HF Sinclair

March 31, 2023

Mr. Carl Chavez
UIC Group - Engineering Bureau
New Mexico Oil Conservation Division (Albuquerque Office)
Energy Minerals and Natural Resources Department
8801 Horizon Blvd
Albuquerque, New Mexico 87113

Re: Work Plan for Monitor Well Installation and Sampling for UIC Wells (UICI-8)
HF Sinclair Navajo Refining LLC, Artesia, New Mexico

Dear Mr. Chavez:

HF Sinclair Navajo Refining LLC is pleased to submit the enclosed second revision to the work plan for installation of 4 groundwater monitor wells and quarterly water quality sample collection at each Navajo Refinery Underground Injection Control (UIC) site: WDW-1, WDW-2, WDW-3, and WDW-4. OCD requested details have been added to the work plan as discussed on February 17, 2023.

Please do not hesitate to contact Mike Holder at (575) 308-1115 or myself at (575) 746-5487 if you require additional information.

Sincerely,

Kawika Tupou
HollyFrontier Sinclair Navajo Refinery
Environmental Manager

Enclosure

cc: Mike Holder, HF Sinclair
Rick Stanford, HF Sinclair Navajo Refinery
Jason Roberts, HF Sinclair Navajo Refinery
Elizabeth Bastien, DBS&A
Chris Wolf, DBS&A

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Work Plan for Monitor Well Installation and Sampling
HF Sinclair Navajo Refinery
Artesia, New Mexico

1. Introduction

Daniel B. Stephens & Associates, Inc. (DBS&A) has prepared this work plan to install four monitor wells and complete water quality sampling at each of the four underground injection control (UIC) wells at the HF Sinclair Navajo Refinery (HFSNR) in Artesia, New Mexico. This work plan has been prepared on behalf of HFSNR at the request of the New Mexico Energy, Minerals, and Natural Resources Department (NMEMNRD) Oil Conservation Division (OCD). This work plan incorporates project details for the drilling of four monitor wells as stated in Condition 2B of the UIC discharge permits (UICI-008-1, UICI-008-2, UICI-008-3, and UICI-008-4), which are up for renewal November 22, 2022. The described monitor wells are intended to evaluate the uppermost water-bearing unit downgradient of injection wells (WDW-1, -2, -3 and -4) for water level and water quality monitoring. All activities proposed in this work plan will be completed under the guidance of OCD's quality assurance project plan (QAPP) (OCD, 2014) and DBS&A standard operating procedures (SOPs).

2. Scope of Work

This work plan includes a detailed description of monitor well installation and groundwater quality monitoring as part of OCD's request and UIC discharge permits (UICI-008-1, UICI-008-2, UICI-008-3, and UICI-008-4). Monitor well installation will meet requirements as stated in discharge permits Section 2B, as well as OCD e-mailed instructions, as follows:

> At least one groundwater monitoring well shall be installed in proximity of and hydrogeologically downgradient from WDW-2. The monitoring well(s) shall be screened into the uppermost water-bearing unit using 15 feet of well screen with the top of the screened interval positioned 5 feet above the water table. (Discharge permit Section 2B)

Objective: Place a groundwater monitoring well within 50 ft hydrogeologically downgradient from each WDW injection well location with a quarterly monitoring schedule consistent with related permit reporting. Monitor well construction shall be as prescribed by the current permit or as approved by the OCD based on site-specific conditions. Provide well logs with water quality (i.e., General Chemistry, TPH and BTEX) data from completed and/or constructed MWs to complete the WQCC Public Notice process. (OCD requirements sent via e-mail by Carl Chavez)

2.1 Site Evaluation and Field Preparation

2.1.1 Project Planning

DBS&A will ensure that all necessary monitor well permits, UIC well access, and utility clearances are obtained. A site-specific health and safety plan (HASP) will be drafted to address health and safety issues associated with the proposed project activities. The HASP will be adhered to by all DBS&A personnel and subcontractors while working on the project.

The following is the projected milestone schedule for monitor well installation. The schedule is subject to change based on driller availability. The schedule with projected dates will be drafted upon OCD acceptance of the work plan and selection of the drilling contractor.

- New Mexico Office of the State Engineer (OSE) permits and drilling contractor quotes: 60 days from OCD work plan approval.
- Contract signed and work scheduled with drilling contractor: 90 days from OCD work plan approval.
- Drillers and DBS&A mobilize to the field: 120 days from contract date with drilling contractor [subject to change depending on driller availability].
- Monitor wells completed and developed: 60 days from field mobilization. Expecting each monitor well may require approximately 1.5 weeks for drilling, water-bearing zone evaluation, construction, and well development.
- Water quality sampling event: Within 60 days of completion and development of the monitor well. Schedule may change due to QED pump availability.
- Monitor well survey: 90 days from date of completion of the monitor well [subject to change depending on contractor availability].
- Waste material characterization and disposal: 90 days from completion of the final monitor well [subject to change depending on contractor availability].

- Well completion report: 90 days after water quality results are received from the analytical laboratory.

2.1.2 Permitting and Well Locations

Bureau of Land Management (BLM) permit form SF-299 will be submitted upon OCD approval of this work plan. OSE W-07 form for monitor well installation will be submitted, with approval received prior to field mobilization. The current land owner for UIC well WDW-1 has been contacted for land access permissions. Written permission of access will be included in the OSE permit applications. Appropriate permits will be obtained with recognition that OCD has environmental jurisdiction. Every effort will be made to ensure permitting does not delay the schedule.

The proposed monitor well locations are provided on Figures 1 through 2d. Monitor well locations will be pre-approved by OCD prior to submission of permit applications. In compliance with OCD, each of the four monitor wells will be installed within 75 feet southwest (hydrologically downgradient) of each UIC well. Monitor wells have been located as close as possible to the requested OCD footage allowance of 50 feet and directionally to the southwest. Monitor wells locations were placed with OCD approval to avoid existing infrastructure and existing UIC well access points. Monitor wells are labeled with UIC well ID in addition to the MW-1 designation; for example, the monitor well at WDW-4 will receive a well name of WDW-4-MW-1 (Figures 1 and 2d).

2.1.3 Utility Clearance

Each of the four well locations will be cleared for underground lines or utilities through proper channels: New Mexico One Call (NMOC) and refinery historical documents and maps. The drilling contractor will be responsible for submitting the request to NMOC at least 10 days prior to project kickoff. Each monitor well location will be clearly marked with stakes and a white paint circle per NMOC directions. In addition to the NMOC utility clearance, each monitor well location will be evaluated with a hydrovac unit. Use of the hydrovac unit will follow standard clearance procedure as directed by HFSNR: The well location will be at the center of the 5-foot by 5-foot "L"-shaped excavation area, where the area will be cleared to a minimum depth of 10 feet. The excavated material will be visually inspected for any evidence of environmental contamination. Regardless of whether impacted or clean, the materials will be contained and transported within the vac truck to the refinery for safe storage and security. Materials will be labeled properly, characterized, and then appropriately managed with off-site disposal. The

NMOC and the hydrovac clearance will be completed prior to any excavation by the drilling contractor.

2.1.4 Drilling Access

Existing dirt and gravel roads are expected to provide stable access for the drilling rig. No overhead obstacles exist.

2.2 Drilling and Well Installation

2.2.1 Drilling and Lithology

HF Sinclair will contract with a drilling contractor that has a current and valid New Mexico well driller license issued by the OSE per 19.27.4 NMAC. The driller will install one monitor well at each of the UIC well locations. Each monitor well will be installed within 750 feet southwest (hydrologically downgradient) of each existing UIC well. The proposed monitor well locations are provided on Figures 1 through 2d.

Because the depths of the significant water-bearing zones are unclear, a temporary well will be installed and used to evaluate observed water-bearing zones.

The drilling contractor will advance each borehole (one at each UIC well location) using a sonic drilling method. The borehole will be advanced to a depth of 70 feet, where water is expected based on other wells in the area. Starting at 70 feet, the sonic core barrel will be removed from the borehole prior to advancement of the sonic outer casing. Drill cuttings from the core barrel will be evaluated by the on-site DBS&A geologist. If the drill cuttings appear saturated, a temporary polyvinyl chloride (PVC) casing will be installed in the borehole, and groundwater will be allowed to fill the borehole for a period of 2 hours.

Borehole groundwater in this temporary setup will be purged with a bailer or pump for initial evaluation. If the borehole appears to yield significant water, an attempt will be made to determine the specific capacity of the well during bailing or pumping. Specific capacity is the flow rate divided by the change in drawdown. Evaluation of the specific capacity results, field observations, and best professional judgement will be used to determine if a significant water-bearing zone was found.

These processes will be repeated in an iterative fashion until the borehole reaches a total depth of 150 feet. The borehole will be advanced to 150 feet regardless of significant water-bearing zone evaluation results unless OCD directs otherwise during borehole installation.

If the formation collapses into the exposed borehole annular space and PVC cannot be lowered to the desired depth, a sonic hydropunch sampler will be advanced to the desired depth. The sonic water sampler is equipped with a solid retrievable point and 2-inch diameter stainless steel screen that is 2 feet in length. The water sampler screen will be exposed, and the borehole will be left for 2 hours to allow for groundwater evaluation.

Final well design will be determined using results from significant water-bearing zone evaluation and best professional judgement. We will attempt to contact OCD as needed during borehole installation and at the completion of borehole drilling for comment on the well design. The monitor well(s) will be screened into the significant water-bearing unit using 15 feet of well screen with the top of the screened interval positioned 5 feet above the water table, as indicated in Section 2B of the UIC discharge permits (UICI-008-1, UICI-008-2, UICI-008-3, and UICI-008-4). If the well design yields a screen interval above the total borehole depth of 150 feet, a bentonite seal will be installed via tremie from borehole bottom to seal off the lower portion of the borehole. The bentonite seal will be allowed to hydrate per manufacturer guidelines, with a minimum hydration time of 1 hour.

If the borehole is advanced to 150 feet without identification of a significant water-bearing zone, no monitor well will be installed.

A photoionization detector (PID) will be available on-site and will be used to measure any cuttings that appear to contain volatile organic compounds based on best professional judgement. If odor or visual staining indicates contamination in cuttings, the drill cuttings will be placed in zip-close bags in the sun for PID analysis (DBS&A SOP 3.8 included in Appendix A). No soil samples will be submitted for laboratory analysis. DBS&A technical staff will maintain detailed logs of materials encountered during drilling and will supervise all field activities.

2.2.2 Construction Water

The drilling contractor will obtain access to potable water needed during construction. Sonic drilling requires 500 to 1,000 gallons of water per day to wet the geologic formation and release cutting materials from the override casing. Potable water is expected to be available at the refinery, and the drilling contractor is expected to coordinate with refinery staff. The drilling contractor will supply a water truck. U.S. Environmental Protection Agency (EPA) environmental site decontamination protocols will be followed at all times. Proper decontamination of the drill rig, tools, drill pipe, drill bits, and equipment cleaning will be completed with potable water on the well pad at each location. Any fluids generated or used in the process of decontamination will be contained and disposed of properly using containment pads or other appropriate materials.

2.2.3 Waste Disposal

All solid waste will be contained on location and removed by the refinery's on-site waste disposal contractor, S Brothers Waste Services, Inc. (S Brothers). All fluid waste will be contained in totes and transported to the refinery for disposal. All waste material will be visually inspected for any evidence of environmental contamination. The materials will be contained and transported to the refinery for storage and characterization. Materials (including hydrovac soils) will be hauled off-site for proper disposal.

2.2.4 Well Installation

As required by the OCD, monitor wells will be constructed in compliance with state requirements (OCD and Ground Water Quality Bureau Monitoring Well Construction and Abandonment Guidelines, Revision 1.1). Wells will be completed using single casing Schedule 40 (SCH 40) PVC materials. The wells will include 0.020-inch-slot, machine-cut, certa-lok well screen with blank casing to the surface. Well screen will be set to split the water table with the screened interval such that 5 feet of screen sits above the water table and 10 feet of screen sits below the water table. Due to a regional decline in groundwater levels, we may consider requesting a longer screen interval than the 15 feet required by OCD. A filter pack consisting of 10/20 silica sand will be installed in the well annulus from the bottom of the soil boring to at least 2 feet above the top of the screen. A minimum 5-foot-thick, activated bentonite pellet seal will then be installed on top of the filter pack and hydrated. The remaining annulus will be filled with a cement/bentonite grout. Each well will be completed with an aluminum riser that is 2 to 3 feet above ground with a locking cap. A 2-foot by 2-foot concrete pad that is 6 inches thick (minimum) will be poured around the well vault. Four bollards will be installed as a protection barrier for the well.

The drilling contractor will file all required documentation with the OSE (e.g., well records) within 30 days of monitor well installation.

2.2.5 Well Development

After completion, each newly installed monitor well will be developed by bailing and pumping methods. Pursuant to DBS&A SOPs (Appendix A), the well will be purged until temperature, pH, and conductivity have stabilized and turbidity has been reduced to the extent practicable.

During pumping well development, water levels will be monitored, and an attempt will be made to calculate the specific capacity (which is the flow rate divided by the change in drawdown). All development water will be contained on-site and disposed of at the refinery or hauled off-site by S Brothers.

2.3 Water Quality Sampling

DBS&A field staff will measure fluid levels in each of the four newly installed monitor wells and will collect water quality samples for laboratory analysis. Water levels will be measured to the nearest hundredth of a foot (0.01 foot) using an electronic water level meter. The water level meter will be decontaminated between wells prior to gauging. The water level measurements will be used to develop a map showing the locations of all monitor wells and the direction and gradient of groundwater flow at the facility. Water quality sampling will be conducted within a few weeks (depending on pump availability) following well installation and development. Standard DBS&A procedures for well sampling will be followed (Appendix A).

Wells will be purged and sampled using permanent newly installed bladder pumps in each well. Water quality sample collection timing will be completed once QED or similar pumps are available. The water level measurement will be used to calculate purge volume, where a minimum of three casing volumes will be purged from each monitor well prior to sampling. These bladder pumps will be set to low flow rates (between 0.25 and 0.5 gallon per minute). During purging, the DBS&A field technician will measure water quality parameters, including temperature, specific conductance, and pH, to ensure that these parameters stabilize to within 10 percent for specific conductance, 2°C for temperature, and ±0.2 pH units prior to sampling. Field parameters and volume purged will be recorded by DBS&A.

If a low-flow sampling technique cannot be sustained due to low formation water production, a standard three casing volume purge method will used. Each monitor well will be purged to ensure that stagnant water is removed from the well and that a representative sample of groundwater is obtained. Field parameters will be collected at least every casing volume during purging.

If the well goes dry, DBS&A will collect a sample upon sufficient water recovery. Sample containers will be filled as directed by an appropriately accredited laboratory. Sample containers will be opened and filled directly; no container will be rinsed prior to sample collection. A minimum volume of 1 liter will be collected and properly field filtered, with acid preservation as directed by Hall Environmental Analysis Laboratory (HEAL).

Quality assurance samples will be collected as directed in the U.S. Environmental Protection Agency (EPA) and OCD's QAPP. For laboratory and field quality assurance, one duplicate, one field blank, one trip blank, and one equipment blank will be collected during each quarterly monitoring event. A blind duplicate will be collected and labeled such that the analytical laboratory cannot determine which location was duplicated. A sample ID such as DUP1-YYYYMMDD will be used. The field blank will consist of deionized water treated as a sample at the well location. The field blank will be labeled FB1-YYYYMMDD.

Samples will be analyzed at HEAL, an OCD approved and appropriately credited analytical laboratory, for the list of constituents in Table 1. These analyses will require approximately of 1 liter of sample. If sufficient sample is not available, analytical priority will be given to volatile organics and majors cations/anions. HEAL will apply the OCD laboratory services methods agreement to these samples.

Monitor wells will be sampled quarterly concurrent with UIC well sampling. The initial sample collection will be analyzed for the baseline list as indicated in Table 1. Results from the initial monitor well sample will be statistically compared to the associated UIC well and evaluated for detections. HFSNR may petition OCD for an analyte list reduction for subsequent quarterly monitoring events based on evaluation of the baseline analytical results. Any reduction in analytical analysis must be approved by OCD prior to the quarterly monitoring event.

2.4 Well Survey

The newly installed monitor wells will be surveyed by a New Mexico Licensed Professional Land Surveyor. Harcow Surveying has completed other surveying at the refinery; they will be contracted for this project. Survey points will be measured from ground level, top of casing inside the well riser, and the top of the cement well pad to the nearest 0.01 foot. Measurements will be collected based on feet above mean sea level from the nearest geodetic marker. Survey data will be collected based on New Mexico State Plane East Zone Coordinates and either collected or converted into latitude and longitude (to the nearest 5 decimal places) in North American Datum 1983 (NAD83).

2.5 Reporting

DBS&A will prepare a well completion report summarizing project activities and well installation details. The report will contain all project-related information including survey-updated well location maps, copies of the OSE-approved permits, a description of drilling methods and materials, as-built monitor well diagrams, water quality results, and lithology. All obtained field data such also be included such as water quality parameters (pH, oxidation/ reduction potential [ORP], electrical conductivity [EC], temperature) and detailed field notes. Conclusion and recommendation sections will be part of the well completion report, as well an evaluation of water quality between the newly installed monitor wells and each associated UIC well.

Reference

New Mexico Energy, Minerals & Natural Resources Department Oil Conservation Division (OCD). 2014. *Quality assurance protection plan, Project management, measurement/data, acquisition, assessment, oversight, data validation and usability*. June 27, 2014.

Figures

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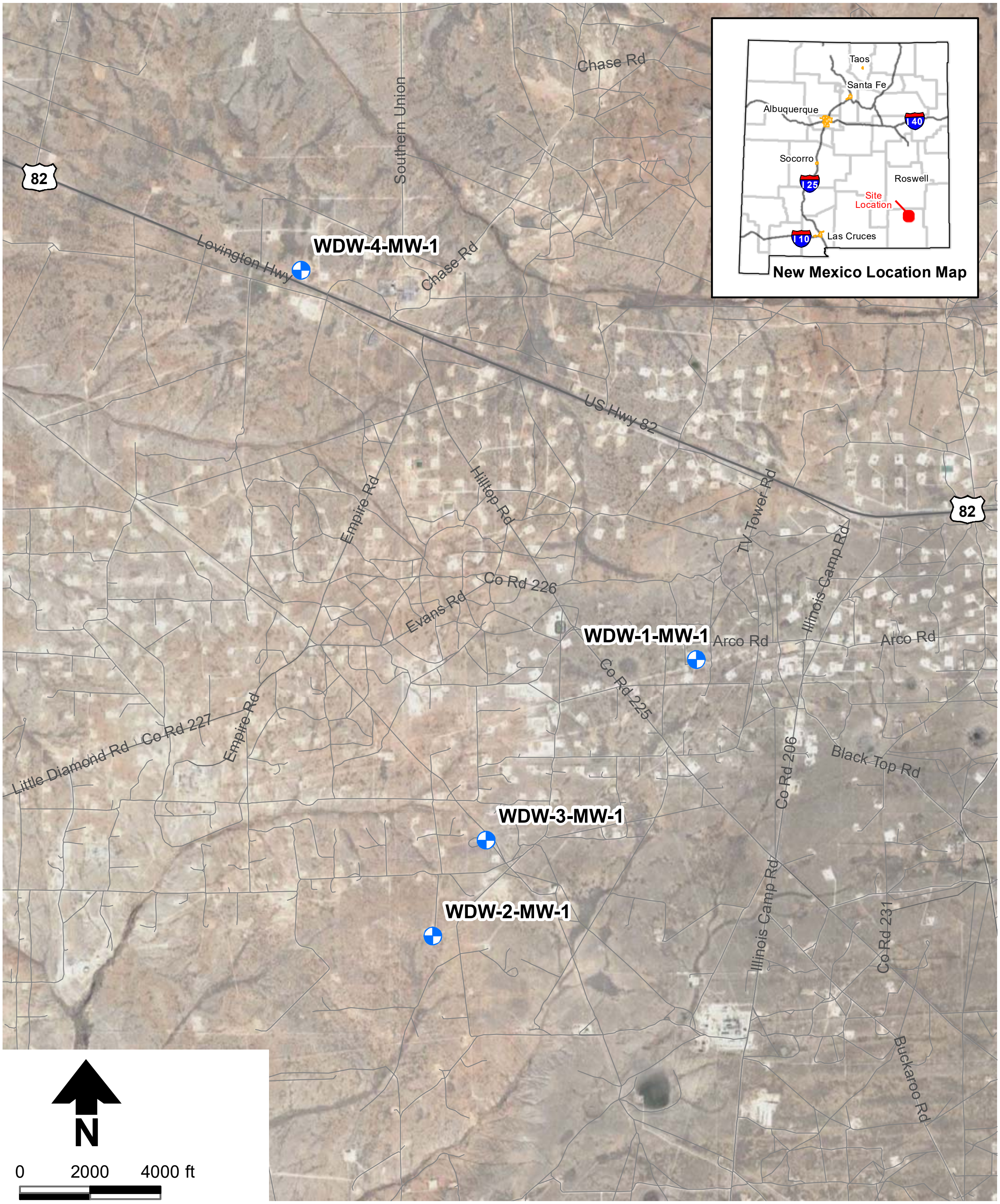

Base image source: Google Earth Pro, 12/21/2019

Explanation

Proposed monitor well location

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DBS&A a Geo-Logic Company

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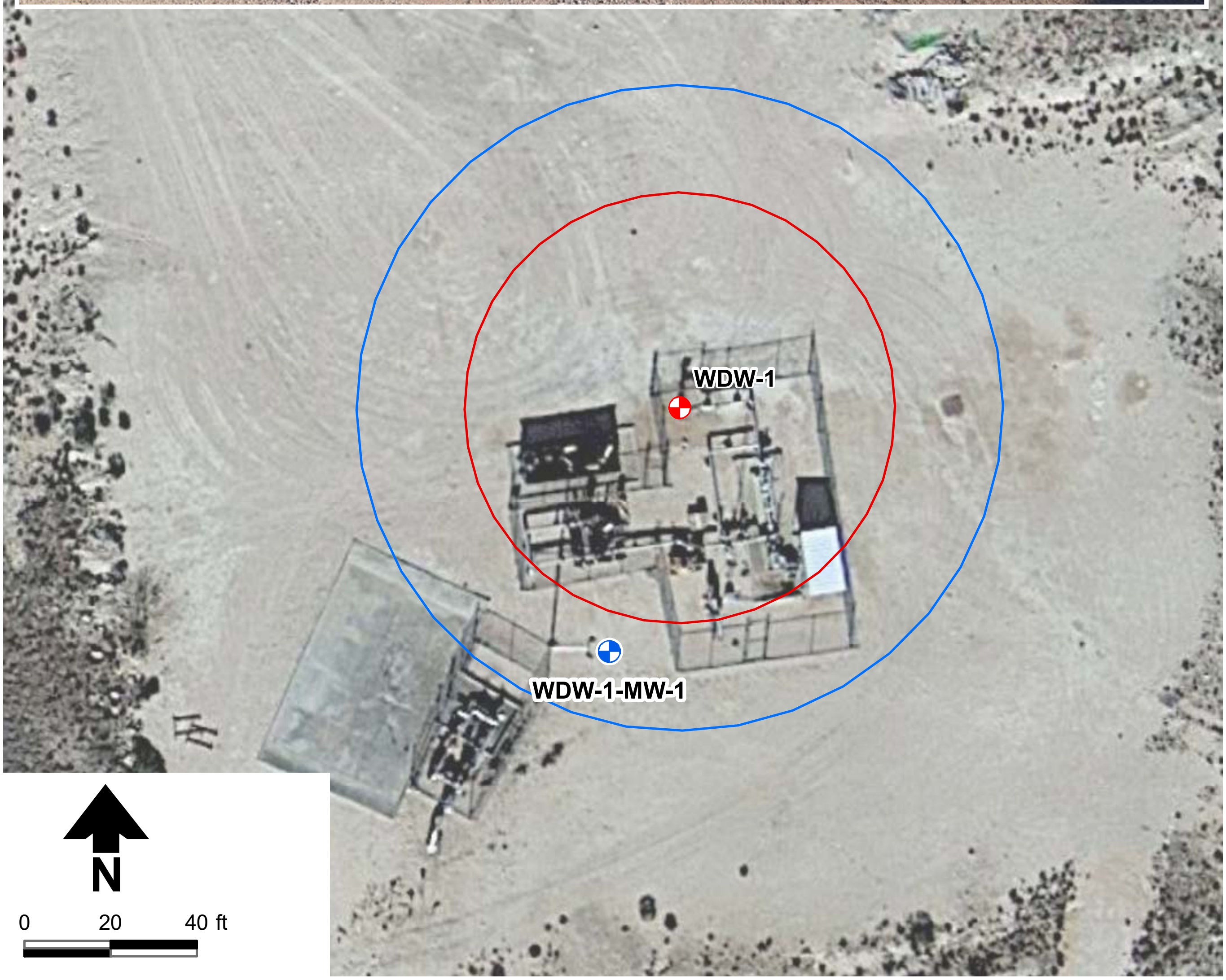
Area Map

Figure 1



Base image source: Google Earth Pro, 12/21/2019

Explanation

- Proposed monitor well
- Underground Injection Control Well (UIC)
- 50 foot radius from UIC well
- 75 foot radius from UIC well

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WDW-1

Proposed Monitor Well Location

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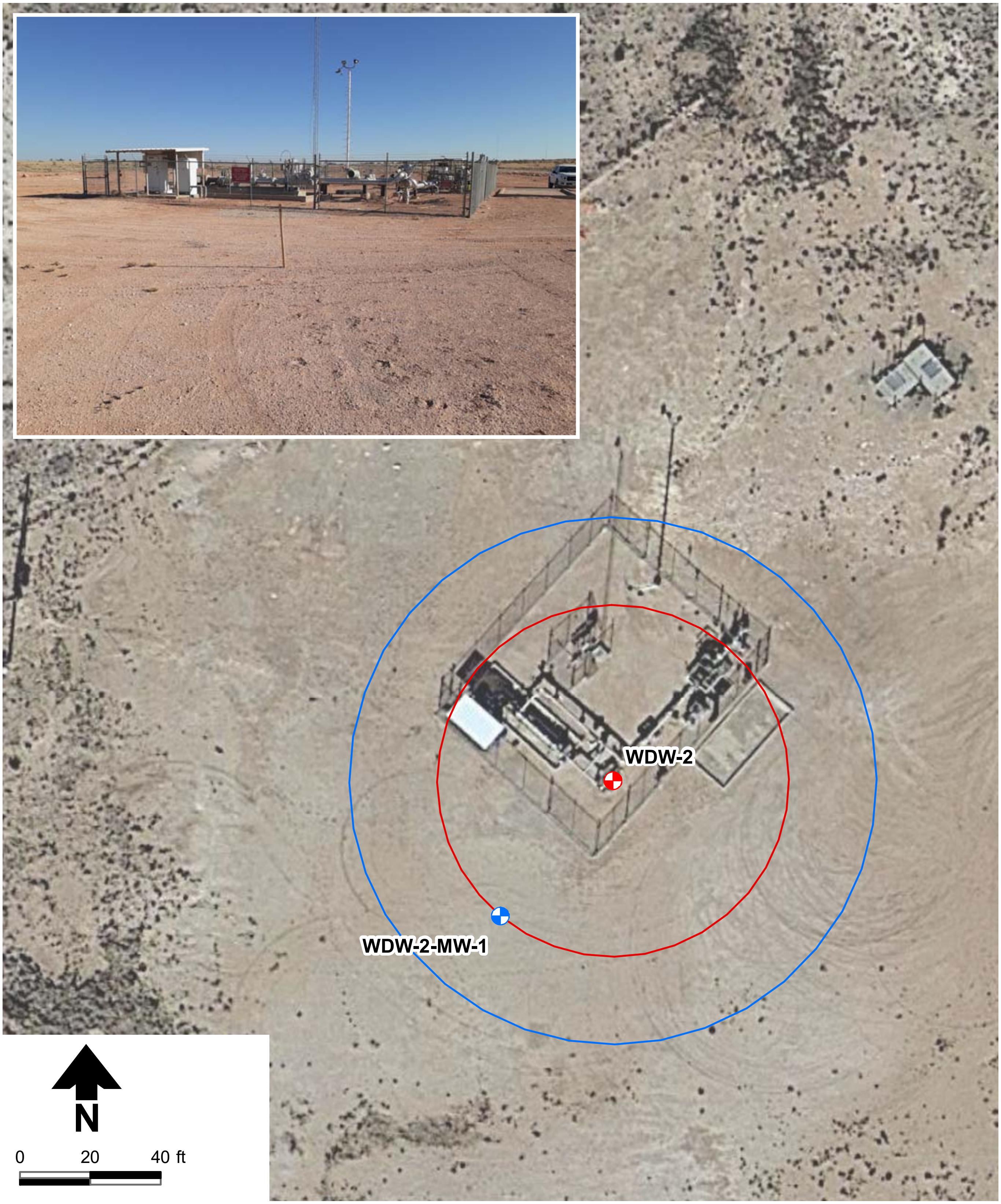
3/15/2023 DB22.1134

Figure 2a



Base image source: Google Earth Pro, 12/21/2019

Explanation

- Proposed monitor well
- Underground Injection Control Well (UIC)
- 50 foot radius from UIC well
- 75 foot radius from UIC well

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WDW-2
Proposed Monitor Well Location

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Figure 2b

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Base image source: Google Earth Pro, 12/21/2019

Explanation

- Proposed monitor well
- Underground Injection Control Well (UIC)
- 50 foot radius from UIC well
- 75 foot radius from UIC well

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WDW-3

Proposed Monitor Well Location

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Figure 2c

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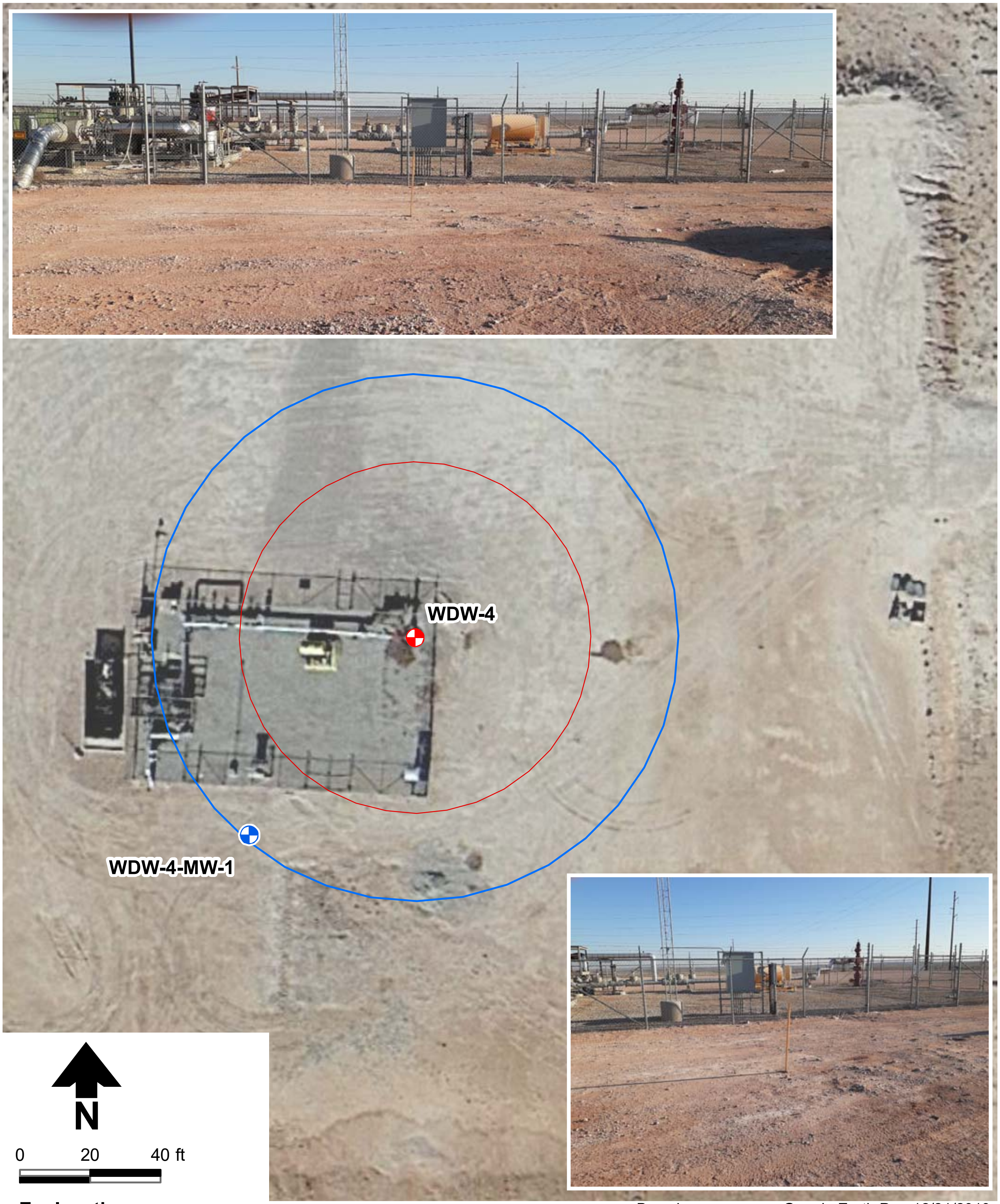

Base image source: Google Earth Pro, 12/21/2019

Explanation

- Proposed monitor well
- Underground Injection Control Well (UIC)
- 50 foot radius from UIC well
- 75 foot radius from UIC well

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WDW-4

Proposed Monitor Well Location

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Figure 2d

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Table

Table 1. Analytical Parameters
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Parameter	Laboratory Method	Concentration (mg/L [a])	
		NMAC Standard	Reporting Limit
Aluminum, dissolved	200.7	5	0.02
Barium, dissolved	200.7	2	0.003
Beryllium, dissolved	200.7	0.004	0.002
Boron, dissolved	200.7	0.75	0.04
Calcium, dissolved	200.7	—	1
Cadmium, dissolved	200.7	0.005	0.002
Chromium, dissolved	200.7	0.05	0.006
Cobalt, dissolved	200.7	0.5	0.006
Iron, dissolved	200.7	1	0.02
Magnesium, dissolved	200.7	—	1
Manganese, dissolved	200.7	0.2	0.002
Molybdenum, dissolved	200.7	1	0.008
Potassium, dissolved	200.7	—	1
Sodium, dissolved	200.7	—	1
Nickel, dissolved	200.7	0.2	0.01
Zinc, dissolved	200.7	10	0.01
Antimony, dissolved	200.8	0.006	0.001
Arsenic, dissolved	200.8	0.01	0.001
Copper, dissolved	200.8	1	0.001
Lead, dissolved	200.8	0.015	0.0005
Selenium, dissolved	200.8	0.05	0.001
Silver, dissolved	200.7	0.05	0.005
Thallium, dissolved	200.8	0.002	0.00025
Uranium, dissolved	200.8	0.03	0.0005
Mercury, total	245.1	0.002	0.0002
Bromide	300	—	0.1
Chloride	300	250	0.5
Fluoride	300	1.6	0.1
Nitrate	300	10	0.1
Nitrite	300	1	0.1
Sulfate	300	600	0.5

Notes are provided at the end of the table.

Table 1. Analytical Parameters
Page 2 of 6

Parameter	Laboratory Method	Concentration (mg/L [a])	
		NMAC Standard	Reporting Limit
Perchlorate (CAS 14797-73-0)	331.0	—	0.00005
Cyanide	335.4	0.2	0.01
1,2-Dibromoethane (ethylene dibromide, EDB) (CAS 106-93-4)	504.1	0.00005	0.00001
Perfluorohexane sulfonic acid (PHHxS) (CAS 355-46-4)	537	—	0.00001
Perfluorooctane sulfonate (PFOS) (CAS 1763-23-1)	537	—	0.00001
Perfluorooctanoic acid (PFOA) (CAS 335-67-1)	537	—	0.00001
Aldrin (CAS 309-00-2)	8081	—	0.0001
DDT (CAS 50-29-3)	8081	—	0.0001
Dieldrin (CAS 60-57-1)	8081	—	0.0001
Polychlorinated biphenyls (PCBs) (CAS 1336-36-3)	8082	0.0005	0.00025
2,4,5-TP (Silvex)	8151	—	0.0001
2,4-D (2,4-Dichlorophenoxyacetic acid)	8151	—	0.0001
Monochlorobenzene (CAS 108-90-7)	8260	—	0.0001
Thiolane 1,1 dioxide (sulfolane) (CAS 126-33-0)	8270	—	Narrative only
2,4,6-Trinitrotoluene (TNT) (CAS 118-96-7)	8330	—	0.00338
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) (CAS 121-82-4)	8330	—	0.00338
Octrahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) (CAS 2691-41-0)	8330	—	0.00338
Alkalinity, total	2320B	—	20
Bicarbonate	2320B	—	20
Carbonate	2320B	—	2
Specific conductance (µmhos/cm)	2510B	—	10 µmhos/cm
Total dissolved solids	2540C	—	20
Cadmium, dissolved	6010B	—	0.002
Chlordane	8081A	—	0.001
Endosulfan (CAS 115-29-7)	8081A	—	0.0001
Endrin	8081A	—	0.0001
Heptachlor (and its epoxide)	8081A	—	0.0001

Notes are provided at the end of the table.

Table 1. Analytical Parameters
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Parameter	Laboratory Method	Concentration (mg/L [a])	
		NMAC Standard	Reporting Limit
Hexachlorocyclohexane (HCH, lindane): alpha-HCH; beta-HCH; gamma-HCH; and, technical-HCH	8081A	—	0.0001
Lindane	8081A	—	0.0001
Methoxychlor	8081A	—	0.0001
Toxaphene	8081A	—	0.001
1,1,1-Trichloroethane (TCA)	8260B	0.2	0.001
1,1,2,2-Tetrachloroethane	8260B	0.01	0.001
1,1,2-Trichloroethane	8260B	0.005	0.001
1,1-Dichloroethane	8260B	0.025	0.001
1,1-Dichloroethene (1,1-DCE) (CAS 75-35-4)	8260B	0.007	0.001
1,2,4-Trichlorobenzene (CAS 120-82-1)	8260B	0.07	0.001
1,2,4-Trichlorophenol	8260B	—	Narrative only
1,2-Dichlorobenzene	8260B	0.6	0.001
1,2-Dichloroethane (EDC)	8260B	0.005	0.001
1,2-Dichloropropane	8260B	0.005	0.001
1,4-Dichlorobenzene	8260B	0.075	0.001
1-Methylnaphthalene (CAS 90-12-0)	8260B	—	0.004
2-Methylnaphthalene (CAS 91-57-6)	8260B	—	0.004
Acrolein (CAS 107-02-8)	8260B	—	0.01
Acrylonitrile (CAS 107-13-1)	8260B	—	0.01
Benzene	8260B	0.005	0.001
Bromodichloromethane (CAS 75-27-4)	8260B	—	0.001
Bromomethane (CAS 74-83-9)	8260B	—	0.002
Carbon tetrachloride	8260B	0.005	0.001
Chlorobenzene	8260B	—	0.001
Chloroform	8260B	0.1	0.001
Chloromethane (CAS 74-87-3)	8260B	—	0.001
Chlorothene (vinyl chloride) (CAS 75-01-4)	8260B	—	0.001
cis-1,2-dichloroethene	8260B	0.07	0.001
Dichlorodifluoromethane (fluorocarbon-12) (CAS 75-71-8)	8260B	—	0.001
Ethylbenzene	8260B	0.7	0.001

Notes are provided at the end of the table.

Table 1. Analytical Parameters
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Parameter	Laboratory Method	Concentration (mg/L [a])	
		NMAC Standard	Reporting Limit
Methyl ethyl ketone	8260B	—	0.01
Methyl tertiary-butyl ether (MTBE)	8260B	—	0.001
Methylene chloride	8260B	0.005	0.001
Naphthalene (CAS 91-20-3)	8260B	—	0.002
Styrene	8260B	0.1	0.001
Tetrachloroethene (perchloroethylene, PCE) (CAS 127-18-4)	8260B	0.005	0.001
Tetrachloromethane (carbon tetrachloride) (CAS 56-23-5)	8260B	—	0.001
Toluene	8260B	1	0.001
trans-1,2-Dichloroethene	8260B	0.1	0.001
Tribromomethane (bromoform) (CAS 75-25-2)	8260B	—	0.001
Trichloroethylene (TCE)	8260B	0.005	0.001
Trichlorofluoromethane (fluorocarbon-11) (CAS 75-69-4)	8260B	—	0.001
Trichloromethane (chloroform) (CAS 67-66-3)	8260B	—	0.001
Vinyl chloride	8260B	0.002	0.001
Xylenes (total) including m-xylene, o-xylene and p-xylene	8260B	0.62	0.002
1,4-Dioxane (CAS 123-91-1)	8270C	—	0.001
2,4,5-Trichlorophenol	8270C	—	0.0005
2,4,6-Trichlorophenol	8270C	—	0.0005
2,4-Dichlorophenol (CAS 120-83-2)	8270C	—	0.0005
2,4-Dinitro-o-cresol (CAS 534-52-1)	8270C	—	0.0005
2,4-Dinitrotoluene	8270C	—	0.0005
2,6-Dinitrotoluene (2,6-DNT) (CAS 606-20-2)	8270C	—	0.0005
3,4-Benzofluoranthene (CAS 205-99-2)	8270C	—	0.0005
Anthracne (CAS 120-12-7)	8270C	—	0.0003
Atrazine	8270C	0.003	0.0015
Benzidine (CAS 92-87-5)	8270C	—	0.0005
Benzo(k)fluoranthene (CAS 207-08-9)	8270C	—	0.0003
Benzo-a-pyrene	8270C	0.0002	0.00014

Notes are provided at the end of the table.

Table 1. Analytical Parameters
Page 5 of 6

Parameter	Laboratory Method	Concentration (mg/L [a])	
		NMAC Standard	Reporting Limit
bis (2-chloroethyl) ether (CAS 111-44-4)	8270C	—	0.0005
bis (2-chloroisopropyl) ether (CAS 108-60-1)	8270C	—	0.0005
bis (chloromethyl) ether (CAS 542-88-1)	8270C	—	0.0005
Cresol	8270C	—	0.0005
Di-2-ethylhexyl phthalate (DEHP) (CAS 117-81-7)	8270C	—	0.0005
Dibutyl phthalate (CAS 84-74-2)	8270C	—	0.0005
3,3-Dichlorobenzidine (CAS 91-94-1)	8270 C	—	0.0001
Dichloropropenes (CAS 542-75-6)	8270C	—	0.0001
Diethyl phthalate (DEP) (CAS 84-66-2)	8270C	—	0.0005
Dimethyl phthalate (DMP) (CAS 131-11-3)	8270C	—	0.0005
Dinitrophenols (CAS 51-28-5)	8270C	—	0.0001
Diphenylhydrazine (CAS 122-66-7	8270C	—	0.0001
Fluoranthene (CAS 206-44-0)	8270C	—	0.0003
Fluorene (CAS 86-73-7)	8270C	—	0.0003
Hexachlorobenzene (CAS 118-74-1)	8270C	—	0.0005
Hexachlorobutadiene (CAS 87-68-3)	8270C	—	0.0005
Hexachlorocyclopentadiene (CAS 77-47-4)	8270C	—	0.0005
Hexachloroethane	8270C	—	0.0005
Isophorone (CAS 78-59-1)	8270C	—	0.0005
m-Cresol	8270C	—	0.0005
Nitrobenzene	8270C	—	0.0005
N-nitrosodibutylamine (CAS 924-16-3)	8270C	—	0.0005
N-nitrosodiethylamine (CAS 55-18-5)	8270C	—	0.0005
N-nitrosodimethylamine (CAS 62-75-9)	8270C	—	0.0005
N-nitrosodiphenylamine (CAS 86-30-6)	8270C	—	0.0005
N-nitrosopyrrolidine (CAS 930-55-2)	8270C	—	0.0005
o-Cresol	8270C	—	0.0005
PAHs (total napthalene plus monomethylnapthalenes)	8270C	0.03	0.0003
p-Cresol	8270C	—	0.0005
Pentachlorobenzene (CAS 608-93-5)	8270C	—	0.0005

Notes are provided at the end of the table.

Table 1. Analytical Parameters
Page 6 of 6

Parameter	Laboratory Method	Concentration (mg/L [a])	
		NMAC Standard	Reporting Limit
Pentachlorophenol	8270C	0.001	0.0003
Phenanthrene (CAS 85-01-8)	8270C	—	0.0003
Phenol (CAS 108-95-2)	8270C	0.005	0.0005
Polynuclear aromatic hydrocarbons (PAHs)	8270C	—	0.0003
Prometon (CAS 1610-18-0)	8270C	—	0.0005
Pyrene (CAS 129-00-0)	8270C	—	0.0005
Pyridine	8270C	—	0.0005
1,2,4,5-Tetrachlorobenzene (CAS 95-94-3)	8270E	—	0.0005
Radium-226 and -228 combined (pCi/L)	903.0 and 904.0	5 pCi/L	<5
pH (s.u.)	9040C	6–9	~ 2–12
Cation/anion balance	Calculation	—	NA
Temperature (°C)	Provided with pH	—	—

Source: 20.6.2.3103 NMAC and 20.6.2.7 NMAC "Toxic Parameters"
[a] Unless otherwise noted
mg/L = Milligrams per liter
— = Unspecified
µmhos/cm = Micromhos per centimeter
pCi/L = Picocuries per liter
s.u. = Standard units
NA = Not applicable

Appendix A

DBS&A SOPs

a Geo-Logic Company

1.1 Equipment

This SOP provides standard procedures for maintaining equipment and for obtaining equipment from the DBS&A warehouse for conducting technical activities in the field.

The SOPs and SOGs included in this section are applicable to all DBS&A employees for the conduct of all activities listed in this section. All SOPs and SOGs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the President or his/her designee for quality assurance. All or parts of the SOPs and SOGs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of the President, his/her quality assurance designee, or a DBS&A Division Director.

These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

1.1.1 Equipment and Vehicle Planning and Ordering

All supplies and equipment required for field projects shall be requested through the Environmental Equipment Coordinator (EEC) on a Field Equipment and Materials Load-Up Sheet (DBS&A Form No. 078), Attachment 1.1-1 to this SOP. Use of vehicles and meters can be reserved using this form. The Load-Up Sheet should be submitted to the EEC with enough notice to allow coordination and, if necessary, requisition of equipment and supplies.

DBS&A or rental vehicles shall be loaded one workday prior to field activity with equipment and supplies, as requested. Vehicle fuel tanks shall be filled and fluid levels checked. It is the vehicle operator's responsibility to conduct a visual check of vehicle and safety equipment.

Rental vehicles can be obtained by filling out a Purchase Order (DBS&A Form No. 111), Attachment 1.1-2 to this SOP with the appropriate signature and Purchase Order number. The EEC will make the vehicle reservations at the rental agency and pick up the vehicle at the appropriate time.

The vehicle and all meters and equipment shall be field cleaned per Section 5.2 of the DBS&A Field Technical SOPs prior to returning to the warehouse to avoid contamination of other equipment. Equipment and supplies shall be thoroughly cleaned once returned to the warehouse.

Any defects in equipment, meters or vehicles shall be brought to the attention of the EEC. This notice shall be in writing to ensure repair or replacement.

Upon return of a vehicle from a technical activity in the field, the EEC will thoroughly inventory all supplies, equipment and meters to ensure proper billing.

Vehicles shall depart from the main office on the first day of a field activity and be returned to the main office on the last day of the activity. Company vehicles and rental vehicles must be returned to ensure proper billing. Upon return, notify the EEC. The vehicle may need to be unloaded, cleaned, and reloaded for another field activity.

Company vehicles shall be used, if available, prior to arranging for a rental or for the use of a personal vehicle.

If supplies and equipment are needed because of unforeseen difficulties, a Field Equipment and Materials Load-Up Sheet shall be left for the EEC. This must be done to ensure that DBS&A can properly bill for supplies and equipment.

1.1.2 Equipment Cleaning, Maintenance, and Calibration

The following procedures should be followed to maintain proper operation of all equipment:

- Equipment returned from a field activity shall be thoroughly inspected for wear, breakage, and proper operation by the EEC.
- Equipment shall be cleaned with a tap water and Liquinox solution and then rinsed with distilled water. If the equipment is used for soil or water sampling, it will then receive a second rinse with distilled water.
- Batteries and power supply units shall be checked for proper power and replaced or repaired as needed.
- Any worn or broken parts that were noted during the inspection shall be either repaired or replaced by the EEC in accordance with manufacturer's recommendations.
- Solinst water level meters shall be inspected by the EEC for short circuiting in the electronic board, low battery charge, and worn, torn, or damaged shrink tubing on the probe. Repair shall be completed as needed.

- Orion pH meters shall be run through the self-test by the EEC as described in the Operations Manual. The probes shall be inspected to ensure good electrical connections. Following the instructions in the operators manual supplied by the manufacturer, probes shall be refilled periodically using the recommended electrode filling solution. Calibration of the instrument is described in the operators manual. Use buffer solution close to the parameters to be found in the water to be tested, usually pH 4.0 and pH 7.0.
- YSI salinity-conductivity-temperature meters shall be inspected by the EEC for damage and water entry. The probe shall be soaked in a solution of 1 part hydrochloric acid (HCl), 10 parts distilled water, and 10 parts isopropyl alcohol for one hour. The probe shall then be washed in a Liquinox solution and rinsed in distilled water. Batteries shall be tested for proper voltage with a voltage tester and replaced as necessary. The instrument shall be calibrated in accordance with manufacturer's recommendations as supplied in the appropriate operators manual. The calibration solution shall be as close as possible to parameters expected in the field.
- The YSI Model 57 dissolved oxygen meter shall be inspected by the EEC for damage and water entry. The probe membrane shall be inspected and changed if needed in accordance with the manufacturer's recommendation in the operators manual. The batteries shall be tested and replaced if needed. The meter shall be calibrated as described in the operators manual.
- The Hydrolab water quality meter shall be inspected thoroughly by the EEC for damage and wear. A close inspection of the probes, cords, and electrical connectors is essential. The batteries shall be tested and replaced as needed. The probes shall be cleaned and calibrated as described in the operators manual supplied with the equipment.
- The combustible gas indicator (MSA #30) shall be visually inspected by the EEC for worn or damaged parts. The batteries for this unit shall be tested using a voltage tester and replaced as necessary. The instructions provided by manufacturer on the lid of the instrument shall be followed.
- The LEL/02 monitor (MX 251) and sampling pump shall be closely inspected by the EEC for damage and wear. Upper and lower explosive set pints and oxygen alarm settings shall be checked. Calibration in accordance with manufacturers specifications, outlined in the users handbook, shall be performed using 100 parts per million (ppm) pentane. The batteries shall be tested and replaced as needed.

- The photoionization detector (PID) shall be thoroughly checked by the EEC prior to cleaning and maintenance. The meter shall be calibrated using 100 ppm isobutylene following procedures in the operators manual and cleaned as needed. The meter shall be fully discharged prior to recharging to avoid memory etching.

Attachments

1.1-1 Field Equipment and Materials Load-Up Sheet (DBS&A Form No. 078)

1.1-2 Purchase Order (DBS&A Form No. 111)

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Field Supplies Load-Up Request Sheet

Project & Task No. ______________________ Date ______________________

Project Name ______________________ Requested Pick-Up Date/Time ______________________

Requestor ______________________ Estimated Return Date ______________________

Required	Packed	Qty./Days Used	Expendables Tub
1			1 Duct Tape, 1 Electrical Tape
1			2 Boxes of Ziplock Bags (1 Gal, 1 Qt)
1			Paper Towel Roll
1			Garbage Bags (1 Sm, 1 Lg)
1			Liquinox
1			Sharpies
5			Sunscreen
1			Scissors
1			Latex Gloves XL__ L__M__ S__

Required	Packed	Qty./Days Used	NAPL Recovery
			NAPL Buckets and Lids
			Was NAPL Disposed at Lab? Record Amount
			Interface Probe
			Metal bailers (2") and socks

Required	Packed	Qty./Days Used	Soil Sampling
			AMS Hand Auger System Size_____
			Plastic Scoops
			Rings and End Caps, (2.5" x 3") Brass
			Rings and End Caps, (2.5" x 6") Brass
			Rings and End Caps, (3" x 3") Stainless
			Soil Sampling Kit
			Solvent-Free Tape

Required	Packed	Qty./Days Used	Sample Containers
			1 Gal Cubitainers
			1 L Cubitainers
			125 ml Soil Jar
			250 ml Soil Jar
			500 ml Soil Jar
			Chip Inspection Tray
			Chip Tray Funnel
			Chip Tray Storage Box
			Chip Trays
			Mason jars/Foil

Required	Packed	Qty./Days Used	Supplies and Miscellaneous
			1 lt Tedlar Bags
			10% HCL Dropper Bottle
			Batteries, Type:_____
			Bubble Wrap
			Chair
			Coolers
			Decon Brushes
			Decon Tubs
			DI water (5 Gal)
			Extension Cord ____ ft.
			Field Table
			Flash Lights/Head Gear Lights
			Flat Hose
			Flat Hose Clamps size:____
			Gas Can
			Ladder 17 feet
			Locks, Large (14T917)
			Locks, Long Shank (2440)
			Locks, Medium(X2289)
			Locks, Small (P225)
			Measure Wheel
			Pin Flags
			Plastic Sheeting
			Project Notebook
			Shovels/Post Hole Digger
			Spray Bottle
			Spray Marking Paint
			Tape Measure (200'-300')
			Tape, Fiberglass 100', 300'
			Tape, Flagging
			Tape, Packing
			Tape, Strapping
			Tent Shade 10' x 10'
			Toolbox
			Trailer Hitch charger
			Tubs for carrying field supplies
			Walkie Talkies
			Zip Ties 15 pack 7.5",8",11",14",18",24"

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Field Supplies Load-Up Request Sheet

Project & Task No. ______________________ Date ______________________
Project Name ______________________ Requested Pick-Up Date/Time ______________________
Requestor ______________________ Estimated Return Date ______________________

Required	Packed	Qty./Days Used	**Water Sampling**
			0.45µ Disposable In-Line Filter
			1000 ft. Power Sounder
			5,000 ml graduated beaker
			500 ml graduated beaker
			Bailer Twine (100', 200', 300')
			Braided Polypropylene Rope
			Calibrated Buckets
			Dipper (Swing Sampler Bottle Pole) 12'
			Dipper (Swing Sampler Bottle Pole) 6'
			Hach Analysis DO Kit
			Hach Colorimeter
			Hach Turbidimeter
			Locking Well Cap (1", 2" or 4")
			Oscar Filter + Syringe
			Poly Bailer (3") Emptying Devices
			Poly Bailers, 2"
			Poly Bailers, 3"
			Poly Bailers, Miscellaneous Sizes
			PVC Bailer, Size 2"x6'
			PVC Bundle
			Spool for Rope/Bailer String
			Sulfate Kit
			Water Level Indicator ____ Feet
			Well Kit
			YSI - 556
			YSI - Pro
			YSI Calibration Kit (3 pH, ORP, Conductivity)

Required	Packed	Qty./Days Used	**Health & Safety**
			Caution Tape
			Ear Plugs
			First Aid Kit
			Health & Safety Kits (PPE)
			Heavy Gloves
			N95 Dust Masks
			Portable Eye Wash Station
			Pull On Overboot
			Safety Goggles/Glasses
			Traffic Cones
			Tyvek w/Hood & Boots

Required	Packed	Qty./Days Used	**Gauges/Meters/Accessories**
			Air Entry Perm.
			Bennett Pump Nitric Acid
			Bennett Pump/Trailer Hitch/Gas Can
			Dewalt Generator/ pigtails/ramp/gas can
			Digital Manometer
			Flow Meter (Velocicalc)
			Gas Powered 5K Generator
			Gas Powered Compressor
			Geiger counter
			Horiba Pump
			Infiltrometer, ponded
			Infiltrometer, tension
			Metal Detector
			Neutron Probe
			Neutron Probe Extra long cable
			Peristaltic Pump
			Peristaltic Pump Medical Grade Hose___ ft.
			PID calibration gas, Isobutylene
			PID/Micro filters and tubing
			Poly Tubing 0.25" x 0.17"
			Poly Tubing 1/2" x 5/8"
			Poly Tubing 3/8" x 1/2"
			QED Development Pump
			Qrae Multi-gas meter
			Regulator
			Sand Cone
			Sand, Calibrated
			Transducer w/logger and desiccant
			Transducer Connector Cable
			Troxler
			Vacuum Box
			Vapor Pin Kit

Required	Packed	Qty./Days Used	**Other**

Is all equipment working?
Comments:

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PURCHASE ORDER

Ship To:
- ☐ 6020 Academy Rd NE, Suite 100, Albuquerque, NM 87109 Phone: 505-822-9400
- ☐ 12303 Technology Blvd, Suite 930D, Austin, TX 78727 Phone: 512-821-2765
- ☐ 4611 50th St, Lubbock, TX 79414 Phone: 806-785-7280
- ☐ 3201 N. Pecos St, Suite 110, Midland, TX 79705 Phone: 432-305-1960
- ☐ 3150 Bristol St, Suite 210, Costa Mesa, CA 92626 Phone: 657-218-4708
- ☐ 3916 State St, Garden Suite, Santa Barbara, CA 93105 Phone: 805-683-2409

Issued To: ____________________

P.O. #:		Date:		Project/Phase/Task #:	
Ship Via:		Terms:		Ship by Date:	

Quantity	Stock No./Description	Unit Price	Total	Rec'd
			-	
			-	
			-	
			-	
			-	
			-	
			-	
			-	
			-	
			-	
			-	
			-	
			-	
			-	
			-	
			-	
		Subtotal	$ -	
		Shipping		
		Tax		
		Total	$ -	

Submit invoice electronically to gla-ap@geo-logic.com.
Purchase order number must appear on all invoices and correspondence.

Requested by

Authorized by

Revised 8/04/2020

1.3 Field Log Book

The following SOG describes the appropriate guidelines for note taking during field activities.

The SOPs and SOGs included in this section are applicable to all DBS&A employees for the conduct of all activities listed in this section. All SOPs and SOGs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the President or his/her designee for quality assurance. All or parts of the SOPs and SOGs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of the President, his/her quality assurance designee, or a DBS&A Division Director.

These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

The field log book is an integral part of the sampling program and forms the basis of the sampling record. A complete field log book is required on most projects. Items documented in the log book are highly relevant to interpreting the subsequent collected data. The objective of taking field notes is to make an accurate written record of the field activities. The field log book serves as a method to record additional site information and observations not easily included on field forms. Field notes often serve as the basis for writing a report after the work is complete. Field notes should be sufficiently accurate and complete that the events that took place can be recreated by someone who was not involved in the activities.

1.3.1 Equipment

- Field log book: water-resistant paper, permanently bound, with sequentially-numbered pages
- Waterproof pens (blue is sometimes preferred to differentiate originals from copies)

1.3.2 General Guidelines

- Make all entries using waterproof pen
- Write legibly. If you abbreviate, be sure to define your abbreviation somewhere in the notes.

- Be as brief as clarity will allow. However, it is better to record too much data than to try and recreate activities from memory.
- Be accurate. If you have to guess, identify your entry as a guess.
- Be detailed and quantify your data as much as possible. When in doubt, measure.
- Sketches and drawings add depth and detail to your notes.
- Do not scribble through entries you want to change. To make a correction, draw a single line through the entry and date the correction.
- Do not remove pages from the log book. Remember that the field log book can become a legal document.

1.3.3 Requirements

- Each day's log should begin at the top of a page
- At the top of each page, include the following:
  - A header that identifies the project name and location
  - The date
  - The name and initials of the person taking notes
- The first entry of the day should identify the location, names of DBS&A personnel, visitors, contractors, etc., and the purpose of the activities (e.g., well installation, development, sampling, etc.).
- Each important observation should start with the time (i.e., when)
- The person taking notes should sign and date each page.
- A diagonal line should be drawn across the bottom of each day's entry, then signed and dated.
- For litigation projects, each person should have their own field log book and keep notes as necessary. If only one log book is used, try to have one person do all the note-taking. If the log book is used by more than one person, each person taking notes should sign at the end of their entry before transferring the log book to another person.
- The log book should stay in the custody of the note taker.

- Do not recopy your field notes. Field notes are notes taken in the field. Remember, a few days (or weeks) later, what you think you saw may not actually be what you did see. Field notes can become a legal document so think of them that way from the start.
- Review your notes at least daily for cryptic entries that need additional explanation.

Examples of Noteworthy Items

- Time of arrival and departure
- Attendees at tailgate safety meetings
- Arrival and departure of visitors
- Contents and conclusions of key phone calls and meetings
- Important instructions to staff and contractors (especially if it leads to standby time charges)
- Weather and changes in weather
- Name, type, and condition of equipment being used
- Procedures and results of instrument calibrations
- Changes in activities (e.g., move to decon pad to clean drill rig)
- Down time and cause (e.g., repair drive line on rig)
- Document and explain field decisions (e.g., why you decide not to tremie grout)
- Important results
  - Field parameters collected during well development or sampling
  - Sample IDs and time of collection
  - Sample containers, volumes, and preservation
- Observations
  - General soil type
  - Hard drilling conditions
  - Soil staining or odor
  - Condition of tanks and associated piping
- Health and safety
  - Document tailgate meetings
  - Document results of utility clearances

- Site inspections (e.g., condition of excavation)
- Health and/or safety violations and warnings
- Results of air or other monitoring (e.g., PID readings)

1.4 Soil Boring Log

This SOP provides standard procedures for completing soil boring logs.

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During boring operations, soil descriptions and other pertinent information will be recorded on the Soil Boring Log form (Attachment 1.4-1). This form consists of a header for recording the boring specifics and a log for describing and classifying soil and tracking soil sampling.

1.4.1 Completing the Header

On the first page of the log, it is important to complete the entire header, most of which is self-explanatory. If subsequent form pages are necessary, fill in only the page number, the site name, the client name, the person logging the soil, the boring number, and the date on continuation page headers. On the first page, sketch a location map for the boring, referencing it to known features or landmarks. When specifying the drilling method and drill rig, note the diameter of the drill bit.

1.4.2 Completing the Boring Log

Fill in the columns as follows:

- *PID/FID Reading:* Record headspace measurements made with the PID/FID to correspond with the depth interval from which the reading was made.
- *Blow Counts:* If driving a split-barrel sampling device with a hammer, record the number of hammer "blows" per 6 inches of penetration. Ensure that the driller marks the 6-inch intervals on the drill stem prior to hammering the split-barrel. Record weight of hammer.

- *Sampling Device:* Specify the sampling device (i.e., split-barrel, split-barrel with brass or stainless steel rings, Shelby tube) and its inside diameter.
- *Sample Recovery:* Record, in tenths of feet, the amount of sample that is recovered over the distance sampled (e.g., 1.2/2.0).
- *Sample Interval:* Specify the sampling interval (starting and finishing) by placing an "X" across the appropriate depth interval.
- *Sample Number:* Record the designated sample number.
- *USCS Symbol:* Provide the Unified Soil Classification System (USCS) symbol(s) for the soil described; draw a contact line at the appropriate depth to identify changes in soil type. A solid horizontal line indicates an abrupt or clear contact, a slanted line indicates a gradual or diffuse contact, and a dashed line indicates an inferred contact not observed in samples.
- *Depth (feet):* Note each 5-foot interval to keep a running tally of the depth of the borehole.
- *Soil Description/Remarks:* Describe the soil in the order listed on the boring log (soil type, color, texture, grain size, sorting, roughness, plasticity, consistency, moisture content), according to the procedures summarized in SOP 3.7.

Attachment

Attachment 1.4-1 Soil Boring Log

DBS&A
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Boring Log

Page___of___

Site		Location Map
Logged By	Client/Project #	
Boring Number	Drilling Co.	
Drilling Method	Drill Rig	
Date Started	Date Completed	

PID/FID Reading	Blow Counts	Sampling Device	Sample Recovery	Sample Interval	Sample Number	USCS Symbol	Depth (feet)	Soil Description/Remarks Soil type, color, texture, grain size, sorting, roughness, plasticity, consistency, moisture content

DBS&A Form No. 080, Updated 1/2023

1.6 Chain of Custody

This SOP provides standard procedures for documenting field activities.

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These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field.

The chain of custody form is used to document sample collection activities and provide the analytical laboratory with a request for analyses. The chain of custody form must be kept with the field personnel at all times during sampling activities and should be completed in the field at the time of sample collection.

1.6.1 Equipment

- Chain of custody form. This is provided by the analytical laboratory; each laboratory uses a slightly different form with the same key elements.
- Waterproof pens (blue is sometimes preferred to differentiate originals from copies).

1.6.2 General Guidelines

Make all entries using waterproof pen.

Write legibly. If you abbreviate, be sure to define your abbreviation somewhere in the notes.

Do not scribble through entries you want to change. To make a correction, draw a single line through the entry and date the correction.

1.6.3 Completing the Chain of Custody Form

- Give the site name and project name/number.

- Enter the sample identification code.
- Indicate the sampling dates for all samples.
- List the sampling times (military format) for all samples.
- Specify the sample location.
- List the analyses/container volume. Include the analytical method (e.g., 8260).
- Obtain the signature of sample team leader.
- State the carrier service, airbill number, and analytical laboratory.
- Sign, date, and time the "relinquished by" section.
- Upon completion of the form, retain the shipper copy, and affix the other copies to the inside of the sample cooler, in a zip-seal bag to protect from moisture, to be sent to the designated laboratory.

1.7 Decontamination of Field Equipment

The following standard operating procedure (SOP) defines activities required to decontaminate field equipment used in the sampling of soils, sludges, surface water, and groundwater in order to prevent cross-contamination of samples from different sampling locations.

The SOPs and SOGs included in this section are applicable to all DBS&A employees for the conduct of all activities listed in this section. All SOPs and SOGs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the President or his/her designee for quality assurance**.** All or parts of the SOPs and SOGs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of the President, his/her quality assurance designee, or a DBS&A Division Director.

These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

All non-disposable field equipment that may potentially come in contact with any soil, sludge, or water sample shall be decontaminated in order to minimize the potential for cross-contamination between sampling locations. Thorough decontamination of all sampling equipment shall be conducted in the warehouse before each sampling event. In addition, the field representative shall decontaminate all equipment in the field as required to prevent cross-contamination of samples collected in the field. The procedures described in this section are specifically for field decontamination of sampling equipment.

A decontamination station should be established using plastic sheeting to contain splashes. At a minimum, field sampling equipment should be decontaminated using the following procedure:

1. Wash the equipment in a solution of non-phosphate detergent (e.g., Liquinox™) and potable or distilled/deionized water. All surfaces that may come in direct contact with the samples shall be washed. Use a clean Nalgene and/or plastic tub to contain the wash solution and a scrub brush to mechanically remove loose particles. Wear clean latex or plastic gloves during all washing and rinsing operations.

2. Rinse twice: once with potable water and a second time with distilled/deionized water. Use clean Nalgene and/or plastic tubs or buckets to contain the rinse solutions.
3. Dry the equipment before use, to the extent practicable, and take measures to keep the equipment clean before use.

For specific projects requiring more rigorous decontamination of field sampling equipment, the following procedures may be used:

1. Wash the equipment in a solution of non-phosphate detergent (e.g., Liquinox™) and potable or distilled/deionized water. All surfaces that may come in direct contact with the samples shall be washed. Use a clean Nalgene and/or plastic tub to contain the wash solution and a scrub brush to mechanically remove loose particles. Wear clean latex or plastic gloves during all decontamination procedures.
2. For field equipment used in the collection of samples for inorganic analyses, an acid rinse may be employed, using either a 10% reagent-grade nitric or a hydrochloric acid solution in deionized water. A 1% acid solution may be used on low-carbon steel equipment in order to avoid damaging such equipment. The project manager will determine if an acid rinse is required for specific equipment and projects.
3. Rinse equipment with potable or distilled/deionized water.
4. If field equipment is to be used in the collection of samples for organic analyses, a solvent rinse may be used. Organic solvents may include reagent grade isopropanol, acetone, or methanol. Project managers will determine if a solvent rinse is required for specific equipment used on their projects.
5. Rinse equipment with reagent grade organic-free distilled/deionized water.
6. Allow equipment to air dry before use, to the extent practicable.
7. Wrap equipment for transport with inert material (aluminum foil or plastic wrap) to prevent direct contact with potentially contaminated material.

All liquid and solid material generated from the decontamination process should be contained and disposed of in accordance with project-specific disposal guidelines.

3.1 Drilling Operations

This section provides standard operating guidelines (SOGs) for drilling programs.

The SOGs included in this section are applicable to all DBS&A employees for the conduct of all activities listed in this section. All SOPs and SOGs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the President or his/her designee for quality assurance**.** All or parts of the SOPs and SOGs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of the President, his/her quality assurance designee, or a DBS&A Division Director.

The scope of the guidelines described in this section includes the following:

- Drilling Methods
- Drilling Fluids
- Drilling Equipment
- Guidelines to Follow During Drilling Activities

Standards for drilling methods and fluids are described in ASTM D 5092-90 ("Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers"). Refer to Driscoll (1986), U.S. EPA (1986) or Aller et al. (1989) for more detailed information about the above subjects as they relate to the drilling of monitor and extraction wells and borings. Site-specific work plans or sampling plans should identify any special needs or circumstances beyond those described in this SOG.

These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high-quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

3.1.1 Drilling Methods (ASTM D 5092-90)

The drilling method required to create a stable, open, vertical borehole for drilling a borehole or installation of a monitor or extraction well shall be selected according to the site geology, the site hydrology, and the intended use of the data. Tables 3.1-1 and 3.1-2 list common drilling methods and will aid in the selection of an appropriate drilling method. Table 3.1-1 lists the advantages and disadvantages of the different types of drilling methods. Table 3.1-2 assesses the performance of different drilling methods in various types of geologic formations.

3.1.2 Drilling Fluids (ASTM D 5092-90)

Whenever feasible, drilling procedures should be used that do not require the introduction of water or drilling fluids into the borehole and that optimize cuttings control at ground surface. Where the use of drilling fluids is unavoidable, the selected fluid should have as little impact as possible on the water samples for the constituents of interest. In addition, care should be taken to remove as much drilling fluid as possible from the well and the aquifer during the well development process (Section 4.2). If an air compressor is used to inject water or blow cuttings from the borehole, it should be equipped with an oil air filter or oil trap to keep from introducing oil into the borehole. If water is added to the borehole or well during drilling and/or development, the volume added shall be recorded in the logbook. Depending on the geologic conditions, it may be appropriate or required to remove that volume of water prior to sampling.

Oil-based drilling fluids should not be used. Air- or water-based drilling fluids shall be used if drilling fluids are needed for the drilling of monitor and extraction wells and borings. Water-based drilling fluids have the least influence on the groundwater quality in the area of drilling. However, potential problems created by the use of water-based drilling fluids need to be kept in mind. These problems include (1) fluid infiltration/flushing of the intended monitoring zone, (2) well development difficulties (particularly where an artificial filter pack has been installed), (3) chemical, biological and physical reactivity of the drilling fluid with indigenous fluids in the ground, and (4) introduction of halomethanes into the groundwater.

3.1.2.1 Drilling Fluid Properties

The drilling subcontractor is responsible for checking and adjusting the properties (weight and viscosity) of the drilling fluid. The proper weight of the drilling fluid (1 liter) is needed to maintain stability of the borehole, and the proper viscosity controls the ability of the drilling fluid to remove cuttings from the borehole. However, the DBS&A project manager/site supervisor or designee should always make sure that the drilling contractor periodically checks the properties of the drilling fluid.

One simple and common way to measure the viscosity of the drilling fluid is a Marsh funnel. With the use of a Marsh funnel, a known volume of drilling fluid is allowed to drain from a special funnel into a cup; the flow time is recorded and calibrated against the time required for an equal volume of water to drain from the funnel (approximately 26 seconds at 70°F [21.1°C]). The mud weight can be measured with a balance.

Table 3.1-3 describes typical additive concentrations, resulting viscosities, and required uphole velocities for major types of drilling fluids used in various aquifer materials. Table 3.1-4 charts drilling fluid weight adjustments with barite or water.

3.1.2.2 Guidelines for Solving Specific Drilling Fluid Problems (from Driscoll, 1986, Chapter 11)

The drilling subcontractor is responsible for any drilling fluid problems. However, the DBS&A project manager/site supervisor or designee and field personnel should be aware of and recognize the problems that may arise. Below are some guidelines for solving specific drilling fluid problems which may be helpful to the DBS&A project manager/site supervisor or designee:

Problem: Inadequate cuttings have been removed from the borehole.

Recommended Action:

1. Clays and polymeric solids in potable water
    a. Increase uphole velocity of the drilling fluid.
    b. Increase viscosity of the drilling fluid by adding more colloidal material.
    c. Increase density of the drilling fluid by adding weighting material (Tables 3.1-3 and 3.1-4).
    d. Reduce penetration rate to limit cuttings load.
2. Air
    a. Increase uphole velocity of fluid system by adding air or water.
    b. Add surfactant to produce foam or to increase concentration of surfactant.
    c. Decrease air injection rate if air is breaking through the foam mix and preventing formation of stable foam.
    d. Decrease water content of the foam system.

Problem: The rate at which cuttings will drop out is too low because the inadvertent addition of native clays during drilling has produced excessive viscosity in the drilling fluid.

Recommended Action:

1. Add potable water to dilute the drilling fluid (Table 3.1-4).
2. Add commercial thinner to reduce the attractive forces between clay colloids.
3. If using clay additives, convert to a polymeric system.
4. Separate the solids from a clay-additive system with a shale shaker or shale shakers and desanders connected in series. A shale shaker or desander may be unnecessary when a polymeric system is being used.
5. Redesign or clean the pit system to increase rate of cuttings settlement.

Problem: Gel strength becomes too great because of strong flocculation, high concentration of solids, or contamination from evaporite deposits or cement. (Excessive gel-strength problems do not occur with polymeric colloids.)

Recommended Action:

1. Add potable water to dilute the drilling fluid.
2. Add polyphosphate or commercial thinner to reduce electrical charges between clay colloids.
3. Use desander or shale shaker to remove solids from a clay-additive system.
4. Lower the pH.

Problem: Excessive fluid loss into the formation causes thick filter cakes that can produce tight places in the hole, development problems, formation (clay) sloughing, and misinterpretation of electric or gamma-ray logs.

Recommended Action:

1. Increase viscosity by adding bentonite or polymeric colloids to any water-based system.
2. Add commercial viscosifiers such as cellulose gum (CMC) or hydroxyethyl cellulose (HEC).
3. Reduce density of the drilling fluid.
4. Prevent drastic changes in downhole pressures and maintain downhole pressures at a minimum. Suggestions include (from Baroid):

a. Raise and lower the drill string slowly.

b. Drill through any tight section; do not spud.

c. Begin rotation of the drill pipe, and then start the pump at a low rate and gradually increase the rate.

d. Operate the pump at the lowest rate that will assure adequate cooling of the bit and removal of cuttings from the bit face.

e. Prevent balling at the bit; do not drill soft formations so fast that the annulus becomes overloaded and pressure builds up.

Problem: Lost circulation in permeable formations, faulted and jointed rock, solution cavities in dolomite and limestone, or fractures created by excessive borehole pressures in semiconsolidated or well consolidated rock can all create problems.

Recommended Action:

1. Reduce the density of the drilling fluid system.
2. Switch from a clay-additive drilling fluid system to an air-foam fluid, or add surfactant to a dry-air system.
3. Gel natural polymeric fluids at the point of fluid loss.
4. Use commercial sealing materials.
5. Drill remainder of the hole with a cable tool rig.
6. Case off, then resume rotary drilling.
7. Fill the borehole with clean sand to the point above lost circulation. Let the material stand in borehole overnight. Resume drilling, using low pump pressure.

Problem: Confined pressures in the formation can contribute to a problem.

Recommended Action:

1. Increase density by adding heavy mineral additives such as barite to drilling fluid systems made with clay additives (Table 3.1-4). To suspend barite, the minimum Marsh funnel viscosity must equal four times the final (desired) drilling fluid weight (in lb/gal).
2. Increase density by adding a salt solution to polymeric drilling fluid systems.

Problem: Hydration (swelling and dispersion), pore pressures, and overburden pressure can cause shale sloughing.

Recommended Action:

1. Use polymeric additive to isolate water from shale.
2. Maintain constant fluid pressures in the borehole.
3. Minimize uphole velocities.
4. Avoid pressure surges caused by raising or lowering drill rods rapidly.
5. Add 3 to 4 percent potassium chloride (KCl) to water-based systems.
6. Raise the pH of the drilling fluid to stiffen the clay.

Problem: Contaminants are present. Contaminants usually consist of cement, soluble salts, and gases (hydrogen sulfide and carbon dioxide). Cement in the hole can cause polymeric drilling fluids to break down, thereby increasing fluid losses. Salts may cause drilling fluids with clay additives to separate into liquid and solid fractions. Gases in water may affect the physical condition of the drilling fluid.

Recommended Action:

1. For cement problems:
   a. Maintain the pH for natural polymeric drilling fluids at 7 or lower.
   b. Add commercial chemicals such as sodium acid pyrophosphate to drilling fluids with clay additives to restore original viscosity.
2. For salt problems:
   a. Change the clay additive from montmorillonite to attapulgite.
   b. Change to a natural polymeric drilling fluid additive.
3. For gas problems, add a corrosion inhibitor.

Problem: Drilling at air temperatures significantly below freezing, causing freeze-up of the recirculation system.

Recommended Action:

Add sodium chloride (NaCl) or calcium chloride ($CaCl_2$) to a natural polymeric drilling fluid. Salt must not be added to a drilling fluid made with bentonite.

3.1.3 Drilling Equipment

The DBS&A Drilling Information Checklist (Table 3.1 5) attached to this SOG should be used for the preparation of drilling programs. The checklist should be used as a communication guide between DBS&A and the drilling subcontractor. The checklist should be completed and checked prior to the field stage of the drilling program by both DBS&A and the drilling subcontractor. The Drilling Information Checklist summarizes important phone contacts, length of job, type of rig, underground utility survey, geologic material, sampling, disposal of cuttings, number of wells and soil borings, grouting, and health and safety issues. The Daily Equipment Checklist (Table 3.1 6) should be used by the DBS&A project manager/site supervisor or designee as a check of equipment needed and daily duties to be performed.

3.1.4 Guidelines to Follow During Drilling Activities

1. A drilling method should be selected that will cause minimal disturbance to the subsurface materials and will not contaminate the subsurface and groundwater (40 CFR 265.91(c)).
2. The drilling contractor is responsible for decontaminating the drilling equipment before it is transported onto the project site (ASTM D 5088-90). DBS&A's project manager/site supervisor or designee will check the equipment when it arrives on-site, prior to starting each borehole, and before leaving the site.
3. A decontamination procedure should be followed before use and between borehole locations to prevent cross contamination of wells where contamination has been detected or is suspected from the site characterization work that precedes the drilling activities (ASTM D 5088-90).
4. The drilling contractor shall be responsible for securing any and all boring or well drilling permits required by state or local authorities and for complying with any and all state or local regulations with regard to the submission of well logs, samples, etc. DBS&A's project manager/site supervisor or designee should check that necessary permits have been obtained and are available.

5. The drilling contractor shall comply with any and all (to include placement) regulations with regard to drilling safety and underground utility detection. DBS&A's Project manager/site supervisor or designee shall document that necessary utility clearances have been obtained. The drilling contractor shall have a safety data sheet (SDS) for each hazardous chemical that he brings on-site or intends to use during the job. SDSs will be available for inspection by all site workers.
6. Air systems shall not be used for drilling, well installation, well development, or sampling without prior approval by the project manager. When used, air systems shall include an airline oil filter, frequently replaced, to remove essentially all oil residue from the air compressor. The use of any air system shall be fully described in the DBS&A field logbook to include equipment description, manufacturer(s), model(s), air pressures used, frequency of oil filter change and evaluation of airline filtering.
7. When air is used as the drilling fluid, shrouds, canopies, blooey lines, or directional pipes should be used to contain and direct the drill cuttings away from the drill crew.
8. Any water that is used during the drilling and installation of a well should be of a known chemical source and verified not to alter or impact the chemistry of the groundwater or the operation of the well.
9. When using commercially available mud or additives for the drilling fluid, DBS&A project manager/site supervisor or designee and field personnel should make sure that the mud or additives do not alter or affect the chemistry of the groundwater or the operation of the well.
10. During rotary drilling, the use of portable recirculation tanks is required. No sumps (lined or unlined) shall be dug without prior approval by the project manager and the client.
11. No dyes, tracers, or other substances shall be used or otherwise introduced into borings, wells, lysimeters, grout, backfill, groundwater, or surface water unless specifically approved by the technical project manager.
12. For water supply wells over 100 feet deep, plumbness and alignment should be checked at preselected intervals during the drilling of the boreholes. The readings should be taken by the driller using a single-shot or multi-shot deviation surveying device and should be verified by the DBS&A field personnel.
13. Any contaminated materials (soil and/or water) should be collected and disposed of in an approved waste disposal container or facility.

14. Soil descriptions, collection of samples, field monitoring, and other pertinent information shall be recorded on the boring log form during drilling operations. the boring log form, soil logging procedures, and instructions for completing the boring log form are included in Section 3.7.

Attachments

Table 3.1-1 Drilling Methods for Monitor Wells

Table 3.1-2 Relative Performance of Different Drilling Methods in Various Types of Geologic Formations

Table 3.1-3 Typical Additive Concentrations, Resulting Viscosities, and Required Uphole Velocities for Major Types of Drilling Fluids Used in Various Aquifer Materials

Table 3.1-4 Drilling Fluid Weight Adjustment with Barite or Water

Table 3.1-5 Drilling Information Checklist

Table 3.1-6 Daily Equipment Checklist

References

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielson, and J.E. Denne. 1989. *Handbook of suggested practices for the design and installation of ground-water monitoring well design and installation*. National Well Water Association. Dublin, Ohio. 398 p.

Driscoll, F.G. 1986. *Groundwater and wells*. Johnson Division. St. Paul, MN. 1089 p.

U.S. Environmental Protection Agency (EPA). 1986. *RCRA ground-water monitoring technical enforcement guidance document*. Washington, D.C. September 1986. 208 p. and 3 Appendices.

Table 3.1-1. Drilling Methods for Monitor Wells Page 1 of 4

Type	Advantages	Disadvantages
Hollow-stem auger	▪ No drilling fluid is used, eliminating contamination by drilling fluid additives ▪ Formation waters can be sampled during drilling by using a screened auger or advancing a well point ahead of the augers ▪ Formation samples taken by split-spoon or core-barrel methods are highly accurate ▪ Natural gamma-ray logging can be done inside the augers ▪ Augers can seal slow-producing formations, making it possible to identify multiple producing zones	▪ Can be used only in unconsolidated materials ▪ Limited to depths of 100 to 150 ft (30.5 to 45.7 m) ▪ Possible problems in controlling heaving sands ▪ May not be able to run a complete suite of geophysical logs ▪ Delays in sample returns on the augers can affect logging accuracy and detail.
Mud rotary	▪ Can be used in both unconsolidated and consolidated formations ▪ Capable of drilling to any depth ▪ Core samples can be collected ▪ A complete suite of geophysical logs can be obtained in the open hole ▪ Casing is generally not required during drilling ▪ Many options for well construction ▪ Fast ▪ Smaller rigs can reach most drilling sites ▪ Relatively inexpensive	▪ Water-based drilling fluid is required and contaminants are circulated with the fluid ▪ Drilling fluid mixes with the formation water and invades the formation and is sometimes difficult to remove ▪ Bentonitic fluids may absorb metals and may interfere with other parameters ▪ Organic fluids may interfere with bacterial analyses and/or organic-related parameters ▪ During drilling, only limited information can be obtained on the location of the water table and the extent of water-producing zones; direct measurements are not possible ▪ Cuttings samples may not be accurate

Table 3.1-1. Drilling Methods for Monitor Wells
Page 2 of 4

Type	Advantages	Disadvantages
Air rotary	▪ No water-based drilling fluid is used, eliminating contamination by additives ▪ Can be used in both unconsolidated and consolidated formations ▪ A limited suite of geophysical logs can be run in the open borehole ▪ A casing hammer can be used to simultaneously drive casing ▪ Capable of drilling to any depth ▪ Formation sampling is excellent in hard, dry formations ▪ Formation water blown out of the hole makes it possible to determine when the first water-bearing zone is encountered ▪ Field analysis of water blown from the hole can provide information regarding changes for some basic water-quality parameters such as chlorides ▪ Fast	▪ Casing is required to keep the hole open when drilling in soft, caving formations below the water table ▪ When more than one water-bearing zone is encountered and hydrostatic pressures are different, flow between zones occurs during the time drilling is being completed and before the borehole can be cased and grouted properly ▪ Relatively more expensive than other methods ▪ May not be economical for small jobs
Cable tool	▪ Only small amounts of drilling fluid are required (generally water with no additives) ▪ Can be used in both unconsolidated and consolidated formations; well suited for extremely permeable formations ▪ Can drill to depths required for most monitoring wells ▪ Highly representative formation samples can be obtained by an experienced driller ▪ Changes in water level can be observed ▪ Relative permeabilities for different zones can be determined by skilled drillers ▪ A good seal between casing and formation is virtually assured if flush-jointed casing is used ▪ Rigs can reach most drilling sites ▪ Relatively inexpensive	▪ Minimum casing size is 4 in (102 mm) ▪ Steel casing must be used ▪ Cannot run a complete suite of geophysical logs ▪ Usually a screen must be set before a water sample can be taken ▪ Slow ▪ A skilled operator is required to maximize the information obtained from this method

Table 3.1-1. Drilling Methods for Monitor Wells
Page 3 of 4

Type	Advantages	Disadvantages
Dual-tube pneumatic hammer	▪ Excellent stratigraphic control. Outer tube eliminates slough so cuttings produced are from interval penetrated; core barrel can be used to collect in-situ samples ▪ Outer tube effectively seals borehole allowing individual water-bearing zones to be identified and preventing cross contamination ▪ Capable of drilling to depths required for most monitor wells ▪ Fast	▪ Limited use in hard, consolidated formations ▪ Because casing is evacuated during drilling, may produce large amounts of formation water and exacerbate flowing sands ▪ Can be very noisy in hard formations ▪ Relatively more expensive than other methods
Casing hammer	▪ Wells can be drilled in unconsolidated geologic materials that may be difficult to drill with other methods. ▪ The borehole is fully stabilized during the entire drilling operation. ▪ Penetration rates are rapid, even under difficult drilling conditions. ▪ Lost-circulation problems are eliminated. ▪ Accurate formation and water samples can be obtained. ▪ Can be used in all weather conditions. ▪ No water-based drilling fluid is required in unconsolidated materials.	▪ Method is more expensive. ▪ Operation is noisy.
Rotosonic	▪ Collects continuous cores and generates very little waste ▪ Very rapid penetration rates are possible (8 to 10 times faster than hollow-stem auger, but slower than mud rotary) ▪ Dual string assembly allows advancement of outer casing with the inner casing used to collect samples ▪ Capable of drilling to depths required for most monitor wells	▪ Vibrating drill bit or core barrel can raise the temperature of samples and volatilize more sensitive compounds ▪ Driving of material into the borehole wall when using a drill bit may create problems for logging, aquifer testing, and may affect monitor well filter pack ▪ More expensive than other methods

Table 3.1-1. Drilling Methods for Monitor Wells
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Type	Advantages	Disadvantages
Reverse rotary	▪ Porosity and permeability of the formation near the borehole is relatively undisturbed compared to other methods. ▪ Large-diameter holes can be drilled quickly and economically. ▪ No casing is required during the drilling operation. ▪ Well screens can be set easily as part of the casing installation. ▪ Most geologic formations, except igneous and metamorphic rocks, can be drilled. ▪ Washouts in the borehole less likely (due to the low velocity of the drilling fluid).	▪ Large water supply is generally needed. ▪ Rigs and components are usually larger and thus more expensive. ▪ Large mud pits are required. ▪ Some drill sites are inaccessible because of the rig size. ▪ More personnel are generally required for efficient operation than for other drilling methods.

Table 3.1-2. Relative Performance of Different Drilling Methods in Various Types of Geologic Formations Page 1 of 2

		Direct Rotary				Reverse Rotary					
Type of Formation	Cable Tool	With Fluids	With Air	Down-the-Hole Air Hammer	Drill-Through Casing Hammer	With Fluids	Dual Wall	Hydraulic Percussion	Jetting	Driven	Auger
Dune sand	2	5	NR	NR	6	5*	6	5	5	3	1
Loose sand and gravel	2	5	NR	NR	6	5*	6	5	5	3	1
Quicksand	2	5	NR	NR	6	5*	6	5	5	NR	1
Loose boulders in alluvial fans or glacial drift	3-2	2-1	NR	NR	5	2-1	4	1	1	NR	1
Clay and silt	3	5	NR	NR	5	5	5	3	3	NR	3
Firm shale	5	5	NR	NR	5	5	5	3	NR	NR	2
Sticky shale	3	5	NR	NR	5	3	5	3	NR	NR	2
Brittle shale	5	5	NR	NR	5	5	5	3	NR	NR	NA
Sandstone-poorly cemented	3	4	NR	NR	NA	4	5	4	NR	NR	NA
Sandstone-well cemented	3	3	5	NR	NA	3	5	3	NR	NR	NA
Chert nodules	5	3	3	NR	NA	3	3	5	NR	NR	NA
Limestone	5	5	5	6	NA	5	5	5	NR	NR	NA
Limestone with chert nodules	5	3	5	6	NA	3	3	5	NR	NR	NA

Notes are provided at the end of the table.

Table 3.1-2. Relative Performance of Different Drilling Methods in Various Types of Geologic Formations Page 2 of 2

Type of Formation	Cable Tool	Direct Rotary: With Fluids	Direct Rotary: With Air	Direct Rotary: Down-the-Hole Air Hammer	Direct Rotary: Drill-Through Casing Hammer	Reverse Rotary: With Fluids	Reverse Rotary: Dual Wall	Hydraulic Percussion	Jetting	Driven	Auger
Limestone with small cracks or fractures	5	3	5	6	NA	2	5	5	NR	NR	NA
Limestone, cavernous	5	3-1	2	5	NA	1	5	1	NR	NR	NA
Dolomite	5	5	5	6	NA	5	5	5	NR	NR	NA
Basalts, thin layers in sedimentary rocks	5	3	5	6	NA	3	5	5	NR	NR	NA
Basalts-thick layers	3	3	4	5	NA	3	4	3	NR	NR	NA
Basalts-highly fractured (lost circulation zones)	3	1	3	3	NA	1	4	1	NR	NR	NA
Metamorphic rocks	3	3	4	5	NA	3	4	3	NR	NR	NA
Granite	3	3	5	5	NA	3	4	3	NR	NR	NA

Modified from Driscoll (1986)
*Assuming sufficient hydrostatic pressure is available to contain active sand (under high confining pressures)
NR = Not recommended
NA = Not applicable
Rate of Penetration:

1	Impossible	4	Medium
2	Difficult	5	Rapid
3	Slow	6	Very rapid

Table 3.1-3. Typical Additive Concentrations, Resulting Viscosities, and Required Uphole Velocities for Major Types of Drilling Fluids Used in Various Aquifer Materials
Page 1 of 2

Base Fluid	Additive/Concentration	Marsh Funnel Viscosity (seconds)	Annular Uphole Velocity (ft/min)	Observations
Water	None	26–0.5	100–120	For normal drilling (sand, silt, and clay)
	Clay (High-Grade Bentonite)			Increases viscosity (lifting capacity) of water significantly
	15-25 lb/100 gal	35–55	80–120	For normal drilling conditions (sand, silt, and clay)
	25-40 lb/100 gal	55–70	80–120	For gravel and other coarse-grained, poorly consolidated formations
	35-45 lb/100 gal	65–75	80–120	For excessive fluid losses
	Polymer (Natural)			Increases viscosity (lifting capacity) of water significantly
	4.0 lb/100 gal	35–55	80–120	For normal drilling conditions (sand, silt, and clay)
	6.1 lb/100 gal	65–75	80–120	For gravel and other coarse-grained, poorly consolidated formations
	6.5 lb/100 gal	75–85	80–120	For excessive fluid losses
				Cuttings should be removed from the annulus before the pump is shut down, because polymeric drilling fluids have very little gel strength
Air	None	NA	3,000–5,000	Fast drilling and adequate cleaning of medium to fine cuttings, but may be dust problems at the surface
			4,500–6,000	This range of annular uphole velocities is required for the dual-wall method of drilling
	Water (Air Mist) 0.25-2 gpm	NA	3,000–5,000	Controls dust at the surface and is suitable for formations that have limited entry of water

Table 3.1-3. Typical Additive Concentrations, Resulting Viscosities, and Required Uphole Velocities for Major Types of Drilling Fluids Used in Various Aquifer Materials
Page 2 of 2

Base Fluid	Additive/ Concentration	Marsh Funnel Viscosity (seconds)	Annular Uphole Velocity (ft/min)	Observations
Air	Surfactant/Water (Air-Foam)	NA	50-1,000	Extends the lifting capacity of the compressor
	1-2 qt/100 gal (0.25-0.5% surfactant)			For light drilling; small water inflow; also for sticky clay, wet sand, fine gravel, hard rock; few drilling problems
	2-3 qt/100 gal (0.5-0.75% surfactant)			For average drilling conditions; larger diameter, deeper holes; large cuttings; increasing volumes of water inflow; excellent hole cleaning
	3-4 qt/100 gal (0.75-1% surfactant)			For difficult drilling; deep, large-diameter holes; large, heavy cuttings; sticky and incompetent formations; large water inflows
				Injection rates of surfactant/water mixture: Unconsolidated formations: 3-10 gpm Fractured rock: 3-7 gpm Solid rock: 3-5 gpm
	Surfactant/Colloids/Water (Stiff Foam)	NA	50-100	Greatly extends lifting capacity of the compressor
	3-5 qt/100 gal (0.75-1% surfactant) plus 3-6 lb polymer/100 gal or 30-50 lb bentonite/100 gal			For difficult drilling; deep, large-diameter holes; large, heavy cuttings; sticky and incompetent formations; large water inflows
	4-8 qt/100 gal (1-2% surfactant) plus 3-6 lb polymer/100 gal or 30-50 lb bentonite/100 gal			For extremely difficult drilling; large, deep holes; lost circulation; incompetent formations; excessive water inflows

Table 3.1-2. Drilling Fluid Weight Adjustment with Barite or Water

Initial Drilling Fluid Weight (lb/gal)	Desired Drilling Fluid Weight (lb/gal)											
	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	1.0	14.5	15.0
9.0	69	140	214	293	371	457	545	638	733	833	940	1050
9.5		69	143	219	298	381	467	557	650	750	855	964
10.0	43		71	145	221	305	390	479	569	667	769	876
10.5	85	30		74	148	229	312	398	488	583	683	788
11.0	128	60	23		74	152	233	319	407	500	598	700
11.5	171	90	46	19		76	157	240	326	417	512	614
12.0	214	120	69	37	16		79	160	245	333	426	526
12.5	256	150	92	56	32	14		81	162	250	343	438
13.0	299	180	115	75	48	27	12		81	167	257	350
13.5	342	210	138	94	63	41	24	11		83	171	264
14.0	385	240	161	112	78	54	36	21	10		86	176
14.5	427	270	185	131	95	68	48	32	19	9		88
15.0	470	300	208	150	110	82	60	43	29	18	8	

Modified from Petroleum Extension Service (1969)

1. The lower left half of this table shows the number of gallons of water which must be added to 100 gal of drilling fluid to produce desired weight reductions. To use this portion of the table, locate the initial drilling fluid weight in the vertical column at the left, then locate the desired drilling fluid weight in the upper horizontal row. The number of gal of water to be added per 100 gal of drilling fluid is read directly across from the initial weight and directly below the desired weight. For example, to reduce an 11 lb/gal drilling fluid to a 9.5 lb/gal drilling fluid, 128 gal of water must be added for every 100 gal of drilling fluid in the system.
2. The upper right half of this table shows the number of pounds of barite which must be added to 100 gal of drilling fluid to produce desired weight increases. To use this portion of the table, locate the initial drilling fluid weight in the vertical column to the left, then locate the desired drilling fluid weight in the upper horizontal row. The number of pounds of barite to be added per 100 gal of drilling fluid is read directly across from the initial weight and directly below the desired weight. For example, to raise a 9 lb/gal drilling fluid to 10 lb/gal, 140 lb of barite must be added per 100 gal of drilling fluid in the system.

Table 3.1-5. Drilling Information Checklist
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Project No_______________________________DBS&A Project Manager _________________________

DBS&A field personnel __________________________

Drilling Company ____________________________

Drilling Company Contact_____________________Phone No. ___________________________

Date work to begin________________Estimated workdays to complete job ______________

Written access agreements in place with property owners ______
Written access agreements in place with owners of property to be crossed to reach drilling site ___
Well permits and/or drilling permits filed with appropriate agency _____
Notify client and/or Agency in timely manner ______
Utility clearance; One-Call contacted _______
Local municipality contacted (water & sewer) ______
Underdetection service contacted (private co.) _______
Utility clearance required time allotted _______
Health and Safety Plan (site specific with emergency medical info) with daily tailgate meeting forms ___
MSDS book for field activities_______
First aid kit, eye wash bottle, and material safety data sheets requested (rental vehicle) ______
Water: Is water available on site or nearby? ________
Can the drilling subcontractor haul adequate amounts of water? _____
Is the water source and equipment used to transport water free of contaminants? ____
Decontamination equipment (steam cleaner, etc.) supplied by drilling contractor____
Decon pad available if required_____Containment of decon water if needed _____
Sample kit for decon water_____Arrange for disposal of decon water ______
Drilling fluids containment______Sample kit for drilling fluids ______

Table 3.1-5. Drilling Information Checklist
Page 2 of 2

Arrange for disposal of drilling fluids ______
Drill cuttings containment______Sample kit for drill cuttings ______
Arrange for disposal of drill cuttings ______
Drilling method (selected for appropriate geologic conditions to be encountered) ___
Wooden knockout plugs (hollow stem augers in flowing sands) ______
Sampling device______Size of sampling device ______
Sample containers ordered to fit the sampling device _____
Sampling containers (appropriate for the chemical and/or physical parameters to be tested) ___
Sand or core catchers supplied by drillers for unconsolidated soils _____
For brass or stainless steel rings, are end caps, Teflon liners, and the appropriate sealing material available __________
What is sampling interval_____ Has an adequate number of sample containers been ordered _____
Well screen and filter pack (well screen and filter pack been sized to match completion formation) ___
Tagline (length, type, and free of contaminants) _____
Tremie pipe (if needed) supplied by drilling contractor ____
Annular seal: selected to prevent grout intrusion and blistering of casing (bentonite vs. cement) ___
Surface well completions; flush mounted well vaults or steel risers with protective posts ____

Table 3.1-6. Daily Equipment Checklist
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Item	Specific Procedures and Equipment
Health and Safety ____________	Conduct tailgate health and safety meeting before starting work and as activities or conditions change. Discuss appropriate safety issues. Ensure work crew is wearing the required personal protective equipment. Always adhere to the site-specific health and safety plan. Ensure that MSDS book is on-site.
Meters (at start of work day) _____	Calibrate all meters to be used and record calibration results in the field book.
	Remove all meters from their storage cases and place storage cases in a dry safe place for the day.
	Place all meter probes in the appropriate temporary storage solution (usually distilled or tap water) to prevent drying out of probe membranes (critical for DO probes).
	Use appropriate in-line dust and moisture filters (critical for photoionization detector and GA90 methane meter).
Meters (at end of work day) ______	Turn off power to all meters to conserve batteries.
	Place all probes in their respective storage solutions.
	Clean (decontaminate as necessary) and dry off all meters and return to their storage cases for transport.
	If back up batteries were used, purchase replacement batteries as necessary.
	Recharge all rechargeable batteries over night. Most nickel/cadmium batteries prefer to be fully discharged and fully recharged to prevent memory imprints (e.g., GA-90 methane meter). Read meter manual for proper recharging instructions. If freezing temperatures are possible, make sure all meters are stored in a secure heated area.
Meters (during the work day) _____	Decon all downhole meters between use to prevent cross contamination.
	If a meter reads over its operating range, recalibrate meter before using again (PID).
	Broken or malfunctioning meters should be replaced as soon as possible. Contact the DBS&A Equipment Coordinator.
Decontamination supplies _______	Purchase distilled water, paper towels, garbage bags, and plastic sheeting as necessary.
Sample containers _______	If containers are broken or become contaminated in any way or the scope of work expands, request the appropriate number and type of sample containers and preservatives immediately. Sample containers are usually provided by the laboratory performing the analysis or the DBS&A Equipment Coordinator.

Table 3.1-6. Daily Equipment Checklist
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Item	Specific Procedures and Equipment
Coolers ________	Purchase adequate ice to keep samples at 4°C at all times. Ice should be placed in double zip-lock baggies and kept from coming in contact with samples. Coolers should be kept as free of melt water as possible to prevent samples from coming in contact with melt water.
Field Book _________	In field book, use indelible ink and record the start and end times of various drilling activities, particularly down-time and standby.
	Meter readings H&S discussions (i.e., tailgate H&S meeting, 8-8:15) Client contacts or visitors Deviations from the work plan or scope of work

3.7 Soil Description

The following guidance provides procedures for describing soil in the field. The basis for this guidance is *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)* developed by the ASTM International (ASTM) as Standard D 2488 (ASTM, 2000). In addition, we have included other field tests d presented in the EPA document *Description and Sampling of Contaminated Soils - A Field Pocket Guide* (U.S. EPA, 1991).

3.7.1 Equipment

Soil sampling tool kits are available from the DBS&A warehouse. Recommended equipment for describing soil includes the following:

- Soil boring logs
- Nitrile gloves
- Grain-size chart
- Dilute hydrochloric acid
- Glass jar with lid
- No. 40 sieve
- Munsell color chart
- Hand lens
- Squirt bottle of water
- Stainless steel spatula or pocket knife
- Tape measure (graduated in 10ths)

3.7.2 Procedure for Describing Soil

This SOP summarizes the process for describing soil in the field. All of the information described here should be recorded on the DBS&A Soil Boring Log Form (Attachment 3.7-1). SOP 1.4 details the procedure for preparing the Soil Boring Log. Attachment 3.7-2 presents all of the information in this SOP in a 2-page summary that can be taken to the field.

3.7.2.1 Is the Material Peat?

If the sample is composed primarily of vegetable tissue in various stages of decomposition with a fibrous to amorphous texture, usually dark brown to black, and an organic odor, it is considered a highly organic soil and identified as peat, USCS symbol "Pt." According to the

USCS procedure, highly organic soil identified as peat is not subjected to any further identification procedures.

3.7.2.2 Coarse-Grained or Fine-Grained?

This determination is the basis for subsequent tests that will be performed to characterize the soil. If more than 50 percent of the grains are visible with the unaided eye, the material is a coarse soil. If less than 50 percent of the grains are visible with the unaided eye, the material is a fine soil. The procedures for describing predominantly coarse-grained and fine-grained soil are in Section 3.4 and 3.5, respectively. The following methods can be used to determine whether the soil is predominantly coarse-grained or fine-grained.

1. Spread a sample of soil in your palm or on a flat surface, such as a clipboard, and examine the particles. Visually estimate the percentage of the sample that is visible with the unaided eye. Use a hand lens, if necessary. If some of the particles could be aggregates of fine particles, wet a small sample of the soil with water. Rub a marble-sized sample between the thumb and forefinger. Sand grains will feel rough and gritty, whereas aggregates of fine material will break down and feel silky.
2. The *jar method* is performed by placing the sample in a glass jar with water and shaking the container to disperse the sample. The rate of settling can be used to judge the predominant soil type(s), whereas the thicknesses of the various soils can be used to judge the gradation of the soil. Sands settle in 30 to 60 seconds, silts generally settle in 30 to 60 minutes, and clays may remain in suspension overnight. The interface between fine sands and silts occurs where individual grains cannot be discerned with the unaided eye. The cloudiness of the water indicates the relative clay content.
3. The *wash test* can be used to estimate the relative percentages of sand and fines. Select and moisten enough minus No. 4 sieve size material (medium sand and finer) and form a 1-inch cube. Cut the cube in half and place half in a shallow dish. Wash and decant the fines out of the material until the water in the dish is essentially clear. Compare the amount of solids left in the dish with the other half of the soil cube and estimate the percentage of sand and fines. The volume comparison provides a reasonable estimate of grain size percentages.

While it is generally preferred to state the approximate percentage of gravel, sand, and fines, those percentages may be stated in terms indicating a range of percentages, as follows:

- *Trace:* Particles present, but estimated to be less than 5 percent
- *Few:* 5 to 10 percent

- *Little:* 15 to 25 percent
- *Some:* 30 to 45 percent
- *Mostly:* 50 to 100 percent

3.7.2.3 *Describing Coarse-Grained Soil*

This section summarizes the steps for describing soil in which more than 50 percent of the grains are visible to the unaided eye. Coarse soil should be identified according to Table 3.7-1.

Table 3.7-1. Field Description of Coarse Soil

Soil Type	Fines	Grading	Silt or Clay	USCS Symbol	Sand or Gravel	Description
Gravel	<5%	Well-graded	—	GW	<15% sand	Well-graded gravel
					≥15% sand	Well-graded gravel with sand
		Poorly graded	—	GP	<15% sand	Poorly graded gravel
					≥15% sand	Poorly graded gravel with sand
	>15%	—	Silt	GM	<15% sand	Silty gravel
					≥15% sand	Silty gravel with sand
		—	Clay	GC	<15% sand	Clayey gravel
					≥15% sand	Clayey gravel with sand
Sand	<5%	Well-graded	—	SW	<15% gravel	Well-graded sand
					≥15% gravel	Well-graded sand with gravel
		Poorly graded	—	SP	<15% gravel	Poorly graded sand
					<15% gravel	Poorly graded sand with gravel
	>15%	—	Silt	SM	≥15% gravel	Silty sand
					<15% gravel	Silty sand with gravel
		—	Clay	SC	≥15% gravel	Clayey sand
					<15% gravel	Clayey sand with gravel

Source: WADOT, 2006
— = Not applicable

Gravel or Sand? Coarse soils are classified as either a gravel or a sand, depending on whether the coarse grains are mostly larger or smaller than a 0.19-inch (4.75-mm) opening. A soil is defined as gravel when the estimated percentage of the gravel-size particles is greater than the percentage of sand-size particles. A soil is defined as sand when the estimated percentage of the sand-size particles is greater than the percentage of gravel-size particles. Grain size criteria for sand and gravel-size material are summarized in Table 3.7-2.

Table 3.7-2. Sand and Gravel Subdivisions

Description	Sand (mm)	Gravel (inches)
Fine	0.075 to 0.425	⅕ to ¾
Medium	0.425 to 2	—
Coarse	2 to 4	¾ to 3

Source: ASTM D 2488 (2009)

"Clean" or "Dirty?" Once the material is classified as either gravel or sand, it is then identified as either clean or dirty. "Clean" means that the sample is essentially free (less than 5 percent) of fines (material that passes a 0.003-inch [0.075 mm] opening) and "dirty" means that the sample contains an appreciable (greater than 15 percent) amount of fines. The use of the terms clean and dirty are for distinction purposes only and should not be used in the description contained on the field log.

There are several ways to determine whether a sample is clean or dirty.

1. Visually estimate the percentage of the material that is individual grains visible to the unaided eye; the remaining material is considered the fines.
2. Remove material coarser than medium sand (greater than 2 mm or passing a No. 10 sieve), wet the sample, and work it with your hands. Evaluate the "staining" of the hand. A clean sand with less than 5 percent fines will not leave an appreciable stain. The dirtier the sand, the more staining will be evident.
3. If necessary, use the jar method or the wash method described in Section 3.7.2.2.

Sorting. If the material is clean, gradation criteria apply, and the material is classified as either a well graded sand (USCS symbol SW) or gravel (GW), or a poorly graded sand (SP) or gravel (GP) (Table 3.7 1). Well-graded (poorly sorted) soil has a wide range of particle sizes and a substantial amount of the intermediate particle sizes. Poorly graded (well sorted) soil consists predominantly of one particle size (uniformly graded) or has a wide range of particle sizes with some sizes obviously missing (gap graded). Once the grading determination has been made, the classification can be further refined by estimating the percentage of the sand-size particles present in the sample.

Silt or Clay? If the material is dirty (i.e., more than 15 percent fines), it will be important to determine whether the fines are silt or clay. If the fines are determined to be silt, the material will be classified as silty sand (USCS symbol SM) or silty gravel (GM). If the fines are determined to be clay, the material will be classified as clayey sand (SC) or clayey gravel (GC) (Table 3.7-1).

Grain-Size Distribution. For sand- and gravel-size material, describe each component as fine, medium, or coarse according to criteria in Table 3.7-2. This is most easily done with a grain-size chart; a hand lens will aid in this evaluation. With practice, the grain-size distribution can be judged without a grain-size chart.

When describing grain size, the sizes should be mentioned in decreasing order of importance. For example, "fine to medium sand" indicates more fine than medium sand, and "coarse to fine sand" indicates more coarse than medium or fine sand.

The classification of coarse soil as outlined in Table 3.7-1 does not take into account the presence of cobbles and boulders within the soil mass. When cobbles and/or boulders are detected, either visually within a test pit or as indicated by drilling action/core recovery, they should be reported on the field log after the main soil description. One of the following descriptor should be used:

- When only cobbles (2.5 to 10 inches) are present, add with cobbles.
- When only boulders (>10 inches) are present, add with boulders.
- When both cobbles and boulders are present, add with cobbles and boulders.

Angularity. The criteria in Table 3.7-3 should be used to describe particle angularity, or range of angularity.

Density. An important index property of cohesionless (non-plastic) soil is its relative density. The standard penetration test (ASTM 1586) is an in situ field test that is widely used to define the density of cohesionless soil. The density test criteria are summarized in Table 3.7-4.

Cementation. The criteria in Table 3.7-5 should be used to describe cementation.

Table 3.7-3. Angularity Criteria for Coarse Particles

Description	Criterion
Angular	Particles have sharp edges and relatively plane sides with unpolished surfaces.
Subangular	Particles are similar to angular description but have rounded edges.
Subrounded	Particles have nearly plane sides, but have well rounded corners and edges.
Rounded	Particles have smoothly curved sides and no edges.

Source: ASTM D 2488 (2009)

Table 3.7-4. Density Criteria for Coarse Soil

Description	Blow Counts	Criteria
Very loose	0–4	Easily penetrated
Loose	4–10	Easily penetrated with a 13-mm- (½-inch) diameter reinforcing rod pushed by hand.
Medium dense	10–30	Easily penetrated with a 13-mm- (½-inch) diameter reinforcing rod driven with a 2.3-kg (5-lb) hammer
Dense	30–50	Penetrated 0.3 meter (1 foot) with a 13-mm- (½-inch) diameter reinforcing rod driven with a 2.3-kg (5-lb) hammer
Very dense	>50	Penetrated only a few centimeters with a 13-mm- (½-inch) diameter reinforcing rod driven with a 2.3-kg (5-lb) hammer

Source: USACE, 2001

Table 3.7-5. Cementation Criteria for Intact Coarse Soil

Description	Criterion
Weak	Crumbles or breaks with handling or a little finger pressure.
Moderate	Crumbles or breaks with considerable finger pressure.
Strong	Will not crumble or break with finger pressure.

Source: ASTM D 2488 (2009)

3.7.2.4 Describing Fine-Grained Inorganic Soil

This section summarizes the procedures for describing soil in which less than 50 percent of the grains are visible to the unaided eye. According to ASTM D 2488, in order to perform the following field tests for fine-grained soils, a representative sample of the soil is selected and particles larger than the No. 40 sieve (medium-grained sand and larger) are removed. This portion of the sample is then used to perform the tests for dry strength, dilatancy, toughness, and plasticity, as described below.

If the soil is estimated to have 15 to 25 percent sand or gravel, or both, the words “with sand” or “with gravel” (whichever is more predominant) shall be added to the group name, for example, “lean clay with sand, CL.” If the percentage of sand is equal to the percentage of gravel, use “with sand.”

If the soil is estimated to have 30 percent or more sand or gravel, or both, the words “sandy” or “gravelly” (whichever is more predominant) shall be added to the group name—for example, “sandy lean clay, CL.” If the percentage of sand is equal to the percentage of gravel, use the word “sandy.”

Tables 3.7 6 through 3.7 9 should be used when identifying fine-grained soil.

Table 3.7-6. Field Descriptions of Silt (ML) Group Soil

Fines	Coarseness	Sand or Gravel	Description
>70%	<15% plus 0.075 mm		Silt
	15-25% plus 0.075 mm	% Sand > % gravel	Silt w/sand
	15-25% plus 0.075 mm	% Sand < % gravel	Silt w/gravel
	% Sand > % gravel	<15% Gravel	Sandy silt
	% Sand > % gravel	>15% Gravel	Sandy silt w/gravel
	% Sand < % gravel	<15% Sand	Gravelly silt
	% Sand < % gravel	>15% Sand	Gravelly silt w/sand

Source: WADOT, 2006

Plasticity. Plasticity criteria are summarized in Table 3.7-10.

Table 3.7-7. Field Descriptions of Elastic Silt (MH) Group Soil

Fines	Coarseness	Sand or Gravel	Description
>70%	<15% plus 0.075 mm		Elastic silt
	15-25% plus 0.075 mm	% Sand > % gravel	Elastic silt w/sand
	15-25% plus 0.075 mm	% Sand < % gravel	Elastic silt w/gravel
	% Sand > % gravel	<15% Gravel	Sandy elastic silt
	% Sand > % gravel	>15% Gravel	Sandy elastic silt w/gravel
	% Sand < % gravel	<15% Sand	Gravelly elastic silt
	% Sand < % gravel	>15% Sand	Gravelly elastic silt w/sand

Source: WADOT, 2006

Table 3.7-8. Field Descriptions of Lean Clay (CL) Group Soil

Fines	Coarseness	Sand or Gravel	Description
>70%	<15% plus 0.075 mm		Lean clay
	15-25% plus 0.075 mm	% Sand > % gravel	Lean clay w/sand
	15-25% plus 0.075 mm	% Sand < % gravel	Lean clay w/gravel
	% Sand > % gravel	<15% Gravel	Sandy lean clay
	% Sand > % gravel	>15% Gravel	Sandy lean clay w/gravel
	% Sand < % gravel	<15% Sand	Gravelly lean clay
	% Sand < % gravel	>15% Sand	Gravelly lean clay w/sand

Source: WADOT, 2006

Table 3.7-9. Field Descriptions of Fat Clay (CH) Group Soil

Fines	Coarseness	Sand or Gravel	Description
>70%	<15% plus 0.075 mm		Fat clay
	15-25% plus 0.075 mm	% Sand > % gravel	Fat clay w/sand
	15-25% plus 0.075 mm	% Sand < % gravel	Fat clay w/gravel
	% Sand > % gravel	<15% Gravel	Sandy fat clay
	% Sand > % gravel	>15% Gravel	Sandy fat clay w/gravel
	% Sand < % gravel	<15% Sand	Gravelly fat clay
	% Sand < % gravel	>15% Sand	Gravelly fat clay w/sand

Source: WADOT, 2006

Table 3.7-10. Criteria for Describing Plasticity

Description	Criterion
Nonplastic	A ⅛-inch thread cannot be rolled at any water content.
Low	The thread can barely be rolled and the lump cannot be formed when drier than the plastic limit.
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	Considerable time spent rolling and kneading is required to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Source: ASTM D 2488 (2009)

Consistency. The consistency test is performed on intact fine-grained soil. According to ASTM D 2488, the consistency test is inappropriate for soil containing a significant amount of gravel. The consistency test criteria are summarized in Table 3.7-11.

Table 3.7-11. Criteria for Describing Consistency

Description	Blows per foot	Penetrometer (tons/ft^2)	Criteria
Very soft	0–2	<0.25	Thumb will penetrate soil more than 1 inch.
Soft	2–4	0.25–0.5	Thumb will penetrate soil about 1 inch.
Medium stiff	4–8	0.5–1.0	Thumb will indent soil about ¼ inch.
Stiff	8–15	1.0–2.0	
Very stiff	15–30	2.0–4.0	Thumb will not indent soil, but readily indented with thumbnail.
Hard	>30	>4.0	Thumbnail will not indent soil.

Source: ASTM D6169-98 (2005)

3.7.2.5 *Describing Fine-Grained Organic Soil*

Identify the soil as an organic soil, OL/OH, if the soil contains enough organic particles to influence the soil properties. Organic soils usually have dark brown to black color and may have an organic odor. Often organic soils will change color (e.g., from black to brown) when exposed to the air. Organic soils will normally not have a high toughness or plasticity. The thread for the toughness test will be spongy.

3.7.3 Finishing the Soil Description

Once the determination has been made as to whether the soil is predominantly coarse-grained or fine-grained and the appropriate tests described in Section 3.7.2 have been conducted, additional information must be collected, as described below.

3.7.3.1 Color

Soil color is described using Munsell soil color charts, which provide precise descriptors for any soil color, to the extent that soils anywhere in the world can be compared. The Munsell system has three components—hue (a specific color), value (lightness and darkness), and chroma (color intensity)—that are arranged in books of color chips.

Soil is held next to the color chips to find a visual match and is then assigned the corresponding Munsell notation. The field description of color should include color name and color notation. For example, a brown soil may be noted as "dark yellowish brown (10YR 4/6)." Soil color should be determined for moist soil. If the soil sample is dry, a note reflecting that should be made on the boring log. Mottling is usually an indication of variable saturation and should be described according to mottle abundance, size, and color(s).

3.7.3.2 Moisture Condition

The moisture condition of the soil is often overlooked in soil descriptions, despite being a key indicator of hydrogeologic conditions. Soil moisture condition criteria are summarized in Table 3.7-12.

Table 3.7-12. Moisture Condition Criteria for Soil

Description	Criterion
Dry	Absence of moisture, dusty, dry to the touch.
Moist	Damp, but no visible water.
Wet	Visible free water, usually seen in soil below the water table.

Source: ASTM D 2488 (2009)

3.7.3.3 *Reaction with Dilute Hydrochloric Acid*

This test primarily evaluates the presence of calcium carbonate, a common cementing agent. To conduct the test, add dilute hydrochloric acid to sulfidic soil, thereby causing the release of hydrogen sulfide gas in cemented soils.

To prepare dilute hydrochloric acid, slowly add one part concentrated hydrochloric acid (10 N) to three parts distilled water. Do not add water to acid.

The reaction criteria are summarized in Table 3.7-13.

Table 3.7-13. Criteria for Soil Reaction to Hydrochloric Acid

Description	Criterion
None	No visible reaction.
Weak	Some reaction, with bubbles forming slowly.
Strong	Violent reaction, with bubbles forming immediately.

Source: ASTM D 2488 (2009)

3.7.3.4 *Sedimentary Structure*

Describe the structure of intact soil samples according to the criteria summarized in Table 3.7-14.

Table 3.7-14. Criteria for Describing Structure

Description	Criterion
Bedded	Alternating layers of varying material or color with layers at least 6 mm thick; note thicknesses.
Laminated	Alternating layers of varying material or color with layers less than 6 mm thick; note thicknesses.
Lensed	Small pockets of different materials; note thicknesses.
Massive	No apparent layering or other sedimentary structures.
Fissured	Breaks along definite planes of fracture with little resistance to fracturing.
Slickensided	Fracture planes appear polished or glossy, sometimes striated.
Blocky	Cohesive soil that can be broken down into small angular lumps that resist further breakdown
Concretions	Accumulations of carbonates or iron compounds
Root holes	Holes remaining after roots have decayed
Burrows	Borings made as animals tunnel through sediments.

Sources: ASTM D 2488 (2009); USACE, 2001

3.7.3.5 *Odor*

Describe the odor if organic or unusual. Soils containing a significant amount of organic material usually have a distinctive odor of decaying vegetation. This is especially apparent in fresh samples. Describe unusual odors, particularly if they indicate the presence of a contaminant (e.g., petroleum product, chemical).

3.7.3.6 *Evidence of Contamination*

In addition to any odor that indicates the presence of contamination, describe any other physical indicators of contaminants such as visible product or staining.

3.7.4 Dual and Borderline Symbols

If a soil has properties that do not distinctly place it in a specific group, dual or borderline symbols may be used, as discussed below.

3.7.4.1 *Dual Symbols*

A dual symbol—two symbols separated by a hyphen (e.g., GP-GM, SW-SC, CL-ML)—is used in laboratory classification of soils and in visual classification when soils are estimated to contain 10 percent fines. Dual symbols should be used to indicate that the soil has the properties of two different classifications.

3.7.4.2 *Borderline Symbols*

Because the visual classification of soil is based on estimates of particle-size distribution and plasticity characteristics, it may be difficult to clearly identify the soil as belonging to one category. To indicate that the soil may fall into one of two possible basic groups, a borderline symbol—that is, two symbols separated by a slash (e.g., CL/CH, SC/CL, GM/SM, CL/ML)—may be used. A borderline classification symbol should not be used indiscriminately. Every effort should be made first to place the soil into a single group.

Cases in which a borderline symbol may be used include the following:

- When the percentage of fines is visually estimated to be between 45 and 55 percent. One symbol should be for a coarse-grained soil with fines and the other for a fine-grained soil (e.g., GM/ML, CL/SC).
- When the percentage of sand and the percentage of gravel are estimated to be about the same (e.g., GP/SP, SC/GC, GM/SM). It is practically impossible to have a soil that would have

a borderline symbol of GW/SW. However, a borderline symbol may be used when the soil could be either well graded or poorly graded (e.g., GW/GP, SW/SP).

- When the soil could be either silt or clay (e.g., CL/ML, CH/MH, SC/SM).
- When a fine-grained soil has properties at the boundary between a soil of low compressibility and a soil of high compressibility (e.g., CL/CH, MH/ML).

The order of the borderline symbol should reflect similarity to surrounding or adjacent soils. For example, in a case where soils in a borrow area have been predominantly identified as CH but one sample has the borderline symbol of CL and CH, the borderline symbol should be CH/CL to show similarity to the adjacent CH soils.

The group name for a soil with a borderline symbol should be the group name for the first symbol, except for the following:

- *CL/CH:* Lean to fat clay
- *ML/CL:* Clayey silt
- *CL/ML:* Silty clay

Attachments

3.7-1 Soil Boring Log

3.7-2 Soil Description Reference Summary

References

ASTM International (ASTM). 2009. *Standard practice for description and identification of soils (Visual-manual procedure)*. D-2488-09a.

Denhom, K.A. and L.W. Schut. 1993. *Field manual for describing soils in Ontario*. Centre for Soil Resource Evaluation. Guelph, Ontario.

U.S. Army Corps of Engineers (USACE). 2001. *Visual identification of soil samples, EM 1110-1-1804.* January 2001.

U.S. Environmental Protection Agency (U.S. EPA). 1991. *Description and sampling of contaminated soils - A field pocket guide.* EPA/625/12-91/002. November 1991.

Washington State Department of Transportation, Environmental and Engineering Programs (WADOT). 2006. *Geotechnical design manual*. Publication Number M 46-03. December 2006.

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Boring Log

Page___of___

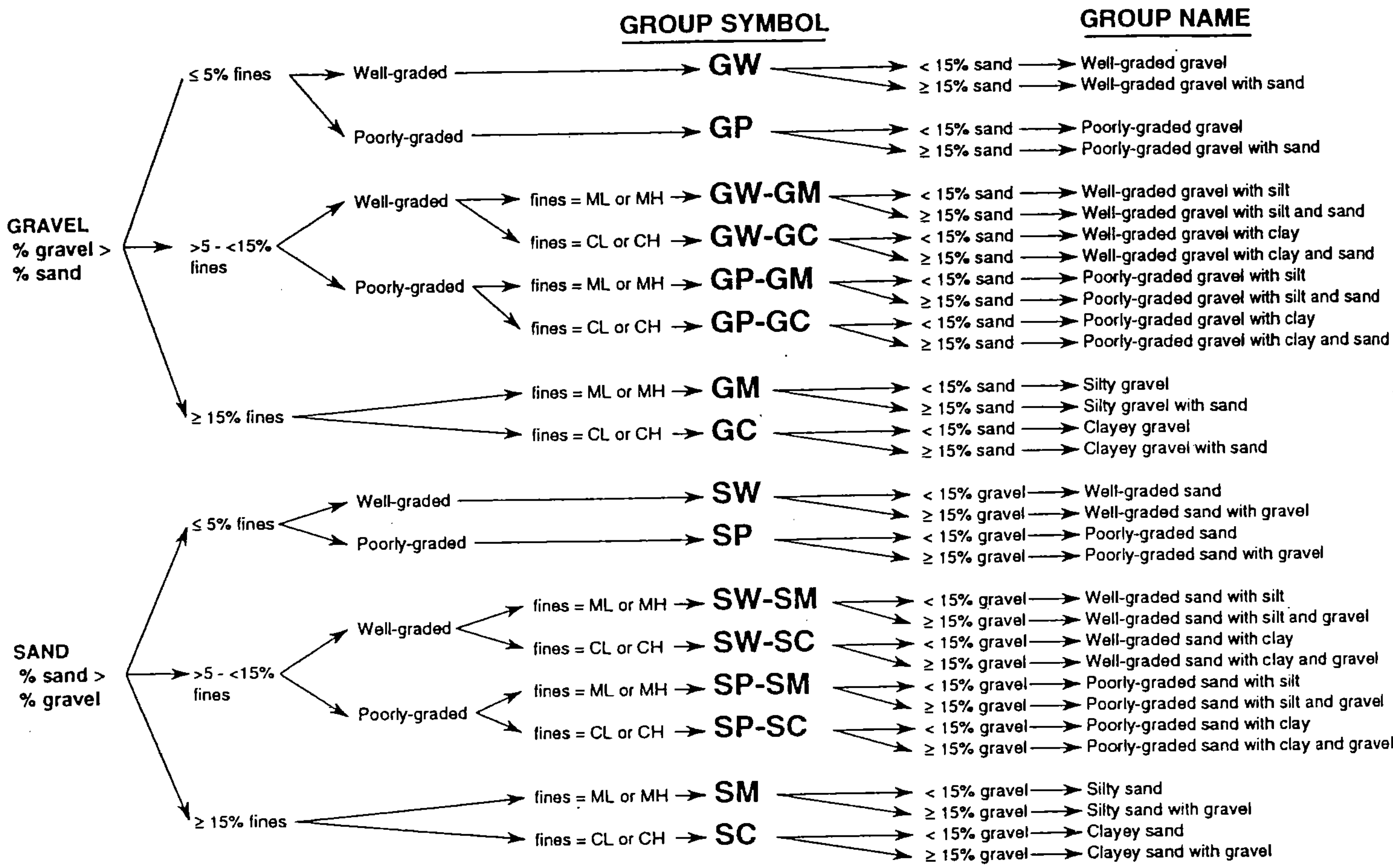
Site		Location Map
Logged By	Client/Project #	
Boring Number	Drilling Co.	
Drilling Method	Drill Rig	
Date Started	Date Completed	

PID/FID Reading	Blow Counts	Sampling Device	Sample Recovery	Sample Interval	Sample Number	USCS Symbol	Depth (feet)	Soil Description/Remarks Soil type, color, texture, grain size, sorting, roughness, plasticity, consistency, moisture content

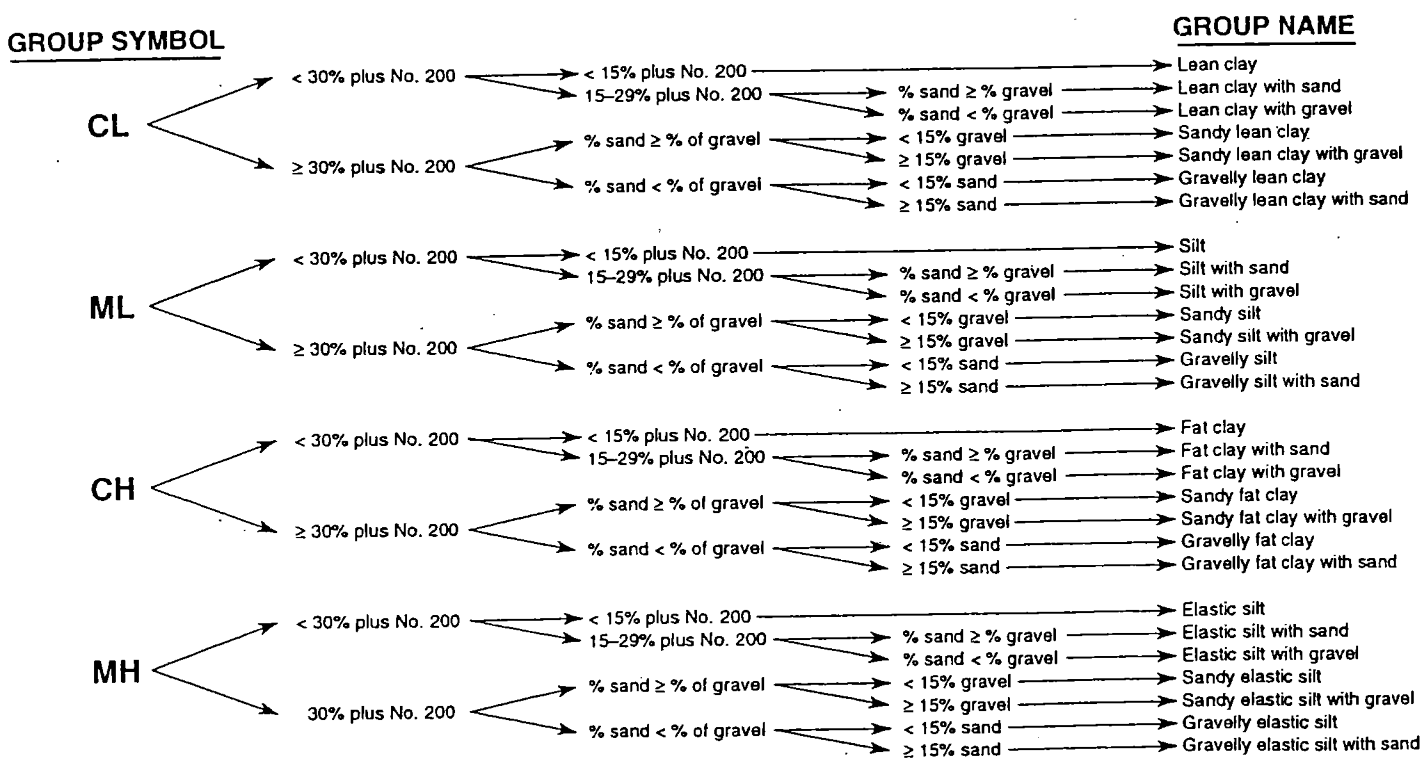
DBS&A Form No. 080, Updated 1/2023

UNIFIED SOIL CLASSIFICATION SYSTEM FIELD GUIDE

Flow Chart for Identifying Coarse-Grained Soils (less than 50% fines)



Flow Chart for Identifying Fine-Grained Soils (more than 50% fines)



NOTES— Percentages are based on estimating amounts of fines, sand and gravel to the nearest 5%.
Material passing a No. 200 sieve is classified as fine; material retained on a No. 200 sieve is classified as sand and coarse-grained particles.

ORDER OF DESCRIPTIONS:
1. USCS Type 2. Group Name 3. Color 4. Density/Consistency 5. Plasticity 6. Moisture 7. Structure 8. Angularity/Mineralogy 9. Miscellaneous

EXAMPLE DESCRIPTION:
SM Silty sand, pale brown (10YR6/3), loose, nonplastic, moist, laminated (4-mm thick laminations), subrounded quartz and feldspar

UNIFIED SOIL CLASSIFICATION SYSTEM

COARSE-GRAINED SOILS <50% passes #200 sieve	GRAVELS <50% coarse fraction passes #4 sieve	GRAVELS with little or no fines	GW	Well graded gravels, gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines
		GRAVELS with ≥15% fines	GM	Silty gravels, poorly graded gravel-sand-silt mixtures
			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures
	SANDS ≥50% coarse fraction passes #4 sieve	SANDS with little or no fines	SW	Well graded sands, gravelly sands, little or no fines
			SP	Poorly graded sands, gravelly sands, little or no fines
		SANDS with ≥15% fines	SM	Silty sands, sand-gravel-silt mixtures
			SC	Clayey sands, sand-gravel-clay mixtures
FINE-GRAINED SOILS ≥50% passes #200 sieve	SILTS & CLAYS Liquid Limit <50		ML	Inorganic silts and very fine sands, silty or clayey fine sands, silts with slight plasticity
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and silty clays of low plasticity
	SILTS & CLAYS Liquid Limit >50		MH	Inorganic silts, micaceous or diatomaceous fine sand or silt
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic silts and clays of medium-to-high plasticity
			PT	Peat, humus, swamp soils with high organic content

NOTE: Well graded (wide range of grain sizes) = poorly sorted; poorly graded (predominantly one grain size) = well sorted

GRAIN SIZE

DESCRIPTION	SIEVE SIZE	GRAIN SIZE		
		mm	in.	
Boulders	>12”	>300	>12	
Cobbles	12” - 3”	300 - 75	12 - 3	
Gravel - Coarse	3” - 0.75”	75 - 19	3 - 0.75	
Fine	0.75” - #4	19 - 4.75	0.75 - 0.19	
Sand - Coarse	#4 - #10	4.75 - 2	0.19 - 0.079	
Medium	#10 - #40	2 - 0.425	0.079 - 0.017	
Fine	#40 - #200	0.425 - 0.075	0.017 - 0.0029	
Fines	Passing #200	<0.075	<0.0029	

COLOR
Assign color using Munsell Soil Color Chart (1992) if possible. Provide name and color code in parentheses.

DEPTH TO WATER
∇ Depth to first water (time and date)
▼ Depth to water after drilling (time and date)

DENSITY (GRANULAR) CONSISTENCY (COHESIVE)

GRANULAR	COHESIVE	FIELD TEST FOR COHESIVE SOIL
Very loose	Very soft	Easily penetrated several inches by thumb. Extrudes between thumb and fingers when squeezed.
Loose	Soft	Easily penetrated 1 inch by thumb. Molded by light finger pressure.
Medium dense	Medium stiff	Penetrated over 1/2 inch by thumb with moderate effort. Molded by strong finger pressure.
Dense	Stiff	Indented about 1/2 inch by thumb but penetrated only with great effort.
Very dense	Very stiff	Readily indented by thumbnail.
	Hard	Indented with difficulty by thumbnail.

MISCELLANEOUS
Organics, carbon, vegetation
Coloration (staining, mottling)
Effervescence
Drilling rate, rig behavior
Odor
Loss of drilling fluid

ROCK CLASSIFICATION
Rock Name - Color - Weathering - Fracturing - Competency - Mineralogy - Miscellaneous

3.8 PID Measurement and Heated Headspace Methodology

The following guidance provides procedures for measurement of ionizable volatile organic compounds (VOCs) and analysis of soil samples in the field using heated headspace methodology. The basis for this guidance is standard New Mexico Environment Department (NMED) Petroleum Storage Tank Regulations. The process entails mildly heating a sealed soil sample until it releases the VOCs, which are subsequently measured with a photoionization detector (PID). With the recent improvements and changes in PIDs, DBS&A typically rents this equipment from one of several vendors. The PID will be calibrated and operated in accordance with the manufacturer's instructions.

3.8.1 Equipment

Soil sampling equipment is available from the DBS&A warehouse. Coordinate with the DBS&A warehouse for rental of PID equipment. Recommended equipment includes the following:

- PID
- Nitrile gloves
- Glass jar with lid
- Aluminum foil

3.8.2 Procedure for Measurement of VOCs

VOCs are measured in the field using a PID or equivalent portable meter capable of measuring ionizable VOCs. The PID should be calibrated in the field each day prior to use in accordance with manufacturer's instructions. The unit should also be operated in accordance with manufacturer's instructions. An external filter should be used at all times to mitigate moisture, dust, or other particles from being sucked into the sensor manifold. When short sections of flexible tubing are used to connect the filter to the PID's inlet tube, replace tubing as needed to ensure accurate measurement of low concentration VOCs.

3.8.3 Heated Headspace Methodology

This SOP summarizes the process for analysis of soil samples in the field using heated headspace methodology.

1. Fill a 0.5-liter/16-ounce/1-pint or larger glass jar (e.g., Mason jar) half full of soil sample. Plastic bags or other non-glass containers are not acceptable.

2. Seal top of jar with clean aluminum foil by threading the lid band onto the jar. If necessary, a rubber band can be used to secure the aluminum foil to the glass container.
3. Ensure that sample is at a temperature of 15 to 25°C or approximately 60 to 80°F. Place the sample on the dashboard of a work vehicle and expose the sample to some combination of sunlight or the front windshield defroster. A warm water bath can also be used if necessary to raise sample temperature to the acceptable range.
4. Aromatic hydrocarbon vapor concentrations must be allowed to develop in the headspace of the sample jar for a minimum of 5 to 10 minutes. Following this headspace development, the sample should be shaken vigorously for 1 minute. Take care not to damage the glass jar or the aluminum foil seal.
5. Immediately pierce the foil seal with the probe of a PID or equivalent meter, and read the highest (peak) measurement. At a minimum, the instrument must be able to accurately detect total aromatic hydrocarbons (TAH) between 0 and 1,000 parts per million (ppm). Detection of TAH contaminant levels of 100 ppm or greater indicates that the soils tested exceed soil cleanup standards of the UST Regulations (NMAC 20.5.12.17).
6. Immediately record PID values in a field book and/or on a DBS&A Soil Boring Log (Attachments 3.2-1, 3.3-1, or 3.7-1).

References

New Mexico Administrative Code (NMAC). 2012. Petroleum storage tank regulations. March 17, 2012.

4.1 Monitor Well Design and Installation

This section provides standard operating guidelines (SOGs) for monitor well design and installation.

The SOPs and SOGs included in this section are applicable to all DBS&A employees for the conduct of all activities listed in this section. All SOPs and SOGs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the President or his/her designee for quality assurance. All or parts of the SOPs and SOGs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of the President or the DBS&A Quality Assurance Manager.

The scope of the procedures described in this section includes the following:

- Monitor Well Materials and Design
- Monitor Well Installation

Standards for monitor well design and installation are described in ASTM D 5092-04 (2010) (*Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers*). Requirements for the State of New Mexico (NMED, 2008) have also been codified. DBS&A technical representatives are required to follow all applicable state regulations pertaining to monitor well design and installation. Refer to Driscoll (1986), U.S. EPA (1992a and 1992b) or Aller et. al. (1989) for more detailed guidelines about the above subjects as they relate to the design and installation of monitor wells.

These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

4.1.1 Monitor Well Materials and Design (ASTM D 5092-04[2010])

The following materials and design are for typical shallow zone (single-cased) and deep zone (multi-cased) wells. Figure 4.1-1 is a diagram showing a typical design for a shallow zone (single-cased) well used at DBS&A. Figure 4.1-2 is a diagram showing a typical design for a deep zone (multi-cased) well used at DBS&A.

4.1.1.1 Water

Water used in the drilling process, to prepare grout mixtures and to decontaminate the well screen, riser, and annular sealant injection equipment, should be obtained from a source of known chemistry or should be characterized. The chemical analysis should confirm that the added water does not contain constituents that could compromise the integrity of the well installation or that may be potential contaminants.

4.1.1.2 Filter Pack

- The grain-size distribution curve for the filter pack can be selected by multiplying the 70% retained size of the finest formation sample by 3 or 4. Use of 2/16 silica sand is usually appropriate for the filter pack of most monitor wells.
- Do not select too fine a filter pack because this will reduce the yield of the well, causing longer sampling times.
- To prevent downward migration of the bentonite or cement into the screen, the filter pack is extended a minimum of 2 feet above the top of the screen.
- The filter pack should not extend into an overlying water-bearing formation because this could permit downward vertical seepage in the pack and either dilute or add to the contamination of the water being monitored. This could also affect the accuracy of the water level measurements in the well.

4.1.1.3 Well Screen

- The well screen should be new, machine-slotted or continuous-wrapped wire-wound, and composed of materials that are inert to the subsurface water being tested. Table 4.1-1 lists the advantages and disadvantages of several common screen materials.
- The well screen and all casing material should be plastic-wrapped and certified by the manufacturer as clean.
- If not certified by the manufacturer as clean, well materials should be steam cleaned or high-pressure water cleaned (if appropriate for the selected well materials) with water from a source of known chemistry immediately prior to installation.
- The screen should be capped at the bottom with the same material as the well screen.
- The minimum nominal internal diameter of the well screen should be chosen based on the criteria that it will permit effective development and rapid sample recovery. In most instances, a minimal diameter of 2 inches is needed to allow for the introduction and

withdrawal of sampling devices. However, a minimum of 4 inches may be needed if pumping tests are to be performed.

- The slot size of the well screen should retain filter pack or natural formation along with permitting efficient development of the wells.
- Without other approval, well screens in monitor wells in New Mexico cannot exceed 20 feet in length.

4.1.1.4 Riser

A riser is a blank casing extending from the screen interval to the ground surface. The following guidelines apply to risers:

- The minimal nominal internal diameter of the riser should be chosen based on the criteria that it will permit effective development and rapid sample recovery. In most instances, a minimum of 2 inches is needed to accommodate sampling devices. However, a minimum of 4 inches may be needed if pumping tests are anticipated.
- Threaded joints are recommended. Alternatively, O-rings composed of materials that would not affect the subsurface water being sampled may be selected for use on flush joint threads.
- The diameter of the casing for filter packed wells should be selected so that a minimum annular space of 2 inches is maintained between the inside diameter of the casing and the outside diameter of the riser.

4.1.1.5 Casing

- The casing material should be new and composed of materials that are inert to the subsurface water being tested. Table 4.1-1 lists the advantages and disadvantages of several common casing materials. The exterior casing (temporary or permanent multi-cased wells) is generally constructed of steel although other appropriate materials may be used.
- Where conditions warrant, the use of permanent casing installed to prevent communication between water-bearing zones is encouraged.
- The casing material should be certified by the manufacturer as clean.
- If not certified by the manufacturer as clean, the casing material should be steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a source of known chemistry immediately prior to installation.

- The material type and minimum wall thickness of the casing should be adequate to withstand forces of installation (e.g., handling during installation and heat produced by curing of cement grout).
- All casing that is to remain as a permanent part of the installation (that is, multi-cased wells) should be new and cleaned of interior and exterior protective coatings.
- The diameter of the casing for filter packed wells should be selected so that a minimum annular space of 2 inches is maintained between the inside diameter of the casing and the outside diameter of the riser. In addition, the diameter of the casings in multi-cased wells should be selected so that a minimum annular space of 2 inches is maintained between the casing and the borehole (that is, a 2-inch-diameter screen will require first setting a 6-inch-diameter casing in a 10 inch-diameter boring).
- The ends of each casing section should be either flush-threaded or beveled for welding.

4.1.1.6 Annular Sealants

The materials used to seal the annulus may be prepared as a slurry or used unmixed in a dry pellet, granular, or chip form. Sealants should be selected to be compatible with ambient geologic, hydrogeologic, and climatic conditions and any man-induced conditions anticipated to occur during the life of the well. Table 4.1-2 lists some of the advantages and disadvantages of using bentonite or cement as grouting material for monitor wells. The following guidelines for the bentonite seal and grout backfill should be considered:

- A bentonite seal of at least 2 feet is placed above the filter pack. Bentonite should be powdered, granular, pelletized, or chipped sodium montmorillonite furnished in sacks or buckets from a commercial source and free of impurities that adversely impact the water quality in the well. The diameter of pellets or chips selected for monitoring well construction should be less than one-fifth the width of the annular space into which they are placed to reduce the potential for bridging.
- The grout backfill that is placed above the bentonite seal is ordinarily a liquid slurry consisting of either a bentonite (powder or granules, or both) base and water or a Portland cement base and water. A mixture of bentonite and Portland cement can be used for the grout backfill. Refer to ASTM D 5092-90 for standards in mixing and placing the grout backfill.

4.1.1.7 Annular Seal Equipment

Prior to use, the equipment used to inject the annular seals and filter pack should be steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a known chemical source. This procedure is performed to prevent the introduction of materials that may ultimately alter the water sample quality.

4.1.2 Monitor Well Installation (ASTM D 5092-04[2010])

A well completion diagram (DBS&A Form No. 048, Attachment 4.1-1) should be completed as an ongoing process during the installation of the monitor well. General steps for monitor well installation are as follows:

1. A stable borehole must be constructed prior to installing the monitor well casing, screen, and riser (refer to Section 3.1 for drilling guidelines). Working components of the drilling rig (drill pipe, subs, collars, belly, and all parts of the rig chassis near the borehole) should be cleaned as described in Step 2.
2. All plastic screens and casing should be joined by threads and couplings or flush threads. Solvent glues must not be used.
3. Prior to installation, the well material should be inspected and measured. Measuring allows more accurate placement of the screen interval.
4. The well screen and riser assembly can be lowered to the predetermined level and suspended and held in position by a ballast or by hydraulic arms on the drilling rig. The assembly must be installed straight to allow for the introduction and withdrawal of sampling devices. #35 centralizers should be used when the casing is installed in an open borehole.
5. The riser should extend above grade and be capped temporarily to deter entrance of foreign materials during completion operations.
6. The volumes of filter pack (gravel and/or silica sand), bentonite seal, and grout required to fill the annular space between the well screen and borehole should be calculated, measured during installation, and recorded on the well completion diagram during installation.
7. The filter pack is placed in the annulus from the bottom of the borehole up to a minimum of 2 feet above the well screen. Note that during the emplacement of the filter pack, air within the borehole, including organic vapors, will be forced up and out of the borehole, drill pipe, and/or casing string. These vapors can present a significant risk to worker health, and should therefore be monitored.

8. As the filter pack is put in place, the temporary casing or hollow-stem auger (if used) is withdrawn, usually in stipulated increments. Care should be taken to minimize lifting the riser with the withdrawal of the temporary casing/augers. To limit borehole collapse, the temporary casing or hollow stem auger is usually withdrawn until the lowermost point on the temporary casing or hollow-stem auger is at least 2 feet, but no more than 5 feet, above the filter pack for unconsolidated materials or at least 5 feet, but no more than 10 feet, for consolidated materials.

9. For filter pack placements well below the water table, it is recommended that the filter pack be surged before emplacing the bentonite seal. This will ensure that the filter pack is properly settled and that no voids are present.

10. A secondary filter pack of finer sand may be emplaced above the primary filter pack to prevent the intrusion of the bentonite grout seal into the primary filter pack. As with the primary filter pack, the secondary filter pack must not extend into an overlying hydrologic unit.

11. A bentonite pellet or chip seal is placed in the annulus between the borehole and the riser pipe on top of the filter pack. To be effective, the bentonite seal should extend above the filter pack a minimum of 2 feet, depending on local conditions.

12. If the water level in the borehole is below the top of the bentonite seal, the bentonite should be hydrated by adding potable water of a known chemical quality. Sufficient time (approximately 1 hour) should be allowed for the bentonite pellet seal to hydrate prior to grouting the remaining annulus. The volume and elevation of the bentonite seal material should be measured and recorded on the well completion diagram.

13. If the water level in the borehole is well above the top of the filter pack, there may be concern about bridging of bentonite being poured through the standing water column. In that case, a thick slurry of high-solids bentonite (e.g., Baroid Quik Grout) can be mixed according to the manufacturer's recommendations and pumped through a tremie pipe to fill the space immediately above the filter pack. The slurry should initially be pumped slowly so as to not disturb the filter pack. Coated bentonite pellets may also be used to slow hydration.

14. Grout, typically cement with up to 5 percent powdered bentonite, should be mixed according to industry specifications (typically 6 to 7 gallons of water per 94-pound sack of Type I Portland cement; refer to Driscoll, 1986). The volume and location of grout used to backfill the remaining annular space is recorded on the well completion diagram.

15. Grout will be pumped into the annulus through a tremie pipe to fill the annulus from bottom to top and should be introduced in one continuous operation until full-strength grout flows out at the ground surface without evidence of drill cuttings or fluid. Grout should be placed in more than one layer if the length of the grout column may be sufficient (greater than 150 feet) to cause collapse (melting) of the casing from the heat liberated as the hydrating grout cures.

16. The riser or casing or both should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser, or grout and casing, or both. The amount of time required for the grout to set and cure will depend on the grout content and climatic conditions. Typically, 24 hours is considered sufficient.

17. Specific grouting procedures for single- and multi-cased wells are included in ASTM D 5092-04 (2010).

18. Well protection refers specifically to installations made at the ground surface to deter unauthorized entry to the monitor well and to prevent surface water from entering the annulus. Typically a concrete pad, protective shroud with a lock, and vented cap are placed on monitor wells constructed for DBS&A projects.

19. In areas where there is a high probability of damaging the well (high traffic, heavy equipment, and/or poor visibility), it may be necessary to enhance the normal protection of the monitor well through the use of posts, markers, signs, etc.

20. Once the monitor well installation is complete, the well should be developed according to standards outlined in Section 4.2.

21. The drilling subcontractor is responsible for filing any paperwork (e.g., well record) with the State Engineer or other regulating agency within the specified time period after completion of the well.

Attachments

Attachment 4.1-1	Well Completion Record (DBS&A Form No. 048)
Figure 4.1-1	Typical Monitor Well Design, Single-Cased Well
Figure 4.1-2	Typical Monitor Well Design, Multi-Cased Well
Table 4.1-1	Well Casing, Screen, and Riser Materials

References

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielson, and J.E. Denne. 1989. *Handbook of suggested practices for the design and installation of groundwater monitoring well design and installation.* National Well Water Association, Dublin, Ohio.

Arizona Department of Water Resources. Undated. *Well construction and licensing of well drillers, handbook.*

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Driscoll, F.G. 1986. *Groundwater and wells*. Johnson Division, St. Paul, Minnesota.

New Mexico Environment Department (NMED). 2008. *Ground water discharge permit monitoring well construction and abandonment requirements.*

U.S. Environmental Protection Agency (EPA). 1992a. *EPA-RCRA ground-water monitoring technical enforcement guidance document*. September 1992.

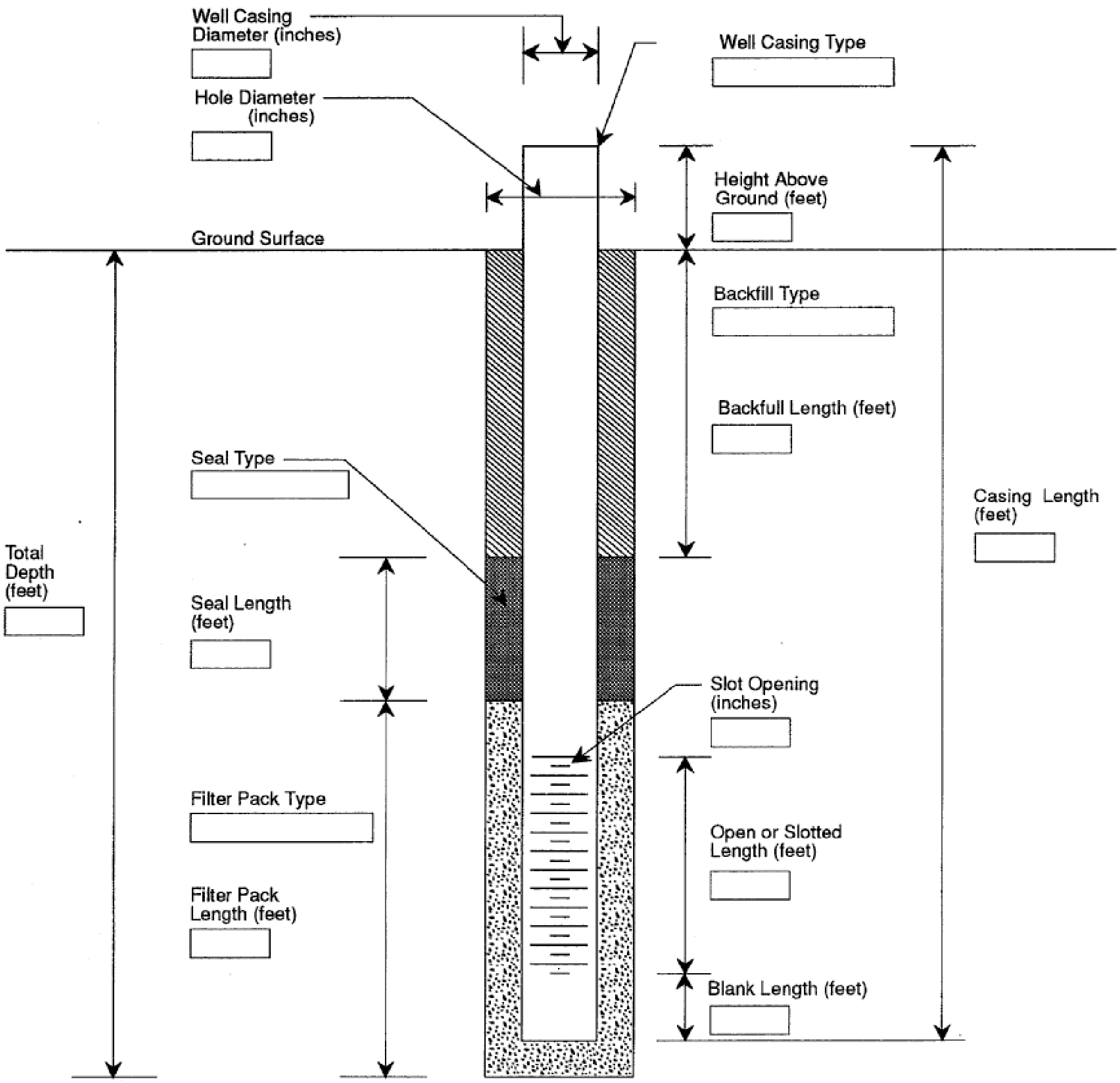
U.S. EPA. 1992b. *RCRA ground-water monitoring: draft technical guidance.* November 1992.

Client ______________________________ Project No. ______________

Well No. ____________ Site ______________________ Date Installed ____________

Formation of Completion ______________________________________

DBS&A Personnel ______________________ Driller ______________________

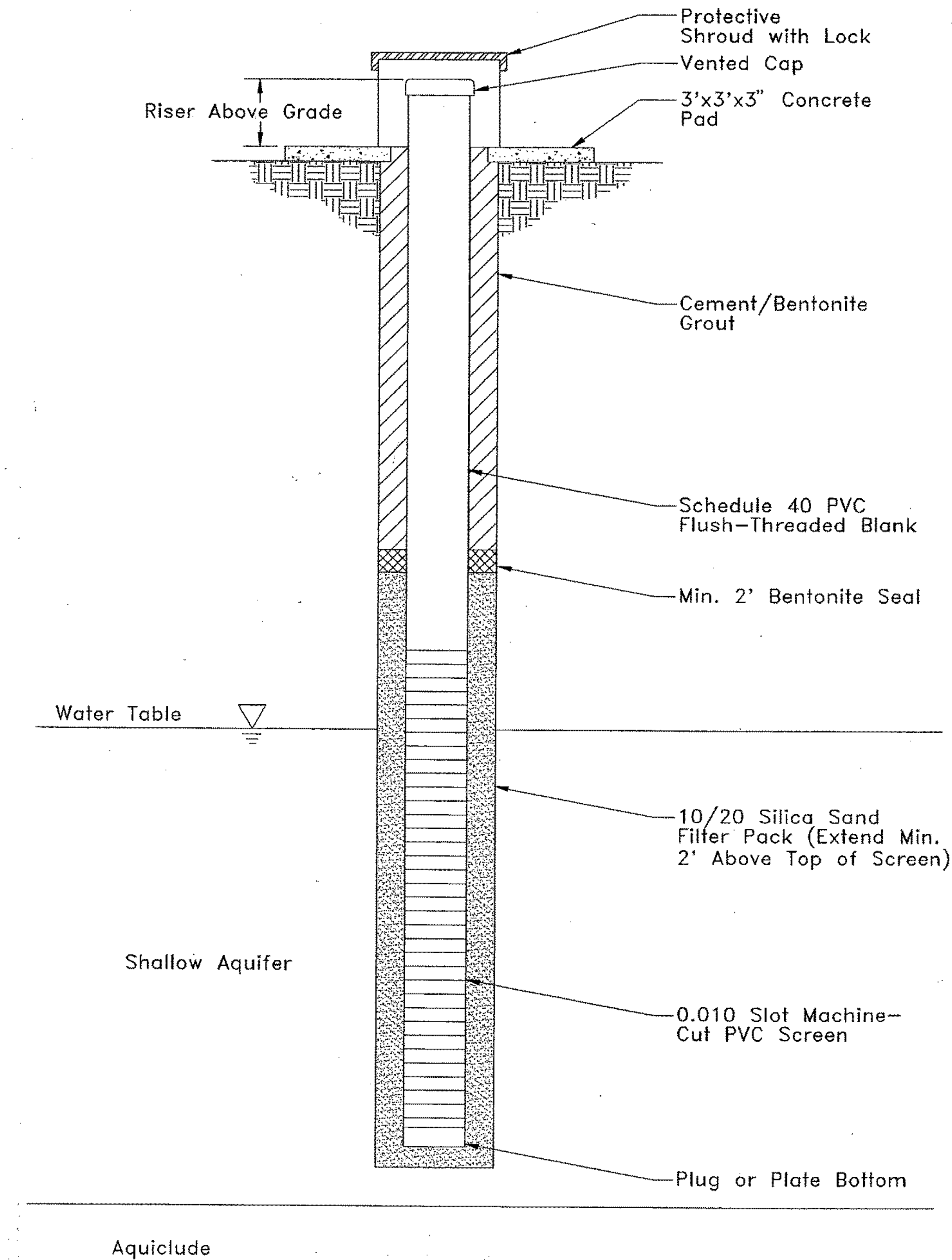


Comments ____

DBS&A Form No. 048 4/92

P:\SOPs\13-Field_New logo for 2023\Attachments\Att 4.1-1_Well Completion.docx

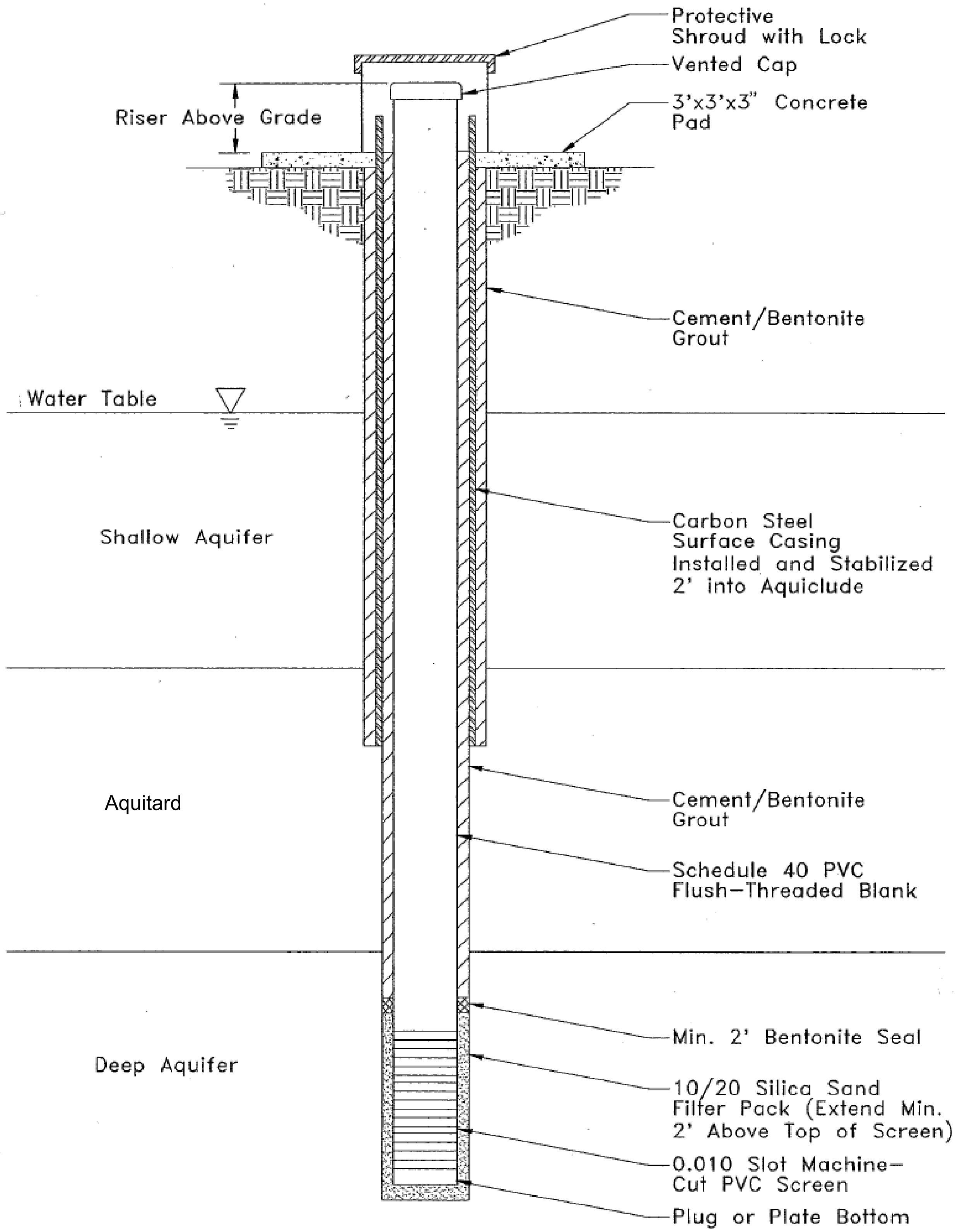
Well Completion Record (DBS&A Form No. 048)



Not to scale

Typical Monitor Well Design
Single-Cased Well

Figure 4.1-1



Not to scale

Typical Monitor Well Design
Multi-Cased Well

Figure 4.1-2

Table 4.1-1. Well Casing, Screen, and Riser Materials

Type	Advantages	Disadvantages
Stainless steel	▪ Least absorption of halogenated and aromatic hydrocarbons ▪ High strength at a great range of temperatures ▪ Excellent resistance to corrosion and oxidation ▪ Readily available in all diameters and slot sizes	▪ May corrode and leach some chromium in highly acidic waters ▪ May act as a catalyst in some organic reactions ▪ Expensive
PVC (polyvinyl chloride)	▪ Lightweight ▪ Excellent chemical resistance to weak alkalis, alcohols, aliphatic hydrocarbons, and oils ▪ Good chemical resistance to strong mineral acids, concentrated oxidizing acids, and strong alkalis ▪ Readily available ▪ Low priced compared to a stainless steel and Teflon	▪ Weaker, less rigid, and more temperature sensitive than metallic materials ▪ May adsorb some constituents from groundwater ▪ May react with and leach some constituents from groundwater ▪ Poor chemical resistance to ketones, esters, and aromatic hydrocarbons
Teflon	▪ Good resistance to attack by most chemicals ▪ Lightweight ▪ High impact strength	▪ Screen slot openings may decrease in size over time ▪ Tensile strength and wear resistance low compared to other engineering plastics ▪ Expensive
Mild steel	▪ Strong, rigid; temperature sensitivity not a problem ▪ Readily available ▪ Low priced relative to stainless steel and Teflon ▪ Can use no riser with stainless steel screen	▪ Heavier than plastics ▪ May react with and leach some constituents into groundwater ▪ Not as chemically resistant as stainless steel

Source: Driscoll, 1986

4.2 Well Development

This section provides standard operating guidelines (SOGs) for well development.

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These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field.

Standards for well development are described in ASTM D 5092-04 (2010) (*Standard Practice for Design and Installation of Groundwater Monitor wells in Aquifers*) and ASTM D 5521-05 (*Standard Guide for Development of Groundwater Monitor wells in Granular Aquifers*). Also refer to Driscoll (1986), U.S. EPA (1992), or Aller et al. (1989) for more detailed guidelines about well development.

Table 4.2-1 summarizes disadvantages and advantages for different well development methods. The scope of the procedures described in this section includes the following:

- Development process
- Development methods
- Timing and duration of well development
- Decontamination of well development equipment
- Well recovery test

Proper well development serves to (1) remove some finer grained material from the well screen and filter pack that may otherwise interfere with water quality analyses, (2) restore the groundwater properties disturbed during the drilling process, and (3) improve the hydraulic characteristics of the filter pack and hydraulic communication between the well and the hydrologic unit adjacent to the screened interval.

Well development methods vary with the physical characteristics of the geologic formation in which the monitor well is screened, the construction details of the well, the drilling method used during the construction of the borehole in which the well is installed, and the quality of the water. The development method for each individual monitor well should be selected from among the several methods described in this guide and should be employed by the well construction contractor or the person responsible for monitor well completion.

The importance of well development in monitor wells cannot be overestimated; all too often, development is not performed or is carried out inadequately. Proper and careful well development will improve the ability of most monitor wells to provide representative, unbiased chemical and hydraulic data. The additional time and money spent performing this important step in monitor well completion will minimize the potential for damaging pumping equipment and in-situ sensors, and increase the probability that groundwater samples are representative of water contained in the monitored formation.

4.2.1 Well Development Process (ASTM D 5092-04 and ASTM D 5521-05)

The well development process consists of three phases: predevelopment, preliminary development, and final development.

4.2.1.1 Predevelopment

Predevelopment refers to techniques used to mitigate formation damage during well construction. This is particularly important when using direct or reverse rotary drilling systems that depend on drilling fluid to carry cuttings to the surface and support an open borehole. Control of drilling fluid properties, during the drilling operation and immediately prior to the installation of screen, casing, and filter pack, is very important.

4.2.1.2 Preliminary Development

Preliminary development takes place after the screen, casing, and filter pack have been installed. Methods used to accomplish this task include surging, bailing, hydraulic jetting, and air lifting. The primary purpose of this operation is to (1) apply sufficient energy in the well to rectify formation damage due to drilling, (2) draw fine-grained materials from the formation, filter pack, and screen into the well where they can be removed, (3) stabilize and consolidate the filter pack, (4) retrieve drilling fluid (if used), and (5) create an effective hydraulic interface between the filter pack and the formation.

4.2.1.3 *Final Development*

Final development refers to procedures performed with a pump, such as pumping and surging, and backwashing. These techniques are used as the final step in achieving the objectives of well development. If preliminary development methods have been effective, the time required for final development should be relatively short. However, if the preliminary methods have not been successful, or if conditions preclude the use of the preliminary techniques listed, the final development phase should be continued until the development completion criteria (described in this SOP) are satisfied.

4.2.1.4 *Well Development Methods (ASTM D 5092-04 and ASTM D 5521-05)*

Of the various methods available for developing wells, the most often used and most appropriate for developing groundwater monitor wells are mechanical surging and bailing or pumping, overpumping and backwashing, and high-velocity hydraulic jetting with pumping. For any method, the development work should be started slowly and gently and be increased in vigor as the well is developed. Most methods of well development require the application of sufficient energy to disturb the filter pack, thereby freeing the fine particles and allowing them to be drawn into the well. The coarser fractions then settle around and stabilize the screen. The well development method chosen should be documented in the field notebook. This section summarizes each of the well development methods; more details for each method are located in ASTM D 5521-05 and ASTM D 5092-04.

4.2.1.5 *Mechanical Surging*

For mechanical surging, a close-fitting surge block is affixed to the end of a length of drill pipe, a solid rod, or a cable, and operated like a piston in the well casing or screen. The up and down plunging action alternately forces water to flow into (on the upstroke) and out of (on the downstroke) the well. The downstroke causes a backwash action to loosen bridges in the formation or filter pack and the upstroke then pulls dislodged fine-grained material into the well. This method is equally applicable to small-diameter and large-diameter wells, but is most effective for small-diameter wells.

Before surging, the well should be pumped or bailed to make sure that the well will yield water. If the screen is completely plugged and water does not enter the well upon bailing or pumping, the strong negative pressure created on the upstroke of the surge block may cause the screen to collapse. Surging should always begin above the screen and move progressively downward to prevent the surge block from becoming sand locked and prevent damage to the screen. Sediment will accumulate in the bottom of the well and should be bailed or pumped out as often as possible. The rate and volume of sediment accumulation should be recorded to provide data on the progress of development. Surging and cleaning should be continued until little or no sediment is measured after surging. The time required to properly surge a well depends on the character of the aquifer material, and may vary widely from well to well.

4.2.1.6 *Overpumping and Backwashing*

The easiest and least expensive technique of well development is some form of pumping. With overpumping, the well is pumped at a rate considerably higher than it would be during normal operation. Theoretically, increasing the drawdown to the lowest possible level will result in increased flow velocities toward the well, thus causing movement of fine-grained materials into the well. However, limitations to overpumping include the following:

- Overpumping by itself will not adequately develop a well because water flows only in one direction.
- Overpumping often requires the use of larger pumping equipment than will fit into the small-diameter casings used in many monitor wells.
- Overpumping subjects the pump used in the operation to abrasion, excessive wear, and loss of efficiency.
- Overpumping results in the production of potentially large volumes of water that may require containment or treatment.

Overpumping is not an adequate development method if used alone and is best used in combination with backwashing. Backwashing is the term applied to the method of well development in which water is added to the well to reverse the flow. A commonly used backwashing procedure is to pump water into the well in a sufficient volume to maintain a head greater than that in the formation. This requires a high-capacity and high-quality water source. The amount of water added should be recorded and recovered during the well development process.

In the case where no backflow prevention valve is installed, the pump can be alternately started and stopped. Starting and stopping the pump allows the column of water that is initially picked up by the pump to be alternately dropped and raised up in a surging action. Each time the water column falls back into the well, an outward surge of water flows into the formation. This surge tends to loosen the bridging of the fine particles into and out of the well.

4.2.1.7 *High-Velocity Hydraulic Jetting*

During high-velocity hydraulic jetting, the well screen area is jetted with water to loosen fine-grained material and drilling mud residue from the formation. The loosened material moves inside the well screen and can be removed from the well by concurrent pumping or bailing. Jetting is particularly successful in developing highly stratified unconsolidated formations, consolidated bedrock wells, large-diameter wells, and naturally developed wells. A drawback of hydraulic jetting is that the water added during the development procedure will alter the natural, ambient water quality and may be difficult to remove. Therefore, the water added should be obtained from a source with known chemistry. Water from the monitor well being developed may be used if the suspended sediments are first removed.

4.2.1.8 *High-Velocity Hydraulic Jetting with Simultaneous Pumping*

Although jetting is effective in dislodging material from the formation, maximum development efficiency is achieved when jetting is combined with simultaneous pumping. This combination of development techniques is particularly successful for wells in unconsolidated sands and gravels. The volume of water pumped from the well should always exceed the volume pumped into the well during jetting, by as much as 1.5 to 2 times, so that a gradient is created toward the well.

4.2.1.9 *Developing With Air*

Developing solely with air is not recommended for monitor wells. Air development may force air into contact with the formation, which may alter the oxidation-reduction potential of the formation water and change the chemistry of the water in the vicinity of the well. The effects of this type of chemical disturbance may persist for several weeks or more after well development.

4.2.2 Timing and Duration of Well Development

The timing and duration of well development are planned to match the type of well, formation or completion, and other conditions of the drilling process. The following subsections outline these considerations.

4.2.2.1 *Timing of Well Development*

Well development should always take place prior to water sampling, but other timing factors depend on the design and construction of the well. For example, if the well is installed with the intent of using natural formation material as the filter pack (that is, a “naturally developed” well), development is generally performed after the screen and casing have been installed and the formation material has collapsed against the screen, but before the annular seal is installed.

Because well development for this well design will remove a significant fraction of the formation materials adjacent to the well screen, developing the well after installing the annular seal may result in portions of the annular seal collapsing into the vicinity of the well screen. On the other hand, properly designed and constructed filter-packed wells may be developed after the annular seal materials have been installed because the well screen is designed to retain at least 90 percent of filter pack materials, and little or no sloughing should occur.

4.2.2.2 *Duration of Well Development*

The duration of well development depends on the primary purpose of the development process. For example, if the primary purpose for development is to remove drilling fluid lost to the formation during borehole installation, the time required for completion of development may be based on the time it takes to remove from the well some multiple of the estimated volume lost. If the primary purpose of development is to rectify damage done during drilling to the borehole wall and the adjacent formation, the time for development may be based on the response of the well to pumping. An improvement in the recovery rate of the well indicates that the localized reduction in hydraulic conductivity has been rectified by development. If the primary purpose of development is to remove fine-grained materials, development may continue until visibly clear water is discharged from the well, or until the turbidity of water removed from the well is at some specified level. These criteria may be difficult or impossible to satisfy in formations with a significant fraction of fine-grained material.

Another criterion used for determining when development is complete is stabilization of indicator parameters, such as pH, temperature, and specific conductivity. While this criterion may be an indicator of when native formation water is being produced, it does not necessarily indicate that well development is complete. The minimum duration of well development will vary according to the method used to develop the well. The duration of well development and the pH, temperature, and specific conductivity readings should be recorded in the field notebook.

4.2.3 Decontamination of Well Development Equipment (ASTM D 5088-90)

Any equipment or materials used to develop a monitor well should be thoroughly cleaned in accordance with the procedures outlined in SOP 1.3. Cleaning should take place before any equipment is used in any monitor well and between uses in either the same well or other wells.

Attachments

Table 4.2-1 Advantages and Disadvantages of Well Development Methods

References

Aller, L., T.W. Bennett, G. Hackett, R.J. Petty, J.H. Lehr, H. Sedoris, D.M. Nielson, and J.E. Denne. 1989. *Handbook of suggested practices for the design and installation of groundwater monitor well design and installation.* National Well Water Association, Dublin, Ohio.

ASTM International (ASTM). 1994. *Standard practice for development of groundwater monitor wells in granular aquifers.* Standard D 5521-94. Philadelphia, Pennsylvania.

ASTM. 1995. *Standard practice for design and installation of groundwater monitor wells in aquifers.* Standard D 5092-90 (Reapproved 1995). Philadelphia, Pennsylvania.

Driscoll, F.G. 1986. *Groundwater and wells.* Johnson Division. St. Paul, Minnesota.

U.S. Environmental Protection Agency (EPA). 1992. *RCRA ground-water monitoring: draft technical guidance.* November 1992.

Table 4.2-1. Advantages and Disadvantages of Well Development Methods
Page 1 of 3

Reference	Over-pumping	Backwashing	Mechanical Surging		Well Jetting	Airlift Pumping
			Surge Block	Bailer		
Gass (1986)	Works best in clean coarse formations and some consolidated rock; problems of water disposal and bridging	Breaks up bridging, low cost and simple; preferentially develops	Can be effective; size made for ≥2" well; preferential development where screen >5'; surge inside screen		Consolidated and unconsolidated application; opens fractures, develops discrete zones; disadvantage is external water needed	Replaces air surging; filter air
U.S. Environmental Protection Agency (1986)	Effective development requires flow reversal or surges to avoid bridges	Indirectly indicates method applicable; formation water should be used	Applicable; formation water should be used; in low-yield formation, outside water source can be used if analyzed to evaluate impact	Applicable		Air should not be used
Barcelona et al.** (1983)	Productive wells; surging by alternating pumping and allowing to equilibrate; hard to create sufficient entrance velocities; often used with airlift		Productive wells; use care to avoid casing and screen damage	Productive wells; more common than surge blocks but not as effective		

Notes are provided at the end of the table.

Table 4.2-1. Advantages and Disadvantages of Well Development Methods Page 2 of 3

			Mechanical Surging			
Reference	Over-pumping	Backwashing	Surge Block	Bailer	Well Jetting	Airlift Pumping
Scalf et al. (1981)		Suitable; periodic removal of lines	Suitable; common with cable-tool; not easily used on other rigs	Suitable; use sufficiently heavy bailer; advantage of removing fines; may be custom made for small diameters		Suitable
National Council of the Paper Industry for Air and Stream Improvement (1981)	Applicable; drawback of flow in one direction; smaller wells hard to pump if water level below suction		Applicable; caution against collapse of intake or plugging screen with clay		Methods introducing foreign materials should be avoided (i.e., compressed air or water jets)	
Everett (1980)	Development operation must cause flow reversal to avoid bridging; can alternate pump off and on		Suitable; periodic bailing to remove fines		High velocity jets of water generally most effective; discrete zones of development	

Notes are provided at the end of the table.

Table 4.2-1. Advantages and Disadvantages of Well Development Methods Page 3 of 3

Reference	Over-pumping	Backwashing	Mechanical Surging		Well Jetting	Airlift Pumping
			Surge Block	Bailer		
Keely and Boateng (1987 a and b)	Probably most desirable when surged; second series of evacuation/recovery cycles is recommended after resting the well for 24 hours; settlement and loosening of fines occurs after the first development attempt; not as vigorous as backwashing	Vigorous surging action may not be desirable due to disturbance of gravel pack	Method quite effective in loosening fines but may be inadvisable in that filter pack and fluids may be displaced to degree that damages value as a filtering media		Popular but less desirable; method different from water wells; water displaced by short downward bursts of high pressure injection; important not to jet air or water across screen because fines driven into screen cause irreversible blockage; may substantially displace native fluids	Air can become entrained behind screen and reduce permeability

* Schalia and Landick (1986) report on Special 2′ valved block
** For low hydraulic conductivity wells, flush water up annulus prior to sealing; pump afterward (compiled by Aller et al., 1989)

5.1 Preparation for Water Sampling

The following standard operating procedure (SOP) defines activities to be completed prior to each sampling event.

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These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

5.1.1 DBS&A Warehouse

Prior to any water sampling event, the water sampler shall requisition all necessary equipment and supplies by completing a DBS&A Field Equipment and Materials Load-Up Sheet (see Section 1.1) and giving it or e-mailing it to the warehouse manager. The load-up sheet should be provided to the warehouse manager as much in advance as is possible, so that equipment and supply requisitions can be made.

All equipment to be used, with the exception of rental equipment, shall be calibrated and tested in the DBS&A warehouse by the warehouse manager prior to being sent to the field per the guidance prescribed in Section 1.1. Meter calibration shall be conducted in accordance with standard manufacturer recommended procedures using clean, fresh reagents. The warehouse manager shall ensure that all equipment is clean and in working order prior to leaving the DBS&A warehouse.

5.1.2 Analytical Laboratory

Prior to a water sampling event, the number and type of samples to be collected (field and quality assurance samples) shall be determined by the project manager (PM) or designated project technical representative (TR). The PM or project TR shall order appropriate sample containers (Section 1.1) from the analytical laboratory and shall inform the analytical laboratory of the expected arrival date of the samples, the analytes to be determined for each sample, and the required turnaround time. It is the water sampler's (field representative [FR]) responsibility to confirm that all sample bottles have been received and are loaded for sampling.

5.1.3 Site-Specific Instructions

Prior to each water sampling event, the PM or TR shall compile a list of samples (including quality assurance samples) to be collected. The order in which the samples should be collected shall also be listed. In general, locations with the lowest concentrations of select analytes shall be sampled before wells with higher concentrations, so the potential for cross-contamination can be minimized. The PM or TR will also list any special procedures that are unique to the site or to the sampling event.

Before each sampling round, the PM or TR shall make all access arrangements with the client and/or property owners. The FR(s) will confirm that access arrangements have been made and should determine if additional on-site access procedures are required.

Prior to leaving for the field, FR(s) shall assemble and be familiar with materials that describe the general conditions of the site, the hydrogeology, well completion information, and objectives of the sampling program. The project health and safety plan shall also be consulted before initiation of the field program.

5.2 Measurement of Field Parameters

This section outlines standard operating procedures (SOPs) for field measurement of electrical conductivity (EC), temperature, pH, alkalinity, oxidation/reduction potential (ORP or Eh), and dissolved oxygen (DO).

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These parameters should be measured during monitor well purging prior to sampling. Surface water samples should also be characterized when they are collected.

5.2.1 Electrical Conductivity and Temperature

This SOP describes the procedure for determining the EC and temperature of a water sample. Electrical conductivity is a measure of the ease of flow of electric current, and is the inverse (reciprocal) of resistivity. The term electrical conductivity, sometimes referred to simply as "conductivity," is defined as the electrical conductance that would occur through the water between the faces of a 1-cm cube of the water. EC is usually reported in units of micromhos per centimeter (µmhos/cm), or microsiemens per centimeter (µS/cm). By measuring the EC of a water sample in the field, one can estimate the total dissolved solids (TDS) concentration of the water using the approximate conversion TDS = 0.6 x EC. Because the EC of a water allows rapid determination of TDS (salinity), EC is probably the single most useful water quality parameter.

The EC of water containing dissolved ions increases with increasing temperature of the water. The temperature dependence varies for different waters and is dependent on the type and concentrations of dissolved ions, but an approximate rule of thumb is that EC increases by 2%

for each 1°C temperature increase. For quantitative comparison of EC values measured on different water samples at different field temperatures, it is necessary to correct all values to the EC at 25°C. For most qualitative work, however, this is unnecessary. Whether or not temperature corrections are to be applied, the EC value as measured at field temperature should always be recorded in the field logbook, along with the temperature of the water sample at the time the measurement was made.

EC can be measured either at the wellhead using the Hydrolab or other EC meter, or by downhole profiling using the Hydrolab. General procedures for these two methods are provided in Sections 5.2.1.1 and 5.2.1.2. Specific procedures for measuring EC using the YSI Model 33 EC meter and probe and the Hydrolab Minisonde are provided in Sections 5.2.1.3 and 5.2.1.4, respectively.

Most pH and EC meters also include a water temperature sensor with a precision of ±0.1°C. Groundwater temperature may be determined either using a downhole probe (Section 5.2.1.1), or above ground at the wellhead during purging (Sections 5.2.1.2 and 5.2.1.3) using a standard pH or EC meter equipped with a temperature sensor. Determine and record the groundwater temperature at the same time and using the same technique as for determining groundwater pH and EC, as described below.

Temperature sensors generally do not require calibration. However, to ensure that the temperature sensor is functioning properly, check it against a high-quality mercury thermometer at least once a year. If not in agreement within ±0.2°C, have the temperature probe serviced by the manufacturer.

5.3a Collection of Groundwater Samples

The following standard operating procedure (SOP) defines activities to be completed for the collection of groundwater samples.

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5.3a.1 Wellhead Preparation

Prior to groundwater sample collection, the following wellhead protection activities shall be conducted:

1. Inspect the area around the well for wellhead integrity, cleanliness, and signs of possible tampering or contamination.
2. Spread a clean plastic sheet over the ground around the wellhead where required.
3. Remove the cap on the wellhead. Note any obvious odors within the wellbore in the field logbook.
4. If possible, measure the static water level (see Section 6.1) prior to initiation of water sampling. Clean the electrical sounder or steel tape used for water level measurement after each use, as described in Section 5.2, to avoid cross contamination.
5. If floating product (e.g., gasoline) is suspected at the site, conduct the following procedures:
    - Use a bailer to extract a sample from the surface of the water within the well, if possible.

- After an initial visual inspection, slowly pour the fluid from the bailer into a small tub or container in order to check for a sheen or any other sign of free product. Note any obvious odors in the field logbook.
- If free product is detected, use the bailer to remove as much free product as is possible from the wellbore. Lower the bailer into the water slowly in order to prevent mixing and volatilization. Contain all recovered product for proper disposal and note the quantity of product removed in the field logbook.
- If the site has not been previously sampled, a sample of the free product may be desired. Consequently, place some of the product in an unpreserved 40-mL glass VOA vial, and store it away from the other samples. Confirm sample analysis with the project manager.
- After any free product has been removed from the wellbore, spread a fresh plastic sheet around the wellhead, and clean all contaminated equipment, or segregate it from the other equipment.

5.3a.2 Well Purging

The purpose of purging the well prior to sampling is to remove stagnant water from the well bore so that a representative groundwater sample can be collected. The method of purging can have a pronounced effect on the quality of the groundwater sample. For example, rapid purging may increase sample turbidity and is, therefore, not recommended.

In general, positive displacement (bladder) pumps are preferred for most sampling situations. However, depending on the hydraulic conductivity of the aquifer to be sampled and the project objectives, wells may either be equipped with dedicated pumps or may need to be purged with bailers. Consequently, purging techniques may vary depending on the aquifer conditions, the presence or absence of a dedicated pump, and the proposed sample analytes.

The optimum amount of water to be purged from each well also varies between sites. According to Barcelona et al., 1985, pg. 47,

> The number of well volumes to be pumped from a monitoring well prior to the collection of a water sample must be tailored to the hydraulic properties of the geologic materials being monitored, the well construction parameters, the desired pumping rate, and the sampling methodology to be employed.

Site-specific purging procedures shall be prepared for each site. The following purging procedure can be used as a general guideline:

1. Calculate the volume of water standing in the casing (cubic feet) by using the formula:

$$V = \pi r2\ L$$

where r = the radius of the casing (remember to convert inches to feet)
L = the length of the water column (total depth of well minus the static water level) [feet]

Note: 1 cubic foot holds 7.48 gallons of water

2. Purge the well at a rate equal to or greater than the sampling rate.
3. Measure applicable field parameters (see Section 5.3) at the pump outlet at a minimum after each 0.5 casing volume is pumped. Purging is generally considered complete when the above parameters are approximately stable over at least one casing volume. Wherever possible, purge a minimum of three casing volumes from each well.
4. In low permeability formations, it may not be possible to purge three casing volumes before the well goes dry. When the formation permeability is too low to allow for continuous purging, remove all of the standing water in the well by pumping or bailing. As soon as the well has recharged sufficiently, collect a sample so as to minimize volatilization in the wellbore.
5. Contain all fluid from obviously contaminated or potentially contaminated wells for later disposal. Anomalous values for the above field parameters, odor, visible sheen, or the presence of free product may be taken as signs of contamination. Results of previous water sampling events will be consulted when available.
6. Take careful notes in order to document all purging procedures. The notes shall include date, time, name(s) of sampler(s), weather, purge rate, purge method, field parameters (at each time measured, with corresponding purge volume), visual observations, odor, and any other relevant information.

The following guidelines as outlined in pertinent references on water sampling can be used when developing site-specific purging procedures:

- The EPA RCRA Technical Enforcement Guidance Document (TEGD) states, "in low yield formations, water should be purged so that it is removed from the bottom of the well" (U.S. EPA, 1992).
- The TEGD also states "Whenever a well is purged to dryness, a sample for field parameters should be collected as soon as the well has recovered sufficiently. A second measurement of

field parameters should be made immediately after sampling. Do not pump a well to dryness if it causes formation water to cascade down the well."

- The inlet line of the sampling pump or the submersible pump should be placed near the bottom of the screen section, and pump approximately one well volume of water at the well's recovery rate, and then collect the sample from the discharge line (U.S. EPA, 1977, p. 211).
- According to Wehrmann (1984), "For high yielding monitoring wells which cannot be pumped to dryness, bailing without pre-pumping the well is not recommended; there is no absolute safeguard against contaminating the sample with stagnant water." The following procedures should be used:
    - Place the inlet line of the sampling pump just below the surface of the well water, and pump three to five volumes of water at a rate equal to the well's recovery rate. This provides reasonable assurance that all stagnant water has been evacuated and that the sample will be representative of the groundwater body at that time.
- Wehrmann (1984) further states, "The rate at which wells are purged should be kept to a minimum. Purging rates should be lower than development rates so that well damage does not occur. Pumping at very low rates in effect, isolates the column of stagnant water in the well bore and negates the need for its removal, if the pump intake is placed at the top of, or in, the well screen. This approach can be very useful when disposal of purge water is a problem."
- If a well completed in a highly permeable formation is being purged, it may be useful to periodically move the intake of the purge pump during purging so that stagnant water does not remain in the well bore while fresh water comes in at only one level (Scalf et al., 1981, pg. 44).

5.3a.3 Groundwater Sample Collection

The following procedure shall be used to collect groundwater samples:

1. If the well is not equipped with a sampling pump, use only Teflon, stainless steel, or disposable polyethylene bailers for sampling.
2. Whenever possible, collect groundwater samples first from wells that have the lowest potential concentrations of analytes of interest, and last from the wells with the highest

suspected concentrations (i.e., clean dirty). The specific sampling order should be detailed in the site-specific sampling plan.

3. Pumps equipped with Teflon tubing or disposable Teflon or polyethylene bailers are generally recommended for collection of samples to be analyzed for volatile organics.
4. Select the appropriate sample container and preservative as described in Section 5.6.
5. After the well has been purged, collect water samples as soon as possible in order to reduce the possibility of volatilization within the wellbore. If a pump has been used for purging, lower the pump rate so that the sampling rate is lower than the purge rate. If volatile organic samples are to be collected, set the pump at the lowest possible setting. If possible, the sampling rate should be less than 100 ml per minute, or the minimum setting on the pump.
6. Collect samples in decreasing order of volatility, i.e., collect samples to be analyzed for volatile organic compounds (VOCs) first, followed by semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs) and pesticides, and inorganics. The preferred order of sampling according to the TEGD is VOCs, SVOCs, total organic carbon (TOC), extractable organics, total metals, dissolved metals, phenols, cyanide, sulfate and chloride, turbidity, nitrate and ammonia, and radionuclides.
7. Do not allow the outlet of the sampling pump discharge tubing to come into direct contact with the sample vial or the water within the vial.
8. Make sure that no air is entrapped in the sample vials to be analyzed for volatile organics. Take the sample by holding the vial at an angle so that aeration is minimized. Avoid touching the lip of the vial or the Teflon liner. If the sample cannot be transferred directly to the vial, (i.e. high production well) use a clean stainless steel cup to pour the water into the vial. Direct the water stream against the inside surface of the vial. Allow a convex meniscus to form across the mouth of the filled vial. Carefully cap the vial, then invert and tap the vial to insure that no entrapped air is present. If entrapped air is present, recollect the sample.
9. If filtering of any samples is required by the site specific sampling plan, use the filtering procedure described in Section 5.7.
10. Preserve the sample as indicated in Section 5.6. Whenever possible, use pre-preserved containers supplied by the analytical laboratory rather than adding preservatives in the field.

11. Measure field parameters as described in Section 5.3. Temperature, EC, and pH generally will be measured at all locations. Alkalinity, dissolved oxygen, and ORP will be measured only as required by the site specific sampling plan.

12. If the sample is to be collected from a domestic well or location other than a monitoring well, it may be necessary to clean the sampling port prior to sample collection (e.g., an outside hose bib or an inside water faucet). Flush the faucet/line by allowing it to run for a minimum of five minutes.

13. Collect samples from domestic wells downstream of water softeners or chlorinators or in-home filters that modify water quality. However, if the objective of the domestic sampling is to evaluate the groundwater prior to treatment, the samples may be taken upstream of such devices.

14. Record all pertinent information in the field notebook. Data to be recorded include the date and time of sample collection, climatic conditions at the time of sampling, well sampling sequence, types of sample containers used, sample identification numbers, field parameter data, name(s) of collector(s), deviations from established sampling protocol (e.g., equipment malfunctions), purpose of sampling (e.g., surveillance, compliance), and collection of quality control samples.

References

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Wehrmann, H.A. 1984. *An investigation of a volatile organic chemical plume in Northern Winnebago County, Illinois*. SWS Contract Report 346. ENR Document No. 84/09. Illinois Department of Energy and Natural Resources, State Water Survey Division, Champaign, Illinois.

5.3b Collection of Groundwater Samples Using Low-Flow Methodology

The following standard operating procedure (SOP) defines activities to be completed for the collection of groundwater samples while utilizing low-flow purging and sampling methodologies.

The SOPs and SOGs included in this section are applicable to all DBS&A employees for the conduct of all activities listed in this section. All SOPs and SOGs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the President or his/her designee for quality assurance. All or parts of the SOPs and SOGs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of the President, his/her quality assurance designee, or a DBS&A Division Director.

These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

The project manager should consult with regulatory officials to confirm that low-flow sampling methodology is acceptable practice. For example, in New Jersey, low flow purging and sampling is not an acceptable method for any wells with screened or open borehole intervals greater than 5 feet in length unless: (1) multiple locations at five-foot intervals along the screen/borehole are sampled, or (2) the data quality objectives warrant sampling a specific zone (e.g., the shallow water table to investigate the potential for vapor intrusion inside a building) or specific zones where sufficient geophysical (e.g., heat-pulse flowmeter, caliper and temperature logs, etc.) and hydrogeological information (e.g., tracer tests) or other evidence (e.g., stained soils or fractures noted on boring logs) that clearly identifies the depth(s) at which contaminants are entering the well screen or open borehole (New Jersey Department of Environmental Protection, 2003).

5.3b.1 Wellhead Preparation

Prior to groundwater sample collection, the following wellhead protection activities shall be conducted:

1. Inspect the area around the well for wellhead integrity, cleanliness, and signs of possible tampering or contamination.
2. Spread a clean plastic sheet over the ground around the wellhead where required.
3. Remove the cap on the wellhead. Note any obvious odors within the wellbore in the field logbook.
4. If possible, measure the static water level (see Section 6.1) prior to initiation of water sampling. Clean the electrical sounder or steel tape used for water level measurement after each use, as described in Section 5.2, to avoid cross contamination.
5. If floating product (e.g., gasoline) is suspected at the site, conduct the following procedures:
    - Use a bailer to extract a sample from the surface of the water within the well, if possible.
    - After an initial visual inspection, slowly pour the fluid from the bailer into a small tub or container in order to check for a sheen or any other sign of free product. Note any obvious odors in the field logbook.
    - If free product is detected, use the bailer to remove as much free product as is possible from the wellbore. Lower the bailer into the water slowly in order to prevent mixing and volatilization. Contain all recovered product for proper disposal and note the quantity of product removed in the field logbook.
    - If the site has not been previously sampled, a sample of the free product may be desired. Consequently, place some of the product in an unpreserved 40-milliliter (mL) glass VOA vial, and store it away from the other samples. Confirm sample analysis with the project manager.
    - After any free product has been removed from the wellbore, spread a fresh plastic sheet around the wellhead, and clean all contaminated equipment, or segregate it from the other equipment.

5.3b.2 Well Purging

The purpose of low-flow purging is to collect a groundwater sample that is representative of aquifer conditions while minimizing waste generation (EPA 1996). To that end, the intake port of the sampling device is placed near the mid-point of the screen interval of the well. If the well has a long screen interval (i.e. greater than 15 feet) or crosses zones of varying permeability, the pump intake should be placed nearest the zone of greatest permeability. The physical/chemical behavior of the contaminants of concern should also be considered when determining the pump intake depth. For example, gasoline-related contaminants may be present near the water table while chlorinated VOCs may be present deeper in the aquifer. By evacuating water at a low flow rate (less than 0.5 liters per minute [L/min]) while monitoring drawdown of the well, one can assume that the water being collected is entering the well via natural recharge, and is therefore representative of aquifer conditions. Representativeness is documented through the monitoring of indicator parameters including temperature, specific conductance, and pH. Additional water quality measurements including dissolved oxygen (DO), turbidity, and oxidation/reduction potential (ORP) are also useful information although their measurement may be more problematic, and consequently should not be used as indicators of stability.

Site-specific purging procedures shall be prepared for each site. The following purging procedure can be used as a general guideline:

1. Measure the depth to water within the well.
2. Lower the intake of the pump to the approximate mid-point of the well's screen interval. If the well is shallow (less than 25 feet) sampling may be performed with a peristaltic pump. In this case, lower the tubing to the desired depth.
3. Once the initial water-level measurement has been recorded and the pump installed, suspend the water-level probe in the well at the point at which drawdown is equivalent to a 0.3-foot drop. Record water levels simultaneously with water quality measurements
4. Begin purging the well at a flow rate of less than 0.5 liter per minute (L/min) (coarse grained sediments). Drawdown should be limited to about 0.3 foot. During pump start-up, drawdown may exceed the 0.3-foot target and then recover as flow-rate adjustments are made. If drawdown occurs, lower the purge rate to 0.1 L/min.
5. Measure applicable field parameters (see Section 5.3) at the pump outlet at a minimum of every two minutes. Purging is generally considered complete when the above parameters are stable (±10 percent for temperature and conductivity and ±0.1 pH units) over at least three readings.
6. Contain all fluid from obviously contaminated or potentially contaminated wells for later disposal. Anomalous values for the above field parameters, odor, visible sheen, or the

presence of free product may be taken as signs of contamination. Results of previous water sampling events will be consulted when available.

7. Take careful notes in order to document all purging procedures. The notes shall include: date, time, name(s) of sampler(s), weather, purge rate, purge method, pump depth, water level drawdown, field parameters (at each time measured, with corresponding purge volume), visual observations, odor, and any other relevant information.

5.3b.3 Groundwater Sample Collection

The following procedure shall be used to collect groundwater samples:

1. Whenever possible, collect groundwater samples first from wells that have the lowest potential concentrations of analytes of interest, and last from the wells with the highest suspected concentrations (i.e., clean dirty). The specific sampling order should be detailed in the site-specific sampling plan.
2. Select the appropriate sample container and preservative as described in Section 5.6.
3. After the well has been purged, collect water samples as soon as possible in order to reduce the possibility of volatilization within the wellbore. If a pump has been used for purging, lower the pump rate so that the sampling rate is lower than the purge rate. If volatile organic samples are to be collected, set the pump at the lowest possible setting. If possible, the sampling rate should be less than 100 ml per minute, or the minimum setting on the pump.
4. Collect samples in decreasing order of volatility, i.e., collect samples to be analyzed for volatile organic compounds (VOCs) first, followed by semivolatile organic compounds (SVOCs), polychlorinated biphenyls (PCBs) and pesticides, and inorganics. The preferred order of sampling according to the EPA (1992) is VOCs, SVOCs, total organic carbon (TOC), extractable organics, total metals, dissolved metals, phenols, cyanide, sulfate and chloride, turbidity, nitrate and ammonia, and radionuclides.
5. Do not allow the outlet of the sampling pump discharge tubing to come into direct contact with the sample vial or the water within the vial.
6. Make sure that no air is entrapped in the sample vials to be analyzed for volatile organics. Take the sample by holding the vial at an angle so that aeration is minimized. Avoid touching the lip of the vial or the Teflon liner. If the sample cannot be transferred directly to the vial, (i.e. high production well) use a clean stainless steel cup to pour the water into the

vial. Direct the water stream against the inside surface of the vial. Allow a convex meniscus to form across the mouth of the filled vial. Carefully cap the vial, then invert and tap the vial to insure that no entrapped air is present. If entrapped air is present, recollect the sample.

7. If filtering of any samples is required by the site specific sampling plan, use the filtering procedure described in Section 5.7.
8. Preserve the sample as indicated in Section 5.6. Whenever possible, use pre-preserved containers supplied by the analytical laboratory rather than adding preservatives in the field.
9. Measure field parameters as described in Section 5.3. Temperature, electrical conductivity, and pH generally will be measured at all locations. Alkalinity, DO, and ORP will be measured only as required by the site specific sampling plan.
10. Record all pertinent information in the field notebook. Data to be recorded include the date and time of sample collection, climatic conditions at the time of sampling, well sampling sequence, types of sample containers used, sample identification numbers, field parameter data, name(s) of collector(s), deviations (and rationale for deviations) from established sampling protocol (e.g., equipment malfunctions), purpose of sampling (e.g., surveillance, compliance), and collection of quality control samples.

References

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5.5 Sample Preservation

The following standard operating guideline (SOG) defines activities to be completed to properly preserve a water sample for shipment to an analytical laboratory for analysis.

The SOPs and SOGs included in this section are applicable to all DBS&A employees for the conduct of all activities listed in this section. All SOPs and SOGs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the President or his/her designee for quality assurance. All or parts of the SOPs and SOGs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of the President, his/her quality assurance designee, or a DBS&A Division Director.

These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

5.5.1 Procedures

Attachment 5.5-1 lists recommended containers, preservatives, and holding times for individual analytes or analytical methods. The suggestions for sample storage and preservation presented are intended to serve as general guidelines. The analytical laboratories shall be consulted for the proper preservation and storage procedure for the analytical methods that will be used (e.g., this guideline recommends preservation of volatile organic samples with hydrochloric acid (HCl), but some laboratories require preservation with mercuric chloride).

Samples for volatile organics analysis (e.g., EPA 602, 624, 8020, or 8260) shall be collected in pre-cooled, pre-acidified, certified-clean 40-mL borosilicate vials with Teflon septum caps supplied by the analytical laboratory. Samples to be analyzed for other constituents should be collected in appropriate containers as listed in Attachment 5.5-1.

Attachments

Attachment 5.5-1 Inorganic Sample Containers, Preservatives, and Holding Times; information provided by Severn Trent Laboratories (STL Tables 8.5-1, 8.5-2, and 8.5-5)

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times

Analytical Parameters	Matrix	Minimum Sample Size(1)	NPDES(2), (3), (7)		RCRA (SW846)(3), (4)	
			Method	Requirements	Method	Requirements
Acidity	Water	100 mL	305.1	250 mL plastic or glass, Cool, 4°C, 14 days	---	Not Applicable
	Solid(5)	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Alkalinity	Water	100 mL	310.1 2320B	250 mL plastic or glass, Cool, 4°C, 14 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Ammonia	Water	400 mL	350.1	500 mL plastic or glass, Cool, 4°C H_2SO_4 to pH < 2, 28 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Biochemical Oxygen Demand (BOD)	Water	200 mL	405.1	1000 mL plastic or glass, Cool, 4°C 48 hours	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Bromide	Water	100 mL	300.0(7)	250 mL plastic or glass, No preservative required, 28 days	9056	Cool, 4°C, analyze ASAP after collection
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Chemical Oxygen Demand (COD)	Water	100 mL	410.4	250 mL glass or plastic, Cool, 4°C, H_2SO_4 to pH < 2, 28 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable

ATTACHMENT 5.5-1

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times
(Continued)

Analytical Parameters	Matrix	Minimum Sample Size(1)	NPDES(2), (3), (7)		RCRA (SW846)(3), (4)	
			Method	Requirements	Method	Requirements
Chloride	Water	50 mL	300.0(7) 325.2	250 mL plastic or glass, No preservative required, 28 days	9056	Method 9056: Cool, 4°C, analyze ASAP after collection.
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Chromium (Cr^{+6})	Water	100 mL	3500 Cr-D	Method 218.4: 200 mL plastic or glass, Cool, 4°C, 24 hours Method 3500 Cr-D: 200 mL quartz, TFE, or polypropylene HNO_3 to pH <2 Cool, 4°C Analyze ASAP after collection	7196A	200 mL plastic or glass, Cool, 4°C, 24 hours
	Solid	Not Applicable	---	Not Applicable	7196A	250 mL plastic or glass, 30 days to digestion, 96 hours after digestion
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable

ATTACHMENT 5.5-1

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times
(Continued)

Analytical Parameters	Matrix	Minimum Sample Size(1)	NPDES(2), (3), (7)		RCRA (SW846)(3), (4)	
			Method	Requirements	Method	Requirements
Color	Water	100 mL	110.2	250 mL plastic or glass, Cool, 4°C, 48 hours	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Conductivity	Water	100 mL	120.1	200 mL glass or plastic, Cool, 4°C, 28 days	9050A	200 mL glass or plastic, Cool, 4°C, 24 hours
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Cyanide (Amenable)	Water	IL	335.3	1 liter plastic or glass, NaOH to pH >12 0.6g ascorbic acid(6) Cool, 4°C, 14 days unless sulfide is present. Then maximum holding time is 24 hours	9010B/ 9012A	1 liter plastic or glass, NaOH to pH >12 0.6g ascorbic acid(6) Cool, 4°C, 14 days
	Solid	50g	---	Not Applicable	9010B/ 9012A	Not Specified
	Waste	50g	---	Not Applicable	9010B/ 9012A	Not Specified
Cyanide (Total)	Water	IL	335.3	1 liter plastic or glass, NaOH to pH >12 0.6g ascorbic acid(6) Cool, 4°C, 14 days unless sulfide is present. Then maximum holding time is 24 hours	9010B/ 9012A	1 liter plastic or glass, NaOH to pH >12 0.6g ascorbic acid(6) Cool, 4°C, 14 days
	Solid	50g	--	Not Applicable	9010B 9012A	8 or 16 oz glass Teflon-lined lids, Cool, 4°C, 14 days

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times (Continued)

Analytical Parameters	Matrix	Minimum Sample Size[(1)]	NPDES[(2), (3), (7)]		RCRA (SW846)[(3), (4)]	
			Method	Requirements	Method	Requirements
Cyanide (Total) (continued)	Waste	50g	--	Not Applicable	9010B/ 9012A	8 or 16 oz glass Teflon-lined lids, Cool, 4°C
Flashpoint (Ignitability)	Liquid	Not Applicable	---	Not Applicable	1010	No requirements, 250 mL amber glass, Cool, 4°C is recommended
	Solid	Not Applicable	--	Not Applicable	---	Not Applicable
	Waste	Not Applicable	--	Not Applicable	---	Not Applicable
Fluoride	Water	300 mL	300.0[(7)] 340.2	500 mL plastic, No preservation required, 28 days	9056	Cool, 4°C, analyze ASAP after collection
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Hardness (Total)	Water	50 mL	130.2 2340B	250 mL glass or plastic, HNO_3 to pH < 2, 6 months	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Iron (Ferrous)	Water	100 mL	3500-Fe D	1 liter glass or polyethylene container, 6 months **This test should be performed in the field.**	-	Not Applicable
	Solid	Not Applicable	-	Not Applicable	-	Not Applicable
	Waste	Not Applicable	-	Not Applicable	-	Not Applicable

ATTACHMENT 5.5-1

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times
(Continued)

Analytical Parameters	Matrix	Minimum Sample Size(1)	NPDES(2), (3), (7)		RCRA (SW846)(3), (4)	
			Method	Requirements	Method	Requirements
Methylene Blue Active Substances (MBAS) (Surfactant)	Water	100 mL	425.1	250 mL plastic or glass, Cool, 4°C, 48 hours	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Nitrate	Water	100 mL	300.0(7) 353.2	Method 300.0: 250 mL plastic or glass, Cool, 4°C, 48 hours. Method 352.1: 250 mL plastic or glass, Cool, 4°C, 48 hours.	9056	Method 9056: Cool, 4°C, analyze ASAP after collection Method 9210: Cool, 4°C Preserve by adding 1 mL of 1M boric acid solution per 100 mL of sample
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	9210	Not Specified
Nitrite	Water	50 mL	300.0(7) 353.2	250 mL plastic or glass Cool, 4°C, 48 hours	9056	Cool, 4°C, analyze ASAP after collection
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times
(Continued)

Analytical Parameters	Matrix	Minimum Sample Size(1)	NPDES(2), (3), (7)		RCRA (SW846)(3), (4)	
			Method	Requirements	Method	Requirements
Nitrate-Nitrite	Water	100 mL	353.3	250 mL plastic or glass, H_2SO_4 to pH < 2, 28 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Ortho-phosphate	Water	50 mL	300.0(7) 365.3	100 mL plastic or glass, Filter on site Cool, 4°C, 48 hours	9056	Cool, 4°C, analyze ASAP collection
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
pH	Water	50 mL	150.1 4500-H^+ B	100 mL plastic or glass. Analyze immediately. **This test should be performed in the field.**	9040B	100 mL plastic or glass. Analyze immediately. **This test should be performed in the field.(8)**
	Solid	Not Applicable	---	Not Applicable	9045C	4 oz glass or plastic, Cool, 4°C, Analyze as soon as possible.(8)
	Waste	Not Applicable	---	Not Applicable	9045C	4 oz glass or plastic, Cool, 4°C, Analyze as soon as possible.(8)
Phenolics	Water	100 mL	420.2	500 mL glass, Cool, 4°C, H_2SO_4 to pH < 2, 28 days	9066	1 liter glass recommended, Cool, 4°C, H_2SO_4 to pH < 4, 28 days
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	9065	Not Specified
Phosphate	Water	50 mL	365.3	Not Applicable	9056	Cool, 4°C, analyze ASAP collection
	Solid	Not Applicable	---	Not Applicable	9056	Not Applicable
	Waste	Not Applicable	---	Not Applicable	9056	Not Applicable

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times
(Continued)

Analytical Parameters	Matrix	Minimum Sample Size[1]	NPDES[(2), (3), (7)]		RCRA (SW846)[(3), (4)]	
			Method	Requirements	Method	Requirements
Phosphorus (Total)	Water	50 mL	365.3	100 mL plastic or glass, H_2SO_4 to pH < 2, 28 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Reactivity (Cyanide and Sulfide)	Liquid	10 g	---	Not Applicable	Chapter 7 Sections 7.3.3.2 and 7.3.4.2	10 oz amber glass, Cool, 4°C, no headspace, analyze as soon as possible.
	Solid	10 g	---	Not Applicable	Chapter 7 Sections 7.3.3.2 and 7.3.4.2	10 oz amber glass, Cool, 4°C, no headspace, analyze as soon as possible.
	Waste	10 g	---	Not Applicable	Chapter 7 Sections 7.3.3.2 and 7.3.4.2	10 oz amber glass, Cool, 4°C, no headspace, analyze as soon as possible.
Settleable Solids	Water	1000 mL	160.5	1000 mL plastic or glass, Cool, 4°C, 48 hours	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Specific Conductance	Water	50 mL	120.1	250 mL plastic or glass, Cool, 4°C, 24 hours	9050A	250 mL plastic or glass, Cool, 4°C, 28 days
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times
(Continued)

Analytical Parameters	Matrix	Minimum Sample Size(1)	NPDES(2), (3), (7)		RCRA (SW846)(3), (4)	
			Method	Requirements	Method	Requirements
Sulfate (SO_4)	Water	100 mL	300.0(7) 375.2	100 mL plastic or glass, Cool, 4°C, 28 days	9056 9038	Method 9056: Cool, 4°C, analyze ASAP collection Method 9038: 200 mL plastic or glass, Cool, 4°C, 28 days
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	100 mL	---	Not Applicable	9038	200 mL plastic or glass, Cool, 4°C, 28 days
Sulfide	Water	100 mL	376.2	500 mL plastic or glass, Cool, 4°C, Add 2 mL zinc acetate plus NaOH to pH > 9, 7 days	9030B/ 9034	500 mL plastic, no headspace, Cool, 4°C, Add 4 drops of 2N zinc acetate per 100 mL of sample, adjust the pH to > 9 with 6 N NaOH solution, 7 days
	Solid	50 g	---	Not Applicable	9030B 9034	Cool, 4°C, fill surface of solid with 2N Zinc acetate until moistened, store headspace-free
	Waste	50 g	---	Not Applicable	9030B 9034	Cool, 4°C, fill surface of solid with 2N Zinc acetate until moistened, store headspace-free

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times
(Continued)

Analytical Parameters	Matrix	Minimum Sample Size[1]	NPDES[2], [3], [7]		RCRA (SW846)[3], [4]	
			Method	Requirements	Method	Requirements
Sulfite (SO_3)	Water	100 mL	377.1	100 mL plastic or glass, No preservative required, analyze immediately **This test should be performed in the field.**	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Total Dissolved Solids (Filterable)	Water	100 mL	160.1	250 mL plastic or glass, Cool, 4°C, 7 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Total Kjeldahl Nitrogen (TKN)	Water	500 mL	351.3	500 mL plastic or glass, Cool, 4°C, H_2SO_4 to pH < 2, 28 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Total Organic Carbon (TOC)	Water	100 mL	415.1	100 mL plastic or glass, Cool, 4°C, H_2SO_4 to pH < 2, 28 days	9060	100 mL glass or 40 mL VOA vials, Cool, 4°C, H_2SO_4 or HCl to pH < 2, 28 days
	Solid	Not Applicable	---	Not Applicable	9060	Not Specified
	Waste	Not Applicable	---	Not Applicable	9060	Not Specified

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times
(Continued)

Analytical Parameters	Matrix	Minimum Sample Size[(1)]	NPDES[(2), (3), (7)]		RCRA (SW846)[(3), (4)]	
			Method	Requirements	Method	Requirements
Total Organic Halides (TOX)	Water	100 mL	---	Method 5320B: 500 mL amber glass, Teflon®-lined lid, Cool, 4°C, HNO_3 to pH <2, no headspace, 14 days Method 450.1: 500 mL amber glass, Teflon®-lined lid, Cool, 4°C, HNO_3 to pH <2, no headspace, 28 days	9020B	500 mL amber glass, Teflon®-lined lid, Cool, 4°C, H_2SO_4 to pH < 2, no headspace, 28 days
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Total Solids	Water	100 mL	160.3	250 mL plastic or glass, Cool, 4°C, 7 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Total Suspended Solids (Nonfilterable)	Water	100 mL	160.2	250 mL plastic or glass, Cool, 4°C, 7 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Turbidity	Water	50 mL	180.1	250 mL plastic or glass, Cool, 4°C, 48 hours	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable
Volatile Solids	Water	100 mL	160.4	250 mL plastic or glass, Cool, 4°C, 7 days	---	Not Applicable
	Solid	Not Applicable	---	Not Applicable	---	Not Applicable
	Waste	Not Applicable	---	Not Applicable	---	Not Applicable

ATTACHMENT 5.5-1

TABLE 8.5-1
Inorganic Sample Containers, Preservatives, and Holding Times
(Continued)

Analytical Parameters	Matrix	Minimum Sample Size(1)	NPDES(2), (3), (7)		RCRA (SW846)(3), (4)	
			Method	Requirements	Method	Requirements
Water Content	Water	Not Applicable	---	Not Applicable	---	Not Applicable
	Solid	10 g	---	Refer to specific method used	---	Refer to specific method used
	Waste	10 g	---	Refer to specific method used	---	Refer to specific method used
Metals (excludes Hg)	Water	100 mL	200 series	1 liter glass or polyethylene container, HNO_3 to pH $\leq$ 2, 6 months	6010B, 6020, 7000A series	1 liter glass or polyethylene container, HNO_3 to pH $\leq$ 2, 6 months
	Solid	200 g	200 series	8 or 16 oz glass or polyethylene container storage at 4 °C	6010B, 6020, 7000A series	8 or 16 oz glass or polyethylene container, storage at 4°C, 6 months
	Waste	200 g	200 series	Not Applicable	6010B, 6020, 7000A series	8 or 16 oz glass or polyethylene container, storage at 4°C, 6 months
Mercury (CVAA)	Water	100 mL	245.1	1 liter glass or polyethylene container, HNO_3 to pH $\leq$ 2, 28 days	7470A	1 liter glass or polyethylene container, HNO_3 to pH $\leq$ 2, 28 days
	Solid	200 g	245.5	8 or 16 oz glass or polyethylene container, Cool, 4°C, 28 days	7471A	8 or 16 oz glass or polyethylene container, Cool, 4°C, 28 days (CORP-MT-0007)
	Waste	200 g	--	Not Applicable	7471A	8 or 16 oz glass or polyethylene container, Cool, 4°C, 28 days (CORP-MT-0007)

5.6 Sample Filtration

The following standard operating procedure (SOP) defines activities to be completed to properly filter water samples in preparation for analysis by an analytical laboratory.

The SOPs and SOGs included in this section are applicable to all DBS&A employees for the conduct of all activities listed in this section. All SOPs and SOGs described in this section are proprietary in nature and shall not be copied or reproduced, or distributed to any person or organization not employed by DBS&A, without the expressed written approval of the President or his/her designee for quality assurance. All or parts of the SOPs and SOGs described in this section may be reproduced and used in DBS&A reports, proposals, and work plans with the verbal consent of the President, his/her quality assurance designee, or a DBS&A Division Director.

These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

5.6.1 Procedures

Research indicates that if samples are obtained correctly, field filtration for metals may not be necessary (Puls and Powell, 1992). However, filtration of samples to be analyzed for dissolved metals may be required in some cases. If filtration is required, it shall be outlined in the site specific sampling plan.

If filtration is required, filter the samples in the field if possible. If field filtering is not possible, preserve the sample by chilling to 4°C (i.e., do not add acid), and immediately ship the sample via overnight delivery to the laboratory. Indicate on the chain of custody that laboratory filtration and preservation are required.

Vacuum filtration of groundwater samples is not recommended (Barcelona et al., 1985, pg. 65). Samples to be analyzed for TOC, VOCs or other organic compounds should not be filtered. Filtration may be performed on samples collected for analysis of dissolved metals, however.

The following procedure shall be followed to filter samples in the field with a peristaltic pump (e.g., GeoPump):

1. Connect the GeoPump to an automobile cigarette lighter or outlet if electricity is available.
2. Replace the tubing for the GeoPump at the beginning of each sampling round. If the samples are collected in any order other than most contaminated to least contaminated, or if very high levels of contamination are suspected or observed, then replace the tubing between each sample or as necessary.
3. If the tubing is not replaced between each sample, flush the lines with Liquinox followed by at least three flushes with distilled water.
4. Collect an unfiltered water sample as discussed in Sections 5.4 and 5.5.
5. Place the intake line in the unfiltered sample.
6. Pump at least a few hundred milliliters of the sample through the GeoPump prior to sample collection in order to flush the line. Set the GeoPump at the lowest rate possible in order to minimize aeration. Dispose of this water appropriately.
7. Place a new disposable 0.45-micron filter on the output line. Direct the output stream from the filter into the pre-acidified sample container, as outlined in Section 5.6.

References

Barcelona, M.J., J.P. Gibb, J.A. Helfrich, and E.E. Garske. 1985. *Practical guide for ground-water sampling*. Prepared in cooperation with RSKERL, Ada, Oklahoma. SWS Contract Report 374. DBS&A #560/BAR/1985.

Puls, R.W. and R.M. Powell. 1992. Acquisition of representative ground water quality samples for metals. R.S. Kerr Environmental Research Laboratory (RSKERL). *Ground Water Monitoring Review* (Summer).

5.7 Quality Assurance/Quality Control (QA/QC) Samples

The following standard operating procedure (SOP) defines activities to be completed to assure quality assurance (QA) and quality control (QC) for water samples collected in the field.

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These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or his/her quality assurance designee.

QA/QC samples include split samples, duplicates, blind duplicates, blind check standards, trip blanks, and equipment blanks. The specific QA/QC samples that will be collected during each sampling event shall be designated in the site sampling plan.

5.7.1 General QA/QC Guidelines

The following general guidelines shall be followed for collection of QA/QC samples:

1. A trip blank is a sample of analyte-free water that is transported with the sample containers from the laboratory to the field site and back again. A trip blank is useful in assessing contamination of volatile organics samples attributable to shipping and field handling procedures. Include a trip blank with each cooler that contains samples to be analyzed for volatile organic compounds (VOCs). Ideally, trip blanks will be prepared at the lab in advance and will be shipped with the sample bottles received from the laboratory. If trip blanks are prepared in the DBS&A warehouse or in the field, prepare them well away from any areas of known or suspected contamination. Prepare the trip blanks by filling a pre-acidified 40-mL VOA vials with organic-free water.

2. An equipment (rinsate) blank is a sample of analyte-free water which has been used to rinse any non-disposable equipment that comes in contact with the water to be sampled, such as non-dedicated pumps or bailers or field filtration devices. The rinsate blank is useful in documenting adequate decontamination of equipment. Collect the equipment blank by running or pouring deionized water through any portion of the device that normally comes in contact with the water sample or presents a potential for cross-contamination, including hoses, valves, etc. Equipment blanks generally are not required for disposable equipment which is certified clean by the manufacturer (e.g., disposable Teflon bailers). The exact number and type of equipment blanks to be collected will be determined on a site-specific basis. Describe the process used to collect the equipment blank in the field log book.
3. A duplicate consists of two separate samples from the same source which are collected as close as possible to the same point in space and time, analyzed independently. Duplicates are used to evaluate laboratory precision, heterogeneity of the material, and precision of field sampling techniques.
4. Split samples are replicate samples collected in the same manner in alternating fashion which are analyzed independently for the same parameters. Split samples are used to evaluate inter- or intra-laboratory precision.
5. In some cases, blind check standards may be submitted to the analytical laboratory. These may be obtained commercially or prepared in advance in the DBS&A laboratory. Alternatively, a duplicate sample may be spiked in the field with a known quantity of the analyte(s) of concern.

5.7.2 Well Security

All monitor wells shall be securely locked following completion of sampling.

6.1 Groundwater Level Measurement

The purpose of this standard operating procedure (SOP) is to provide DBS&A personnel with the information necessary to collect accurate water level data from groundwater wells. Water level measurements provide the fundamental data needed to determine aquifer characteristics; therefore, it is crucial that the appropriate methods are used to meet the data requirements of an aquifer investigation.

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These SOPs and SOGs shall be reviewed periodically, and revisions and additions to these SOPs and SOGs shall be made as needed to assure consistency with industry standards and the collection of high quality data in the field. Requests for revisions shall be made in writing to the President or the DBS&A Quality Assurance Manager.

Several methods are available for determining the depth to water (DTW). This SOP briefly describes methods used to measure water levels manually and automatically with dataloggers equipped with pressure transducers. This information is intended to help DBS&A personnel determine the appropriate equipment to collect water levels for background trend analysis and aquifer tests.

Immediately following well construction (SOP 4.1), a measuring point (MP) shall be established and clearly labeled "MP" with a permanent marker at the top of the casing. The designated MP shall be located at a point that is unlikely to change in elevation during the life of the well. This mark will prevent repeated surveys to determine the reference elevation of the measuring point. If the MP does change, it shall be clearly re-marked and referenced to the original elevation, or a new survey will be necessary. Water levels will be measured in accordance with ASTM D 4750-87 (reapproved 1993), Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).

The DTW shall be recorded in the project logbook as described in SOP 1.3. The following information shall be recorded on the form: the person making the measurement, the measuring device, the surveyed point from which the measurement is made, the time of day (military time), the date, the wellhead condition, and any MP changes. Groundwater level data may also be recorded in the field log and on other applicable DBS&A forms, including but not limited to those used for water sampling and drilling/soils logging.

The following subsections describe the most commonly used techniques for obtaining water level data in the field.

6.1.1 Electrical Sounders

Electrical sounders are most often used to measure groundwater levels on DBS&A projects. Electrical sounders operate by completing an electrical circuit when the probe contacts the water, thus providing a measure of the depth to water. When the circuit is completed, a light, buzzer, or ammeter needle indicates that the probe is in contact with the water surface. The probe is connected to a graduated tape, usually made from plastic and fiberglass. Batteries supply the necessary current through electrical wires contained in the graduated tape. Electrical sounders measure depths to within 0.02 foot.

The major advantage of electrical sounders is that measurements can be made rapidly and accurately without removing the probe from the well. Field personnel should position themselves near the MP so the DTW can be read at eye level. A second confirmatory reading should be performed before the electrical tape is withdrawn from the well. The length of the electrical line shall be calibrated annually with an engineer's tape by the DBS&A Environmental Equipment Coordinator. Information from these calibrations shall be kept at the DBS&A equipment supply facility.

6.1.2 Dataloggers

Electronic dataloggers equipped with pressure transducers are commonly used and are useful for collecting large quantities of water level data rapidly during labor-intensive aquifer tests. Measurements are accurate to approximately 0.01 foot, depending on the type of pressure transducers used. When deploying dataloggers, record the manufacturer and serial number of the logger in the field book and follow the manufacturer SOP.

6.1.3 Steel Tape

Graduated steel tapes provide accurate measurements to within approximately 0.01 foot for depths of 100 feet or less. The rigidity of the tape allows it to hang straight in the well. The main disadvantage of the steel tape method is that the approximate DTW must be known prior to the measurement. In addition, interferences such as cascading water, smearing, and/or evaporation may compromise the accuracy of the wetted-end measurement. Steel tapes should generally not be used when many measurements must be made in rapid succession, such as during aquifer testing. Measurement with a steel tape is relatively time consuming.

When a steel tape is used, the lower 2 to 3 feet are wiped dry and coated with carpenter's chalk or water finding paste before the tape is lowered into the well to the estimated DTW. The tape should be held on a foot marker at the wellhead MP. After the tape is removed, the wetted end is read and subtracted from the previous reading; the difference is the actual depth to water. If tape graduations are greater than 0.1 foot apart, a separate engineering tape or scale shall be used to accurately determine the wetted end measurement.

References

ASTM International (ASTM). 1993. *Standard test method for determining subsurface liquid levels in a borehole or monitoring well (observation well)*. Standard D 4750-87 (reapproved 1993). Philadelphia, Pennsylvania.

ASTM. 1995. *Standard practice for design and installation of ground water monitoring wells in aquifers*. Standard D 5092-90 (reapproved 1995). Philadelphia, Pennsylvania.

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COMMENTS

Action 202974

COMMENTS

Operator:	
HF Sinclair Navajo Refining LLC ATTN: GENERAL COUNSEL Dallas, TX 75201	OGRID: 15694
	Action Number: 202974
	Action Type: [UF-DP] Discharge Permit (DISCHARGE PERMIT)

COMMENTS

Created By	Comment	Comment Date
cchavez	WDW-1 Monitor Well (MW) Work Plan Signed 3-31-2023	4/20/2023

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CONDITIONS

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HF Sinclair Navajo Refining LLC ATTN: GENERAL COUNSEL Dallas, TX 75201	OGRID: 15694
	Action Number: 202974
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CONDITIONS

Created By	Condition	Condition Date
cchavez	Conditions of Approval are: 1. Subject to final communication between Permittee & OCD on 4/18/2023; 2. Ensure all water-bearing zones encountered during drilling (especially uppermost) are assessed for basic field water quality parameters, (i.e., specific conductivity; pH; ORP; PID, etc.) with laboratory TDS sample to be collected when field parameters may indicate TDS could be greater than 10,000 ppm; and 3. Provide drilling schedule updates in advance to OCD staff listed in work plan communications.	4/20/2023