MONITOR WELL INSTALLATION

SOP#: 2048
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1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to provide an overview of the methods used for groundwater monitor wells. Monitor well installation create permanent access for collection of samples to assess groundwater quality and the hydrogeologic properties of the aquifer in which contaminants may exist. Such wells should not alter the medium which is being monitored.

The most commonly used drilling methods are: the hollow-stem auger, cable tool, and hydraulic rotary. Rotary drilling can utilize mud rotary or air rotary methods.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, depending on site conditions, equipment limitations, or limitations imposed by the procedures themselves. In all instances, the ultimate procedures employed should be documented and described in the final report as well as in logbooks.

Mention of trade names or commercial products does not constitute United States Environmental Protection Agency (U.S. EPA) endorsement or recommendation for use.

2.0 METHOD SUMMARY

There is no ideal monitor well installation method for all conditions therefore, hydrogeologic conditions at the site as well as project objectives must be considered before deciding which drilling method is appropriate.

2.1 Hollow-Stem Augering

Outside diameters of hollow-stem augers generally range from 6 1/4 inches to 22 inches with corresponding inner diameters ranging from 2 1/4 inches to 13 inches. Auger lengths are usually 5 feet which allows easy handling. However, lengths of 10 or 20 feet may be used for deeper holes drilled with machines capable of handling the extended lengths. Formation samples can be taken in a number of ways, depending on the accuracy required. Cuttings may suffice for shallow depths but become less representative with depth, particularly below the water table. The most accurate samples are obtained with various coring devices, such as split spoons or shelby tubes which can be used inside the augers. Continuous cores can also be taken with a thin-walled tube which is inserted into the lowest auger and locked in place. The tube is retracted with a wire line and hoist after the hole has been advanced the length of the auger. A bottom plug in the cutting head or bit prevents cuttings from entering the augers until the first core sample is taken and the plug is knocked out.

In unconsolidated material, the augers serve as a temporary casing and gravel-packed wells can be constructed inside the augers and then the augers withdrawn. Well development is usually less difficult than with wells drilled by the mud rotary method because a bentonite drilling fluid is not normally used.

2.2 Cable Tool Drilling

Cable tool drilling is a percussion method in which a bit, attached to a drilling string, is lifted and dropped. The drilling string, consists (bottom to top) of the bit, drill stem, drilling jars, socket, and wire cable. A walking beam on the drilling rig provides the lifting and dropping motion to the wire cable and hence to the drilling string. The repeated action breaks or loosens the formation material which mixes with formation water or water added to the hole by the operator to form a slurry. The slurry facilitates removal of the cuttings which are periodically removed from the hole with a bailer. In unconsolidated formations, steel casing must be driven or pushed into the ground as the drilling progresses in order to prevent hole collapse. A hardened steel drive shoe on the bottom end of the casing prevents damage during driving. A well may then be constructed inside the steel casing and the casing pulled back. In consolidated formations, the casing may be driven through the weathered zone, and seated in solid rock. The hole below the casing may remain open or may be fitted with a smaller diameter inner casing and screen, depending on the sampling requirements. Depending on formation material, extensive well development may often not be necessary.

2.3 Rotary Drilling

2.3.1 Mud Rotary Method

In the mud rotary method the drill bit is rotated rapidly to cut the formation material and advance the borehole. The drill bit is attached to hollow drilling rods which transfer power from the rig to the bit. In conventional rotary drilling, cuttings are removed by pumping drilling fluid (water, or water mixed with bentonite or other additives) down through the drill rods and bit, and up the annulus between the borehole and the drill rods. The drilling fluid flows into a mud pit where the cuttings settle out and then is pumped back down the drill rods. The drilling fluid also cools the bit and prevents the borehole from collapsing in unconsolidated formations.

Sampling may be done from the cuttings but samples are generally mixed and the amount of fine material may not be accurately represented. Coring may be done through the drill rods and bit if a coring bit (with a center opening big enough to allow passage of the coring tube) is used. When drilling unconsolidated formations, a temporary surface or shallow casing may have to be installed in order to prevent cross-contamination, hole collapse, or wall erosion by the drilling fluid. Casing (riser pipe), screen, and gravel pack are usually installed in the open hole or through the surface casing. Once the well is constructed, extensive well development may be necessary in order to remove drilling fluid from the formation.

2.3.2 Air Rotary Method

The air rotary method uses air as the drilling fluid. Air is forced down the drill rods by an air compressor, escapes out of the bit and returns to the surface in the annular space between the hole wall and the drill string. Cuttings are moved out of the hole by the ascending air and collect around the rig. Cuttings are mixed and may not always be representative of the depth currently being drilled. In the conventional air rotary method, the drill string operates in a manner similar to that described for the mud rotary system. In a "hammer" or "down-the-hole" air rotary method, the bit is pneumatically driven rapidly against the rock in short strokes while the drilling string slowly rotates. The use of air rotary methods are generally limited to consolidated and semi-consolidated formations. Casing is often used in semi-consolidated formations and through the weathered portion of consolidated formations to prevent hole collapse. In environmental work, the air supply must be filtered to prevent introduction of contamination into the borehole.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING, AND STORAGE

Often, a primary objective of the drilling program is to obtain representative lithologic or environmental samples. The most common techniques for retrieving samples are:

In unconsolidated formations:

- Split spoon sampling, carried out continuously or at discrete intervals during drilling, as summarized in ASTM Method D-1586-84, Split Barrel Sampling
- Shelby tube sampling when an undisturbed sample is required from clayey or silty soils, especially for geotechnical evaluation or chemical analysis
- Cutting collection when a general lithologic description and approximate depths are sufficient

In consolidated formations:

- Rock coring at continuous or discrete intervals
- Cutting collection when a general lithologic description and approximate depths are sufficient

When collecting environmental samples, the amount of sample to be collected and the proper sample container type (i.e., glass, plastic), chemical preservation, and storage requirements are dependent on the matrix being sampled and the parameter(s) of interest. Sample preservation, containers, handling and storage for air and waste samples are discussed in the specific SOPs for the technique selected.

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

Advantages and disadvantages of the various drilling methods are summarized below.

4.1 Auger Drilling

The advantages of auger drilling are:

- Relatively fast and inexpensive
- Because augers act as temporary casing, drilling fluids are not used resulting in reduced well development

The disadvantages of auger drilling are:

- Very slow or impossible to use in coarse materials such as cobble or boulders
- Cannot be used in consolidated formations and is generally limited to depths of approximately 100 feet in order to be efficient

4.2 Cable Tool Drilling

The advantages of cable tool drilling are:

- Relatively inexpensive with minimum labor requirements
- The water table and water bearing zones are easily identified
- Driven casing stabilizes borehole and minimizes potential for cross-contamination
- Especially successful in drilling caving formations or formations containing boulders
- Accurate formation samples can usually be obtained from cuttings

The disadvantages of cable tool drilling are:

- Extremely slow rate of drilling
- Necessity to drive casing may limit depth in large diameter holes.

4.3 Rotary Drilling

4.3.1 Mud Rotary Drilling

The advantages of mud rotary drilling are:

- Fast, more than 100 feet of borehole advancement per day is common
- Provides an open borehole, necessary for some types of geophysical logging and other tests

The disadvantages of mud rotary drilling are:

- Potential for cross-contamination of water-bearing zones
- Drill cuttings may be mixed and not accurately represent lithologies at a given drilling depth
- Drilling mud may alter the groundwater chemistry
- Water levels can only be determined by constructing wells
- Drilling mud may change local permeability of the formation and may not be entirely removed during well development
- Disposal of large volumes of drilling fluid and cuttings may be necessary if they are contaminated

4.3.2 Air Rotary Drilling

The advantages of air rotary drilling are:

- Fast, more than 100 feet of borehole advancement a day is possible
- Preliminary estimates of well yields and water levels are often possible
- No drilling fluid to plug the borehole

The disadvantages of air rotary drilling are:

- Generally cannot be used in unconsolidated formations

- In contaminated zones, the use of high-pressure air may pose a significant hazard to the drill crew because of transport of contaminated material up the hole

- Introduction of air to the groundwater could reduce concentration of volatile organic compounds

5.0 EQUIPMENT

The following equipment is necessary for the site geologist:

- Metal clipboard box case (container for well logs)
- Ruler
- Depth sounder
- Water level indicator
- All required health and safety gear
- Sample collection jars
- Trowels
- Description aids (Munsell color chart, grain size charts, etc.)
- Geolis® Logbooks (Appendix A)
- Field Logbook

Equipment and tools to install the well are normally provided by the drilling contractor.

6.0 REAGENTS

Reagents are not required for preservation of soil samples. Samples should, however, be cooled to 4° C and protected from sunlight in order to minimize any potential reaction due to the light sensitivity of the sample. Decontamination of drilling equipment should follow the Sampling Equipment Decontamination SOP and the site-specific work plan.

7.0 PROCEDURES

7.1 Preparation

All drilling and well installation programs must be planned and supervised by a professional geologist/hydrogeologist.

The planning, selection and implementation of any monitor well installation program should include the following:

- Review of existing data on site geology and hydrogeology including publications, air photos, water quality data, and existing maps. These may be obtained from local, state or federal agencies

- Assesment of the site to determine potential access problems for drill rig, locate water supply sources, establish equipment storage area, and observe outcrops

- Perform utilities check, note location of underground utilities and of overhead electrical wires

- Preparation of a Site Safety Plan

- Select drilling, sampling and well development methods

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

- Determination of the need for containing drill cuttings and fluids and their method of disposal

- Preparation of work plan including all of the above

- Preparation of and execute the drilling contract

7.2 Field Preparation

Prior to mobilization, the drill rig and all associated equipment should be thoroughly decontaminated by a steam/pressure washer to remove all oil, grease, mud, etc. Before drilling each boring, all the "down-the-hole" drill equipment should be steam cleaned and rinsed with potable water to minimize cross-contamination. Special attention should be given to the threaded section of the casings, and to the drill rods. All drilling equipment should be steam-cleaned at completion of the project to ensure that no contamination is transported to or from the sampling site.

7.3 Well Construction

The well casing material should not interact with the groundwater. Well casings for environmental projects are usually constructed of polyvinyl chloride (PVC), Teflon™, fiberglass, or stainless steel. Details of the construction methods are given in Sections 7.3.1 and 7.3.2.

7.3.1 Bedrock Wells

Wells completed in bedrock will be drilled using the air or mud rotary method. Crystalline rock wells are usually drilled most efficiently with the air rotary method while consolidated sedimentary formations are drilled using either the air rotary or mud rotary method. The compressed air supply will be filtered prior to introduction into the borehole to remove oil or other contaminants. Bedrock wells may be completed as an open-hole, providing that borehole cave-in is not a possibility.

Bedrock wells will be advanced with air or mud rotary methods until a minimum of 5 feet of competent rock has been drilled. Minimum borehole diameter will be 8 inches. The drill string will then be pulled from the borehole and 6-inch I.D. Schedule 80 or 40 PVC casing inserted. Portland cement/bentonite grout will be pumped into the hole and up the annular space outside the casing. After the grout has set (minimum of 24 hours), the cement will be drilled out and the borehole advanced to the desired depth. Figure 1 (Appendix B) shows typical construction details for an open-hole bedrock well.

The preferred method of well completion for the bedrock wells will be open-hole. However, if the open borehole is subject to cave-in, the well(s) will be completed as screened and cased sand-packed wells. For details of completion see Section 7.3.2.

7.3.2 Overburden Well Construction

Any of the drilling methods discussed in this SOP can be used to drill or set a well in the overburden. The hollow-stem method is the preferred choice for shallow (<100 ft.) overburden wells because the well can be constructed inside of the augers. Details of the construction are provided below and are shown in Figure 2 (Appendix B).

1. The screen slot size will be determined by the site hydrologist, based upon sand-pack size. The length of screen used will be site-dependent. Casing sections will be flush-threaded. Screw-threaded bottom plugs will be used. To prevent introduction of contaminants into the well, no glue-connected fittings will be used. Each piece of PVC pipe, screen, and the bottom plug will be steam-cleaned before lowering into the borehole. The site hydrogeologist is responsible for the supervision of all steam cleaning procedures.

2. The annular space between the well screen and the borehole wall will be filled with a uniform gravel/sand pack to serve as a filter media. For wells deeper than approximately 50 feet, or when recommended by the site geologist, the sand pack will be emplaced using a tremie pipe. A sand slurry composed of sand and potable water will be pumped through the tremie pipe into the annulus throughout the entire screened interval, and over the top of the screen. Allowance must be made for settlement of the sand pack.

3. The depth of the top of the sand will be determined using the tremie pipe, thus verifying the thickness of the sand pack. Additional sand shall be added to bring the top of the sand pack to approximately 2 to 3 feet above the top of the well screen. Under no circumstances should the sand pack extend into any aquifer other than the one to be monitored. In most cases, the well design can be modified to allow for a sufficient sand pack without threat of crossflow between producing zones through the sand pack.

4. In materials that will not maintain an open hole using hollow-stem augers, the temporary or outer casing will be withdrawn gradually during placement of sand pack/grout. For example, after filling two feet with sand pack, the outer casing should be withdrawn 2 feet. This step of placing more gravel and withdrawing the outer casing should be repeated until the level of the sand pack is approximately 3 feet above the top of the well screen. This ensures that there is no locking of the permanent (inner) casing in the outer casing.

5. A bentonite seal of a minimum 2-foot vertical thickness will be placed in the annular space above the sand pack to separate the sand pack from the cement surface seal. The bentonite will be placed through a tremie pipe or poured directly into the annular space, depending upon the depth and site conditions. The bentonite will be pourable pellets. The hydrogeologist will record the start and stop times of the bentonite seal emplacement, the interval of the seal, the amount of bentonite that was used, and problems that arise. The type of bentonite and the supplier will also be recorded.

   A cap placed over the top of the well casing before pouring the bentonite pellets will prevent pellets from entering the well casing.

6. If a slurry of bentonite is used as annular seal, it is prepared by mixing powdered or granular bentonite with potable water. The slurry must be of sufficiently high specific gravity and viscosity to prevent its displacement by the grout to be emplaced above it. As a precaution (regardless of depth) and depending on fluid viscosity, a few handfuls of bentonite pellets may be added to solidify the bentonite slurry surface.

7. Cement and/or bentonite grout is placed from the top of the bentonite seal to the ground surface.

   Only Type I or II cement without accelerator additives may be used. An approved source of potable water must be used for mixing grouting materials. The following mixes are acceptable:

   C Neat cement, a maximum of 6 gallons of water per 94 pound bag of cement

   C Granular bentonite, 1.5 pounds of bentonite per 1 gallon of water

   C Cement-bentonite, 5 pounds of pure bentonite per 94 pound bag of cement with 7-8 gallons of water

   C Cement-bentonite, 6 to 8 pounds of pure bentonite per 94 pound bag of cement with 8-10 gallons of water, if water mixed

   C Non-expandable cement, mixed at 7.5 gallons of water to one half (1/2) teaspoon of Aluminum Hydroxide, 94 pounds of neat cement (Type I) and 4 pounds of bentonite

   C Non-expandable cement, mixed at 7 gallons of water to one half (1/2) teaspoon of Aluminum Hydroxide, 94 pounds of neat cement (Type I and Type II)

8. Grout is pumped through a tremie pipe (normally a 1.25-inch PVC or steel pipe) to the bottom of the annulus until undiluted grout flows from the annulus at the ground surface

9. In materials that will not maintain an open hole, the temporary steel casing should be withdrawn in a manner that prevents the level of grout from dropping below the bottom of the casing.

10. Additional grout may be added to compensate for the removal of the temporary casing and the tremie pipe to ensure that the top of the grout is at or above ground surface. After the grout has set (about 24 hours), any depression due to settlement is filled with a grout mix similar to that described above.

11. The protective casing should now be set. Casing may be a 5 foot minimum length of black iron or galvanized pipe extending about 1.5 to 3 feet above the ground surface, and set in concrete or cement grout. The protective casing diameter should be 4 inches greater than the well casing. A 0.5-inch drain hole may be installed near ground level. A flush-mount protective casing may also be used in areas of high traffic or where access to other areas would be limited by a well stick-up.

12. A protective steel cap, secured to the protective casing by a padlock, should be installed.

13. Steel guard posts should be installed around the protective casing in areas where vehicle traffic may be a problem. Posts should have a minimum diameter of 3 inches and be a

minimum of 4 feet high.

14. All monitor wells should be labelled and dated with paint or steel tags.

7.4 Well Development

Well development is the process by which the aquifer's hydraulic conductivity is restored by removing drilling fluids, and fine-grained formation material from newly installed wells. Two methods of well development that are commonly used are surging and bailing, and overpumping. A well is considered developed when the pH and conductivity of the groundwater stabilizes and the measured turbidity is <50 nephelometric turbidity units (NTUs).

Surging and bailing will be performed as follows:

1. Measure the total depth (TD) of the well and depth to water (DTW).

2. Using an appropriately sized surge block, surge 5-foot sections of well screen, using 10-20 up/down cycles per section. Periodically remove the surge block and bail accumulated sediment from the well, as required.

3. For open-hole wells, a 6-inch surge block will be used inside the cased portion of the well. Sediments will be bailed periodically, as required. Overpumping may be used in combination with surging and bailing for development of bedrock wells. The method(s) used will be based on field conditions encountered, and will be determined by the site hydrogeologist. However, sediment will initially be removed from the wells by bailing in order to minimize the volume of development water generated.

The pump used must be rated to achieve the desired yield at a given depth. The pump system should include the following:

- A check valve to prevent water from running back into the well when the pump is shut off
- Flexible discharge hose
- Safety cable or rope to remove the pump from the well
- Flow meter monitoring system (measuring bucket or inline flow meter)
- Generator
- Amp meter, to measure electrical current (load)

The amp meter is used to monitor pump performance. If the pump becomes clogged, the current will increase due to stress on the pump. If the water level drops below the intake ports, the current will drop due to decreased resistance on the pump.

8.0 CALCULATIONS

To maintain an open borehole during rotary drilling, the drilling fluid must exert a pressure greater than the formation pore pressure. Typical pore pressures for unconfined and confined aquifers are 0.433 define (psi/ft) and 0.465 psi/ft, respectively.

The relationship for determining the hydrostatic pressure of the drilling fluid is:

Hydrostatic Pressure (psi) = Fluid Density (lb/gal) x Height of Fluid Column (ft) x 0.052

The minimum grout volume necessary to grout a well can be calculated using:

Grout Vol (ft^3) = Vol of Borehole (ft^3) - Vol of Casing (ft^3) = $L\ (r_B^2 - r_C^2)$

where:

L	=	length of borehole to be grouted (ft)
r_B	=	radius of boring (ft)
r_C	=	radius of casing (ft)

9.0 QUALITY ASSURANCE/ QUALITY CONTROL

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

1. All data must be documented on standard well completion forms, field data sheets or within field/site logbooks. Descriptive logs, pump tests, and well completion date are entered on Geolis® forms. The Geolis® forms are used to ensure data is collected uniformly by all Site Geologists and provide

input to a standardized computer well file. Appendix A contains examples of Geolis® forms used to record descriptions of geologic samples.

2. All instrumentation must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and must be documented.

10.0 DATA VALIDATION

This section is not applicable to this SOP.

11.0 HEALTH AND SAFETY

Drilling rigs and equipment present a variety of safety hazards. REAC personnel working around drilling rigs should know the position of the emergency "kill" switch. Wirelines and ropes should be inspected and frayed or damaged sections discarded. Swivels and blocks should turn freely. Gages should be operational and controls clearly marked. All underground utilities should be clearly marked, and drillers should be aware of any overhead hazards such as power lines. Avoid drilling in these areas. Ear protection should be worn when working around drilling equipment for extended periods of time, particularly air rotary equipment. Failure to follow safety procedure or wear the proper personal protection gear on the part of either the drilling crew or REAC personnel may result in dismissal from the job.

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety practices.

12.0 REFERENCES

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APPENDIX A

Geolis Forms

Form 1. Geolis® Borehole Logging Form

GEOLIS® Borehole Logging Form

COMPANY: ______ LOCATION ID: ______
CLIENT: ______ DATE: ______
PROJECT: ______ LOGGER: ______
SITE / AREA: ______ SIGNATURE: ______

SAMPLING METHOD: SPS - CSS - STB - CTS - CUT - COR - NS
OTHER: ______
SAMPLING INTERVAL: ______ TO ______ FT/M BGS
RECOVERY: ______ / ______ FT/M NA
BLOW COUNT: [ ] [ ] [ ] [ ] / [ ] IN/CM NA
RQD: ______ % NA

FLUID ENTRY/ LOSS ZONES: ______ FT/M BGS ______ GPM
______ FT/M BGS ______ GPM
ANALYTICAL SAMPLE ID INTERVAL (FT/M BGS)
______ ______ - ______
TYPE / LAB : UND - DIS - CMP / MOB - GEO - CHM - ______
/ ______ ______ - ______
TYPE / LAB : UND - DIS - CMP / MOB - GEO - CHM - ______

SAMPLING INTERVAL No.: ______
LITHOLOGIC INTERVAL No.: ______
LITHOLOGIC INTERVAL: ______ TO ______ FT/M BGS
LITHOLOGY ARCHIVED? YES - NO
NO RECOVERY
MATERIAL: NATURAL - FILL - UNCERTAIN
OBSERVED: STN - SHN - ODR - PRD - NA - OTHER: ______
INSTRUMENT 1 TYPE: ______ READING: ______
INSTRUMENT 2 TYPE: ______ READING: ______

OVERBURDEN (SECONDARY)

SECONDARY TYPE: NA - BED - CLS - MIX
COLOR: MUN - GSA ______
COLORATION: UNI - STN - MOT - VAR
BOULDERS: ______ % MAX DIAM: ______ IN
COBBLES: ______ % MAX DIAM: ______ IN
TEXTURE: C - M - F
GRAVEL: __ __ __ ______ % ______ %
SAND: __ __ __ ______ % ______ %
SILT: ______ % ______ %
CLAY: ______ % ______ %
ORGANIC: ______ % ______ %
ROUNDNESS:
GRAVEL: FAC - STR - ANG - SUB - RND - NA
SAND: ANG - SUB - RND - NA
SORTING: WEL - MOD - POR - NA
PLASTICITY: NON - LOW - MOD - HGH - NA
MOISTURE: DRY - MST - WET - SAT - NA
CEMENTATION: NON - SLT - MOD - WEL - NA
GRAIN TYPE: QTZ - FRG - FOS - BIO - NA ______
MATRIX: MSM - CSM - CAL - OXD - ARG - SIL - NA
STRENGTH:
COHESIVE: VSF - SFT - FRM - STF - VST - HRD
NONCOHESIVE: VDN - DEN - FIR - LSE - NA
UPPER CONTACT: SHP - GRD - DIF - SME - NA
BEDDING THICK: ______ IN/CM No.: ______
TYPE: XBD - RPL - HOR - INC - NA
MAS - LNS - LAM - GRU - GRD

GRAPHIC LOG

BEDROCK (SECONDARY)

SECONDARY TYPE: NA - BED - VEN - MIX
COLOR: MUN - GSA ______
ROCK TYPE: OTHER: ______
SED: SHL - SLT - SST - CGL - LST - DOL - COL
MET: SLA - PHY - SHS - GNS - HRN - QZT - MBL
IGN: GRN - RHY - BSL - GBR - TUF - BRC
TEXTURE: C - M - F NA
GRAVEL: __ __ __ ______ % ______ %
SAND: __ __ __ ______ % ______ %
SILT: ______ % ______ %
CLAY/LIME MUD: ______ % ______ %
GRAIN TYPE: QTZ - FRG - FOS - BIO - NA
MATRIX: CAL - MIC - OXD - ARG - SIL - ORG - NA
STRENGTH: EWK - VWK - WEK - MOD
STR - VST - EST
UPPER CONTACT: SHP - GRD - DIF - SAM - NA
SECONDARY POROSITY: VUG - FRC - BED - NA - OTHER
HGH - MOD - LOW
WEATHERING: FRS - SLT - MOD - HGH - CPL - NA

STRAT UNIT: [ ]
NOTE LINE : [ ]

NEXT INTERVAL: SAMP/LITH No. ______ / ______ DEPTH INTERVAL ______ TO ______ NOT SAMPLED NO RECOVERY

NATURAL FRACTURE SETS

INTERVAL (FT/M BGS)	#/FT-M	DIP	DIR	FILL/SHAPE/ROUGH/SURFACE
-				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH
-				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH
-				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH
-				FILL: OPN - PRT - FUL SHAPE: PLN - CUR - UND - STP - IRR ROUGH: SMH - MOD - RGH SURFACE: CLN - MIN - OXD - STN - WTH

COMMENTS: (1) ______
______
(2) ______

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APPENDIX A (Cont'd)

Geolis Forms

Form 2. Geolis® Well Construction Form

GEOLIS® Well Construction Form Sheet ____ of ____

COMPANY: ____________ LOCATION ID: ____________
PROJECT: ____________ DATE: ____________
PROPERTY: ____________ LOGGER: ____________
SITE/AREA: ______ / ______ SIGNATURE: ____________

START DATE: ____________
COMPLETION DATE: ____________
WELL STATUS: PMP - ABN - COL - NOR
STATUS DATE: ____________

SURVEYED ELEVATIONS (MSL)
GROUND LEVEL: ________ FT/M
MEASURING POINT: ________ FT/M
(TOP OF CASING)

DEPTH TO WATER	DATE / TIME
________ FT/M(TOC)	________
________ FT/M(TOC)	________
________ FT/M(TOC)	________

WELL DIAGRAM - NOT TO SCALE	DEPTH (FT. BGS)	WELL CODE
	0	GRS

WELL TYPE: SCREEN - MULTIPLE SCREEN - OPEN HOLE - NESTED - PROBE
CASING: SINGLE - DOUBLE - TRIPLE COMPLETION: FLUSH - PROT - VAULT - CAP - NA
TOTAL NO. OF SCREENS/WELLS: ______ SCREEN/WELL NO.: ______
WELL USE: DOM - PUB - IRR - FIR - MON - HYD - EXT - DEW - RCH - VEW - INJ - OTH: ______

WELL DESIGN CONSTRUCTION

CASING #1: (INNERMOST) DIAMETER: ______ IN/CM INTERVAL: ______ TO ______ FT/M BGS
TYPE: PVC - STN - LCS - GAL - ____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - ____
CASING JOINTS: FLT - BUT - EUT - SOL - WLD - SCW - CAM - OTH: ______

CASING #2: DIAMETER: ______ IN/CM INTERVAL: ______ TO ______ FT/M BGS
TYPE: PVC - STN - LCS - GAL - ____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - ____

CASING #3: (OUTERMOST) DIAMETER: ______ IN/CM INTERVAL: ______ TO ______ FT/M BGS
TYPE: PVC - STN - LCS - GAL - ____ SCHEDULE: 5 - 10 - 20 - 40 - 80 - ____

STICK UP: INNER CASING: ______ FT/M OUTER CASING: ______ FT/M

GROUT: TYPE: CMT - C/B - BEN - HSB - OTH: ______
INTERVAL: ______ TO ______ FT/M BGS
PLACEMENT: TRM - PRS - GRV CENTRALIZERS: NON - 1 - 2 - 3 - OTH: ____

SEAL: TYPE 1: ______ INTERVAL: ______ TO ______ FT/M BGS
TYPE 2: ______ INTERVAL: ______ TO ______ FT/M BGS

SAND PACK: TYPE: ______ INTERVAL: ______ TO ______ FT/M BGS

SCREEN OR DEVICE: DIAMETER: ______ IN/MM INTERVAL: ______ TO ______ FT/M BGS
TYPE: PVC - STN - LCS - TEF - CER - HDP - OTH: ______
SLOTS: CON - SLH - SLV - BRG - CUT - OTH: ______
SLOT SIZE: 6 - 10 - 20 - 30 - 40 - ______ SLOT

STRAT UNIT MONITORED: ______
ESTIMATED WELL YIELD: ______ GPM/LPM DRAWDOWN: ______ FT/M BMP
WATER SAMPLING SYSTEM: NON - PMP - PKR - MLS TYPE: ______
SEAL INTERVAL: ______ TO ______ FT/M BGS INTAKE DEPTH: ______ FT/M BGS
NOTES: ______

OPEN HOLE: DIAMETER 1: ______ IN/CM INTERVAL: ______ TO ______ FT/M BGS
DIAMETER 2: ______ IN/CM INTERVAL: ______ TO ______ FT/M BGS

SILT TRAP/SUMP: YES - NO INTERVAL: ______ TO ______ FT/M BGS
INSIDE WELL T.D.: ______ FT/M BGS COLLAPSE/BACKFILL: COL - BFL - BTH - NON
COLLAPSE INTERVAL: ______ TO ______ FT/M BGS
BACKFILL INTERVAL: ______ TO ______ FT/M BGS TYPE: ______

COMMENTS: ______

WELL CONSTRUCTION CODES

GRS - GROUND SURFACE	TSC - TOP OF SCREEN
BPC - BOTTOM OF PROTECTIVE CASING	TST - TOP OF SILT TRAP
TBS - TOP OF BENTONITE SEAL	WTD - TOTAL DEPTH INSIDE WELL
TBR - TOP OF BEDROCK	BTD - BOREHOLE TOTAL DEPTH
BOC - BOTTOM OF OUTER CASING	TOC - TOP OF CASING (INNER)
TSP - TOP OF SAND PACK	BGS - BELOW GROUND SURFACE

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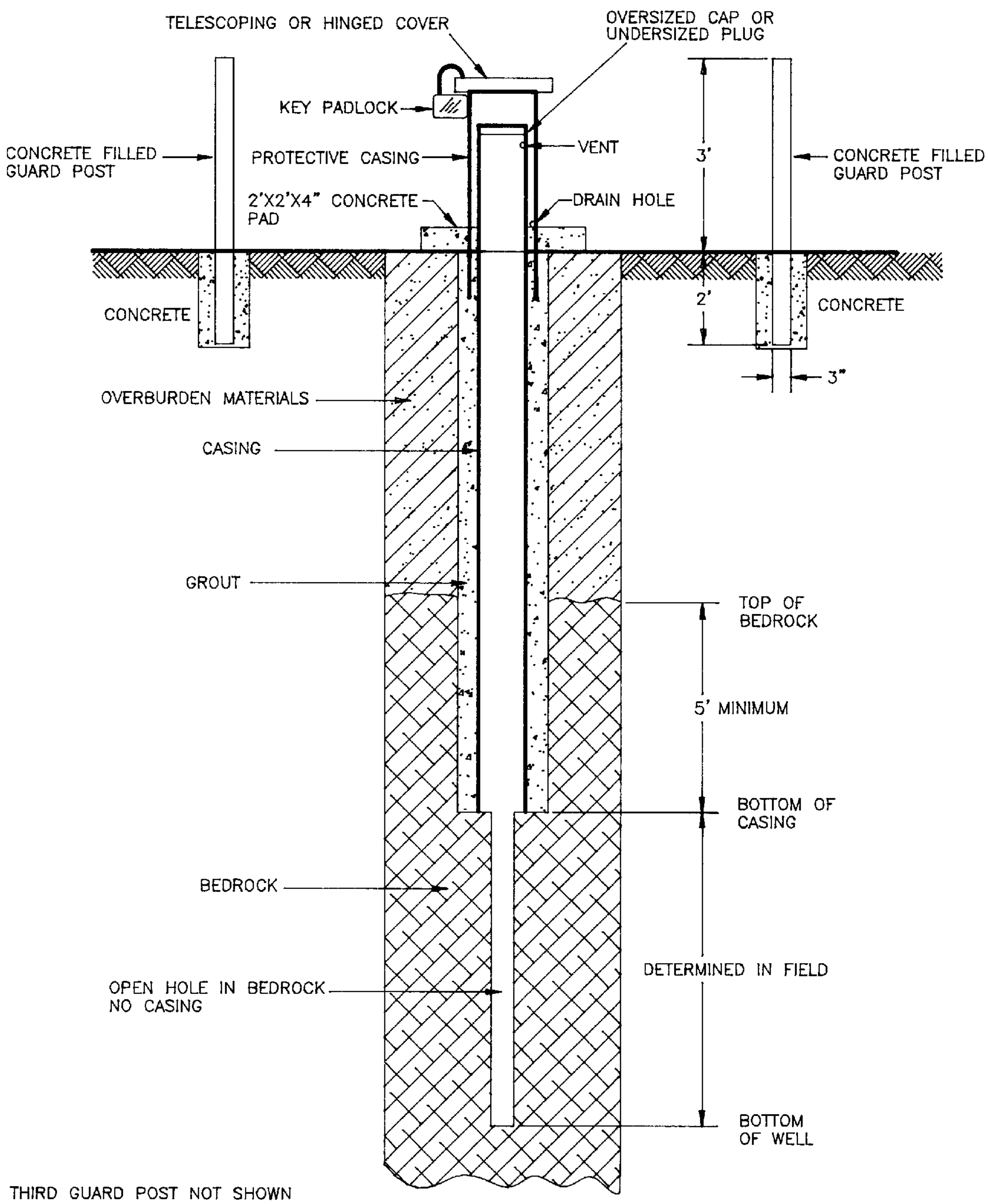
APPENDIX B

Figures

FIGURE 1. Typical Bedrock Well Construction



APPENDIX B (Cont'd)

Figures

FIGURE 2. Typical Overburden Well Construction