Chapter 3
Drilling Operations

3-1. Physical Security

The FDO should comply with all security policies at the project site. The FDO is responsible for securing its own equipment. The FDO should address any special situations in the drilling plan.

3-2. Drilling Safety and Underground Utility Detection

When drilling in areas of known or suspected hazardous materials, appropriate health and safety precautions should be implemented. Guidance adaptable for drilling activities is available in Occupational Safety and Health Administration (OSHA) documents (particularly, 29 CFR 1910.120 and 29 CFR 1926), ER 385-1-92, and EM 385-1-1. The FDO should determine all applicable regulations, requirements, and permits with regard to drilling safety and underground utility detection. These items should be included in the safety plan. The safety plan should be approved by the FA prior to any drilling.

3-3. Permits, Licenses, Professional Registration, and Rights-of-Entry

The FA should be responsible for identifying all applicable permits, licenses, professional registration, rights-of-entry, and applicable state and local regulatory procedures for drilling, well installation, well decommissioning/ abandonment, and topographic surveying (to include any requirements for the submission of well logs, samples, etc.). Acquisition and submission of these items to state or local authorities should be coordinated between the FA and FDO, with the responsibilities of each specified in the drilling plan. The need for any rights-of-entry should be specified in the drilling plan along with the organization(s) responsible for their acquisition.

3-4. Site Geologist

A “site geologist” (defined as an earth science or engineering professional with a college degree in geology, civil engineering, or related field; experienced in HTRW projects, soil and rock logging, and monitoring well installation), should be present at each operating drill rig. This geologist should be responsible for logging; acquisitioning (and possibly shipment) of samples; monitoring of drilling operations; recording of water losses/gains and groundwater data; preparing the boring logs and well diagrams; and recording the well installation and decommissioning procedures conducted with that rig. Each site geologist should be responsible for only one operating rig. The geologist should have onsite sufficient tools, forms, and professional equipment in operable condition to efficiently perform the duties as outlined in this manual and other relevant project documents. Items in the possession of each site geologist should include, as a minimum, a copy of this manual, a copy of the approved drilling and well installation plan, log forms, the approved safety plan, a 10-power (minimum) hand lens, and a measuring tape (weighted with stainless steel or chemically stable, nonmetallic material) long enough to measure the deepest boring/well within the project, heavy enough to reach that depth, and small enough to readily fit within the appropriate annulus or opening. Each site geologist should also have onsite a water-level measuring device (preferably electrical), pH and electric conductivity meters, a turbidimeter, a thermometer, an instrument for measuring dissolved oxygen, and materials necessary to prepare the samples for storage or shipment. At some sites, the geologist may be also responsible for monitoring gases during drilling. If so, the geologist should have the necessary instruments and be proficient in their use and calibration.

3-5. Equipment

a. Condition. All drilling, sampling, and supporting equipment brought to a site should be in operable condition and free of leaks in the hydraulic, lubrication, fuel, and other fluid systems where fluid leakage would or could be detrimental to the project effort. All switches (to include safety switches), gages, and other electrical, mechanical, pneumatic, and hydraulic systems should be in a safe and operable condition prior to arrival onsite.

b. Cleaning. All drilling equipment should be cleaned with steam or pressurized hot water before arriving at the project installation/site. After arrival but prior to project commencement, all drilling equipment including rigs, support vehicles, water tanks (inside and out), augers, drill casings, rods, samplers, tools, recirculation tanks, etc., should be cleaned with steam or pressurized hot water using approved water (see paragraph 3-9*b*) at the installation decontamination point. Guidance for decontamination of field equipment may be found in ASTM D 5088. Samplers and other equipment, such as water level indicators, oil/water interface probes, etc. may require additional decontamination steps. A similar cleaning should also occur between each boring/well site. After the onsite cleaning, only the equipment used or soiled at a particular boring or well should need to be recleaned between sites. Unless circumstances require otherwise, water tank interiors may not need to be cleaned between each boring/well at a given project. Prior to use, all casings, augers, recirculation and water tanks, etc., should be devoid both inside and out of any asphaltic, bituminous, or other encrusting or coating materials, grease, grout, soil, etc. Paint, applied by the equipment manufacturer, may not have to be removed from drilling equipment, depending upon the paint composition and its contact with the environment and contaminants of concern. All equipment should be decontaminated before it is removed from the project site. If drilling requires telescoping casing because of differing levels of contamination in subsurface strata, then decontamination may be necessary before setting each string of smaller casing and before drilling beyond any casing. To the extent practical, all cleaning should be performed in a single remote area that is surficially crossgradient or downgradient from any site to be sampled. Waste solids and water from the cleaning/decontamination process should be properly collected and disposed. This may require that cleaning be conducted on a concrete pad or other surface from which the waste materials may be collected. Guidance for decontamination of field equipment used at low level radioactive waste sites may be found in ASTM D 5608.

3-6. Drilling Methods

a. Objective. The objective of selecting a drilling method for monitor well installation is to use that technique which

(1) Provides representative data and samples.

(2) Eliminates or minimizes the potential for subsurface contamination and/or cross-contamination.

(3) Minimizes drilling costs.

b. Methods. Table 3-1 presents types of drilling methods. Detailed descriptions of different drilling methods may be found in EPA/600/4-89/034, EPA/625/R-93/003a, USGS WRI Report 96-4233, USGS TWRI Book 2 Chapter F1, ASTM D 6286, Driscoll (1986), and U.S. Army FM 5-484. Where possible, ASTM drilling method-specific guides are referenced with the drilling methods listed below.

(1) Hollow stem augers. Method references: ASTM D 5784 and EPA/600/4-89/034.

(2) Cable tool/churn drill. Method reference: ASTM D 5875.

(3) Water/mud rotary. Method references: ASTM D 5781, D 5783, and D 5876.

(4) Air/pneumatic rotary methods. Method reference: D 5782.

(5) Sonic/vibratory. Method reference: EPA/625/R-94/003.

(6) Direct Push. Method references: ASTM Standard Guides D 6001 and D 6282, and EPA/510/B-97/001.

c. Special concerns.

(1) Dry methods.

(a) Hollow stem augers are technically advantageous in most situations because of their “dry” method of drilling. A dry drilling method is preferred for HTRW work. Dry methods advance a boring using purely mechanical means without the aid of an aqueous or pneumatic drilling “fluid” for cuttings removal, bit cooling, or borehole stabilization. In this way, the chemical interface with the subsurface is minimized, though not eliminated. Local aeration of the borehole wall, for example, may occur simply by the removal of compacted or confining soil or rock.

(b) Vibratory, or sonic drilling, employs the use of high-frequency mechanical vibration to take continuous core samples of overburden soils and most hard rock. A sonic drill rig uses an oscillator, or head, with eccentric weights driven by hydraulic motors, to generate high sinusoidal force in a rotating drill pipe. The frequency of vibration of the drill bit or core barrel can be varied to allow optimum penetration of subsurface materials. Sonic drilling penetrates a formation by displacement, shearing, or fracturing. Displacement occurs by fluidizing the soil particles (sands and light gravels) and causing them to move either into the formation or into the center of the drill pipe. Shearing occurs in dense silts, clays, and shales, if the axial oscillations of the drill pipe overcomes the elastic nature of the material. The penetration of cobbles, boulders, and rock is caused by fracturing of the material by the inertial moment of the drill bit. Although, rock drilling and sampling requires the addition of water or air to remove drill cuttings, the volume of drill cuttings generated during sonic drilling is usually much less than those generated from some other drilling methods. Drilling through unconsolidated material can be done in the dry, without the use of drilling fluids such as air or water-based fluids and additivies. Overall, the sonic drilling method can also offer the advantages of obtaining relatively undisturbed soil and rock samples at higher drilling rates than conventional methods, with high percentage of core recovery, and produces less investigation-derived waste.

TABLE 3-1
DRILLING METHODS

Method	Drilling Principle	Depth Limitation m (Ft.)	Advantages	Disadvantages
Direct-Push	Advancing a sampling device into the subsurface by applying static pressure, impacts, or vibration or any combination thereof to the above ground portion of the sampler extensions until the sampler has been advanced its full length into the desired soil strata.	30 (100)	Avoids use of drilling fluids and lubricants during drilling. Equipment highly mobile. Disturbance of geochemical conditions during installation is minimized. Drilling and well screen installation is fast, considerably less labor intensive. Does not produce drill cuttings, reduction of IDW.	Limited to fairly soft materials such as clay, silt, sand, and gravel. Compact, gravelly materials may be hard to penetrate. Small diameter well screen may be hard to develop. Screen may become clogged if thick clays are penetrated. The small diameter drive pipe generally precludes conventional borehole geophysical logging. The drive points yield relatively low rates of water.
Auger, Hollow- and Solid-Stem	Successive 1.5m (5-ft) flights of spiral-shaped drill stem are rotated into the ground to create a hole. Cuttings are brought to the surface by the turning action of the auger.	45 (150)	Fairly inexpensive. Fairly simple and moderately fast operation. Small rigs can get to difficult-to-reach areas. Quick setup time. Can quickly construct shallow wells in firm, noncavey materials. No drilling fluid or lubricants required. Use of hollow-stem augers greatly facilitates collection of split-spoon samples, continuous sampling possible. Small-diameter wells can be built inside hollow-stem flights when geologic materials are cavey.	Depth of penetration limited, especially in cavey materials. Cannot be used in rock or well-cemented formations. Difficult to drill in cobbles or boulders. Log of well is difficult to interpret without collection of split spoons due to the lag time for cuttings to reach ground surface. Soil samples returned by auger flight are disturbed making it difficult to determine the precise depth from which the sample came. Vertical leakage of water through borehole during drilling is likely to occur. Solid-stem limited to fine-grained, unconsolidated materials that will not collapse when unsupported. Borehole wall can be smeared by previosly-drilled clay. With hollow-stem flights, heaving sand can present a problem. May need to add water down-auger to control heaving or wash materials from auger before completing well.
Jetting	Washing action of water forced out of the bottom of the drill rod clears hole to allow penetration. Cuttings brought to surface by water flowing up the outside of the drill rod.	15 (50)	Relatively fast and inexpensive. Driller often not needed for shallow holes. In firm, noncavey deposits where hole will stand open, well construction fairly simple. Minimul equipment required. Equipment highly mobile.	Somewhat slow with increasing depth. Limited to drilling relatively shallow depth, small diameter boreholes. Extremely difficult to use in very coarse materials, i.e., cobbles and boulders. Large quantities of water required during drilling process. A water supply is needed that is under enough pressure to penetrate the geologic materials present. Use of water can affect groundwater quality in aquifer. Difficult-to-interpret sequence of geologic materials from cuttings. Presence of gravel or larger materials can limit drilling. Borehole can collapse before setting monitoring well if borehole uncased.

TABLE 3-1
DRILLING METHODS

Method	Drilling Principle	Depth Limitation m (Ft.)	Advantages	Disadvantages
Cable-tool (percussion)	Hole created by dropping a heavy "string" of drill tools into well bore, crushing materials at bottom. Cuttings are removed occasionally by bailer. Generally, casing is driven just ahead of the bottom of the hole; a hole greater than 6 inches in diameter is usually made.	300+ (1,000 +)	Can be used in rock formations as well as unconsolidated formations. Can drill through cobbles and boulders and highly cavernous or fractured rock. Fairly accurate logs can be prepared from cuttings if collected often enough. Driving a casing ahead of hole minimizes cross-contamination by vertical leakage of formation waters and maintains borehole stability. Recovery of borehole fluid samples excellent throughout the entire depth of the borehole. Excellent method for detecting thin water-bearing zones. Excellent method for estimating yield of water-bearing zones. Excellent method for drilling in soil and rock where lost circulation of drilling fluid is possible. Core samples can be easily obtained. Excellent for development of a well.	The potential for cross-contaminated samples is very high. Decontamination can be difficult. Heavy steel drive pipe used to keep hole open and drilling "tools" can limit accessibility. Cannot run some geophysical logs due to presence of drive pipe. Relatively slow drilling method. Heavier wall, larger diameter casing than that used for other drilling methods normally used. Temporary casing can cause problems with emplacement of effective filter pack and grout seal. Heaving of unconsolidated sediment into bottom of casing can be a problem.
Mud Rotary	Rotating bit breaks formation; cuttings are brought to the surface by a circulating fluid (mud). Mud is forced down the interior of the drill stem, out the bit, and up the annulus between the drill stem and hole wall. Cuttings are removed by settling in a "mud pit" at the ground surface and the mud is circulated back down the drill stem.	1,500+ (5,000 +)	Drilling is fairly quick in all types of geologic materials, hard and soft. Borehole will stay open from formation of a mud wall on sides of borehole by the circulating drilling mud. Eases geophysical logging and well construction. Geologic cores can be collected. Can use casing-advancement drilling method. Borehole can readily be gravel packed and grouted. Virtually unlimited depths possible.	Expensive, requires experienced driller and fair amount of peripheral equipment. Completed well may be difficult to develop, especially small diameter wells, because of mud or filter-cake on wall of borehole. Lubricants used during drilling can contaminate the borehole fluid and soil/rock samples. Geologic logging by visual inspection of cuttings is fair due to presence of drilling mud. Beds of sand, gravel, or clay may be missed. Location of water-bearing zones during drilling can be difficult to detect. Drilling fluid circulation is often lost or difficult to maintain in fractured rock, root zones, or in gravels and cobbles. Difficult drilling in boulders and cobbles. Presence of drilling mud can contaminate water samples, especially the organic, biodegradable muds. Overburden casing usually required. Circulation of drilling fluid through a contaminated zone can create a hazard at the ground surface with the mud pit and cross-contaminate clean zones during circulation.

TABLE 3-1
DRILLING METHODS

Method	Drilling Principle	Depth Limitation m (Ft.)	Advantages	Disadvantages
Reverse Rotary	Similar to hydraulic rotary method except the drilling fluid is circulated down the borehole outside the drill stem and is pumped up the inside, just the reverse of the normal rotary method. Water is used as the drilling fluid, rather than a mud, and the hole is kept open by the hydrostatic pressure of the water standing in the borehole.	1,500+ (5,000 +)	Drilling readily accomplished in soils and most hard rock. Drilling is relatively fast and for drilling large diameter boreholes. Borehole is accessible for geophysical logging prior to installation of well. Creates a very "clean" hole, not dirtied with drilling mud. Large diameter of borehole permits relatively easy installation of monitoring well. Can be used in all geologic formations. Very deep penetrations possible. Split-spoon sampling possible.	Drilling through cobbles and boulders may be difficult. Use of drilling fluids, polymeric additives, and lubricants can affect the borehole chemistry. A large water supply is needed to maintain hydrostatic pressure in deep holes and when highly conductive formations are encountered. Expensive--experienced driller and much peripheral equipment required. Hole diameters are usually large, commonly 18 inches or greater. Cross-contamination from circulating water likely. Geologic samples brought to surface are generally poor; circulating water will "wash" finer materials from sample.
Air Rotary	Very similar to hydraulic rotary, the main difference is that air is used as the primary drilling fluid as opposed to mud or water.	1,500+ (5,000 +)	Can be used in all geologic formations; most successful in highly fractured environments. Useful at most any depth. Drilling in rock and soil is relatively fast. Can use casing-advancement method. Drilling mud or water not required. Borehole is accessible for geophysical logging prior to monitoring well installation. Well development relatively easy.	Relatively expensive. Cross-contamination from vertical communication possible. Air will be mixed with the water in the hole and blown from the hole, potentially creating unwanted reactions with contaminants; may affect "representative" samples. Air, cuttings and water blown from the hole can pose a hazard to crew and surrounding environment if toxic compounds encountered. Compressor discharge air may contain hydrocarbons. Organic foam additives to aid cuttings removal may contaminate samples. Overburden casing usually required.
Sonic (vibratory)	Employs the use of high-frequency mechanical vibration to take continuous core samples of overburden soils and most hard rock.	150 (500)	Can obtain large diameter, continuous and relatively undisturbed cores of almost any soil material without the use of drilling fluids. Can drill through boulders, wood, concrete and other construction debris. Can drill and sample most softer rock with high percentage of core recovery. Drilling is faster than most other methods. Reduction of IDW.	Rock drilling requires the addition of water or air or both to remove drill cuttings. Extraction of casing can cause smearing of borehole wall with silt or clay. Extraction of casing can damage well screen. Equipment is not readily available and is expensive.

TABLE 3-1
DRILLING METHODS

Method	Drilling Principle	Depth Limitation m (Ft.)	Advantages	Disadvantages
Air-Percussion Rotary or Down-the-Hole (DTH) Hammer	Air rotary with a reciprocating hammer connected to the bit to fracture rock.	600 (2,000)	Very fast penetrations. Useful in all geologic formations. Only small amounts of water needed for dust and bit temperature control. Cross-contamination potential can be reduced by driving casing. Can use casing-advancement method. Well development relatively easy.	Relatively expensive. As with most hydraulic rotary methods, the rig is fairly heavy, limiting accessibility. Overburden casing usually required. Vertical mixing of water and air creates cross-contamination potential. Hazard posed to surface environment if toxic compounds encountered. DTH hammer drilling can cause hydraulic fracturing of borehole wall. The DTH hammer requires lubrication during drilling. Organic foam additives for cuttings removal may contaminate samples.

(c) Another dry method, known as the direct push method, involves sampling devices that are directly inserted into the soil to be sampled without drilling or borehole excavation. Direct push sampling also includes the use of the Site Characterization and Analysis Penetrometer System (SCAPS) which has contaminant screening capability in addition to indirect soil stratigraphy information (ASTM D 5778 and D 6067). Direct push sampling consists of advancing a sampling device into the subsurface by applying static pressure, impacts, or vibration or any combination thereof to the above ground portion of the sampler extensions until the sampler has been advanced its full length into the desired soil strata. Direct push methods may be used to collect both soil (ASTM D 6282) and water samples (ASTM D 6001). In some cases the method may combine water sampling and/or vapor sampling with soil sampling in the same investigation. The direct push sampling method is widely used as a preliminary site characterization tool for the initial field activity of a site investigation. Direct push sampling is an economical and efficient method for obtaining descrete soil and water samples without the expense of drilling and its related decontamination and waste cuttings disposal costs. This method may be especially advantageous at a radioactive site, where the reduction of IDW is of special importance. The equipment generally used in direct push sampling is small and relatively compact allowing for better mobility around the site and access to confined areas. The rapid sample gathering provided by direct push methods can be used to determine the chemical composition of the soils and ground water in the field in certain circumtances. This method may offer an immediate determination of the need for further monitoring points. It must be cautioned, however, that certain temporary well points installed by this method may not be allowed as permanent monitoring wells by some state and local regulations.

(2) Pneumatic methods. When air is used it should be detailed in the drilling plan, to include the following items:

(a) Situation favoring air usage.

(b) Air drilling method to be used.

(c) Expected subsurface contaminants, and how field personnel will be protected from any adverse effects caused by these contaminants in the returned air and particles blown from the borehole or well.

(d) The potential effects of air usage upon the chemical analyses of groundwater and soil (especially for volatile species) and the mitigation procedures to negate the detrimental aspects of these effects.

(e) The potential effects of air usage upon the physical, hydrological, and structural character of the surrounding soil and/or rock and the mitigation to address the negative aspects of these effects.

(f) Measures to be taken to reduce oil usage and to limit aquifer aeration.

(g) Specify the type of air compressor and compressor lubricating oil and require that sufficient samples of the initial reservoir (and any refill) oil be retained by the FDO, along with a record of oil loss (recorded on the boring log), for evaluation in the event of future problems. The oil sample(s) may be disposed of upon project completion.

(h) Require an air line oil filter and that the filter be changed per manufacturer's recommendation during operation with a record kept (on the boring log) of this maintenance. More frequent changes should be made if oil is visibly detected in the filtered air, as by an oil stain on clean, writing paper after directing the filtered air from a hose onto the paper “300 mm” (“a foot”) away for “15 seconds.” (While these numbers are arbitrary, they are provided as examples for FDO guidance and intra/interproject consistency.)

(i) Prohibit the use of any additive except approved water for dust control and cuttings removal.

(j) Detail the use of any downhole hammer/bit with emphasis upon those procedures to be taken to preclude residual groundwater sample contamination caused by the lubrication of the downhole equipment.

(k) Discuss the volume of air and pressure rating required for drilling and whether a downhole hammer, rotary bit, or both can be used. The air volume and pressure required should be adequate for the hole diameter, boring depth, available equipment, and site conditions.

(l) Detail the use of any bottled gas with emphasis on air composition, quality, quantity, method of bottling, and anticipated use.

(m) Air usage should be fully described in the boring log to include equipment description(s), manufacturer(s), model(s), air pressures used, frequency of oil filter change, and evaluation of the system performance, both design and actual.

(3) Aqueous methods.

(a) Aqueous drilling methods use a fluid, usually water, or a water and bentonite mix, for cuttings removal, bit cooling, and hole stabilization. For HTRW work, the use of these materials increases the potential to add a new contaminant or suite of contaminants to the subsurface environment adjacent to the boring. Even the removal of one or more volumes of water equal to that which was lost during drilling will not remove all of the lost fluid. In addition, the level of effort to be expended upon well development is directly tied to the amount of water loss during drilling: a minimum of three times the volume lost to be removed during development. Therefore, the less fluid loss, the less the development effort (time and cost).

(b) The situation is further complicated when bentonite is used. While bentonite tends to reduce the amount of drilling fluid loss, the residual bentonite remaining around the boring after development may provide sufficient sorptive material to modify local groundwater chemistry for some parameters (for example, metals).

3-7. Recirculation Tanks and Sumps

If possible, only portable recirculation tanks should be used for mud/water rotary operations and similar functions. The use of dug sumps or pits (lined) should be used only if necessary, as when the volume necessary to handle problem holes that encounter running sand or gravel is greater than can be handled by a portable tank. This is important in order to minimize cross-contamination and to enhance both personal safety and work area restoration.

3-8. Materials

a. Bentonite. Bentonite is the only drilling fluid additive that is typically allowed under normal circumstances. This includes any form of bentonite (powders, granules, or pellets) intended for drilling mud, grout, seals, etc. Organic additives should not be used. Exception might be made for some high yield bentonites, to which the manufacturer has added a small quantity of polymer. The use of any bentonite should be discussed in the drilling plan and approved by the FA. Bentonite should only be used if absolutely necessary to ensure that the borehole will not collapse or to improve cuttings removal. The following data should be included in the drilling plan and submitted along with a sample of the material for approval:

(1) Brand name(s).

(2) Manufacturer(s).

(3) Manufacturer's address and telephone number(s).

(4) Product description(s) from package label(s) or manufacturer's brochure(s), to include any polymer or other additives.

(5) Intended use(s) for this product.

(6) Potential effects on chemical analyses of subsequent samples.

b. Water.

(1) To the extent practical, the use of drilling water should be held to a minimum at HTRW sites. When water usage is deemed necessary, the source of any water used in drilling, grouting, sealing, filter placement, well installation, well decommissioning/abandonment, equipment washing, etc. should be approved by the FA prior to arrival of the drilling equipment onsite and specified in the drilling plan. Desirable characteristics for the source include:

(a) An uncontaminated aquifer origin;

(b) Wellhead upgradient of potential contaminant sources;

(c) Be free of survey-related contaminants by virtue of pretesting (sampling and analysis) by the FDO using a laboratory validated by USACE for those contaminants using methods within that validation, and knowledge of the water-chemistry is the most important factor in water approval;

(d) The water is untreated and unfiltered;

(e) The tap has accessibility and capacity compatible with project schedules and equipment; and

(f) Only one designated tap for access.

(2) Surface water bodies should not be used, if at all practical.

(3) If a suitable source exists onsite, that source should be used. If no onsite water is available, the FDO should both locate a potential source and submit the following data in writing to the FA for approval prior to the arrival of any drilling equipment onsite. A suggested format is given in Figure 3-1.

(a) Owner/address/telephone number.

(b) Location of tap/address.

(c) Type of source (well, pond, river, etc.). If a well, specify static water level (depth), date measured, well depth, and aquifer description.

(d) Type of any treatment and filtration prior to tap (e.g., none, chlorination, fluoridation, softening, etc.).

(e) Time of access (e.g., 24 hours per day, 7 days per week, etc.).

(f) Cost per liter (gallon) charged by owner/operator.

(g) Results and dates of all available chemical analyses over past 2 years. Include the name(s) and addresses of the analytical laboratory(s).

(h) Results and date(s) of chemical analysis for project contaminants by a laboratory validated by USACE for those contaminants.

(4) The FDO should have the responsibility to procure, transport, and store the water required for project needs in a manner to avoid the chemical contamination or degradation of the water once obtained. The FDO also should be responsible for any heating, thermal insulation, or agitation of the water to maintain the water as a fluid for its intended uses.

c. Grout.

(1) Cement. Cement grout, when used in monitoring well construction or borehole/well decommissioning, should be composed of Type I Portland cement (ASTM C 150), bentonite (2-5% dry bentonite per 42.6 kg (94 lb) sack of dry cement) and a maximum of 23 to 26 L (6-7 gal) of approved noncontaminated-water per sack of cement. The addition of bentonite to the cement admixture will aid in reducing shrinkage and provide plasticity. Note that the maximum amount of dry bentonite allowed here varies from the 10 percent allowable in ASTM D 5092. The amount of water per sack of cement required for a pumpable mix will vary with the amount of bentonite used. The amount of water used should be kept to a minimum. When a sulfate resistant grout is needed, Types II or V cement should be used instead of Type I. Neither additives nor borehole cuttings should be mixed with the grout. The use of air-entrained cement should be avoided to negate potential analytical interference in groundwater samples by the entraining additives.

(2) Bentonite. Bentonite grout is a specially designed product, which is differentiated from a drilling fluid by its high solids content, absence of cement and its pumpability. A typical high solids bentonite grout will have a solids content between 20 and 30 percent by weight of water and remain pumpable. By contrast, a typical low solids bentonite, as used in a drilling fluid, contains a solids content between 3 and 6 percent by weight of water. The advantages of using bentonite grout include (Oliver 1997) :

- Bentonite grouts, when hydrated, exert constant pressure against the walls of the annulus, leaving no room for contaminants to travel in the well.
- Bentonite grouts are more flexible and do not shrink and crack when hydrated, creating a low permeability seal.
- Placement using bentonite grouts is much easier because more time is allowed for setting.
- Bentonite high solids grouts require less material handling than cement.
- Bentonite grouts are chemically inert, which protects personal safety, equipment, and water quality.
- Bentonite grouts have no heat of hydration making them compatible with polyvinyl chloride (PVC) casing.
- Wells constructed with bentonite grouts can be easily reconstructed if necessary.
- Cleanup of bentonite grouts is much easier than with cement grouts.

Situations where bentonite grout should not be used are when additional structural strength is needed or when excessive chlorides or other contaminants such as alcohols or ketones are present. Under artesian conditions the bentonite does not have the solids content found in a cement-bentonite grout and will not settle where a strong uplift is present. Where structural support is needed, bentonite grout does not set up and harden like a cement and will not supply the support a cement-bentonite grout will provide (Colangelo 1988).

(3) Equipment. All grout materials should be combined in an aboveground rigid container or mixer and mechanically (not manually) blended onsite to produce a thick, lump-free mixture throughout the mixing vessel. The mixed grout should be recirculated through the grout pump prior to placement. Grout should be placed using a grout pump and pipe/tremie. The grout pipe should be of rigid construction for vertical control of pipe placement. Drill rods, rigid polyvinyl chloride (PVC) or metal pipes are suggested stock for tremies. If hoses or flexible plastics must be used, they may have to be fitted with a length of steel pipe at the downhole end to keep the flexible material from curling and embedding itself into the borehole wall. This is especially true in cold weather when the coiled material resists straightening. Grout pipes should have **SIDE** discharge holes, **NOT** end discharge. The side discharge will help to maintain the integrity of the underlying material (especially the bentonite seal).

d. Granular filter pack.

(1) Proper design of hydraulically efficient monitoring wells can be accomplished by designing the well in such a way that either the natural coarse-grained formation materials or artificially introduced coarse-grained materials, in conjunction with appropriately sized intake openings, retain the fine materials outside the well while permitting water to enter. Thus, there are two types of wells and well intake designs for wells installed in unconsolidated or poorly-consolidated geologic materials: natural developed wells and wells with an artificially introduced filter pack. In both types of wells, the objective of a filter pack is to increase the effective diameter of the well and to surround the well intake with an envelope of relatively coarse material of greater permeability than the natural formation material (EPA/600/4-89/034). The decision to design the well using the natural formation as the filter pack should include consideration that the natural formation material may slough in high enough above the top of the well screen to leave insufficient room for the bentonite seal. All granular filters should be approved by the FA prior to drilling and should be discussed in the drilling plan. Discussions should include composition, source (natural formation or artificial), placement, and gradation. The FDO should either prescribe the gradation of the filter pack in the field sampling plan (FSP) or detail that it will be determined after a sieve analysis of the stratum in which the screen is to be set has been performed. If the actual gradation is to be determined during drilling, more than one filter pack gradation should be on hand so that well installation will not be unnecessarily delayed. A 0.5 L (one-pint) representative sample for visual familiarization of each proposed granular filter pack, accompanied by the data below, should be submitted by the FDO to the FA for approval prior to drilling. Each sample should be described, in writing (see Figure 3-2 for submittal format), in terms of:

(a) Lithology;

(b) Grain size distribution;

(c) Brand name, if any;

(d) Source, both manufacturing company and location of pit or quarry of origin for artificial filter packs;

(e) Processing method for artificial filter packs, e.g., pit run, screened and unwashed, screened and washed with water from well/river/pond, etc.; and

(f) Slot size of intended screen.

(2) Granular filter packs should be visually clean (as seen through a 10-power hand lens), free of material that would pass through a No. 200 (75 µm [0.0029 in.]) sieve, inert, siliceous, composed of rounded grains, and of appropriate size for the well screen and host environment. Organic matter, soft, friable, thin, or enlongated particles are not permissible. A chemical analysis, including analytes of project concern, may be advisable in some circumstances. However, the reproducibility of that result should be evaluated against the spatial and temporal variability of the aggregate source and processing methods. The filter material should be packaged in bags by the supplier and therein delivered to the site.

e. Well screens, casings, and fittings.

(1) Typically, only PVC, polytetrafluoroethylene (PTFE), and/or stainless steel should be used. All PVC screens, casings, and fittings should conform to National Sanitation Foundation (NSF) Standard 14 for potable water usage or ASTM Standard Specification F 480 and bear the appropriate rating logo. If the FDO uses a screen and/or casing manufacturer or supplier who removes or does not apply this logo, the FDO should

WATER APPROVAL

Project for Intended Use:

1. Water source:
   Owner:
   Address:
   Telephone Number:

2. Water tap location:
   Operator:
   Address:

3. Type of source:
   Aquifer:
   Well depth:
   Static water level from ground surface:
   Date measured;

4. Type of treatment prior to tap:

5. Type of access:

6. Cost per liter (gallon) charged by Owner/Operator:

7. Attach results and dates of chemical analyses for past 2 years. Include name(s) and address(s) of analytical laboratory(s).

8. Attach results and dates of chemical analyses for project analytes by the laboratory certified by, or in the process of being certified.

SUBMITTED BY:

Company:

Person:

Telephone Number:

Date:

FOA APPROVAL (A)/DISAPPROVAL (D)	(Check one)
Project Officer:	A D
Project Geologist/Date:	A D

Figure 3-1. Suggested format for use in obtaining water approval

include in the drilling plan a written statement from the manufacturer/supplier (and endorsed by the FDO) that the screens and/or casing have been appropriately rated by NSF or ASTM. Specific materials should be specified in the drilling plan approved by the FA. All materials should be as chemically inert as technically practical with respect to the site environment.

(2) All well screens should be commercially fabricated, slotted or continuously wound, and have an inside diameter (ID) equal to or greater than the ID of the well casing. An exception may be needed in the case of continuously wound screens because their supporting rods may reduce the full ID. If the monitoring well is to be subject to aquifer testing (slug test or pump test), a continuous wound screen should be used. Stainless steel screens may be used with PVC or PTFE well casing. No fitting should restrict the ID of the joined casing and/or screen. All screens, casings, and fittings should be new.

(3) Couplings within the casing and between the casing and screen should be compatibly threaded. Thermal or solvent welded couplings on plastic pipe should not be used. This caution also applies to threaded or slip-joint couplings thermally welded to the casing by the manufacturer or in the field. Several thermally welded joints have been known to break during well installation on a single project. The avoidance should remain until the functional integrity of thermal welds has been substantiated.

(4) Pop rivets, or screws should not be used on monitor wells. Particular problems with their use include anomalous analytical results, restriction of the well ID, and a loss of well integrity at the point of application.

f. Well caps and centralizers.

(1) The tops of all well casings should be telescopically covered with a slip-joint-type cap. Each cap should be composed of PVC, PTFE, or stainless steel. Each cap should be constructed to preclude binding to the well casing due to tightness of fit, unclean surface, or frost, and secure enough to preclude debris and insects from entering the well. Caps and risers may be threaded. However, sufficient annular space should be allowed between the well and protective casing to enable one to thaw any frosted shut caps. Caps should be vented, or loose enough to allow equilibration between hydrostatic and atmospheric pressures. Special cap (and riser) designs should be provided by the FA or FDO for wells in floodplains and those instances where the top of the well may be below grade, e.g., in roadways and parking lots.

(2) The use of well centralizers should be considered for wells deeper than 6 m (20 ft). When used, they should be of PVC, PTFE, or stainless steel and attached to the casing at regular intervals by means of stainless steel fasteners or strapping. Centralizers should not be attached to any portion of the well screen or bentonite seal. Centralizers should be oriented to allow for the unrestricted passage of the tremie pipe(s) used for filter pack and grout placement.

g. Well protection materials. Elements of well protection are intended to protect the monitoring well from physical damage, to prevent erosion and/or ponding in the immediate vicinity of the monitoring well, and to enhance the validity of the water samples.

(1) The potential for physical damage is lessened by the installation of padlocked, protective iron/steel casing over the monitoring well and iron/steel posts around the well. The casing and posts should be new. The protective casing diameter or minimum dimension should be 100 mm (4 in.) greater than the nominal diameter of the monitor well, and the nominal length should be 1.5 m (5 ft). The protective posts should be at least 80 mm (3 in.) in diameter and the top modified to preclude the entry of water. If extra protection is necessary, the protective posts can be filled with concrete. Nominal length of the posts should be 1.8 m (6 ft). Special circumstances necessitating different materials should be addressed in the drilling plan.

(2) Erosion and/or ponding in the immediate vicinity of the monitoring well may be prevented by assuring that the ground surface slopes away from the monitoring well protective casing and by the spreading of a 150 mm (6-in.) thick, 2.4 m (8-ft) diameter blanket of 19- to -75-mm (3/4- to 3-in.) gravel around the monitoring well.

(3) The validity of the water samples is enhanced by a locking cover on the protective casing. The cover should be hinged or telescoped but not threaded. Lubricants on protective covers should be avoided. Threaded covers tend to rust and/or freeze shut. Lubricants applied to the threads to reduce this closure tend to adhere to sampling personnel and their equipment. All locks on these covers should be opened by a single key and, if possible, should match any locks previously installed at the site(s), and be made of noncorrosive matrial, such as brass.

h. Glues and solvents. The use of glues and solvents in monitoring well installation should be prohibited.

i. Tracers. Tracers or dyes should not be used or otherwise introduced into borings, wells, grout, backfill, groundwater, or surface water unless specifically approved in the drilling plan. The drilling plan should describe any

GRANULAR FILTER PACK APPROVAL

Project for Intended Use:

1. Filter Material Brand Name:
2. Lithology:
3. Grain Size Distribution:
4. Source:

   Company that made product:

   Location of pit/quarry of origin:
5. Processing Method:
6. Slot Size of Intended Screen:

Submitted by:

Company:

Person:

Telephone:

Date:

FOA APPROVAL (A)/DISAPPROVAL (D)	(Check one)	
Project Officer Name/Date:	A	D
Project Geologist Name/Date:	A	D

Figure 3-2. Suggested format for obtaining approval for filter pack

approved usage; chemical, radiological, and/or biological composition of the substances; and potential effects upon subsequent chemical, radiological, or biological analyses of the injected media. Discussion should also be provided of the expected, post-injection visual appearance of the media into which the substances are to be introduced. The discussion should also include relevant Federal and state regulations and those agencies' opinions relative to the approved usage.

j. Lubricants. If lubrication is needed on the threads or couplings of downhole drilling equipment, it should be biodegradable and nontoxic. Vegetable oil/shortening or PTFE tape may be used. Additives containing lead or copper should not be used. The only lubricant recommended for monitoring well joints is PTFE tape. The use and type of lubricants should be included in the drilling plan and boring logs/well construction diagrams.

k. Hydraulic fluids. Any hydraulic or other fluids in the drilling rig, pumps, transmissions, or other field equipment/vehicles should **NOT** contain any polychlorinated biphenyls (PCBs).

l. Antifreeze. The use of any antifreeze (either a commercially available automotive variety or a local derivation) to prevent overnight water line freezing should require FA approval. If antifreeze is added to any pump, hose, etc., where contact with drilling fluid is possible, this antifreeze should be completely purged with approved water prior to the equipment's use in drilling, mud mixing, or any other part of the overall drilling operation. A sample of the clean (approved) water that has been circulated through the equipment after antifreeze removal should be retained for laboratory analysis. Only antifreeze without rust inhibitors and/or sealants should be considered. Antifreeze usage should be noted on the boring log, including the dates, reasons, quantities, composition, and brand names of antifreeze used. Antifreeze usage should be a last resort option. No antifreeze should be used in the drilling operation. Overnight storage in a heated garage may be a better option than spending time purging antifreeze and getting frozen equipment ready to operate.

m. Agents and additives. The use of any materials or substances other than those recommended herein for drilling, well installation, or development should be prohibited. Included in this suggested prohibition are lead shot, lead wool, burlap, dispersing agents (e.g., phosphates), acids, explosives, disinfectants, organic based drilling additives, metallic based lubricants, chlorinated and petroleum based solvents, adhesives, etc.

n. Summary. A materials usage summary, or MSDS should be provided of any drilling/well construction materials which potentially could have a bearing on subsequent interpretation of the analytical results. An example summary is provided at Figure 3-3.

3-9. Surface Runoff

Surface runoff, e.g., precipitation, wasted or spilled drilling fluid, and miscellaneous spills and leaks, should not enter any boring or well either during or after construction. To help avoid such entry, the use of starter casing, recirculation tanks, berms around the borehole, surficial bentonite packs, etc., is recommended.

3-10. Drilling Through Contaminated Zones

a. Many borings and wells are drilled in areas that are clean relative to the deeper zones of interest. However, circumstances do arise that require drilling where the overlying soils or shallow aquifer may be contaminated relative to the underlying environment. This situation may be addressed by the placement of, at least, double casing: an outer permanent (or temporary) casing sealed in place and cleared of all previous drill fluids prior to proceeding into the deeper, “cleaner” environment. In this procedure, the outer drill casing is set and sealed within an “impermeable” layer or at a level below which the underlying environment is thought to be cleaner than the overlying environment. The drilling fluids used to reach this point are appropriately discarded, replaced by a new or fresh supply. This system can be repeated, resulting in telescopic drill casing through which the final well casing is placed. These situations should be addressed on a case-by-case basis in the drilling plan.

b. Caution should be exercised to prevent further migration of contaminants via boreholes, especially dense non-aqueous phase liquid (DNAPL) migration. A recommended investigation strategy is to drill in expected DNAPL zones only after subsurface conditions have been characterized by drilling in surrounding DNAPL-free areas (the “outside-in” strategy). In DNAPL zones, drilling should generally be minimized and should be suspended when a potential trapping layer is first encountered. Drilling through DNAPL zones into deeper strategraphic units should be avoided. Also non-invasive methods, such as geophysical or geochemical surveys, can be useful at some sites to roughly define subsurface geologic or contaminant conditions (USEPA OSWER Directive 9283.1-06).

3-11. Soil Sampling

a. Intact samples. Unless otherwise specified in the drilling plan, intact soil samples for physical descriptions, retention, and physical analyses should be taken continuously and retained for the first 3 m (10 ft) and every 1.5 m (5 ft) or at each change of material, whichever occurs first, thereafter. Soil samples should be collected at intervals that are consistent with the goals of the project. These samples should be representative of their host environment. Borehole cuttings do not usually provide the desired information and, therefore, are not usually satisfactory. Sampling procedures should be detailed in the drilling plan. Additional guidance on soil sampling can be found in EM 200-1-3, EM 1110-1-1906 and ASTM Standard Guide D 6169.

b. Odors. At the detection of any anomalous odors (or vapor readings) from the boring or intact samples, drilling should cease for an evaluation of the odors and to determine the crew's safety. After the field safety representative completes this evaluation and implements any appropriate safety precautions as may be required in the site safety and health plan (SSHP), drilling may only then resume. If the odors or vapor readings are judged by the field personnel to be contaminant-related, intact soil samples should be continuously taken until the odors/readings are within background ranges. These samples should be retained and preserved in appropriate screw-capped sample jars for possible chemical analysis. With the resumption of background readings, routine sampling should resume. Specific procedures should be detailed in the FSP and SSHP.

c. Volume. Representative soil samples of sufficient volume for physical testing from each sampled interval should be retained for future reference or appropriate analysis. Upon boring completion, the number of samples retained from that boring may be reduced, retaining at least representative samples of major units, key samples, and those for testing requirements. Minimum information on each sample container should include the project, depth below surface, and boring and sample number. All samples known or suspected to contain contaminants of concern should be so marked on both the sample container and boring log. No geotechnical data should appear on the container that is not specified on the boring log. Containers should be kept from becoming frozen. Soil samples known or suspected of being contaminated may have to be handled, stored, tested, and/or disposed of as hazardous waste. Storage, packaging, and shiping instructions for soil samples for physical testing should be prescribed in the drilling plan. USEPA has published additional guidance concerning the management of investigation-derived wastes (IDW) for Superfund projects (USEPA, EPA/540/G-91/009 and USEPA, OSWER Publication 9345.3-03FS) that should be incorporated into the drilling plan, as appropriate.

d. Physical testing. Physical soil testing is a function of the project. The drilling plan should detail specific testing guidance and requirements. The appropriate number of field samples selected for physical soil testing as well as sample retrieval locations should be determined by the project geotechnical personnel. Procedures and equipment for soil testing are described in the current EM 1110-2-1906 (or ASTM Standard Test Method D 2487). Downhole geophysical logging may reduce the need for sampling. Tested samples should be representative of the range and frequency of soil types encountered in the project area and should specifically include the screened interval of each completed well. In addition, samples should be obtained from borings that cover the geographic and geologic range within the project area. The FDO should select the particular samples. Samples selected for physical testing that are suspected to be contaminated should be labeled as such. Tests should include moisture content and those tests necessary to determine the soil classification as described in D 2487. Laboratory and summary sheets should be submitted to the FA after final test completion. The drilling and safety plans should address any contaminant-related safety precautions for the physical analysis of these samples. The FDO is responsible for communicating these concerns to the laboratory performing the soil testing. The testing laboratory is responsible for taking all the necessary health and safety precautions adequate to protect the laboratory personnel. Samples for physical analysis which are known or suspected to be contaminated should be tested only in a soils laboratory equipped and managed to process contaminated samples.

e. Soil samples for chemical analysis.

(1) Samples should be extracted from an as intact, minimally disturbed condition as technically practical. Once at the surface, the sampler should be opened, sample extracted, and bottled in as short a time as possible. Samples for volatile analysis should be bottled, and capped within a **VERY** short time (about 15 seconds from the time of opening the sampler). Each soil sample for volatile analysis should have minimal head space for representative analytical results.

(2) All sampling equipment that will contact the sample should be thoroughly decontaminated between samples. This can be accomplished by the use of a hot-water pressure washer or as follows:

(a) Scrub equipment with a low-sudsing, nonphosphate detergent in approved water.

(b) Rinse with approved water.

(c) When sampling for metals, rinse with 0.1 N nitric acid (4.2 mL of concentrated nitric acid added to 1,000 mL (33 fl oz) of water). (**CAUTION**: Add acid to water, never add water to concentrated acid.) Continue rinsing the sampling equipment now with distilled or deionized water. If the sampling equipment being used is made of stainless steel, the use of 0.1 N hydrochloric acid (rather than 0.1 N nitric acid) is preferred to avoid oxidation (rusting) of the stainless steel. The 0.1 N hydrochloric acid is prepared by adding 3.1 mL of concentrated hydrochloric acid to 1,000 mL (33 fl oz) of water. The same **CAUTION** applies: add the concentrated acid to the water, not the water to the acid.

(d) When sampling for organic volatiles, semivolatiles, or pesticides/PCBs, rinse with pesticide grade isopropanol followed by rinsing with distilled or deionized water. When using isopropanol to decontaminate a sampler, the sampler must be allowed to completely air dry prior to reassembly.

MATERIALS SUMMARY

PROJECT: GENERAL AAP

Date: Oct-Nov 1987

Brand/Description (Example Entries)	Material Source/Supplier (Example Entries*)	(Example Entries*)
PVC casing	4.0" ID, Schedule 40, flush threaded;	ABC Mfg; Aville, Minnesota 2" ID, Schedule 40, flush
threaded		
PVC screen	0.05" slot, 4.0" ID; Schedule 40,	ABC Mfg; Aville, Minnesota flush threaded, 0.02" slot, 2" ID; Schedule 40, flush threaded
Bentonite (drilling fluid and grout)	Tru-gel	A. O. Bentonite; Bville,
Wyoming		
Granular bentonite (seal)	Gran-Bent	White Mud, Cville, Montana
Bentonite pellets (seal)	(No brand name available)	PELBENT, Dville, Utah
Sand (filter pack)	8-12 silica sand	State Sand, Mville,
Colorado; supplier:		
EFG Co., Eville, Utah		
Cement (grout)	Portland Type II	A. Lumber Co., Eville, Utah
Drilling water	St. Peter Sandstone	Production Well #1, Tap at
well house		
Drilling rod lubricant	Slick Turn	Oil Products Co., Fville,
Texas		
Air compressor oil	Oil #40	Oil Products Co., Fville,

Figure 3-3. Example materials summary

(3) Additional acquisition, preservation, and handling criteria for the chemical analysis of soils are found in EM 200-1-3.

f. Liners. If sample liners are used, the following should apply:

(1) Use clear liners or take extra samples to ensure that the sample is of sufficient quantity and quality for the intended analyses;

(2) Liner seams and ends should be "airtight," i.e., "moisture impermeable";

(3) Borehole/drilling fluids should not be trapped within the liner;

(4) Liner or sealant interaction with the sample should not alter the sample's chemical composition; and

(5) Liners must be free of contamination and be decontaminated prior to use. Decontamination may not be necessary if the liners have been packaged by the manufacturer and has intact packaging up to the time of use.

g. Location. All soil samples, except those for physical and/or chemical analysis and reference should remain onsite, neatly stored at an FA-designated location. The disposition of these samples should be arranged by the FA. Samples from HTRW sites may have to be stored, and later disposed of, off site. Depending on the site and its accessibility to the public, it may be permissible (depending on state regulations) to stage the drums neatly on pallets immediately adjacent to the boring/monitoring well location. If the option exists to dispose of IDW by spreading it on the ground at the sampling location, it may not be cost-effective to stage the drums in a central location and then move them back to the boring/monitoring well location for disposal. Sample retention and disposal should be given detailed attention in the SAP.

3-12. Rock Coring

Bedrock should be cored unless the drilling plan specifies otherwise. Coring, using a diamond- or carbide-studded bit (ASTM D 2113) , produces a generally intact sample of the bedrock lithology, structure, and physical condition. The use of a gear-bit, tricone, etc., to penetrate bedrock should only be considered for the confirmation of the "top of rock" (where penetration is limited to a few meters [feet]), the enlargement of a previously cored hole, or the drilling of highly fractured intervals. Except as noted below, guidance for preserving, storing, photographing, marking, cataloging, and handling of rock core samples may be found in ASTM D 5079.

a. The coring of bedrock or any firm stratigraphic unit should be conducted in a manner to obtain maximum intact recovery. The physical character of the bedrock (i.e., fractures, poor cementation, weathering, or solution cavities) may lessen recovery, even with the best of drillers and equipment.

b. The minimum core size should be an "N" series, 50 mm (2 [plus]-in.) diameter. Larger bit (hence, core) diameters may be needed to enhance core recovery.

c. While drilling in bedrock, and especially while coring, drilling fluid pressures should be adjusted to minimize drilling fluid losses and hydraulic fracturing. All pumping pressures should be recorded.

d. Rock cores should be stored in covered core boxes to preserve their relative position by depth. Intervals of lost core should be noted in the core sequence. Boxes should be marked on the cover (both inside and outside) and on the ends to provide project name, boring number, cored interval, and box number in cases of multiple boxes. Any core box known or suspected to contain contaminated core should be appropriately marked on the log and on the box cover (inside and out), and on both ends. The weight of each fully loaded box should not exceed 34 kg (75 lb). No geotechnical or contaminant data should appear on or within the box that is not specified on the boring log. As a minimum, the estimated number of boxes required for a given boring should be on hand prior to coring that site.

e. The core within each completed box should be photographed after the core surface has been cleaned or peeled, as appropriate, and wetted. Each photo should be in sharp focus and contain a legible scale in centimeters (feet and tenths of feet). The core should be oriented so that the top of the core is at the top of the photo. Each photo should be annotated on the back with the project name, bore/well designation, box number, cored depths pictured, and date photographed. One set of glossy color prints should be sent to the FA after the last coring. In addition, all negatives should be delivered to the FA after the FA has received the prints. (See ER 1110-1-1803 for additional guidance on core management.)

f. All rock core, except that for analysis and reference, should be neatly stored at an FA-designated location. The disposition of these samples should be arranged by the FDO. Specific instructions for the storage or required packaging and method of shipment to the laboratory should be provided in the drilling plan.

g. Bedrock cores known or suspected of being contaminated may have to be handled, stored, tested, and/or disposed of as hazardous waste. Such a consideration and determination should be made prior to drilling plan approval. This determination may alter drilling methods, coring frequency, data quality, costs, etc. Geophysical downhole logging or borehole camera techniques could be considered as alternatives in some cases. The drilling plan should reflect the final decision and possible alternatives that retain viability.

3-13. Abandonment/Decommissioning

Abandonment (also termed decommissioning) is that procedure by which any boring or well is permanently closed. Abandonment/decommissioning procedures should preclude any current or subsequent fluid media from entering or migrating within the subsurface environment along the axis or from the endpoints of any boring or well penetrating that environment.

a. Planned abandonment requirements and procedures should be described in the FSP plan and incorporate USACE guidance and applicable state and/or Federal regulatory abandonment requirements.

b. The closure of any borings or wells not scheduled for abandonment per drilling plan should be approved by the FA prior to any casing removal, sealing, or back-filling. Abandonment requests should be submitted by the FDO to the FA with the following data, plus recommendation:

(1) Designation of boring/well in question;

(2) Current status (depth, contents of hole, stratigraphy, water level, etc.);

(3) Reason for closure; and

(4) Action taken, to include any replacement boring or well.

c. Each boring or well to be abandoned/decommissioned should be sealed by grouting from the bottom of the boring/well to the ground surface. This should be done by placing a tremie pipe to the bottom of the boring/well (i.e., to the maximum depth drilled/bottom of well screen) and pumping grout through this pipe until undiluted grout flows from the boring/well at ground surface. Any open or ungrouted portion of the annular space(s) between the innermost well casing and borehole (to include any casings in between) should be grouted in the same manner.

d. After 24 hours, the FDO should check the abandoned site for grout settlement. That day, any settlement depression should be filled with grout and rechecked 24 hours later. Additional grout should be added using a tremie pipe inserted to the top of the firm grout, unless the depth of the unfilled portion of the hole is less than 4.5 m (15 ft) and this portion is dry. This process should be repeated until firm grout remains at ground surface.

e. An abandoned well may be grouted with the well screen and casing in place. However, local regulations or a lack of data concerning well construction, condition, or other factors may require the removal of the well materials and a partial or total hole redrilling prior to sealing the well site. See ASTM Standard Guide D 5299 for a discussion of other decommissioning procedures.

f. For each abandoned boring/well, a record should be prepared to include the following as applicable.

(1) Project and boring/well designation.

(2) Location with respect to the replacement boring or well (if any); e.g., 6 m (20 ft) north and 6 m (20 ft) west of Well 14.

(3) Open depth of well/annulus/boring prior to grouting.

(4) Casing or items left in hole by depth, description, composition, and size.

(5) Copy of the boring log.

(6) Copy of construction diagram for abandoned well.

(7) Reason for abandonment.

(8) Description and total quantity of grout used initially.

(9) Description and daily quantities of grout used to compensate for settlement.

(10) Dates of grouting.

(11) Disposition of materials removed/displaced from decommissioned boring/well; e.g., objects, soil, and groundwater.

(12) Water or mud level (specify) prior to grouting and date measured.

(13) Remaining casing above ground surface: type (well, drill, protective), height above ground, size, and composition of each.

(14) Report all depths/heights from ground surface.

(15) The original record should be submitted to the FA.

g. Replacement well/borings (if any) should be offset at least 6 m (20 ft) from any abandoned site in a presumed up- or cross-gradient groundwater direction.

3-14. Work Area Restoration and Disposal of Drilling and Cleaning Residue

All work areas around the wells and/or borings should be restored to a condition essentially equivalent to that of preinstallation. This includes the disposal of borehole cuttings and rut removal. Borehole cuttings, discarded samples, drilling fluids, equipment cleaning residue, and water removed from a well during installation, development, and aquifer testing should be disposed of in a manner approved by the FA, host installation, and consistent with applicable state and federal regulations. These types of materials are considered investigation-derived wastes (IDW). (See USEPA EPA/540/G-91/009 for USEPA guidance on the management of these materials.) Whatever procedures are followed, the leaving of barrels containing drill cuttings, excess samples, and water at various unsecured locations around the site at the completion of well installation is not appropriate. All drums/barrels filled onsite should be permanently labeled (in a waterproof manner and resistant to fading) and inventoried as to their contents and source. Restoration and disposal procedures (to include disposal location(s)) should be discussed in the FSP. Depending on the site and its accessibility to the public, it may be permissible (depending on state regulations) to stage the drums neatly on pallets immediately adjacent to the boring/monitoring well location. If the option exists to dispose of IDW by spreading it on the ground at the sampling location, it may not be cost-effective to stage the drums in a central location and then move them back to the boring/monitoring well location for disposal.