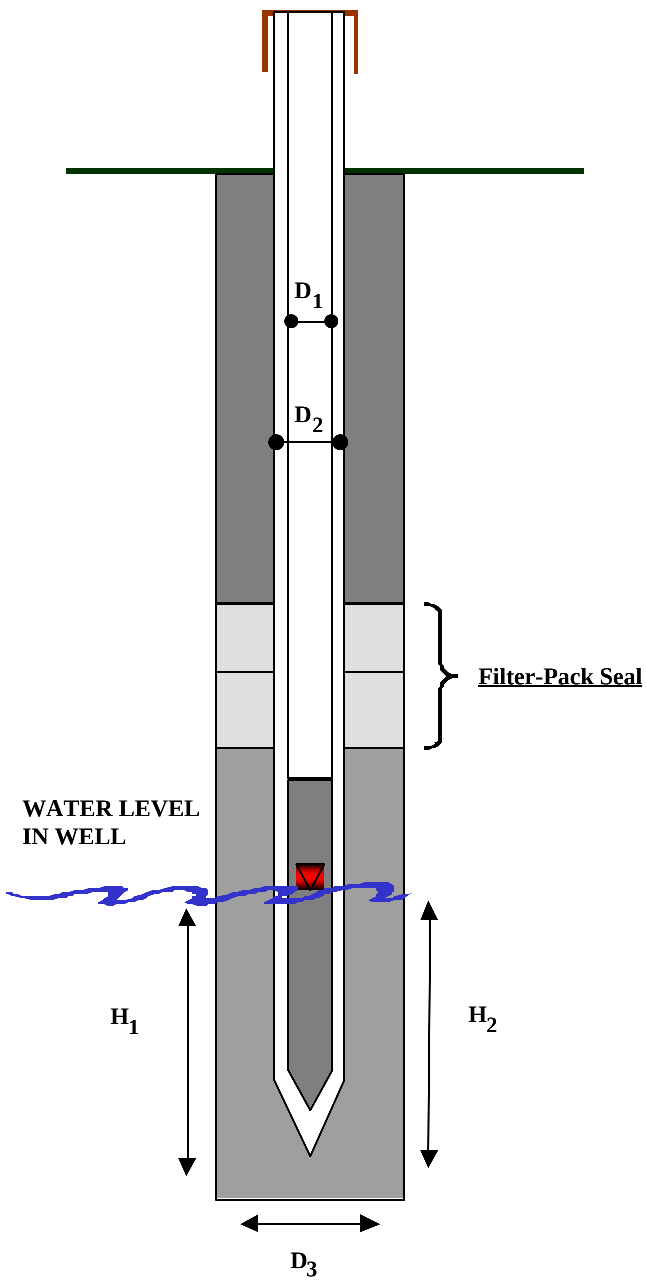
GROUNDWATER MONITORING WELL DRILLING, CONSTRUCTION, AND DECOMMISSIONING

State of Oregon
Department of Environmental Quality

DEQ GUIDANCE DOCUMENT



August 24, 1992

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NOTE

This is a reprint of a Department of Environmental Quality guidance document that was first issued on August 24, 1992. Although the format has been updated, the contents of the document have not been changed. The original document was approved for use by:

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1.0 INTRODUCTION

These Guidelines have been developed by the Department of Environmental Quality (DEQ) in recognition of the need for uniform standards regarding the drilling, construction and decommissioning of groundwater monitoring wells.

The technique used to install a groundwater monitoring well can influence the accuracy and reliability of: (1) Water quality samples obtained from the well, (2) Information on the position of the water table or potentiometric surface, or (3) Test results to determine physical properties of the aquifer, such as hydraulic conductivity.

An improperly constructed well may produce water samples that do not accurately reflect the chemical composition of the water, or may yield data that is not representative of the physical properties of the aquifer. An improperly constructed or abandoned well can act as a conduit for the migration of contaminants from the surface into a water-bearing zone, or between water-bearing zones in the well.

Proper monitoring well design and construction: (1) Includes consideration of, and is compatible with, site specific hydrogeologic conditions, including site stratigraphy and the physical and chemical properties of the groundwater and any contaminants known or suspected to be present in site soils or groundwater; (2) Allows collection of accurate and representative water quality samples; (3) Maximizes well efficiency, while minimizing sediment or turbidity in water samples; (4) Prevents introduction of surface water or contaminants into groundwater; (5) Prevents vertical movement of water or contaminants between water-bearing zones in either the well bore or well annulus; (6) Prevents waste or contamination of groundwater resources; and (7) Results in permanent wells which will last for the duration of the monitoring period, including any post-closure monitoring requirements.

2.0 APPLICABILITY OF GUIDELINES; DISCLAIMER; RELATIONSHIP TO OAR CHAPTER 690, DIVISION 240

These Guidelines apply to the installation and abandonment (decommissioning) of monitoring wells, piezometers and exploratory borings at facilities requiring hydrogeologic site characterization and/or groundwater monitoring pursuant to a DEQ operating permit or other DEQ regulatory authority.

These facilities include, but are not limited to, solid and hazardous waste storage, treatment or disposal facilities, sewage treatment and storage facilities, wastewater treatment and storage facilities, underground storage tank installations or cleanup projects, sites being evaluated or cleaned up under the authority and oversight of the State Environmental Cleanup Program, or area-wide non-point source groundwater pollution monitoring.

These Standards are intended solely as guidance for employees of the DEQ. They do not constitute rule making by the Environmental Quality Commission (EQC) and may not be relied upon to create a right or benefit, substantive or procedural, enforceable at law or in equity, by any person. The DEQ may take action at variance with these Standards.

On August 3, 1990, the Water Resources Commission (WRC) adopted Administrative Rules OAR Chapter 690, Division 240, effective January 1, 1991, relating to monitoring well construction and monitoring well constructor licensing. Concepts, definitions and procedures described in these Guidelines may differ from those in OAR Chapter 690, Division 240. Compliance with or use of these Guidelines does not waive compliance with OAR Chapter 690, Division 240.

3.0 DEFINITIONS

Annular Space, Annulus or Well Annulus: The space between the well casing and borehole wall, or between two concentric casings.

Annular Seal: Low-permeability seal placed in the well annulus between the top of the filter pack seal and land surface. The annular seal is composed of cement or bentonite grout, cement-bentonite grout, or bentonite granules, pellets or chips.

ASTM: American Society for Testing and Materials.

Bentonite: A rock formed from devitrified and altered volcanic ash of tuff, and composed predominantly of smectite or montmorillonite group clay minerals. Bentonite in which sodium as the dominant cation has very high swelling capacity and forms gel-like masses when added to water; it is the most common commercial form of bentonite used in well drilling and construction activities. Calcium bentonite has a louver swelling capacity but can also be obtained for special applications in well drilling and construction. Various grades of bentonite are commercially available in powder, granule, pellet, or chip form for use in well drilling, construction or decommissioning.

Aquifer: A geologic formation, group of formations or part of a formation that is saturated and is capable of providing water to a well.

Bentonite Grout: A mixture of granular bentonite and water used as an annular sealant or borehole sealant that forms a semi-rigid low-permeability seal which prevents movement of fluids in the annular space or borehole, and maintains the alignment of the casing in the borehole.

Borehole: A circular opening or uncased subsurface hole, deeper than it is wide, created by drilling for the purpose of either installing a well or obtaining geologic, hydrogeologic, geotechnical or geophysical data.

Bridge: An obstruction in the annular space which may prevent proper emplacement of filter pack, filter pack seal, or annular seal.

Casing: Impervious, durable pipe, finished in sections with either threaded connections or beveled edges to be field-welded, which is installed temporarily or permanently in a borehole to counteract caving, to advance the borehole, or to isolate the zone being monitored.

Caving: The inflow. of unconsolidated material into a borehole that occurs when the borehole walls lose their cohesive strength. Synonymous with *sloughing*.

Cement: Portland cement, as described and defined in ASTM Standard Designation C 150-86.

Cement Grout Slurry: A mixture of cement and water used as an annular sealant or borehole sealant that forms a rigid low-permeability seal which prevents movement of fluids in the annular space or borehole, and maintains the alignment of the casing in the borehole.

Cement-Bentonite Grout Slurry: A mixture of cement, bentonite and water used as an annular sealant or borehole sealant that forms a rigid low-permeability seal which prevents movement of fluids in the annular space or borehole, and maintains the alignment of the casing in the borehole.

Centralizer: A device that assists in the centering of a casing within a borehole or within another casing.

Confining Layer: A geological unit or strata that has a relatively low permeability, stratigraphically adjacent to an aquifer or water-bearing zone.

Contaminant: Any chemical, ion, radionuclide, synthetic organic compound, microorganism, waste, or other substance in soil or water that is not normally present, or occurs naturally but at a lower concentration; usually of anthropogenic origin or related to anthropogenic activities.

Contaminated, Contamination: Refers to the presence of contaminants.

Decommission: To remove a well from service by completely sealing it with grout in such a manner that vertical movement of water within the well bore and within the annular space surrounding the well casing is permanently prevented. Synonymous with *permanent abandonment*, OAR 690-200-050.

DEQ: The Oregon Department of Environmental Quality.

Drill Cuttings: Soil or rock particles removed from the borehole in the drilling process.

Drilling Fluid: A fluid, liquid or gas, that is used in drilling operations to remove cuttings from the borehole, clean, lubricate and cool the drill bit, and stabilize the borehole during drilling.

Exploratory Boring: Any uncased temporary excavation or opening into the ground, with greater depth than width, made by digging, boring, drilling, driving, jetting or other methods for the purpose of obtaining geologic, hydrogeologic, geotechnical, or geophysical information about subsurface strata, or obtaining information on the physical, chemical, biological or radiological properties of groundwater.

Filter Pack: Sand, gravel, or sand and gravel mixture of selected grain size and gradation installed in the annular space between the borehole wall and the well screen for the purpose of retaining and stabilizing the screened formation, and supporting the filter pack seal and the annular seal.

Filter Pack Seal: Low-permeability seal placed in the well annulus between the top of the filter pack and the bottom of the annular seal.

Geologic Log: A sequential record of the geologic materials penetrated during the drilling of a borehole.

Geophysical Log: A sequential record obtained from sensing devices lowered into a borehole or well of the physical, electrical, radiological, or other properties of rocks penetrated by a borehole, fluids contained in the rocks, or well construction.

Groundwater: Subsurface water in the zone of saturation.

Groundwater Monitoring Well: Any cased excavation or opening into the ground, with greater depth than width, made by digging, boring, drilling, driving, jetting or other methods for the purpose of determining the physical, chemical, biological, or radiological properties of groundwater.

Grout: A mixture of water and insoluble solid material (*e.g.* a slurry) used to fill void spaces (*e.g.* the annular space) *(noun)*; To fill up or fix in place with grout *(verb)*.

Heaving Sands: Loose sands in a confined water-bearing zone or aquifer which tend to rise up into the drill stem when the unit confining the aquifer is breached by the drill bit, because the water in the aquifer has a pressure head great enough to cause upward flow into the drill stem with enough velocity to overcome the weight of the sand, creating a 'quick-sand' condition, and carrying sand into the drill stem. Usually associated with hollow stem auger drilling.

Hollow Stem Auger: A drilling method using drill pipe consisting of continuous screw-auger flighting welded to the outside of hollow pipe. The flighting is rotated into the ground. The auger flights maintain the stability of the borehole. Geologic and water samples are collected through the auger flights from below the drill bit. Monitoring wells are typically constructed inside the auger flights, as the flights are slowly withdrawn from the borehole.

Hydraulic Conductivity: The volume of water at the existing kinematic viscosity that will move in unit time under a unit hydraulic gradient through a unit area measured at a right angle to the direction of flow.

Licensed and Bonded Monitoring-Well Constructor: A well driller who, pursuant to ORS 537.747 through 537.753, is in compliance with Oregon Administrative Rules (OAR) 690-240-055 through -080.

Neat Cement Slurry: A mixture of Portland cement and water; see "*Cement Grout Slurry*."

OWRD: Oregon Water Resources Department.

Percussion Drilling: A drilling method where the borehole is advanced using repetitive dropping or striking of a weighted drill bit on the bottom of the borehole to break up the geological materials. Drill cuttings may be removed from the borehole by bailing, as in cable tool drilling, or by a circulating drilling fluid, such as air, as in down-hole air hammer drilling. Often a casing advancement system, or casing driver, is used in conjunction with percussion drilling, to maintain the stability of the borehole.

Piezometer: Any cased excavation or opening into the ground, with greater depth than width, made by digging, boring, drilling, driving, jetting or other methods for the primary purpose of determining the depth to, or elevation of, the water table or potentiometric surface.

Potable Water: Water that is safe for human consumption and which meets water quality standards for inorganic, organic, particulate, radionuclide and microbiological contaminants, as described in 40 Code of Federal Regulations (CFR) Parts 141, 142 and 143, pursuant to Sections 1401 and 1412 of the Federal Safe Drinking Water Act (42 USC 300f *et seq.*).

Potentiometric Surface: An imaginary surface representing the total head of groundwater in a well or piezometer. The total head is typically the sum of the elevation and pressure head, and is the height the kinetic energy of the liquid is capable of lifting the liquid. The water table represents the potentiometric surface of an unconfined aquifer, where the pressure head is zero and the elevation head equals the total head.

Registered Civil Engineer: Civil Engineer with current Oregon State registration as defined in ORS Chapter 672.

Registered Geologist: Geologist with current Oregon State registration, as defined in ORS Chapter 672.

Registered Land Surveyor: Land Surveyor with current Oregon State registration, as defined in ORS Chapter 672.

Rotary Drilling: A drilling method where the borehole is advanced using a circular rotating action applied to a string of drilling rods which have a diffused discharge bit attached to the bottom of the rods. Drilling fluid, typically either air, water, or a bentonite-water slurry ('drilling mud'), are circulated through the drill rods, drill bit and borehole to lubricate and cool the drill bit and remove drill cuttings from the borehole, and maintain the stability of the borehole.

Security Casing: A metal casing with a locking cap set in concrete that encloses and covers the well casing, preventing damage to or unauthorized entry into the monitoring well or piezometer.

Slurry: A mixture of water and insoluble solid materials, *e.g.* cement or bentonite; See Grout.

Sodium Bentonite: See "*Bentonite.*"

Static Water Level: The elevation of the top of the water column in a monitoring well, piezometer, or borehole that is not influenced by conditions related to drilling of the borehole, installation of the well or piezometer, or to pumping of the well or nearby wells.

Surface Seal: Concrete or suitable alternative used to grout the security casing in place.

Surge: An action causing water to move rapidly in and out of the well screen, thereby stabilizing and removing fine material from the surrounding filter pack and water-bearing formation.

Tremie Pipe: A pipe or hose used to install well construction materials (*e.g.* filter pack or grout slurry) into an annular space or borehole.

Uniformity Coefficient: The ration of the 60 percent finer (d-60) grain size to the 10 percent finer (d-10) finer grain size of a sample of granular material (See ASTM Standard Test Method D-2487).

Water-Bearing Zone: A subsurface hydrologic zone in which all void spaces are filled with water under pressure greater than atmospheric pressure, from which water will drain freely into a borehole or well.

Water Table: The groundwater surface in an unconfined aquifer where the water pressure is equal to atmospheric pressure; see "*Potentiometric Surface*."

Well Bore Volume, Well Volume: The volume of water contained in the well casing and filter pack.

Well Development: The process of agitating, surging and pumping a well to remove fine-grained particulate sediment from the well and filter pack, stabilize the filter pack, and remedy any damage to the screened water-bearing formation resulting from drilling activities.

Well Screen: A filtering device which permits water to enter the well while retaining the filter pack in the well annulus; usually a cylindrical pipe with openings of uniform width, orientation and spacing.

Zone of Saturation: A subsurface hydrologic zone in which all voids are filled with water under pressure greater than atmospheric pressure. See "*Aquifer*" and "*Water-Bearing Zone*."

4.0 DESIGN OF MONITORING WELLS AND SUPERVISION OF CONSTRUCTION; DEPARTMENT REVIEW OF WORK PLANS

Monitoring wells must be designed by or under the direct supervision of a geologist, engineering geologist or civil engineer with current Oregon registration and experience in hydrogeologic investigations and monitoring well design and installation.

Monitoring well drilling and installation should be continuously observed and supervised in the field by personnel familiar with well drilling, sampling and construction techniques, such as a registered geologist or civil engineer, geologist-in-training, engineer-in-training, or geological or engineering technician under the direct supervision of a registered geologist or civil engineer with current Oregon registration and experience in hydrogeologic investigations and monitoring well design and installation.

Individual DEQ programs may have policies requiring submittal of a work plan which describes and justifies monitoring well placement, design and construction prior to drilling and installation. Contact a DEQ hydrogeologist in the appropriate program to determine whether plans need to be submitted for approval prior to initiation of field activities. Appendix A lists typical information that must be included in a work plan.

5.0 MONITORING WELL DRILLING AND CONSTRUCTION

5.1 Well Placement and Protection

Select monitoring well locations based on: (1) The type of facility or situation requiring groundwater monitoring, (2) The purpose of the groundwater monitoring program (*i.e.* detection monitoring vs. rate and extent of contamination studies), and (3) Available existing information on subsurface conditions, such as previous reports or studies, which preferably include the results of a thorough hydrogeologic characterization study. Provide adequate justification for placement of each groundwater monitoring well.

Monitoring wells may be placed individually or in well clusters. Well clusters consist of multiple individual wells approximately ten (10) feet apart, screened at varying depths, each consisting of a single well installed in its own borehole.

Do not construct wells consisting of multiple depth completions in a single borehole without prior DEQ approval.

Do not install monitoring wells in locations where they are subject to periodic or seasonal inundation by floodwaters, unless the top terminal casing height is at least two (2) feet above the 100-year flood elevation or prior DEQ approval for special watertight construction has been granted.

Locate and construct monitoring wells in such a manner as to protect against loss of integrity by soil erosion, soil settlement, shrink-swell soil conditions, frost heaving of soils, damage by vehicles or heavy equipment, and/or other site specific hazards.

Secure monitoring wells against unauthorized entry with appropriate locking devices.

5.2 Drilling And Sampling

5.2.1 Drilling Methods. Drilling methods chosen will depend on site-specific geologic and hydrogeologic conditions, site accessibility, availability of equipment, contaminants present, monitoring well design, and the objectives of the monitoring program.

Typical drilling methods used for installation of monitoring wells include: Auger (solid or hollow stem), Direct Circulation Rotary (air or mud), Reverse Circulation Rotary, or Percussion (cable tool or downhole air hammer) Drilling. Various types of casing advancement systems are available for use with these drilling methods. Discussions of these drilling systems, and their advantages and disadvantages in monitoring well construction, can be found in (Aller, et al, 1989), (Driscoll, 1986), U.S. EPA (September, 1986), and other References listed at the back of these Guidelines.

5.2.2 Decontamination of Drilling Equipment. Decontaminate all equipment that will be placed in the borehole on-site prior to use, and again between boreholes. Decontamination methods include steam cleaning, high-pressure hot water washing, detergent washing followed by thorough rinsing with potable water, and/or other appropriate methods. Include decontamination of internal plumbing of the drilling equipment, and any other items, that will contact potentially contaminated materials.

To the extent possible, plan drilling activities to proceed in order from the least to the most contaminated locations; therefore, drill upgradient wells first.

5.2.3 Use of Permanent or Temporary Casing During Drilling. Use permanent or temporary casing during well drilling and construction in cases where contaminated groundwater could migrate through the borehole into uncontaminated water-bearing zones, or where the formations penetrated have a tendency to slough or cave into the borehole and affect filter pack and annular seal placement or integrity.

In cases where monitoring wells are to be installed in a deeper water-bearing zone separated from a shallow contaminated zone by a low permeability confining layer, set and grout permanent or temporary surface casing into the confining layer prior to drilling into the deeper zone. Use a grouting method described in **Section 7.0**. Do not drill into the deeper zone until the grout has set for at least 12 hours, or until the integrity of the grout seal is verified and determined to be adequate for site conditions, whichever is longer.

5.2.4 Use of Lubricants and Drilling Fluids. Take every appropriate precaution during drilling to avoid introducing contaminants related to drilling into the borehole. Do not use drilling mud or gel, synthetic drilling fluids, petroleum-or metal-based pipe joint compounds, or other potential contaminants unless necessary.

Equip air drilling systems with in-line air filters in good working order to remove compressor oils entrained in the air stream.

Use only potable water if it is necessary to add water to the borehole during drilling. Identify the source of the water in the drilling report. Provide a chemical analysis of the drilling water, if requested.

High-yield powdered sodium bentonite clay gel, free of organic polymers, mixed with potable water, is the preferred drilling fluid if it is necessary to add drilling fluid to the borehole during drilling to stabilize the hole or control downhole fluid losses. Air drilling systems may require the use of alternative drilling fluid additives, such as foaming agents. Identify all drilling fluids or additives used in the Well Construction Report **(Section 8.1)**.

Maintain a record of the volume of water or drilling fluid lost to the formation or screened zone of the well during drilling. Recover an equivalent volume of water during well development.

When drilling exploratory borings or other holes which will not subsequently be used to obtain groundwater quality data, drilling fluids may be used as necessary to stabilize the borehole, control heaving sands or downhole fluid losses, or enhance core or sample recovery, provided other information such as identification of saturated zones is not compromised as a result of the use of the drilling fluids.

5.2.5 Management of Contaminated Drill Cuttings and Water. Properly manage and dispose of any contaminated drill cuttings or water removed from the borehole during drilling. Document the method of cuttings and water management and disposal in the well construction report **(Section 8.1)**.

5.2.6 Borehole Size, Plumbness and Straightness. Boreholes, hollow-stem auger flights, or permanent or temporary surface casing should have a minimum inside working diameter at least four (4) inches larger than the outside diameter of the well casing and screen, to ensure that: (1) Casing and screen can be properly centered in the borehole, (2) The filter pack and annular seal are of sufficient thickness, (3) There is sufficient working room for a Tremie pipe to be properly used in the well, and/or (4) Filter pack and annular seal materials can be poured into the well, without causing bridging in the annulus or binding of the well casing or screen when auger flights or temporary casing are withdrawn from the well.

Therefore, for 2-inch and 4-inch nominal diameter well casings, the borehole, auger or casing used should have a nominal inside diameter of 6 and 8 inches, respectively.

Level the drilling machine prior to drilling, to ensure that the borehole is plumb with respect to the vertical. Recheck leveling frequently during drilling.

Employ drilling practices which produce the straightest possible borehole during drilling. For rotary drilling, for example, this requires selection of the appropriate drill bit, drill collars, rotating speed, and weight on the drill bit for the materials being penetrated. For cable tool drilling, this requires selection of the appropriate drill bit, drill stem, stroke length and stroke rate for the materials being penetrated.

5.2.7 Geologic Sampling. Appropriate sampling intervals and techniques will depend on the materials penetrated, the drilling method(s) used, and degree of prior knowledge of subsurface site conditions.

Sampling techniques for hollow-stem auger drilling include continuous split barrel core samples, Shelby tube (ASTM D-1587) or split spoon (ASTM D-1586) samples. Sampling techniques for rotary drilling include Shelby tube samples, split spoon samples, wireline or conventional core samples (ASTM D-21-13), or grab samples. Sampling techniques for cable tool drilling include bailer grab samples, Shelby tube or split spoon samples.

Collect formation samples frequently during drilling, preferably using continuous sampling techniques to recover minimally disturbed samples. In fine-grained cohesive soils and in competent bedrock, the most appropriate sampling techniques are continuous coring methods. Depending on the scope of the overall monitoring project and the complexity of the site geology, at least one and, at the DEQ's discretion, multiple continuously cored borings may be required. In non-cohesive soils, use alternatives to continuous sampling methods, such as split spoon sampling, if attempts at core recovery are unsuccessful.

Collect formation samples every five feet, or at each significant change in lithology, whichever interval is smaller. Additional sampling to determine the presence and concentration of contaminants in the soil, rock or water may also be required by the DEQ. Five (5) feet is the maximum acceptable interval between samples.

Do not composite samples for testing purposes without adequate justification and prior DEQ approval.

When installing well clusters, drill and continuously sample the deepest well in the cluster first. After drilling the deepest well, drill shallower wells in the cluster, and collect grab samples every five (5) feet, or at every significant change in lithology, whichever interval is smaller.

5.2.8 Sealing an Overdrilled Borehole. Seal any boreholes drilled deeper than the well to be constructed in the borehole to within one (1) foot of the bottom of the well by a method described in **Section 7.0**. Leave temporary casing or auger flights in the hole prior to grouting to prevent caving of the borehole. Withdraw temporary casing or augers slowly as the well is backfilled with grout.

Sound the top of the seal following installation to check for proper placement. Allow sufficient time for the seal to set or hydrate before constructing the well in the borehole above the seal (one to two hours for bentonite chips or pellets; 12 to 24 hours for cement or mixtures of cement and bentonite).

5.2.9 Sealing an Unused Borehole. Seal any borehole not completed as a monitoring well immediately following drilling, from the total depth of the borehole to land surface as described in Section 6.2.1. Leave temporary casings or auger flights in the hole prior to grouting to prevent movement of contaminants or caving of the borehole. Withdraw temporary casing or augers slowly as the well is backfilled with grout.

Under certain circumstances a borehole may be left open for up to 24 hours, if subsequent activities such as geophysical logging or formation testing of the borehole are planned. A borehole may only be maintained in an open condition following drilling if there is no potential for migration of contaminants within the borehole, or collapse of the borehole, during the time the hole will remain open. Obtain prior DEQ approval to leave any hole open for extended time periods in excess of 24 hours. Submit a Decommissioning Record for each decommissioned boring according to **Section 8.2**.

5.3 Monitoring Well Construction

Typical monitoring well construction is illustrated in **Figure 1**.

5.3.1 Selection of Construction Materials. Select well screens and casings, annular sealant, and other monitoring well components composed of new materials designed to last for the duration of the monitoring program or life of the facility being monitored, including any post-closure monitoring period, without loss of structural integrity and without contributing contaminants to or removing contaminants from the groundwater.

Casing and screen materials selected may include Polyvinyl Chloride (PVC) or other thermoplastic materials, Type 304 and Type 316 stainless steel or other steel formulations, Polytetrafluorethylene (PTFE) or other fluoropolymers, or fiberglass reinforced epoxy. Each of these materials has different characteristics with respect to strength, resistance to chemical or microbiological attack, and resistance to chemical interference. Review the properties of the various casing materials with respect to the objectives of the monitoring program during the design phase of a project.

Do not construct screen and casing assemblies with dissimilar metals, unless separated by a dielectric bushing, to minimize galvanic corrosion of the well materials.

5.3.2 Minimum Dimensions and Strengths. The minimum inside diameter for well screen and casing is 1.9 inches. The collapse strength of all casing used in monitoring well construction must be great enough to withstand the pressure exerted by the annular seal during seal placement, under conditions when the inside of the well casing is evacuated of fluid. Perform collapse strength calculations to verify that casing of sufficient strength has been selected.

All PVC used in monitoring well construction must conform to ASTM F-480, Standard Specification for Thermoplastic Water Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR). Wells constructed of other materials must meet applicable standards for the type of material utilized.

All wells constructed with PVC casing to depths greater than 100 feet must be constructed with at least Schedule 80 PVC.

Use Schedule 80 PVC in all PVC wells grouted with cement. The heat of hydration of cement may weaken and distort thinner grades of PVC casing. This is more likely to occur when large voids or washouts occur in the borehole, and large volumes of cement are locally present in the annular space adjacent to the casing.

Extend casings to a minimum height of eighteen (18) inches and a maximum height of thirty (30) inches above land surface, unless the well is completed with a flush mounted seal; then follow **Section 5.3.9.** Seal casings with caps. Vent casing caps to allow for pressure equalization, unless watertight construction is required.

5.3.3 Well Screen. Install well screen in all monitoring wells. Use factory fabricated screen (*i.e.* machine slotted or wire-wrapped). Do not use hand cut screen (*i.e.* hack saw or torch slotted). Maximum screen length is ten (10) feet unless otherwise approved by the DEQ.

Select a screen slot size which is compatible with the grain size of the filter pack (*e.g.* the screen should be capable of retaining at least ninety (90) percent of the filter pack). Consider site stratigraphy, water table variations, saturated thickness of the water-bearing zone, groundwater flow patterns and velocity, expected contaminant behavior, and monitoring objectives when selecting the screen composition, length, and position.

Where existing contamination is suspected or known to exist, the DEQ may require the use of surface or downhole geophysical techniques, or groundwater sampling prior to or during well installation, as an aid in selecting the screened interval.

Provide justification for the screen composition, length and placement interval in the work plan for DEQ approval, prior to well installation. Adequate justification typically requires some prior knowledge of site conditions, generally from performance of a subsurface site characterization investigation, with field observations and laboratory analyses of samples of soil, rock and water, as appropriate.

5.3.4 Casing and Screen Assembly, Cleaning and Centering. Use bottom caps or end plugs on all monitoring well casing and screen assemblies. Use of a bottom cap with a bail handle may make retrieval of the casing and screen assembly easier when the well is decommissioned. In some instances use of a tail pipe or sediment sump at the base of the well may be appropriate. Joints, caps, and end plugs must be watertight and secured by welds, threads, or force fittings. Do not use solvents, glues or adhesives for casing or screen assembly without prior DEQ approval.

Clean all well screen and casing thoroughly on-site before installation in the well by steam cleaning, high-pressure hot water washing, detergent washing followed by thorough rinsing with potable water, and/or other appropriate methods, unless delivered to the site in sealed packaging with documentation from the manufacturer that appropriate decontamination was performed prior to shipping.

Center all well screen and casing in the borehole. Use casing centralizers as necessary to center the well assembly in the borehole. At a minimum, use one casing centralizer at the bottom of the screened interval in each well to ensure proper positioning of the screen and filter pack with respect to the borehole wall. In most cases, a second casing centralizer should also be installed at the top of the screened interval, unless use of a centralizer in this location significantly increases the potential for bridging of the filter pack during placement. Suspend the casing and screen in the borehole under slight tension during placement of the filter pack and annular sealing materials to improve plumbness and centering of the casing in the borehole.

In deeper wells, use one casing centralizer for every 20 to 50 feet of well depth. Use flush-jointed Tremie pipe and run the Tremie pipe and the casing at the same time, to avoid tangling of the Tremie pipe with the centralizers.

5.3.5 Filter Pack. The filter pack is the primary barrier preventing particulate matter such as fine-grained sands and silt from the screened formation from entering the well; therefore, extreme care must be taken in the selection of materials for the filter pack, and in filter pack installation and development.

Use clean, chemically inert, well rounded, siliceous material for the filter pack surrounding the well screen. Do not use filter fabrics in conjunction with, or in place of, filter packs without prior DEQ approval. Choose a filter pack material which will: (1) Minimize the amount of fine-grained sediment entering the well, (2) Allow for proper well development, (3) Not inhibit the inflow of water to the well, and (4) Not affect the chemistry of water samples taken from the well.

Do not extend the filter pack more than three (3) feet above the top, or one (1) foot below the bottom of the well screen. Prior to filter pack placement, calculate the volume of filter pack material required. Record calculated and actual volumes used, and report these volumes in the Well Construction Report **(Section 8.1)**.

Base the grain size of the filter pack placed in wells screened in water-bearing zones composed of non-cohesive granular materials upon a representative sieve analysis of the formation materials opposite the well screen. Choose a filter pack material with a d-30 grain size (30 percent passing) 4 to 6 times larger than the d-30 grain size of the finest formation materials screened, and a uniformity coefficient of 2.5 or less. Use a multiplier of 4 for fine-grained, uniform, poorly graded or well sorted formation materials, and a multiplier of 6 for non-uniform well graded or poorly sorted materials. Alternatively, choose a filter pack material with a d-50 grain size two (2) times larger than the d-50 grain size of the finest formation sample. Selection of filter packs is discussed in more detail in (Aller, *et al.*,1989) and (Driscoll, 1986).

Alternative methods of selecting filter pack materials may be necessary if the well is screened in consolidated rock or in very fine grained sands or silty formations.

Place the filter pack material through a Tremie pipe in order to ensure positive placement opposite the well screen without bridging or size segregation of the filter pack material.

If the fluid level in the well is within about 10 feet of the top of the well screen, set the Tremie pipe above the fluid level, to avoid plugging of the Tremie pipe during filter pack placement.

If the fluid level in the well is greater than about 10 feet above the top of the well screen, the Tremie pipe may need to be set deeper than the fluid level, and placement of the filter pack through the Tremie pipe may require the use of water to wash the filter pack through the pipe.

If water is used for filter pack placement, use only potable water, and record the source and volume of water used. Identify the source of the water in the drilling report. Provide a chemical analysis of the water if requested. Recover a volume of water at least equivalent to the volume of water used to place the filter pack by pumping or bailing the well during filter pack placement and/or subsequent well development.

If augers or temporary casing are used and the well is less than 50-feet deep, the filter pack may also be installed by slowly and carefully pouring the filter pack material into the annular space. Slowly withdraw the augers or casing as the filter pack rises in the well annulus.

Sound the top of the filter pack frequently during placement, and following installation, to ensure that the filter pack is not bridging in the annulus, and to document final placement depth. Develop the well by surging, bailing or pumping during placement of the filter pack, to improve initial settlement of the filter-pack and reduce the possibility of creating a void space in the annulus between the filter pack and the annular seal during subsequent well development.

5.3.6 Filter Pack Seal. The filter pack seal prevents infiltration of grout slurry into the filter pack. The filter pack seal consists of a two foot thick fine-grained sand cushion overlain by a three-(3) foot thick bentonite seal, placed in the annulus above the filter pack.

For the sand cushion, use sand with a d-50 grain size two to three times finer than the d-50 grain size of the filter pack material, but no coarser than 20 mesh (0.833 millimeters). For the bentonite seal, use a type of bentonite and method of placement consistent with **Subsections 7.2.3** or **7.3** of these Guidelines.

Sound the top of both the sand cushion and the bentonite seal following installation to check for proper placement. If a grout slurry will be used to seal the annular space, and bentonite chips or pellets are used for the bentonite seal, allow the bentonite seal to hydrate for at least two hours prior to placing the annular seal, to prevent invasion of the filter pack by the grout slurry.

5.3.7 Annular Seal. The annular seal is the primary safeguard against movement of water or contaminants from the surface into a monitoring well, or movement of water or contaminants between water-bearing zones penetrated during drilling of the well; therefore, extreme care must be taken in the selection of materials for the seal, and in seal installation.

Seal the entire annular space from the top of the bentonite seal to the bottom of the surface seal by a method described in **Section 7.0**. Leave temporary casings or auger flights in the hole prior to grouting to prevent caving of the borehole or vertical migration of contaminants within the borehole. Withdraw temporary casing or augers slowly as the well is backfilled with grout.

Allow the annular seal to set for at least 24 hours prior to installing the security casing and surface seal. Any settlement of the annular seal should be topped off before installing the security casing and surface seal.

5.3.8 Security Casing and Surface Seal. Complete each well with a security casing and surface seal. The security casing and surface seal are the primary safeguard against unauthorized entry, vandalism or tampering with the well, and also protect against movement of water or contaminants from the surface into the monitoring well.

Use heavy gauge metal casing at least four (4) inches in diameter larger than the nominal diameter of the well casing for the security casing. Install the security casing in a drilled or excavated hole at least four (4) inches in diameter larger than the outside diameter of the security casing, to a minimum depth of three (3) feet below land surface, or to below the frost line, whichever is deeper. Permanently installed (grouted) surface casing may also function as the security casing. Fill the annulus outside the security casing with concrete-to-land surface.

Extend the security casing-above-land surface to a minimum height of twenty-four (24) inches and a maximum height of thirty-six (36) inches, but not more than six (6) inches higher than the well casing. Install a locking cap on the security casing that fully encloses the casing collar. Mark the security casing or cap clearly and permanently with pertinent well identification information.

Complete the well with a wire-mesh or steel-rod reinforced concrete surface slab with minimum lateral dimensions of three (3) feet and a minimum thickness of four (4) inches, which is sloped to allow water to drain away from the well in all directions. Place a drain hole near the base of the exposed security casing, unless water tight construction is required.

Fill the annulus between the security casing and the well casing with bentonite, rather than cement, so the two casings remain decoupled to minimize damage to the well by frost heaving. The top of the bentonite should be just below the drain hole. Sand or gravel may be used to fill the remainder of the annulus above the drain hole.

In areas where a combination of climatic and soil conditions are conducive to frost heaving, alternative construction techniques and materials may be required to prevent damage to the well, such as use of bentonite rather than concrete to grout the surface casing in place, or use of a tapered cement plug or bentonite pad protected by a gravel blanket, as described by (Gates, 1989), in place of the surface slab.

5.3.9 Flush-Mount Well Installations. Flush-mounted well installations are only allowed in high vehicular traffic areas and are only allowed in areas subject to ponding of water or flooding with prior DEQ approval.

Install locking, watertight, unvented caps on the well casings in flush-mounted installations. Install a watertight, tamper-proof, flush-mounted security casing around the well casing. The security casing must be constructed of heavy gauge metal, at least 12 to 18 inches long, at least four (4) inches in diameter larger than the nominal diameter of the well casing, and of unitized (one-piece) construction. Cement the security casing in a drilled or excavated hole at least four (4) inches in diameter larger than the outside diameter of the casing.

The lid or cover on the flush mounted security casing must bear the words **<u>Monitoring Well</u>** in permanent raised or engraved lettering.

Flush mounted security casings must be installed through an impervious surface such as asphalt or concrete. If an impervious surface does not exist, one must be constructed, with a recompacted subgrade which will support the maximum traffic loads in the area, and sloped to allow water to drain away from the well in all directions.

5.4 Well Development

The objective of well development is to remove any water or drilling fluids introduced into the well during drilling, stabilize the filter pack and formation materials opposite the well screen, minimize the amount of fine-grained sediment entering the well, and maximize well efficiency and inflow of water to the well.

Initial development of the well occurs during placement of the filter pack, prior to placing the filter pack and annular seals in the well. Final development of the well occurs after the annular seal has been placed and allowed to set.

Develop wells as soon as possible after construction, but no sooner than 24 hours after placing the annular seal. Develop the entire vertical screened interval using surge blocks, bailers, pumps, or other equipment which frequently reverses the flow of water through the well screen and prevents bridging of formation or filter pack particles.

Do not introduce non-formation water into the well during development.

If air-lift pumping techniques are use for well development, the preferred air lift pumping method contains the air within an eductor line and thus prevents air from entering the well screen or filter pack. If air is introduced into the screened zone of the well, air development should be followed by a period of pumping or bailing of sufficient duration that all oxygenated water in the vicinity of the well bore is removed as documented by measurements of dissolved oxygen and/or related geochemical measurements.

Development should not disturb the annular seal or the formations above the water-bearing zone, or damage the well. Special development techniques which minimize agitation and disturbance of the formation materials may be required in monitoring wells which screen very fine grained sands or silty formations.

Development is considered complete only when all water introduced during drilling plus a minimum of five (5) to ten (10) well bore volumes have been removed from the well, the water is chemically stable, and is, as free of sediment as possible.

During development, remove at least five (5) well bore volumes from wells completed in fine-grained strata such as silty or clayey sands, or silts (ASTM Groups SM, SC, ML) with estimated hydraulic conductivities less than 10^{-3} centimeters per second (cm/sec). Remove at least ten well bore volumes from wells completed in coarse-grained strata such as sands, gravels, or mixtures of sand and gravel (ASTM Groups SP, SW, GP, GW) with estimated hydraulic conductivities greater than 10^{-3} cm/sec.

Water produced from the well is considered chemically stable when field parameters (pH, temperature, specific conductance, Eh or dissolved oxygen) remain within five percent of the previous measurement for at least three successive borehole volumes.

Water produced from the well is considered free of sediment when water produced is clear and/or has a total suspended solids content of less than 100 milligrams per liter (mg/L) for at least three successive borehole volumes. The DEQ may require additional well development or replacement of the well, if water reasonably free of sediment cannot be obtained from the well following development.

The method of calculating well bore volume is given in **Appendix B** and illustrated in **Figure 2**. The volumes of some common casings and annuli are given in **Table 1**. Properly manage and dispose of any contaminated water withdrawn from the well during development. Report the method of water disposal in the Well Construction Report **(Section 8.1)**.

5.5 Field Testing of Hydraulic Conductivity

After development, allow the well to recover until stabilized static water level measurements are obtained. Following stabilization of water levels, conduct a field test to determine the hydraulic conductivity of the screened formation. The test must be of long enough duration and provide sufficient data to allow a representative estimate of the actual hydraulic conductivity of the formation to be calculated.

Test methods will vary depending upon the hydraulic characteristics of the screened interval. Use rising or falling head slug tests to test fine-grained strata such as silty or clayey sands, or silts (ASTM Groups SM, SC, ML) with estimated hydraulic conductivities less than 10^{-3} centimeters per second (cm/sec). Use constant discharge pumping tests to test coarse-grained strata such as sands, gravels, or mixtures of sand and gravel (ASTM Groups SP, SW, GP, GW) with estimated hydraulic conductivities greater than 10^{-3} cm/sec.

5.6 Location and Elevation Survey

Survey the location, elevation of the land surface, and the elevation of the top of the casing of each well. The location survey should have a horizontal accuracy of 0.5 foot, the land surface elevation should have a vertical accuracy of 0.1 foot, and the top of well casing elevation should have a vertical accuracy of 0.01 foot. Use a registered land surveyor to perform the survey.

Use the National Geodetic Vertical Datum of 1929 for vertical elevation control and the Oregon State Plane Coordinate System (ORS 93.330) for horizontal control.

Provide latitude-longitude coordinates for the well, accurate to the nearest one-tenth of a second.

Mark the well casing with a permanent reference point for water level measurements, such as a notch filed in the top of the casing or other similar recognizable and labeled mark.

6.0 MONITORING WELL DECOMMISSIONING

6.1 Introduction

Permanently decommission every monitoring well by sealing the well with grout: (1) When the well is no longer in active use, (2) If unrepairable leakage in the well or annular space is known or suspected, or (3) If the integrity of the well is permanently compromised in some other manner. The decommissioning procedures used should completely seal the well bore to prevent entrance of surface contaminants into the groundwater, and prevent all vertical movement of water or contaminants between water-bearing zones within both the well casing and the annular space.

Decommissioning procedures also apply to exploratory borings and piezometers. A licensed monitoring well constructor must perform the decommissioning procedure. A geologist or engineer must observe the decommissioning procedure in the field.

6.2 Decommissioning Procedures

Several decommissioning procedures are described below. The procedure chosen will depend on several factors, including: (1) Local geology and hydrogeology; (2) Presence and nature of contaminants in the soil or water-bearing zone(s) penetrated by the boring or screened by the well; and (3) Adequacy and documentation of well construction, including the size, type and condition of the casing and screen, and the type, condition and placement interval of the annular seal.

More rigorous requirements are described for removal of 2-inch casings from boreholes, as opposed to larger casings, because tools for ripping or perforating 2-inch casings in place are not generally available. Use of a bottom cap with an inside bail handle, and a flexible (*i.e.* bentonite) rather than a rigid (*i.e.* cement or cement-bentonite) grout may make removal of 2-inch casings less difficult.

6.2.1 Borings. Any borehole intersecting the water table, encountering contaminated soil, or greater than 10 feet deep, must be decommissioned according to the timelines in **Section 5.2.9**, by a grouting method described in **Section 7.0**.

6.2.2 Monitoring Wells

6.2.2.1 Monitoring Wells: 2-inch or smaller diameter wells in unconsolidated deposits; wells encountering contaminated soil or groundwater; wells not constructed according to standards in these Guidelines (or DEQ approved variance); wells with insufficient construction documentation.

Remove the security casing and surface seal from the well. Remove the well casing from the well prior to sealing by pulling the casing, overboring around the casing and pulling the casing, or drilling the casing out completely.

Clean the well bore out by redrilling the well to the total depth and diameter of the original borehole prior to sealing. Seal the well by a method described in **Section 7.0** from the total depth of the well-to-land surface.

6.2.2.2 Monitoring Wells: Wells greater that 2 inches in diameter; wells not encountering contaminated soil or groundwater; wells constructed according to Standards in these Guidelines (or DEQ approved variance), with adequate construction documentation. Remove the security casing and surface seal from the well. Either remove the well casing from the well prior to sealing by pulling the casing, overboring around the casing and pulling the casing, or drilling out the casing completely, or rip or perforate the casing in place prior to decommissioning. Seal the well by a method described in **Section 7.0** from the total depth of the well-to-land surface.

7.0 GROUTING

7.1 Introduction

Grout seals consist of a physically and chemically stable hydrated grout slurry composed of either neat cement, sodium bentonite, or a cement-bentonite mixture containing no more than four (4) percent bentonite by weight; or of sodium bentonite granules, pellets or chips placed in an unhydrated state, and subsequently hydrated downhole. The design permeability of the grout seal must be less than 1×10^{-7} cm/sec.

Preparation and placement of the grout must conform to the methods described below. Variances for alternative methods of grouting will be considered by the DEQ on a case-by-case basis. Justification for alternative methods must be provided at the time the request for the variance is made.

Special grouting procedures may be necessary in some instances when downhole conditions or the presence of contaminants are not compatible with the grouts or grouting procedures described in **Sections 7.2** and **7.3**. Evaluate grouting methods for compatibility with site specific conditions such as those described below:

(1) Ordinary cement (*e.g.* ASTM Type 1 or American Petroleum Institute (API) Class A) can deteriorate in high sulfate environments; sulfate resistant cements (*e.g.* ASTM Type II or API Class B for moderate sulfate resistance and ASTM Type V for high sulfate resistance) are available for use in high sulfate environments.

(2) Use cement with caution for the annular seal in wells constructed with Schedule 40 PVC casing, because the heat of hydration of the cement may weaken and distort the casing. This is more likely to occur when large voids or washouts occur in the borehole, and large volumes of cement are locally present in the annular space adjacent to the casing. Use of ASTM Type IV Cement, which has a lower heat of hydration, may be indicated if borehole washouts are known to be present.

(3) In fractured or highly permeable formations, cement grout may migrate rapidly along fractures or through the formation into the screened zone of the well and affect subsequent water quality measurements. The use of bentonite chips, cement containing lost circulation control additives or setting accelerators, may be indicated.

(4) In deep wells, downhole hydrostatic pressures created during grouting may cause hydro-fracturing of the formation or excessive grout loss to the formation. It may be necessary to stage the grouting operation, add lost circulation materials to the grout, and/or use setting accelerators to prevent excessive pressure build-up or grout loss to the formation.

(5) The swelling capacity and final permeability of bentonite may be affected by high levels of calcium or other exchangeable cations in the groundwater or soils; use calcium bentonite or cement in place of sodium bentonite in highly calcic environments.

(6) Free hydrocarbon product or other hydrophobic synthetic chemicals present as contaminants in soils or groundwater may coat bentonite chips or pellets with a hydrophobic barrier, preventing or inhibiting swelling of the bentonite.

(7) Synthetic organic compounds present as contaminants may react with bentonite, preventing or inhibiting swelling of the bentonite, or affecting the final permeability of the bentonite seal.

(8) Bentonite slurry may dehydrate and desiccate when very low soil moisture conditions are present in the soils surrounding the borehole, and should not be used under these conditions.

7.2 Grout Slurries

To be effective, grout slurries must be mixed in the proper proportions and properly placed in the borehole. Proper mixing prevents excessive grout shrinkage, water loss, or chemical breakdown of the grout; proper placement prevents bridging of the grout in the borehole or annular space, or invasion of the grout into the filter pack. Use of improper grout mixtures or improper grout placement techniques may allow water or contaminant movement in the borehole or well annulus, cause alteration of the water chemistry in the target monitoring zone, or otherwise shorten the life of the monitoring well.

It has been claimed that the addition of bentonite to cement grout reduces shrinkage and water-loss of the grout; however, experimental results indicate that the use of this type of grout results in longer setting times, decreased final strength, and a somewhat higher final permeability. Experimental results do not substantiate that shrinkage of the cement is significantly altered by the addition of bentonite to the cement, as long as the cement and water are mixed in the proper proportions (Edil, 1988).

Prior to use, thoroughly evaluate grout additives such as expanding agents or accelerators for use with neat cement, and catalysts or hydration inhibitors for use with bentonite, for potential impacts on long-term grout integrity and water chemistry of the target monitoring zone. Obtain prior DEQ approval for the use of additives.

Special grouting equipment designed to mix and pump grout slurries may be required to handle grout slurries mixed to the specified water-route ratios, and to the specified mud weights.

Leave temporary casing or auger flights in place prior to grouting to prevent caving of the borehole. Calculate borehole or annular space volume prior to grouting to determine the amount of grout slurry required to fill the borehole or annular space. Mix from twenty (20) to fifty (50) percent additional slurry prior to placing the slurry, to account for unanticipated borehole washout or variability.

Measure the mud weight of the grout by ASTM Standard Method D 4380-4 prior to placing the grout in the borehole. Measure the mud weight of the grout 'returns' from the well annulus. Grout placement should continue until undiluted grout returns are obtained from the annulus. Record the measured mud weight of the grout and the calculated and actual volumes of grout used. Provide grouting records with the as-built well construction or decommissioning record.

7.2.1 Neat Cement Slurry. Use ASTM C-150 Type I or II, or API Class A or B neat cement with no additives, mixed in the proportion of 5.2 gallons of water per standard 94-pound sack to a final mud weight of approximately 15.6 pounds per gallon. Special conditions may dictate use of other cements, such as ASTM C-150 Types III, IV, or V (or API equivalents) when special properties such as high early strength, low heat of hydration, or high-sulfate resistance are required.

7.2.2 Sodium Bentonite Slurry. Use granular sodium bentonite containing no additives, mixed according to the manufacturer's directions, mixed to a minimum mud weight of at least 9.5 pounds per gallon, and containing at least 15 to 20 percent solids. Use mixing methods which prevent the slurry from being excessively lumpy.

7.2.3 Cement-Bentonite Slurry. Use ASTM C-150 Type I or II, or American Petroleum Institute (API) Class A or B neat cement with no additives. Add up to four (4) percent (by weight of cement) standard sodium bentonite gel powder to the cement (3.75 pounds per 94 pound sack of cement). For each pound of bentonite added, an additional 0.7 gallons of water are added to the original neat cement mix of 5.2 gallons per sack, for a maximum water content of 7.8 gallons per sack of cement with four (4) percent bentonite. The water and bentonite should be mixed first, and the cement added to the bentonite slurry. The water content and mud weight of the grout slurry will vary as shown in **Table 2**.

7.2.4 Placement of Grout Slurries. Place grout slurries through a side-discharge Tremie pipe to ensure positive placement without bridging or wash-out of previously placed annular materials. Set the discharge end of the Tremie pipe at the bottom of the borehole or well annulus. Raise the Tremie pipe as the grout level rises, keeping the end of the Tremie pipe submerged in the grout throughout the sealing operation. Continue grouting until grout returns with a mud weight comparable to the mud weight of the initial grout mixture are obtained from the borehole or annular space at the ground surface. The seal must displace all standing fluid in the zone being sealed and set up without being diluted by formation water.

7.3 Grouting with Unhydrated Sodium Bentonite

If dry bentonite is used for well sealing or decommissioning activities, use the following procedures:

(1) Only use dry, poured bentonite seals if the depth to the bottom of the borehole or annular space is less than fifty (50) feet, and the height of standing water in the borehole or annular space is less than twenty-five (25) feet at the time of seal placement.

(2) Below the water table, use sodium bentonite chips or pellets. Above the water table, use #6 to #8 mesh sodium bentonite granules.

(3) Remove all viscous drilling fluids and drill cuttings from the borehole prior to placing the seal. Formation water or potable water should be the only fluid in the borehole or annular space at the time of seal placement.

(4) Examine bentonite chips and pellets on-site prior to using to ensure that size gradation has not been affected by handling during transport.

(5) To reduce the potential for bridging, use chips or pellets that are less than one-fifth the diameter of the borehole or the width of the annular space into which they are being placed. Thus, for example, use 1/4- to 3/8-inch chips to seal a 2-inch well casing in a 6-inch borehole; use 1 /2- to 3/4-inch chips to seal an uncased 4-inch borehole.

(6) Calculate the borehole or annular space volume prior to grouting to determine the amount of material required to fill the borehole or annular space. Record calculated and actual volumes used on the boring log, as-built well construction figure, or decommissioning record.

(7) Use a pour rate of 3 minutes or slower per standard 50-pound sack.

(8) Run a sounding or tamping bar in the borehole or annular space during pouring to measure fill-up rate and break up possible bridges or cake formation.

(9) Above the water table, install bentonite granules in individual lifts with a maximum thickness of two (2) feet. Tamp each lift in place and hydrate with potable water prior to placement of subsequent lifts. Pour the water through a Tremie pipe to reduce wetting of the borehole wall or well casing. Wetting of the borehole wall or well casing may cause bentonite cake to form, restrict the annular working space, and increase the potential for bridging. If very low moisture soils are present in the borehole, the bentonite granules may be placed in unhydrated tamped lifts.

8.0 WELL CONSTRUCTION AND DECOMMISSIONING DOCUMENTATION

8.1 Well Construction Report

Submit the following information in duplicate to the DEQ within thirty (30) days following completion of construction of any monitoring well, or according to another schedule contained in a DEQ approved work plan:

8.1.1 Certification. Stamped and signed written certification by the registered geologist or civil engineer that the well has been constructed in accordance with **Section 5.0** of these Guidelines or a DEQ approved variance from the Guidelines.

8.1.2 Well Location Map. A site map which accurately shows the as-built location of the monitoring well.

8.1.3 Geologic Log. A detailed geological log of the monitoring well which includes information on the location of the well, penetration rate or standard penetration resistance, sampled intervals and percent recovery, stratigraphic and lithologic information, aquifers, water-bearing zones and zones of high permeability or fracture encountered, contamination observed, and any other drilling observations including lost circulation zones or other difficulties encountered during drilling.

Classify unconsolidated deposits on the log according to ASTM D-2487, and describe in detail by texture, color, mineralogy, moisture content, degree of weathering, geologic origin, and other relevant characteristics. Include a description of the classification system used with the log.

Describe rock on the log according the lithology, mineralogy, color, grain size, degree of cementation, degree of weathering, density and orientation of fractures, other primary and secondary features and physical characteristics of the rock, and the rock quality designation. Descriptions must conform to ASTM C-294, or another standard system of nomenclature for rock classification. Include a description of the classification system used with the log. Submit a clear, labeled, photographic record of all rock cores if rock cores were recovered during drilling.

8.1.4 As-Built Construction Record. Include the following information with the as-built construction record of the monitoring well:

(1) Date of drilling and well installation, driller's name and affiliation, site geologist's name and affiliation;

(2) Type of drilling equipment used, method of drilling, volume of water used, and type and volume of drilling fluids or additives used;

(3) The size (diameter) and total depth of the borehole, and depth of the completed well;

(4) Method of disposal of drill cuttings;

(5) Screened interval; screen composition, diameter, slot size and percent open area; and installation procedure;

(6) Casing composition, diameter and installation procedure;

(7) Method of joining used to assemble screen and casing; type and location of all casing centralizers used;

(8) Type of filter pack material, placement interval and method of placement of filter pack, volume of filter pack material used, sieve analysis of filter pack material;

(9) Type of annular sealant, placement interval and method of placement of annular sealant, calculated and actual volume of sealant used, mud weight of sealant (if grout slurry was used);

(10) Surface seal and security casing design and construction;

(11) Well construction diagram;

(12) Development method(s), time spent on development, pumping rate and volume of water produced during development, clarity of water before and after development, record of field measurements of water quality made during development, method of disposal of development water;

(13) Results of location and elevation survey;

(14) Static water level measured to the nearest 0.01 foot, with the date of measurement;

(15) Copies of geophysical logs;

(16) Results of hydraulic conductivity tests, including raw data, test methods, analytical procedures, and data plots;

(17) Copy of drillers' log submitted to OWRD;

(18) Any additional data requested by the DEQ, including copies of field notes, drilling records, sampling logs, notes on well construction, results of water quality tests made during drilling and development, notes and calculations on hydraulic conductivity testing, and any other aspects of well construction and testing.

8.2 Well Decommissioning Report

Submit the following information in duplicate to the DEQ within thirty (30) days following decommissioning of any monitoring well, or according to another schedule contained in a DEQ approved work plan:

8.2.1 Certification. Stamped and signed written certification by the registered geologist or engineer that the well has been decommissioned in accordance with **Section 6.0** of these Guidelines, or a DEQ approved variance from these Guidelines.

8.2.2 Description and Diagram of Decommissioned Well. A description of the decommissioning procedure and an as-built diagram illustrating the decommissioned well, which includes: (1) Information on the location of the decommissioned well including a well location map; (2) A copy of the original geologic log and as-built well construction record; (3) Method of decommissioning; casing and screen removed from and remaining in the well; (4) Interval of placement of all plugs and seals; calculated and actual volume of grout used to seal the well; (5) Difficulties encountered in decommissioning the well; (6) Copy of drillers' decommissioning record submitted to OWRD; and (7) Any other relevant information.

9.0 EXCEPTIONS FROM GUIDELINES FOR PIEZOMETERS

Construct piezometers in accordance with all requirements of these Guidelines with the following exceptions:

(1) **Section 5.2.4:** Drilling fluids may be used as necessary without prior DEQ approval to stabilize the borehole, control heaving sands or down-hole fluid losses, or enhance core or sample recovery, provided other information such as identification of saturated zones during drilling is not compromised as a result, and the drilling fluid can be removed during development, so that representative water levels can be obtained.

(2) **Section 5.3.3:** Alternative screen materials such as porous stone piezometer tips, or field-slotted screen may be selected or used, without prior DEQ approval.

(3) **Section 5.3.2 and 5.2.6:** Minimum nominal diameter for piezometers is one inch. Minimum borehole working diameter is four inches.

(4) **Section 5.3.5:** Pre-selected filter pack material may be used.

(5) **Section 5.4:** It is only necessary to continue development until all drilling water, drilling fluid, and drill cuttings have been removed from the borehole.

(6) **Section 5.5:** Hydraulic conductivity testing is not required, unless requested by the Department.

10.0 SPECIAL CIRCUMSTANCES AND EXCEPTIONS

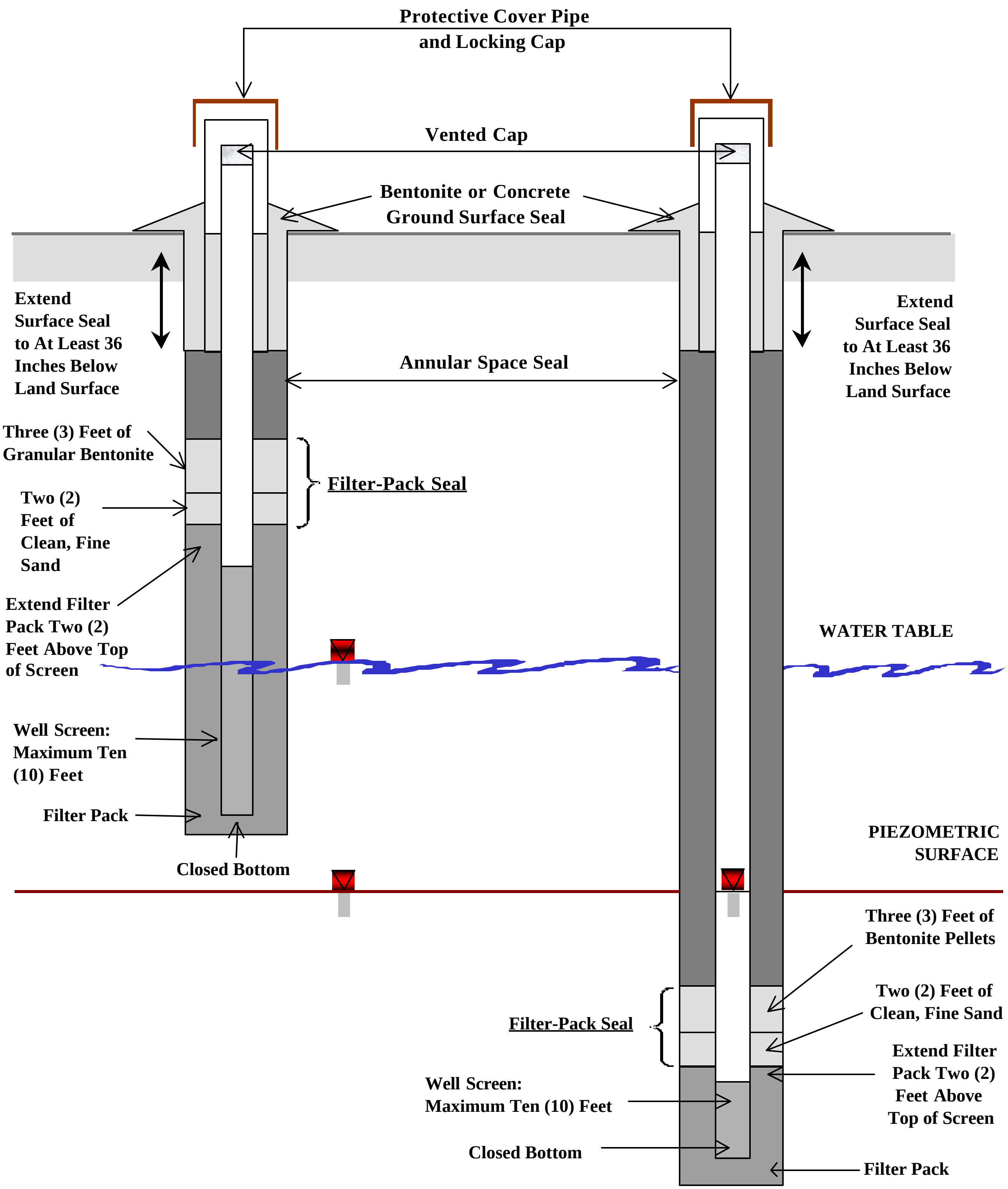
The DEQ may require more restrictive or approve alternative well drilling methods, construction materials, installation and construction methods, development methods, or decommissioning procedures if methods of investigation, local geology, hydrogeology, or contaminant concentration or distribution requires such special considerations. Obtain prior written approval from the DEQ before using alternative construction methods or materials.

Variance requests must be made in writing to a DEQ hydrogeologist in the program under which the work is being conducted. The variance request must state the reasons why compliance with the guidelines is not feasible. **Appendix C** describes information that must be included in a variance request in order for the DEQ to consider the request.

The DEQ will make every effort to act on variance requests within thirty (30) days of receipt, or within another negotiated time frame. If the variance is approved, the DEQ will authorize the variance in writing. Failure to comply with the conditions of the variance voids the DEQ's approval of the variance.

The DEQ will also make every effort to provide rapid, verbal approval of variance requests arising from changed or unanticipated conditions encountered in the field during well drilling and construction operations. Contact a hydrogeologist in the program under which the work is being conducted for approval of an emergency variance. A written variance request must be prepared and submitted within ten (10) days of the emergency request for a variance.

FIGURE 1: TYPICAL MONITORING WELL CONSTRUCTION



Not to Scale

FIGURE 2: CALCULATION OF WELL VOLUMES

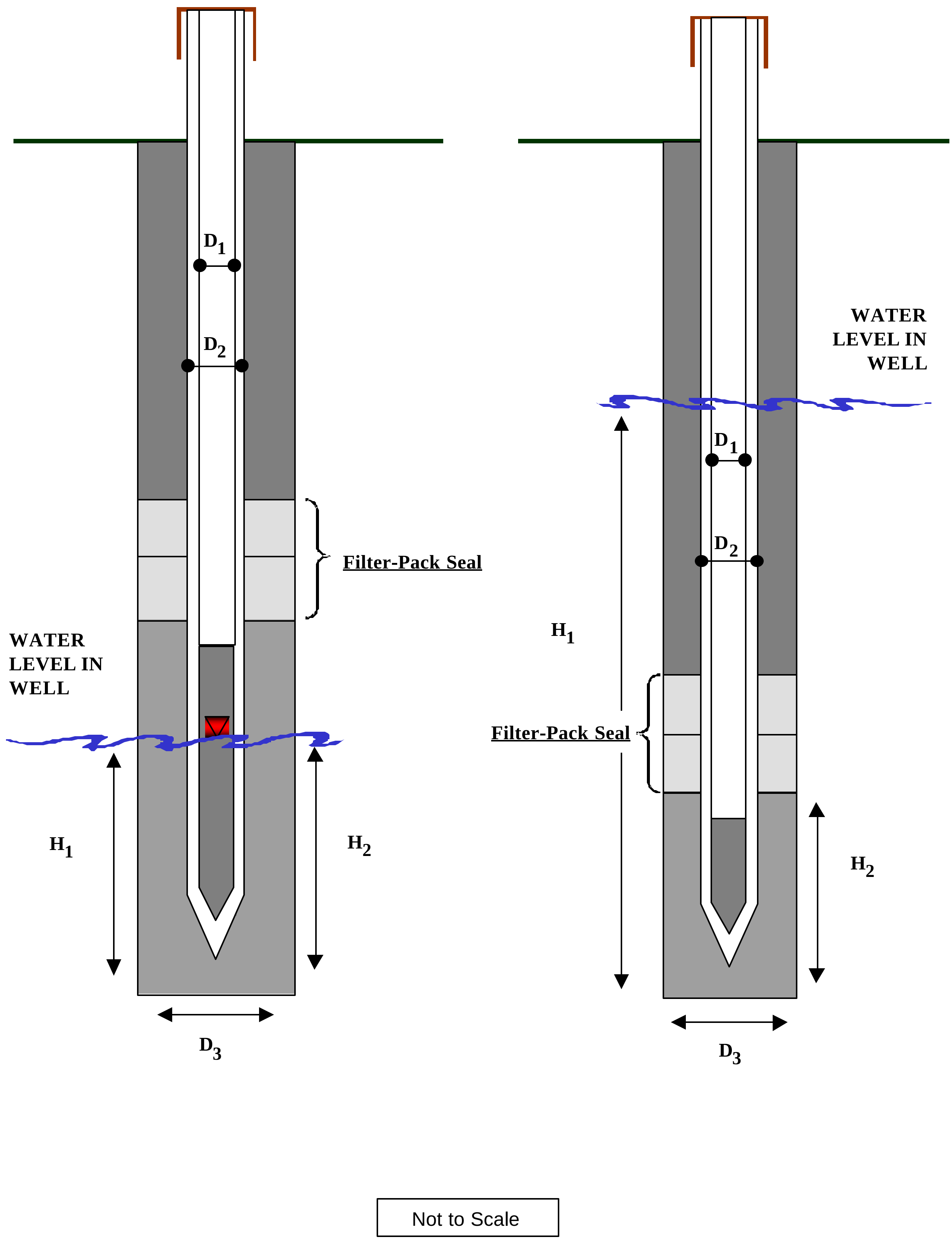


TABLE 1: WELL CASING AND ANNULAR SPACE VOLUMES

WELL CASING VOLUMES		
Nominal Casing Diameter, Inches	**Volume Gallons per Foot**	**Volume Cubic Feet per Foot**
1	0.04	0.01
2	0.17	0.02
3	0.37	0.05
4	0.65	0.09
5	1.02	0.14
6	1.46	0.20
ANNULAR SPACE VOLUMES		
Annular Space	**Volume Gallons per Foot**	**Volume Cubic Feet per Foot**
1 x 4	0.61	0.08
1 x 6	1.43	0.19
2 x 6	1.31	0.17
2 x 8	2.45	0.33
2 x 10	3.92	0.52
3 x 8	2.24	0.30
3 x 10	3.71	0.50
4 x 8	1.96	0.26
4 x 10	3.43	0.46
5 x 10	3.06	0.41
6 x 10	2.61	0.35
6 x 12	4.41	0.59

NOTE: Volumes given are only approximate. No attempt has been made to account for wall thickness of pipe, or for displacement volume of joints or couplings.

TABLE 2: WATER CONTENT AND MUD WEIGHT OF CEMENT-BENTONITE GROUT MIXTURES

PORTLAND CEMENT API CLASSS A OR B WITH BENTONITE (Halliburton, 1975)			
Percent Bentonite	**Water Requirements Gallons per Sack**	**Slurry Weight Pounds per Gallon**	**Slurry Volume Cubic Feet per Sack**
0	5.2	15.6	1.18
2	6.5	14.7	1.36
4	7.8	14.1	1.55

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DEQ Solid Waste Permits and Compliance Section

APPENDIX A: REQUIREMENTS FOR DESIGN APPROVAL

(1) **Site Map.** A map of the site accurately showing the location of the proposed monitoring well.

(2) **Drilling Method.** A description of the proposed method of drilling, type of drilling equipment, and drilling fluid to be used; include a description of methods which will be used to isolate surface soils or shallow water-bearing zones during drilling of the borehole and well construction.

(3) **Geologic Sampling Methods and Intervals.** A description of proposed formation sampling methods and sampling intervals, including provisions for samples to be collected and described in the field by a qualified geologist as to color, texture, composition, grain size, moisture content, evidence of contamination, and other relevant characteristics.

(4) **Description of Borehole.** Proposed size (diameter) and depth of the borehole.

(5) **Construction Methods and Materials.** A description of proposed construction methods and materials, including size and type of casing and screen, screened interval, type of filter pack and annular seal and methods of filter pack and seal placement.

(6) **Construction Diagram.** A diagram illustrating proposed construction of the monitoring well.

(7) **Development Methods.** A description of proposed well development methods and procedures.

(8) **Geophysical Locating Methods.** A description of borehole geophysical methods which will be used to log the monitoring well.

(9) **Field Testing of Hydraulic Conductivity.** A description of proposed methods to test the hydraulic conductivity of the screened interval.

(10) **Location and Elevation Survey.** Provisions for a registered surveyor to survey the location and elevation of the well.

(11) **Health and Safety Plan.** Written verification that the well drilling and construction program will be conducted under a health and safety plan meeting the minimum requirements of 29 CFR Part 1910, Hazardous Waste Operations and Emergency Response, or other safety standards, as appropriate for the anticipated site conditions.

(12) **Notification Of Site Activities.** Provisions to notify the DEQ at least five (5) working days prior to the commencement of all drilling and sampling activities in order that the DEQ may, if desired, send a representative to be present for drilling and sampling of the well(s).

APPENDIX B: CALCULATION OF WELL BORING VOLUME

Calculate the volume of the well bore in the following manner:

Well Bore Volume = $V_1 + V_2$

V_1 = Volume of Water in Casing

V_2 = Volume of Water in Filter Pack or Annular Space

$$V_1 = \pi (D_1/2)^2 H_1$$

$$V_2 = \pi [(D_3/2)^2 - (D_2/2)^2] H_2 N$$

Where:

D_1 = Inside Diameter of Well Casing

D_2 = Outside Diameter of Well Casing

D_3 = Diameter of Borehole

H_1 = Height of Water Column in Well

H_2 = Length of Filter Pack or Height of Water Column in Well, whichever is smaller.

N = Porosity of Filter Pack (typically 0.3 to 0.5)

NOTE: The nominal diameter of well casing may be used for both D_1 and D_2, when casing wall thickness is less than or equal to 3/8-inch.

APPENDIX C: SUBMITTAL REQUIREMENTS FOR DEPARTMENT CONSIDERATION AND APPROVAL OF SPECIAL STANDARDS FOR MONITORING, WELL CONSTRUCTION, ALTERATION, OR DECOMMISSIONING

(1) Common name of site; DEQ permit number or other unique DEQ project identification number; name and address of permittee or site operator; name and address of landowner;

(2) Location of project, including township, range and section, to nearest quarter section; street address; and county in which project is located;

(3) Reason for requesting special standards; citation of section number of standards for which special construction or decommissioning standards are requested;

(4) Purpose of monitoring well construction or decommissioning; description of monitoring well construction or decommissioning procedures proposed, including drilling method, screen, casing and grout types and installation methods, as applicable;

(5) Legible, scale drawing showing the proposed monitoring well design, construction, or decommissioning procedure proposed;

(6) Name, affiliation, stamp and signature of registered professional geologist, engineering geologist, civil or environmental engineer responsible for monitoring well design for which special standards are requested;

(7) Name, affiliation, monitoring well constructors license number and signature of contractor operating drilling machinery or other machinery proposed to be used to drill, construct or decommission monitoring well for which special standards are requested.