential Problems

The primary goal in performing ground-water sampling is to obtain a representative sample of the groundwater. Sample integrity and analytical results can be compromised by field personnel in two primary ways:

- Taking an unrepresentative sample.
- Incorrect handling of the sample.

There are numerous ways of introducing foreign contaminants into a sample, and these must be avoided by following strict sampling procedures and utilizing trained field personnel.

4.1.4 Sample Preservation, Storage, Handling, and Documentation

The type of analysis for which a sample is being collected determines the type of sample container, preservative, holding time, and filtering requirements which are used. Samples should be collected directly from the sampling device into the appropriate laboratory cleaned containers. Check that a Teflon liner is present in the cap, if required. Attach a sample identification label to the container. Complete a field-data sheet, a chain of custody form, and record all pertinent data in the site logbook while at the sampling location.

Samples shall be appropriately preserved, labeled, logged, and placed in a cooler with ice to be maintained at 4^{o}C. Samples must be shipped well before the holding time is up and ideally should be shipped within 24 hours of sample collection. It is recommended that these samples be shipped or delivered daily to the analytical laboratory in order to maximize the time available for the laboratory to perform the analyses. The containers should be shipped with adequate packing and cooling to ensure that they arrive intact.

Certain conditions may require special handling techniques. Special requirements must be determined prior to conducting fieldwork. This can be done by consulting with the analytical lab(s) that will be analyzing the water sample(s).

4.1.5 Equipment/Apparatus

4.1.5.1 *General*

- Water-level indicator (i.e., electric sounder, steel tape, transducer, or air line)
- Appropriate keys for well-cap locks
- Steel brush
- Organic Vapor Meter (FID/PID)
- Logbook
- Calculator
- Field-data sheets and sample labels
- Chain of custody records and seals
- Sample containers
- Engineer's ruler
- Sharp knife (locking blade)
- Toolbox (to include at least: screwdrivers, pliers, hacksaw, hammer, flashlight, adjustable wrench)
- Leather work gloves
- Appropriate health and safety gear
- Five-gallon pail
- Plastic sheeting
- Shipping containers
- Packing materials
- Bolt cutters
- Sealable plastic bags
- Containers for evacuation liquids
- Decontamination solutions
- Tap water
- Nonphosphate soap
- Several brushes
- Pails or tubs
- Aluminum foil
- Protective gloves (examples: rubber, plastic, or latex)
- Preservatives
- Distilled or deionized water
- Ice or other coolant

4.1.5.2 *Purging and Sampling Equipment and Materials*

Materials of construction for purging and sampling equipment (bladders, pump, bailers, tubing, etc.) should be limited to stainless steel, Teflon, and glass in areas where concentrations are expected to be at or near the detection limit. The tendency of organics to leach into and out of many materials make the selection of materials critical for trace analyses. The use of plastics, such as PVC (polyvinyl chloride) or polyethylene, should be avoided when analyzing for organics. However, PVC may be used for evacuation equipment as it will not come in contact with the sample, and in highly contaminated wells, disposable equipment (i.e., polypropylene bailers) may be appropriate to avoid cross contamination. Following are lists of equipment typically associated with the various purging and sampling methods.

4.1.5.2.1 *bailer*

- Clean, decontaminated bailers of appropriate size and construction material
- Nylon line, enough to dedicate to each well or Teflon coated bailer wire (preferably on some type of reel or spool)
- Sharp knife
- Wire cutters
- Five-gallon pail

4.1.5.2.2 *submersible pump*

- Pump(s)
- Generator (110/120 or 240 volt) or 12-volt battery if necessary
- PVC pipe (solid or coil type) - enough to dedicate to each well
- Toolbox supplements (to include at least: pipe wrenches, wire strippers, electrical tape, heat shrink wrap, hose connectors, Teflon tape)
- Hose clamps
- Safety cable
- Winch, pulley or hoist
- Gasoline for generator/gas can
- Flow meter with gate valve
- Nipples and various plumbing fittings (i.e., pipe connectors)

4.1.5.2.3 *noncontact gas bladder pump*

- Noncontact gas bladder pump
- Compressor or nitrogen gas tank
- Generator (110/120 or 240 volt) or 12-volt battery, if necessary
- Gasoline for generator/gas can
- Teflon tubing - enough to dedicate to each well
- Toolbox supplements (to include at least: pipe wrenches, wire strippers, electrical tape, heat shrink wrap, hose connectors, Teflon tape)
- Control box (if necessary)
- Spare batteries for control box if necessary

4.1.5.2.4 *suction pump*

- Pump
- PVC pipe (solid or coil type) - enough to dedicate to each well
- Generator (110/120 or 240 volt) or 12-volt battery if necessary
- Gasoline for generator/gas can
- Toolbox supplements (to include at least: pipe wrenches, wire strippers, electrical tape, heat shrink wrap, hose connectors, Teflon tape)
- Plumbing fittings
- Flow meter with gate valve

4.1.5.2.5 *inertia pump*

- Pump assembly
- Five-gallon pail

4.1.5.2.6 *air-lift pump*

- Air compressor and motor
- Air-storage tank
- Toolbox supplements (to include at least: pipe wrenches, wire strippers, electrical tape, heat shrink wrap, hose connectors, Teflon tape)
- Hose or tubing with perforated lower end
- Filter for the air entering the well

4.1.6 Reagents

Reagents may be utilized for preservation of samples and for decontamination of sampling equipment. Consult the procedures for Sample Preservation, Storage, and Handling and check with the analytical laboratory in order to determine which preservative(s) to use, if any, and the quantities required.

4.1.7 Procedures

4.1.7.1 *Initial Office and Field Preparation*

Determine the extent of the sampling effort, the sampling methods to be employed, and the types and amounts of equipment and supplies needed.

Obtain necessary sampling and monitoring equipment, appropriate to type of contaminant being investigated.

Decontaminate or preclean equipment and ensure that it is in working order.

Prepare scheduling and coordinate with staff, clients, land owners, and regulatory agencies.

Perform a general site survey prior to site entry in accordance with the site specific health and safety plan.

Identify and mark all sampling locations.

4.1.7.2 *Field Preparation*

1. Start at the least contaminated well, if known.

2. Lay plastic sheeting, or other suitable material, around the well to minimize the likelihood of contamination of equipment from soil adjacent to the well.

3. Remove locking wellcap, note location, time of day, and date in the site logbook.

4. Remove well-casing cap.

5. Screen headspace of well with an appropriate monitoring instrument to determine the presence of volatile-organic compounds and record in site logbook.

6. Lower water level measuring device into well until water surface is encountered.

7. Measure distance from water surface to reference measuring point on well casing or protective barrier post and record in site logbook. Alternatively, if no reference point, note that water-level measurement is from top of steel casing, top of PVC riser pipe from ground surface, or some other position on the well head.
8. Measure total depth of well (at least twice to confirm measurement) and record in site logbook.

9. Calculate the volume of water in the well and the volume to be purged using the calculation in Section 4.1.8.

10. Select the appropriate purging and sampling equipment.

4.1.7.3 *Purging*

During purging, water-level measurements may be taken at regular intervals. These data may be used to compute aquifer transmissivity and other hydraulic characteristics.
The following well evacuation devices are most commonly used. Other evacuation devices are available, but have been omitted in this discussion due to their limited use.

4.1.7.3.1 *bailer*

Bailers are the simplest purging device used and have many advantages. They generally consist of a rigid length of tube, usually with a ball-check valve at the bottom. A line is used to lower the bailer into the well and retrieve a volume of water. The three most common types of materials used in making bailers are PVC, Teflon, and stainless steel.

This manual method of purging is best suited to shallow or small-diameter wells. For deep, larger-diameter wells which require evacuation of large volumes of water, other mechanical devices may be more appropriate. Equipment needed will include a clean decontaminated bailer, Teflon-coated wire or nylon line, a sharp knife or wire cutters, and plastic sheeting or other suitable material.

1. Determine the volume of water to be purged as described in Section 4.1.7.2, *Field Preparation*.
2. Lay plastic sheeting, or other suitable material, around the well to prevent contamination of the bailer line with foreign materials.
3. Attach the line to the bailer and slowly lower until the bailer is completely submerged, being careful not to drop the bailer to the water, causing turbulence and the possible loss of volatile-organic contaminants.
4. Pull bailer out ensuring that the line either falls onto a clean area of plastic sheeting, or is wound onto a clean reel or spool, and never touches the ground.
5. Empty the bailer into a graduated vessel or container of known volume in order to determine the number of bails necessary to achieve the required purge volume.
6. Samples may be periodically collected to determine if field parameters such as pH, temperature, and electrical conductivity have stabilized.
7. Thereafter, pour the water into a container and dispose of purge water as specified in the site specific sampling plan.

4.1.7.3.2 *submersible pump*

Submersible pumps are generally constructed of plastics, rubber, and metal parts, which may affect the analysis of samples for certain trace organics and inorganics. As a consequence, submersible pumps may not be appropriate for some investigations requiring analyses of samples for trace contaminants. However, they are still useful for presample purging in most instances. The pump must have a check valve to prevent water in the pump and the pipe from rushing back into the well.

Submersible pumps generally use one of two types of power supplies, either electric or compressed gas or air. Electric-powered pumps may run off a 12 volt DC rechargeable battery or a 110/120 volt AC power supply. Those units powered by compressed air normally use a small electric or gas-powered air compressor. They may also utilize compressed gas (i.e., nitrogen) from bottles. Different size pumps are available for different depth or diameter monitoring wells.

1. Determine the volume of water to be purged as described in Section 4.1.7.2, *Field Preparation*.

2. Lay plastic sheeting, or other suitable material, around the well to prevent contamination of pumps, hoses, or lines with foreign materials.

3. Assemble pump, hoses, and any safety cables, and lower the pump into the well. Make sure the pump is deep enough so that it stays submerged during pumping. Running the pump without water around it may cause damage.

4. Attach flow meter to the outlet hose to measure the volume of water purged or use a graduated vessel to determine the flow rate.

5. Use a ground fault circuit interrupter or ground the generator to avoid possible electric shock.

6. Attach power supply, and purge well until specified volume of water has been evacuated (or until field parameters, such as temperature, pH, conductivity, etc., have stabilized). Do not allow the pump to run dry. If the pumping rate exceeds the well-recharge rate, lower the pump farther into the well or decrease the pumping rate and continue pumping.

7. Collect and dispose of purge waters as specified in the site specific sampling plan.

4.1.7.3.3 *noncontact gas bladder pump*

For this procedure, an all stainless steel and Teflon bladder pump is used to provide the least amount of material interference to the sample (Barcelona and others, 1984). Water comes into contact with the inside of the Teflon bladder and the Teflon sample tubing that may be dedicated to each well. Some wells may have permanently installed bladder pumps that will be used to sample for all parameters.

1. Assemble Teflon tubing, pump, and control box.

2. The procedure for purging with a bladder pump is the same as for a submersible pump as described in Section 7.3.2.1.

3. Be sure to adjust flow rate to prevent violent jolting of the hose as sample is drawn in.

4.1.7.3.4 *suction pump*

There are many different types of suction pumps. They include:

- Centrifugal
- Peristaltic
- Diaphragm.

Diaphragm pumps can be used for well evacuation at a fast pumping rate and sampling at a low pumping rate. The peristaltic pump is a low volume pump that uses rollers to squeeze the flexible tubing thereby creating suction. This tubing can be dedicated to a well to prevent cross contamination. Peristaltic pumps, however, require a power source.

1. Assembly of the pump, tubing, and power source if necessary.

2. Procedure for purging with a suction pump is the same as for a submersible pump as described in Section 7.3.2.1.

4.1.7.3.5 *inertia pump*

Inertia pumps are generally manually operated, although some are motorized. They are most appropriate to use when wells are too deep to bail by hand or too narrow (or inaccessible) to warrant an automatic (i.e., submersible) pump. Inertia pumps are generally made of plastic and may be either decontaminated or discarded.

1. Determine the volume of water to be purged as described in Section 4.1.7.2, *Field Preparation*.
2. Lay plastic sheeting, or other suitable material, around the well to prevent contamination of pumps or hoses with foreign materials.
3. Assemble pump and lower to the appropriate depth in the well.
4. Begin pumping, discharging water into a 5-gallon pail (or other graduated vessel). Purge until specified volume of water has been evacuated (or until field parameters such as temperature, pH, conductivity, etc., have stabilized).
5. Collect and dispose of purge waters as specified in the site specific project plan.

4.1.7.3.6 *air-lift pump*

An air lift purging device uses compressed air that mixes with the water in the well. This air/water mixture is lighter than the water in the well; therefore, this air/water mixture is driven out of the top of the well.

This method of purging requires a gas or electric-driven compressor and an air- storage tank. Flexible tubing (preferably Teflon) with an in-line air filter is also required.

1. Determine the volume of water to be purged as described in Section 4.1.7.2, *Field Preparation*.
2. Lay plastic sheeting, or other suitable material, around the well to prevent contamination of hoses or lines with foreign materials.
3. Assemble all hoses and safety cables and lower the perforated end of the hose into the well. Make sure that the hose remains a minimum of 10 feet above the well screen to prevent aeration of the well screen.

4. Open the valve on the compressor tank and begin purging water.
5. Adjust the pressure in the compressor tank to achieve the desired flow rate.
6. Periodically collect samples to determine if field parameters have stabilized.
7. Collect and dispose of purge waters as specified in the site specific sampling plan.

4.1.7.4 *Sampling*

There are several factors to take into consideration when choosing a sampling device. Care should be taken when reviewing the advantages or disadvantages of any one device. It may be appropriate to use a different device to sample than that which was used to purge. A common example of this is the use of a submersible pump to purge and a bailer to sample.

4.1.7.4.1 *bailer*

The positive displacement volatile sampling bailer is perhaps the most appropriate for collection of water samples for volatile analysis. Other bailer types (messenger, bottom fill, etc.) are less desirable, but may be mandated by cost and site conditions.

1. Surround the monitoring well with clean plastic sheeting or other suitable material.
2. Assemble and label appropriate sample containers.
3. Attach a line to a clean decontaminated bailer.
4. Lower the bailer slowly and gently into the well, taking care not to shake the casing side or to splash the bailer into the water. Stop lowering at a point adjacent to the screen.
5. Allow bailer to fill and then slowly and gently retrieve the bailer from the well avoiding contact with the casing, so as not to knock flakes of rust or other foreign materials into the bailer.
6. Remove the cap from the sample container and place it in a location where it won't become contaminated.
7. Begin slowly pouring from the bailer into the prelabeled sample container or filtering device.

8. Filter and preserve samples if required by sampling plan.
9. Cap the sample container tightly and place prelabeled sample container in a carrier.
10. Replace the well cap.
11. Log all samples in the site logbook.
12. Package samples and complete necessary paperwork.
13. Transport sample to decontamination zone and prepare for transport to analytical laboratory.

4.1.7.4.2 *submersible pump*

Although it is recommended that some water samples not be collected with a submersible pump due to the reasons stated in previous sections, there are many situations where they may be used.

1. Allow the monitor well to recharge after purging, keeping the pump just above screened section.
2. Attach gate valve (or other flow control device) to hose (if not already fitted), and reduce flow of water to a manageable sampling rate (several hundred milliliters per minute is preferred).
3. Assemble and label the appropriate sample containers.
4. If no gate valve or other flow-control device is available, run the water down the side of a clean jar and fill the sample containers from the jar.
5. Fill the prelabeled sample container, cap it tightly, and place it in a carrier.
6. Replace the well cap.
7. Log all samples in the site logbook and on the field-data sheets and label all samples.
8. Package samples and complete necessary paperwork.

9. Transport sample to decontamination zone and prepare for transport to the analytical laboratory.

10. Upon completion, remove pump and assembly and fully decontaminate prior to setting into the next sample well. Dedicate the tubing to the hole.

4.1.7.4.3 *noncontact gas bladder pump*

The use of a noncontact gas positive displacement bladder pump is often mandated by the use of dedicated pumps installed in wells. They are somewhat difficult to clean, but may be used with dedicated sample tubing to avoid cleaning. They may be operated at variable flow and pressure rates making them ideal for both purging and sampling.

Barcelona and others (1984) and Nielsen and Yeates (1985) report that the noncontact gas positive displacement pumps cause the least amount of alteration in sample integrity as compared to other sample retrieval methods.

1. Allow well to recharge after purging.

2. If the bladder pump is not dedicated to the well to be sampled, a clean bladder pump must be lowered into the appropriate interval of the well.

3. Assemble and label the appropriate sample containers.

4. Turn pump on, increase the cycle time and reduce the pressure to the minimum that will allow the sample to come to the surface.

5. Fill the prelabeled sample container, cap it tightly, and place it in a carrier.

6. Replace the well cap.

7. Log all samples in the site logbook and on field-data sheets and label all samples.

8. Package samples and complete necessary paperwork.

9. Transport sample to decontamination zone and prepare for transport to analytical laboratory.

10. On completion, remove the tubing from the well and either replace the Teflon tubing and bladder with new dedicated tubing and bladder or rigorously decontaminate the existing materials.
11. Unfiltered samples shall be collected directly from the outlet tubing into the sample container.

12. For filtered samples, connect the pump outlet tubing directly to the filter unit. The pump pressure should remain decreased so that the pressure does not build up on the filter and blow out the pump bladder or displace the filter.

4.1.7.4.4 *inertia pump*

Inertia pumps may be used to collect samples. It is more common, however, to purge with these pumps and sample with a bailer as described in Section 7.4.1.

1. Following well evacuation, allow the well to recharge.

2. Assemble and label the appropriate sample containers.

3. Since these pumps are generally manually operated, the flow rate may be regulated by the sampler. The sample may be discharged from the pump outlet directly into the appropriate sample container.

4. Fill the prelabeled sample container, cap it tightly, and place it in a carrier.

5. Replace the well cap.

6. Log all samples in the site logbook and on field-data sheets and label all samples.

7. Package samples and complete necessary paperwork.

8. Transport sample to decontamination zone and prepare for transport to the analytical laboratory.

9. Upon completion, remove pump and decontaminate or discard, as appropriate.

4.1.7.5 *Post Operation*

After all samples from a well are collected and preserved, the sampling equipment should be decontaminated prior to sampling another well to prevent cross contamination of equipment and monitor wells between locations.

1. Decontaminate all equipment in the field, if appropriate.

2. Replace sampling equipment in storage containers.

3. Prepare and transport water samples to the laboratory. Check sample documentation and make sure samples are properly packed for shipment.

4.1.7.6 *Special Considerations for Volatile Organic Compound Sampling*

The proper collection of a sample for volatile-organic compounds requires minimal disturbance of the sample to limit volatilization and therefore a minimal loss of volatiles from the sample.

Sample-retrieval systems suitable for the valid collection of samples for volatile-organic analysis are: positive displacement bladder pumps, gear driven submersible pumps, syringe samplers and bailers (Barcelona and others, 1984; Nielsen and Yeates, 1985). Field conditions and other constraints will limit the choice of appropriate systems. The focus of concern must be to provide a valid sample for analysis, one which has been subjected to the least amount of turbulence possible.

The following procedures should be followed:

Open the vial, set cap in a clean place, and collect the sample. When collecting duplicates, collect both samples at the same time.

Fill the vial to just overflowing. Do not rinse the vial or excessively overflow it. There should be a convex meniscus on the top of the vial.

Check that the cap has not been contaminated (splashed) and carefully cap the vial. Place the cap directly over the top and screw down firmly. Do not over tighten and break the cap.

Invert the vial and tap gently. Observe vial for at least 10 seconds. If an air bubble appears, discard the sample and begin again. It is imperative that no entrapped air is in the sample vial.
Immediately place the vial in the protective foam sleeve and place into the cooler.

Samples should be shipped or delivered to the laboratory daily so as not to exceed the holding time or recommended storage temperature.

4.1.8 Calculations

To calculate the water volume of a well (in gallons of water per foot of casing), utilize the following equation:

$$\text{Water volume} = \Pi r^2 h \text{ (cf)} \qquad \text{[Equation 1]}$$

where: Π = pi (approximately 3.14)
r = radius of monitoring well (feet)
h = height of the water column (feet) [This may be determined by subtracting the depth to water from the total depth of the well as measured from the same reference point.]
cf = conversion factor (gal/ft^3) = 7.48 gal/ft^3 [In this equation, 7.48 gal/ft^3 is the necessary conversion factor.]

If the diameter of the monitor well is known, there are a number of standard conversion factors which can be used to simplify the equation above.

The volume, in gallons per linear foot, for various standard monitor well diameters can be calculated as follows:

$$\text{volume (in gal/ft)} = \Pi r^2 \text{ (cf)} \qquad \text{[Equation 2]}$$

where: Π = pi (approximately 3.14)
r = radius of monitoring well (feet)
cf = conversion factor (7.48 gal/ft^3)

For a 2-inch diameter well, the volume per linear foot can be calculated as follows:

$$\begin{aligned} \text{volume (in gal/ft)} &= \Pi r^2 \text{ (cf)} \qquad \text{[Equation 2]} \\ &= 3.14\ (1/12\ \text{ft})^2\ 7.48\ \text{gal/ft}^3 \\ &= 0.1632\ \text{gal/ft} \end{aligned}$$

Remember that the well diameter in inches must be converted to a radius in feet in order to use the equation. Some examples of volumes in gallons per linear foot for some different well diameters are listed below.

Well diameter	2 inches	3 inches	4 inches	6 inches
Approximate Volume (gal/ft.)	0.1632	0.3672	0.6528	1.4688

If volumes in gallons per foot, such as those listed above, are utilized, then Equation 1 should be modified as follows:

Water volume = (h) volume (in gal/ft) [Equation 3]

where: h = height of water column (feet)

The water volume of a well casing is typically tripled to determine the volume to be purged.

4.1.9 Quality Assurance/Quality Control

There are no specific quality assurance (QA) activities which apply to the implementation of these procedures. However, the following general QA procedures apply:

- All data must be documented within site logbooks.
- All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and they must be documented.
- The collection of rinsate blanks is recommended to evaluate potential for cross contamination from or between the purging and/or sampling equipment.
- Trip blanks are required if analytical parameters include volatile-organic compounds.
- All equipment which is to be reused must be decontaminated as described in section 3.4.

4.1.10 Data Validation

Results of quality-control samples will be evaluated by lab personnel and the project leader. This information will be utilized to qualify the sample results in accordance with the project's data-quality objectives.

4.1.11 Health and Safety

When working with potentially hazardous materials, follow U.S. Environmental Protection Agency (U.S. EPA), Occupational Safety and Health Administration (OSHA), or corporate health and safety guidelines. More specifically, depending upon the site specific contaminants, various protective programs must be implemented prior to sampling the first well. The site health and safety plan should be reviewed with specific emphasis placed on the protection program planned for the well-sampling tasks. Standard safe operating practices should be followed such as minimizing contact with potential contaminants in both the vapor phase and liquid matrix through the use of respirators and disposable clothing.

When working around volatile organic contaminants:

- Avoid breathing constituents venting from the well.
- Survey the well headspace with a flame-ionization detector (FID) or photo-ionization detector (PID) prior to sampling.
- If monitoring results indicate organic constituents, sampling activities may be conducted in protective clothing. At a minimum, skin protection will be afforded by disposable protective clothing.

Physical hazards associated with well sampling include:

- Lifting injuries associated with pump and bailers retrieval; moving equipment.
- Cuts associated with the use of pocket knives for cutting discharge hose, etc.
- Heat/cold stress as a result of exposure to extreme temperatures and because of protective clothing.
- Situations conducive to slipping, tripping, or falling as a result of wet or icy conditions.

- Electrical shock associated with use of submersible pumps is possible. Use a ground fault circuit interrupter or a copper grounding stake to avoid this problem.

- Acid burns may occur if acid preservatives are mishandled.

- Long-term exposure to hazardous chemicals found at many sites of investigation may pose a health hazard, especially if proper protective clothing is not worn.

4.2 Surface Water

Surface water samples will potentially be collected from excavations, streams, creeks, rivers, or lakes. Protocols for surface water sampling are identical to groundwater sampling, with the exception of the well purging process.

5.0 Drilling And Monitoring Well Installation

5.1 Preparatory Methods

Monitoring wells in Colorado must be adapted to a number of purposes in widely varying local geologic and hydrologic conditions. Consequently, there is no ideal monitoring well installation method. The planning, selection, and implementation of any monitoring well installation program should include the following:

- Review of existing data on site geology and hydrogeology including Colorado Geological Survey (CGS) and U.S. Geological Survey (USGS) publications and unpublished databases, county soils surveys (available from the county Soil Conservation Service [SCS] offices), air photos, water- quality data, and existing maps available from local, state, or federal agencies. Maps and photos showing historical land uses from local city or county planning agencies and historical societies or groups may also be significant. Every effort should be made to collect and review all applicable field and laboratory data from previous investigations of the project area.

- A visit to the site to observe field geology and potential access problems for a drilling rig, to secure a water supply for drilling (if needed), and to check for hazards to personnel and equipment (such as utilities on and near the site).

- Preparation of site safety plan in compliance with applicable U.S. Environmental Protection Agency (U.S. EPA) and Occupational Safety and Health Administration (OSHA) guidelines.

- Definition of project objectives, selection of drilling, well development, and sampling methods.

- Selection of well-construction materials including well-construction specifications (i.e., casing and screen materials, casing and screen diameter, screen length and interval, and filter pack and screen size).

- Determine need for containing and disposing of potentially contaminated soil and water generated by the monitoring well installation process.

- Preparation of a work plan including site safety plan, definition of objectives and work methods, listing of material and equipment specifications, and plan for disposal/treatment of contaminated materials.

- Preparation and execution of the drilling contract.

- Field implementation of the drilling program.

- Final report preparation including background data, project objective, field procedure, and well-construction data, including well logs and well-construction information. Reports should be prepared according to OIS formats.

All drilling activities must be performed by a contractor licensed by the Colorado State Board of Examiners of Water Well Construction and Pump Installation Contractors, Office of the State Engineer, Colorado Department of Natural Resources, Water Resources Division (303-866-3581). Well construction rules which govern testhole drilling, monitoring well drilling, and other drilling related to water resources are available from the Water Resources Division. The driller must apply for a variance if the planned monitoring wells will not meet the water well construction rules (2 CCR 402-2).

5.2 Drilling Methods

Monitoring wells may be constructed in holes drilled by any of several methods. The most commonly used drilling methods are:

- Hollow-stem auger
- Direct push
- Reverse-air rotary

The type of equipment used depends upon the site geology, hydrology, equipment available, and monitoring design. Control of cuttings and other potentially contaminated materials at the drill site may influence drilling method selection. Depending upon equipment availability and site geology, more than one method may be combined to complete a particular monitoring well installation. A discussion of each method is presented below.

5.2.1 Hollow-Stem Auger

Hollow stem auger drilling uses large diameter (up to 14-inch outside diameter [OD]) continuous-flight augers which mechanically excavate drilled materials from the hole. These augers are built with a large (up to 10.25-inch inside diameter [ID]) axial opening to allow access to the bottom of the hole without withdrawing the auger string. The augers act as temporary casing during and at the completion of drilling to facilitate the sampling of sediment and water and the installation of monitoring wells.

Some advantages of hollow stem auger drilling often make it the preferred method of installing monitoring wells. Hollow stem auger drilling is relatively rapid, especially in shallow applications in poorly lithified to unlithified sediments. Little or no outside fluid is required in the drilling process. Though a relatively large volume of cuttings are generated, they are normally easily contained. The volume of effluent, resulting from well-development efforts and requiring disposal, is normally lower than with some methods, notably mud rotary. Hollow stem auger drilling readily supports thin-wall and split-tube sampling in poorly lithified sediments.

There are some disadvantages and limitations to the use of the hollow stem auger method in the construction of monitoring wells. It is limited to drilling in poorly lithified to unlithified sediments and to a maximum depth of about 150 feet. Shallow bedrock or other hard-to-drill materials may reduce this depth significantly. Hollow-stem augers are prone to cross contamination of fluids within the bore hole along the large annular space around the auger tubing. High hydrostatic pressures in the bore hole can cause problems with sand heaving up into the augers during sampling and well-installation procedures. Wide variations in bore-hole size, common to auger drilling in poorly cohesive sediments, may complicate effective sealing of the annular space during monitoring-well installation. The design of hollow-stem augers produce an approximately 1-inch thick rind of smeared cuttings which may effectively seal the bore-hole walls in clayey sediments. This rind may interfere with the flow of fluids to the monitoring well.

U.S. Environmental Protection Agency guidelines (U.S. Environmental Protection Agency, 1986, 1987) recommend that hollow-stem auger inside diameters be 3 to 5 inches greater than the outer diameter of well casings to allow effective placement of filter and sealing materials. Ideally, 2-inch diameter monitoring wells should therefore be installed within 5.5 inch ID or larger hollow-stem augers.

5.2.2 Direct Push

The direct push drilling method refers to tools and sensors that are "pushed" into the ground without the use of conventional rotating drilling mechanisms to remove soil or to make a path for the tool. Direct push drilling utilizes a hydraulically-powered percussion/probing machine designed to obtain continuous soil cores or discrete soil samples to depths of 30 to 60 feet. Rigs rely on a relatively small amount of static (vehicle) weight combined with percussion as the energy for advancement of a tool string. Samplers can be driven to obtain groundwater samples or vapor samples, and install permanent sampling implants. Small diameter monitoring wells and air sparging points can also be installed.

Some of the benefits to the direct push method are as follows:

- No cuttings are produced during the sampling process.
- Probing is fast; typical penetration rates are from 5 to 25 feet (2 to 8 m) per minute.
- Mobilization is quick and economical.
- Rapid sampling process.
- Probing machines are easy to operate and relatively simple to maintain.
- Probing tools create small diameter holes which minimize surface and subsurface disturbance.
- Labor requirements are much less than for conventional drilling.

5.2.3 Reverse-Air Rotary

The reverse air rotary method operates by the same general principles as direct-mud rotary except that compressed air is pumped down the drill rods and returns with the drill cuttings up through the annulus. The reverse air rotary method is best suited to drilling in relatively stable to consolidated formations. Casing is sometimes used to prevent caving in poorly consolidated formations.

Reverse air rotary drilling is a very fast and efficient means of drilling. Rigs that are properly equipped and staffed can drill several hundred feet of hole per day. Sediment sampling is supported both in poorly lithified materials (by split-barrel samplers) and in consolidated rock (by coring). Reverse air rotary drilling supports the telescoping of casings to successively smaller sizes to isolate drilled intervals and protect lower geologic units from contamination by previously drilled contaminated upper sediments. Reverse air rotary rigs are sometimes fitted with a casing driver to overcome bore hole instability problems in unconsolidated sediments. When so equipped, reverse air rotary rigs minimize the potential for interaquifer contamination. Reverse air rotary rigs are available at several locations in the state.

Introduction of air to groundwater could interfere with chemical analyses primarily by oxidation and by vigorous agitation and mixing. Concentrations of volatile contaminants are very likely to be reduced in groundwater adjacent to holes drilled using the reverse air rotary method. The air discharged from air compressors normally contain finely atomized lubricating oil. To help prevent this oil from contaminating monitoring well drill holes, compressor discharge filters must be installed (and maintained during regular intervals) on rigs used to drill monitoring wells. Cuttings above the water table are usually very fine and hard to interpret. Also, the drying effect of the air in the annulus may reduce or eliminate any natural moisture in the cuttings, thereby masking low yield water producing zones. Conversely, when high-yield aquifers are encountered, large volumes of water may be produced during drilling, a definite disadvantage if the water is contaminated and requires special handling and disposal.

When reverse air rotary methods are used, hole diameters should be 3 to 5 inches larger than the outer diameter of the well casings to allow effective placement of filter and sealing materials. Two-inch diameter monitoring wells should therefore be installed within 5.5-inch diameter or larger holes.

5.3 Field Equipment

Verify that the drilling contractor will arrive onsite with all proper and operational equipment for the drilling program outlined in the work plan and contract. OIS recommends that field oversight personnel bring the following equipment to the site:

- Soil boring log forms.
- Organic Vapor Meter (PID or FID).
- Ruler and other measuring apparatus for verifying borehole depths, water levels, and equipment dimensions.

- All required health and safety gear (e.g., hard hat, steel-toed boots, hearing and eye protection); refer to applicable OSHA and U.S. EPA guidance documents.

- Contaminant detection equipment appropriate with information derived during the program planning stage and in the site-safety plan.

- Sample collection containers, sealable plastic bags (quart and gallon sizes), or other containers, as appropriate.

- Trowels, knives, hammers, chisels, as appropriate.

- Description aids (Munsell-color charts, grain-size charts, etc.) as appropriate.

5.4 Procedures

5.4.1 Drilling Equipment Cleaning and Decontamination

Prior to mobilization, the drill rig and all associated equipment should be thoroughly cleaned to remove all oil, grease, mud, etc. Any equipment that is not required at the site should be removed from the rig prior to entering the site. To the greatest extent possible, drilling should proceed from the least to most contaminated sections of the work site.

Before drilling each boring, all the down-the-hole drill equipment, the rig, and other equipment (as necessary) should be steam cleaned, or cleaned using high-pressure hot water, and rinsed with pressurized potable water to minimize cross contamination, if appropriate. Special attention should be given to the thread section of the casings and to the drill rods. Additional cleaning may be necessary during the drilling of individual holes to minimize the carrying of contaminated materials from shallow to deeper strata by contaminated equipment.

Equipment with porous surfaces, such as rope, cloth hoses, and wooden blocks or tool handles cannot be thoroughly decontaminated. These should be disposed of properly at appropriate intervals. These intervals may be the duration of drilling at the site, between individual wells, or between stages of drilling a single well, depending upon characteristics of the tools, site contamination, and other considerations.

Cleaned equipment should not be handled with soiled gloves. Surgical gloves, new clean cotton work gloves, or other appropriate gloves should be used and disposed of when even slightly soiled.

All drilling equipment should be steam cleaned or cleaned using high-pressure hot water, if appropriate, at completion of the project to ensure that no contamination is transported from the sampling site.

5.4.2 Field Recording and Logging

Lithologic description and all field measurements and comments are to be recorded on the well-log form. OIS recommends that the following data be recorded on the well-log form:

- Name and complete mailing address of the site.
- Legal description of the well location.
- Completion date.
- Driller's log of geologic formations (and description thereof) plus any geophysical logs collected.
- Well depth.
- Depth to static-water level.
- Size of the drill hole and method of drilling.
- Length, depth, and size of the casing; changes in size of the casing and type of casing.
- The amount, type, slurry weight, and location of grout used in the hole.
- A narrative description of the grouting procedure.
- The length of the screen or casing perforations.
- The location of the top and bottom of the screen, the top and bottom of the aquifer, and the location of multiple screens.
- The screen slot or perforation size.
- The gravel pack and its volume, type, or size.
- Well-test data that include specific capacity, static-water level, flow, shut-in pressure, or pump-test data, if available.

In addition, the well-log form should identify the datum from which well measurements are made, the depth of the drilled hole, and the height of riser pipe above the ground. The datum should be a bench mark whenever possible or a permanent structure. Monitoring wells should not be used as datum points for other monitoring wells except at sites were no other points are available.

5.5 Monitoring Well Installation

5.5.1 Well-Construction Materials

The most commonly used casing materials include polyvinyl chloride (PVC), stainless steel, and Teflon. Monitor-well casing and screen materials should be selected to be structurally competent to withstand any mechanical, hydrodynamic, or chemical stresses anticipated to be present on the site. The casings should preclude the movement of fluids into the well bore except where intended by the well designer.

All well-construction materials must be new, steam cleaned or cleaned using high-pressure hot water, if appropriate, and protected from contamination at the well site. Well-site safeguards should include keeping all materials covered with plastic sheeting, off the ground, and ensuring that they are touched only with clean tools and gloves. Equipment or materials to be inserted into the bore hole must not be allowed to touch the ground.

Monitoring-well casing and screen must be of sufficient diameter to achieve the purposes of the well. Normal sampling operations typically require casing which has an inside diameter greater than or equal to 2 inches, though some well-monitoring apparatus may require much larger casing. Additional criteria are drilling method used, well depth (strength requirements), well-development requirements (contaminated-water disposal), presampling well purging volumes (contaminated-water disposal), rate of recovery, and costs.

Mechanical and hydrodynamic stability of monitoring-well casing and screens are generally measured in terms of "collapse strength," or the ability of the casing to maintain its cylindrical shape during and after installation. American Society for Testing and Materials standard F 480 (American Society for Testing and Materials, 1989) should be consulted for aid in specifying casing materials.

The possibility of casing collapse can be minimized by attention to some important installation method details:

- The drilling of a straight, smooth bore hole.
- The slow, even introduction of filter-pack materials.
- The control of grout temperature during the sealing of the annular space around PVC casing.
- The balance of hydrostatic pressures between the inside and outside of the well during installation and development.

5.5.2 Casing Joining Methods

A variety of methods are available for joining individual lengths of casing and screen to form a completed monitoring-well string. Heat welding, solvent welding, joining by metal fasteners such as rivets, tacks or screws, threaded and coupled, and flush-joint threaded couplings are available.

Heat welding, solvent welding, and metal fasteners are normally rejected because each process may contribute to interferences with water-chemistry analyses. The cements used in solvent welding of plastic casing materials are organic solvents which can have a major long-term effect upon samples analyzed for organic constituents. The casing materials themselves are mobilized in heat welding of thermoplastics or metals. Casing joined with metal fasteners are prone to leakage and resultant cross contamination between different parts of the well. The metals used in the fabrication of the fasteners are prone to corrosion and subsequent interference with water-chemical analyses.

Threaded and coupled pipe construction is discouraged because the uneven outer diameter creates problems with filter pack and annular seal placement. Monitoring well annular seals may be affected sufficiently by external upset couplings to promote water migration along the outer casing wall (U.S. Environmental Protection Agency, 1991).

All monitoring-well joints must be water tight. Some flush joint casing manufacturers provide o-ring joint seals only as an option. The failure to obtain and install these optional o-rings may result in joint leakage. The field oversight personnel must ensure that all casing joints are properly constructed and sealed, including o-ring installation.

5.5.3 Monitoring Well Intake Structures

The selection of monitoring well screen materials (PVC, Teflon, stainless steel or others) are governed by the previously mentioned considerations. The selection of well screens must place additional emphasis upon structural strength because the openings of the structure inherently weaken it in comparison to casing. Screens are also typically placed at the bottom of a well where collapse stresses are at a maximum.

The primary function of well-intake structures is to allow water and other underground fluids to flow into the well while holding the surrounding sediments in place. The width of the openings must be tightly controlled and designed to reflect filter pack and formation characteristics. Well screens or casings should have openings which are sawed, drilled, punched, rolled, welded, stamped, or made by any means which will control the size of the openings. Screens should be sized to retain 90 percent of the filter-pack material. Screens within naturally developed filter packs must be sized to retain 50 percent of the aquifer material. Commercially manufactured well intakes are recommended because stricter quality control is normally achieved in the factory setting. Additionally, the process of cutting or drilling openings in casing at the drill site is discouraged because it produces fresh-cut surfaces prone to leaching for a time after fabrication.

Monitoring well screen length is also a variable worthy of some consideration in well design. Most monitoring wells function as both fluid-sampling points and as a piezometer. Monitoring-well intakes are normally from 2 to 10 feet long. Shorter intakes provide more specific and precise information about vertically distributed water quality, hydraulic head, and flow. If the objective of the well is to monitor for the gross presence of contaminants in an aquifer, a longer intake may be appropriate. However, long intakes may cause a dilution of depth-specific contaminants during sampling, and thereby provide inaccurate data on the nature of aquifer contamination.

Monitoring wells installed in unconfined aquifers for the purpose of monitoring light non-aqueous phase liquids (LNAPLs) must extend above the top of the water table. Water-table fluctuations should be considered when designing wells to intersect the top of water-table aquifers.

5.5.4 Filter Pack

The annular space between the well screen and the borehole wall is often filled with uniform gravel/sand media to serve as a filter pack. The driller shall ensure that all well construction materials, including gravel pack, are clean and sanitary prior to placement. Monitoring well filter pack must be chemically inert and composed primarily of clean quartz sand or glass beads. The filter pack should contain less than 5 percent of nonsiliceous material and be free of claystone and carbonaceous debris. The individual grains should be well rounded. The reader is referred to U.S. Environmental Protection Agency (1991), Driscoll (1986), or U.S. Environmental Protection Agency (1975) for guidance on selecting optimum filter pack grain size.

The annular space of the well along the entire screened interval must be filled to at least 1 foot above the top of the screen. The depth to the top of the filter pack should be probed, verifying the thickness of the sand pack. Additional filter pack may sometimes be required to compensate for additional settling of the filter pack after emplacement. Under no circumstances should the filter pack extend into any aquifer other than the one to be monitored. In most cases, the well design can be modified to allow for a sufficient filter pack without threat of cross flow between producing zones through the filter pack.

In materials that will not maintain an open hole, the hollow-stem auger or temporary casing is withdrawn gradually during placement of the filter pack and grout to the extent practical.

5.5.5 Annular Seal

The materials used to seal the annular space must prevent the migration of contaminants to the sampling zone from the surface or intermediate zones and prevent cross contamination between strata. The materials should be chemically compatible with the anticipated waste to ensure seal integrity during the life of the monitoring well and chemically inert so they do not affect the quality of the groundwater samples. An annular seal consisting of a minimum of two feet of coarse-granular, chipped or pelletized bentonite installed above the filter pack is appropriate for most monitoring wells. This seal is to prevent grout infiltration into the filter pack and the well screen.

5.5.6 Cement-Bentonite Grout

Water used in making cement grout must be clean and may not contain oil or other organic material. The cement grouting of the well casing must be completed in one continuous operation. Bentonite may be added to cement grout.

Care should be exercised to prevent bore hole sealing materials from entering the well bore. A cap placed over the top of the well casing before beginning the sealing process will prevent this.

Additional grout may be added to compensate for the removal of any hollow-stem augers or temporary casing and the tremie pipe.

5.5.7 Protective Casing

5.5.7.1 *At-Grade Completion*

Wells completed at-grade should include the following features:

- A protective cover or street box that is traffic rated with a steel skirt submerged in concrete. The protective cover should include a gasket to prevent the entry of surface waters into the wellhead.

- A locking cap with padlock installed on the top of the well casing to prevent unauthorized access the well.

5.5.7.2 *Above-Ground Completion*

A protective casing is installed around all monitor wells. Exceptions are on a case-by-case basis. The minimum elements in the protection design include:

- A protective steel cap to keep precipitation out of the protective casing, secured to the casing by padlock.

- A 5-foot-minimum length of metal tubing, extending about 1.5 to 3 feet above the ground surface, and set in cement grout. The tubing may be circular, square, or rectangular. The tubing size should be large enough to allow easy placement over the well. A 0.5-inch drain hole in the tubing near ground level is recommended.

- The installation of guard posts in addition to the protective casing in areas where vehicle traffic may pose a hazard. These guard posts may consist of 3-inch diameter steel posts or tee-bar driven steel posts. Groups of three are radially located around each well. Wells constructed in road ditches should be protected by installing a minimum of two steel posts around the well.

5.6 Well Development

All monitoring wells should be developed to create an effective filter pack around the well screen, to rectify damage to the formation caused by drilling to remove fine particles from the formation near the borehole, and to assist in restoring natural water quality of the aquifer in the vicinity of the well. Development stresses the formation around the screen, as well as the filter pack, so that mobile fines silts, and clays are pulled into the well and removed. The process of developing a well creates a graded filter pack around the well screen. Development is also used to remove any foreign materials (drilling water, muds, etc.) that may have been introduced into the well borehole during drilling and well installation and to aid in the equilibration that will occur between the filter pack, well casing, and the formation water.

The commonly accepted methods for developing wells are bailing, pumping and overpumping, and surging with a surge block.

6.0 Pilot Testing

6.1 Pilot Tests for Remedial Alternatives

A pilot test should be used to decide whether or not the most economically feasible technology is also technologically feasible. Past experience with similar systems may not be considered adequate justification for implementing a proposed remedial technology. Derived data from another site may be substituted only in the instances where another site is in close proximity and the geologic and hydrologic conditions are similar.

6.1.1 Requirements for Soil Vapor Extraction Pilot Studies

The purpose of this section is to provide general guidelines for the performance of Soil Vapor Extraction pilot studies. It is not the purpose to provide site specific technical procedures but rather to provide a framework from which to operate when performing the studies. Although discussion in this document is limited to the performance of soil vapor extraction pilot studies, the same general framework should apply to the performance of air sparging pilot studies, air sparging/soil vapor extraction pilot studies, and biosparging/bioventing pilot studies.

Before initiating work on a soil vapor extraction pilot study previous assessment work at the site must indicate that the technology is appropriate and feasible.

The following presents a brief description of the components of a soil vapor extraction pilot study once the above criteria has been met.

Establish flow rates at the pilot study soil vapor extraction well for a given applied well-head vacuum. This can be accomplished using a stepped applied vacuum technique. The test is typically initiated by applying 5 inches of water column vacuum at the soil vapor extraction well and recording the corresponding flow rate. The vacuum is typically increased in increments of 5 inches of water column until the blower's maximum output is reached. The applied vacuum and achieved flow rates should be recorded at each step. The water level at the soil vapor extraction well should also be monitored at each step.

Establish the radius of influence for the soil vapor extraction well. This can be accomplished using a constant applied vacuum technique. The constant applied vacuum test should be performed using at least two different vacuums/flow rates using data obtained from the stepped applied vacuum test. For example, if two vacuums/flow rates are desired for the constant applied vacuum test, use the vacuum/flow rate achieved when the blower was operating at approximately one-half of its maximum output during the stepped applied vacuum test and the vacuum/flow rate achieved when the blower was operating at its approximate maximum output during the stepped applied vacuum test as the first and second vacuums/flow rates, respectively, for the constant applied vacuum test. The constant applied vacuum test should be performed for a minimum period of 2-4 hours per vacuum/flow rate. Vacuum measurements should be taken at the observation wells, and water levels; vacuum measurements and flow rate measurements should be taken at the soil vapor extraction well. Measurements should be taken every 15 minutes for the first hour of the study then every 30 minutes for the duration of that portion of the test.

Establish the potential for hydrocarbon recovery from the vadose zone soils at the site. This can be accomplished by obtaining samples of the soil vapor extraction effluent during the constant applied vacuum portion of the pilot study. The sample should be screened in the field for the presence and concentration of organic vapors, carbon dioxide, percent oxygen and percent of the lower explosive limit. The effluent should also be analyzed in the laboratory for the presence and concentration of total petroleum hydrocarbons as gasoline and benzene, toluene, ethylbenzene and xylenes by gas chromatograph/flame ionization detector/photo ionization detector (NIOSH 1500 or equivalent for total petroleum hydrocarbons and NIOSH 1501 or equivalent for benzene, toluene, ethylbenzene and xylenes).

The findings of the pilot study along with recommendations regarding the feasibility of soil vapor extraction as a remedial alternative for the site should be presented in the CAP. If it is determined that soil vapor extraction is feasible, the CAP should include information regarding the conceptual design of the remediation system.

- Proposed number and location of soil vapor extraction wells.

- Generalized construction details of the soil vapor extraction wells and associated piping.
- Anticipated well-head vacuums and flow rates and anticipated cumulative flow rate for the system.

- Anticipated horsepower requirements for the soil vapor extraction system blower(s).

- Location of proposed soil vapor extraction blower enclosure.

6.1.2 Requirements for Groundwater Pump and Treat

A pilot test to determine the effectiveness of a pump and treat remedial system can be satisfied by performing a pump test.

6.1.3 Requirements for Natural Attenuation

Natural Attenuation should not be considered for wells containing free product and should be carefully evaluated when utilized for high dissolved phased contamination. Supersaturated contaminant concentrations can be inhibitory to the microbial populations. Size of plume and site specific conditions should be evaluated to determine the contaminant mass. This information should be used to determine if natural attenuation or an alternative technology is more appropriate.

6.1.3.1 *pH*

The majority of microbial populations are most active at a neutral pH. Ground water samples should be collected in one upgradient and one source monitoring well. An acceptable pH range is between 5.5 and 9. The closer the pH is to 7.0 the more optimal the conditions.

6.1.3.2 *Dissolved O_2 Levels*

Minimum acceptable oxygen concentration for natural microbial activity is 0.5 mg/l; however, a higher concentration (2 mg/l is more desirable). Ground water samples should be collected in one upgradient and one source monitoring well.

6.1.3.3 *Dissolved CO_2 Levels*

Increases in carbon dioxide levels should indicate increases in microbial activity. Ground water samples should be collected in one upgradient and one source monitoring well.

6.1.3.4 *Ground Water Temperature*

Microbial activity is usually optimum between temperatures ranging from 7ºC to 17ºC. Cooler ground water temperatures slow metabolic rates of bacteria. For every 10ºdecrease in temperature a 50% reduction in microbial activity occurs. Higher temperatures promote faster degradation and bacterial expansion. While ground water, at four feet below grade, maintains a constant temperature, ground water at zero to four feet may be affected in colder regions of the country during winter months.

6.1.4 Oxygen Enhanced Bioremediation

Oxygen Enhanced Bioremediation should not be considered for wells containing free product and should be carefully evaluated when utilized for high dissolved phased contamination. Supersaturated contaminant concentrations can be inhibitory to the microbial populations. In addition, if microbial populations are present in these conditions, the addition of oxygen generated can be spent too quickly and be cost prohibitive. Size of plume and site specific conditions should be evaluated to determine the contaminant mass, this information should be used to determine if oxygen enhanced bioremediation or an alternative technology is more appropriate.

6.1.4.1 *Chemical Oxygen Demand (COD)*

The COD test is a useful tool to identify oxygen demand “hot spots”, which are areas that may consume oxygen at an above average rate.

6.1.4.2 *pH*

The majority of microbial populations are most active at a neutral pH. Ground water samples should be collected in one upgradient and one source monitoring well. An acceptable pH range is between 5.5 and 9. The closer the pH is to 7.0 the more optimal the conditions.

6.1.4.3 *Nutrients*

Concentrations of ammonium, nitrates, and/or phosphorous may be limiting factors for microbial activity. Nitrate (NO_3-), like oxygen, can serve as an electron acceptor, so it is important not to add too much and change the balance from aerobic to anoxic to anaerobic depending upon which electron acceptor is most prevalent. When evaluating groundwater conditions in regional areas with high porosity and low sorptive capabilities (e.g., coarse sands, etc.) it may be necessary to determine whether oxygen is the only limiting factor.

6.1.4.4 *Dissolved O_2 Levels*

Minimum acceptable oxygen concentration for natural microbial activity is 0.5 mg/l; however, a higher concentration (2 mg/l is more desirable). Ground water samples should be collected in one upgradient and one source monitoring well.

6.1.4.5 *Dissolved CO_2 Levels*

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Microbial activity is usually optimum between temperatures ranging from 7ºC to 17ºC. Cooler ground water temperatures slow metabolic rates of bacteria. For every 10? decrease in temperature a 50% reduction in microbial activity occurs. Higher temperatures promote faster degradation and bacterial expansion. While ground water, at four feet below grade, maintains a constant temperature, ground water at zero to four feet may be affected in colder regions of the country during winter months.

6.1.4.7 *Iron*

Iron (Fe), like manganese, is inorganic and can create an additional oxygen demand. For every 7 parts of Fe (molecular weight of Fe is 56) it requires one part of O_2 (molecular weight of O_2 is 8). Typically when iron is present in ground water, an additional oxygen demand factor of 1 to 2 should be added. There may be upper limits to iron concentrations ($\geq$ 300 ppm) which may preclude the efficiency of oxygen enhanced bioremediation. BTEX concentrations must be in higher concentration then iron. Oxygen can precipitate iron out of the aquifer, which could then clog interstitial pore spaces and alter flow patterns (biofowling). Additional study of these parameters will help determine limitations. This test is necessary in areas suspected to have high iron concentrations. If these conditions exist oxygen enhanced bioremediation may not be the remedial action of choice.

6.1.4.8 *Hydraulic Conductivity*

Low hydraulic conductivity could significantly reduce the migration of oxygen in the surrounding aquifer. High hydraulic conductivity may transport the increased oxygen through the contaminant plume too quickly.

7.0 Monitoring Well and Test-Hole Abandonment

7.1 Plugging of Monitoring Wells or Test Holes in Confined or Multiple Aquifers

Colorado Water Well Construction Rules (contain specific requirements for plugging and abandonment of test holes and wells. Test holes or wells completed into confined aquifers or encountering more than one aquifer must be plugged with bentonite grout if the weight of the bentonite grout column is sufficient to overcome the bottom hole pressure or must be plugged with cement grout placed from the bottom of the well or hole to within eight feet of the ground surface. Cement grout must be placed from eight feet below ground surface to within three feet of the ground surface. The top three feet may be filled with native material. If a pipe cannot be lowered inside the well casing to place grout from the bottom to the top, the well may be plugged by making a tight connection to the top of the casing and pumping a volume of cement grout, sufficient to fill the well, under pressure into the well. If it cannot be verified that a well's casing was grouted in accordance with this chapter, an effort must be made to plug the annulus from the bottom of the annulus up to the ground surface with the same type of material or materials required for plugging inside the casing.

7.2 Plugging of Monitoring Wells or Test Holes in Unconfined Aquifers

Wells completed into unconfined aquifers with only one aquifer encountered may be backfilled with clean sand or gravel to the top of the aquifer. Test holes encountering a single, unconfined aquifer may be backfilled with drill cuttings or clean sand or gravel to the top of the aquifer. Above the aquifer, clay, bentonite grout, or cement grout shall be used for plugging to within at least three feet of the ground surface. If clay is to be used as a backfill material, a minimum of two feet of dry bentonite, bentonite grout, or cement grout must be placed at the top of the aquifer. The top three feet of casing or hole, if not filled with clay, bentonite grout, or cement grout, shall be filled with native material. Plugging materials must be added to the well or hole via tremie pipe to any well or test hole less than 16 inches in diameter and to any well or test hole more than 50 feet deep. If it cannot be verified that a well's casing was grouted in accordance with this chapter, an effort must be made to plug the annulus from the bottom of the annulus up to the ground surface with the same type of material or materials required for plugging inside the casing.

7.3 Plugging of Wells or Test Holes in Low Permeability Formations

Test holes that encounter no water or only low-permeability formations such as clays, shales, and till must be backfilled to restore natural conditions as nearly as possible. Backfill material must be free of contamination and have a permeability equal to or less than the permeability of the formations encountered in the borehole.

7.4 Plugging Records

The Colorado State Engineers office should be notified that monitoring wells at closed sites have been plugged according to the standards specified above.

8.0 On-Site Staging and Handling of Contaminated Soil

8.1 Applicability

This section does not apply to management or disposal of sludge generated from storage tank closures, corrective actions and/or spills. It does not apply to petroleum wastes generated from any other source that exceeds TCLP limits (e.g., aboveground storage tank leaks, highway accidents, etc.). It does not apply to those wastes determined to be hazardous by appropriate analytical tests (i.e., TCLP, ignitability, corrosivity, and reactivity). Such wastes shall be handled as provided in solid and/or hazardous waste disposal laws and regulations. If laboratory analyses do not indicate that the soils are characteristic hazardous wastes, petroleum contaminated soils will be considered as a solid waste and require disposal in accordance with the Solid Waste Disposal Act or through use of the following procedures at regulated storage tank facilities.

Petroleum contaminated soils encountered during the investigation or remediation of storage tank(s) may be stockpiled on site. Stockpiled soils should be placed on a plastic liner or on asphalt, and bermed and covered to prevent product from infiltrating into soils or migrating off site. Soil stockpiles should be sampled as described in Section 3.0. Results of sample analyses should be compared to the risk-based screening levels (RBSLs) designated for the site.

8.2 On-site Treatment

In the event the hydrocarbon concentrations in the remaining subsurface soils or in the stockpiled soils exceed the site specific RBSLs, a contaminated materials handling plan, which will be part of an OIS approved corrective action plan, may allow for the following on-site treatments which may include bioremediation, soil venting, thermal treatment, etc., as long as samples are collected after treatment to confirm cleanup levels:

- Contaminated soils left in place must be managed in accordance with an approved corrective action plan.
- Contaminated soils removed from the excavation may be treated on-site in accordance with methods outlined in a contaminated materials handling plan and then if treated soils are used or disposed of off site, it must comply with the appropriate State Solid Waste Regulations.

Management of petroleum contaminated soils with contaminant concentrations equal to or less than the designated RBSLs shall occur in accordance with a contaminated materials management plan which may be required by the OIS as part of an approved corrective action plan. Petroleum contaminated soil may be handled in the following manner:

- In-situ, undisturbed soils may remain so.
- Excavated material may be placed back into the excavation.
- Soils removed from the excavation may be treated on site prior to final disposal or use at an off-site location in accordance with the appropriate State Solid Waste Regulations.
- The owner/operator may utilize other appropriate disposal/handling options mentioned in this section. These options may be implemented at the discretion of the owner/operator, based on an approved contaminated materials management plan.

8.3 Off-site Treatment

In the event the hydrocarbon concentrations in the stockpiled soils exceed the site specific RBSLs, they can be disposed or treated off-site at a State-approved solid waste facility according to Solid Waste Regulations:

- Contaminated soils removed from the excavation may be disposed at a waste disposal facility with a special waste acceptance plan for petroleum contaminated soils approved by the CDPHE Solid Waste Section.

- Contaminated soils removed from the excavation may be disposed at a waste disposal facility, without a special waste acceptance plan for petroleum contaminated soils, with prior OIS approval.

- Contaminated soils removed from the excavation may be treated offsite in accordance with methods and at a site(s) approved by the CDPHE Solid Waste Section. Potential methods may include bioremediation, soil aeration, thermal treatment, etc., as long as samples are collected after treatment to confirm cleanup levels. Disposal or use of treated soils will comply with the appropriate State Solid Waste Regulations (such materials may be considered as recycled and may therefore not be considered a solid waste).

In the event the hydrocarbon concentrations in the stockpiled soils exceed RBSLs, the following off-site uses may be considered:

- Treated or untreated contaminated soils removed from the excavation may be incorporated at an asphalt batch plant for use in standard asphalt construction applications, with prior approval of the CDPHE.

- One acceptable off-site use of untreated petroleum contaminated soil is the construction of paved roads with prior CDPHE approval (such materials may be considered as recycled and may therefore not be considered a solid waste). The OIS requires submittal of a signed document by the owner of the petroleum contaminated soils, the recipient of the wastes, and the owner of the road if different from the recipient. Materials should be placed within the top 24 inches immediately below asphalt or concrete pavement. Placement shall be at least 15 feet above ground water and outside of flood plains, wetlands and/or surface drainages. All appropriate Local Government Agencies (e.g., City, County, and Local Health Departments) must be contacted prior to use of petroleum contaminated soils in road construction.

The OIS reserves the authority to implement more stringent levels on a site specific basis.

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