GEOTECHNICAL EXPLORATION EQUIPMENT AND PROCEDURES FOR WESTERN FEDERAL LANDS PROJECTS

This is a description of the typical geotechnical drilling equipment, operations and procedures used on Western Federal Lands projects. Geotechnical drilling provides subsurface information while collecting soil/rock samples and conducting in-place soil/rock field testing. The drilling operations may consist of several different types of drilling methods and equipment.

There is a wide variety of drilling equipment to support the geotechnical field investigations that Western Federal Lands conducts. The drilling equipment includes truck-mounted geotechnical drills, track-mounted geotechnical drills, and skid-mounted geotechnical drills. The typical geotechnical drilling equipment is described below, and pictures of the equipment are attached.

Truck-Mounted Geotechnical Drills

Examples of typical truck-mounted geotechnical drills are a Longyear BK-81, CME – 55, and a CME - 75. The truck drills complete the majority of the easy access drilling that is conducted on roadway shoulders or within traffic lanes. Typically site impact is very minimal with this operation (Figure 1).

Figure 1. Typical truck-mounted geotechnical drilling operation

Track Mounted Geotechnical Drills

An example of a typical track-mounted drill is the Longyear CME – 850 track-mounted geotechnical drill. These drills are capable of climbing 60 degree slopes under their own power and even steeper slopes with the assistance of cable winches (Figure 2). The main feature of these drills is the low ground pressure rated tracks at 2.5 psi for a drill rig that weighs approximately 30,000 pounds when fully tooled. It is capable of accessing very soft ground and moderate off road terrain. Generally, the track drills leave little trace of being there (Figure 3). The track drills typically measure 8.5 ft wide by 19 ft long.

Figure 2. Typical track-mounted geotechnical drilling operation.

Figure 3. An example of wetland impacts following a track-mounted drilling operation in a wetland environment.

Skid-Mounted, Portable Geotechnical Drills

Examples of skid-mounted portable drills are the Longyear CME-45 and a Burley 4500. These drills are used for very difficult access. They can be put on any site regardless of the terrain or obstacles (Figure 4). In some cases, they will be used on a pontoon barge to drill over water (Figure 5).

The CME-45 typically measure 5 ft wide and 10 ft long. These drills can be skidded by winch, or set on-site with a boom truck/crane/helicopter. One constraint is that if the drill is to be skidded or pulled by winch a stable anchor needs to be available to attach the winch to (typically large trees or bunches of trees are utilized with a protective strap around the bark).

The Burley 4500 can be broken down quickly and easily into components weighing less than 1000 pounds and lifted into place with either a boom truck, crane, or flown in by helicopter. When flown by helicopter the rig leaves little to no trace of ever being there, but requires an opening in the trees to lower the pieces through. Once these components are on site, the drill can be easily reassembled. When set up it takes an area of approximately 6 ft wide, by 13 ft long, plus the work area for the crew of about 6 ft by 20 ft. All additional support equipment such as a toolbox, small storage box, drill rod and a few drilling supplies are also flown on-site.

Figure 4. Typical helicopter or crane portable geotechnical drilling operation.

Figure 5. Typical pontoon barge with skid-mounted geotechnical drilling operation.

Typical Drill Support Vehicles and Equipment

The drill rigs described above are often supported with a water truck that also hauls the extra tools and equipment. When compressed air is used to drill in prolonged freezing conditions, a support truck with a compressor trailer may be used. The support truck and associated equipment is parked near as possible to the drilling equipment, and a 2-inch hose supplies the drill site with water when coring and a 3 inch hose when drilling with compressed air. Each vehicle has a set of fire tools and a spill kit on board in case of any spills.

Exploration activities during drilling adhere to Western Federal Lands Best Management Practices to mitigate for sediment/erosion control and spill prevention. For example, where needed, a silt fence, straw bales, and/or wattles can be constructed around the drill site to contain any fluid loss, should it occur. Straw and wattles will likely require weed free certification. Fueling will often occur when moving to a good containment area between holes or offsite before arriving at the site. When fueling on-site, spill kits located in each vehicle are readily available in the event of a spill.

Typical Drilling Methods

The geotechnical field exploration equipment described above is capable of supporting multiple drilling methods. The primary drilling methods used for Western Federal Land's geotechnical explorations includes the use of hollow-stem augers, direct rotary wireline casing advancement, and diamond bit rock coring. These methods for advancing geotechnical borings should be in accordance with the following ASTM standards:

- D6151-97(2003) Standard Practice for Using Hollow-Stem Augers for Geotechnical exploration and Soil Sampling
- D5876-95(2000) Standard Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
- D2113-99 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

The typical outside diameter of hollow-stem augers is approximately 8 inches and rotary drilling methods in soil and rock using direct rotary wireline casing advancers can be as large as 6 inches. Mud rotary diamond bit drilling without casing is typically no larger than 4 inches (HQ and NQ sized core barrels). These are the most typical drilling methods utilized by WFL.

Drilling Method for Lakes, Streams, or Rivers

When drilling in a coarse bottomed lake, stream, or riverbed, an alternate drilling process is required to minimize turbidity. This method has been repeatedly used by WFL drill crews and our drill contractors for over 20 years. Because the bottom of the water body contains boulders, cobbles, and gravels in a coarse sand matrix, it is best to push a larger (~6 inch) casing advancer at least 3 feet into the surface material with very limited turning of the steel rods. Bentonitic (swelling) clay chips are placed inside the advancer casing as it is slowly lifted back up to within 6 inches of the surface so the bentonitic clays can swell and fill the spaces between the pervious soils and begin to create a seal for the drilling. After about 15 minutes, a smaller drill steel with the rock coring diamond bit is placed inside the larger advancer casing and drilling begins for a couple feet so the return of drill fluid and stream turbidity can be checked. If turbidity is measured below permitting thresholds and drilling fluids return in-between the smaller drill steel and the larger casing advancer, the upper portion of the hole is sealed and typical drilling methods can commence. If it is not properly sealed, additional bentonitic clays will need to be added to the hole in the same process as described above until a seal is formed. Drill fluids are completely contained and reused in this drilling process. Upon completion of the boring, the drill fluid and associated sediments are hauled away and disposed of. No return drill water is allowed to enter the water body.

Subsurface Sampling Methods

Sampling of subsurface materials should be in accordance with the following ASTM standards:

- D1586-99 Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils
- D3550-01 Standard Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
- D1587-00 Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes

- D4823-95(2003)e1 Standard Guide for Core Sampling Submerged, Unconsolidated Sediments

Down-the-hole hammers are not allowed for use in performing Standard Penetration Tests. Samples should be handled in accordance with the following ASTM standards:

- D4220-95(2000) Standard Practices for Preserving and Transporting Soil Samples
- D5079-02 Standard Practices for Preserving and Transporting Rock Core Samples

Disturbed soil samples should be placed in watertight plastic bags. For moisture-critical geotechnical issues, a portion of the sample should be placed in a moisture tin and sealed with tape. Extreme care must be exercised when handling and transporting undisturbed samples of soft/loose soil; undisturbed samples must also be kept from freezing. Rock cores of soft/weak rock should be wrapped in plastic to preserve in situ moisture conditions. Rock cores should be placed in core boxes from highest to lowest elevation and from left to right. Coring intervals should be clearly labeled and separated. Core breaks made to fit the core in the box must be clearly marked on the core. All soil and rock samples should be removed from the drill site at the end each day of drilling and transported to the laboratory as soon as possible.

In-Situ Testing Methods and Groundwater Monitoring

In situ testing methods commonly employed in geotechnical investigations should be in accordance with the following ASTM standards:

- D2573-01 Standard Test Method for Field Vane Shear Test in Cohesive Soil

Groundwater monitoring and in situ characterization methods commonly employed in geotechnical investigations should be in accordance with the following ASTM standards:

- D5092-02 Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers
- D4750-87(2001) Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
- D4044-96(2002) Standard Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers

As a minimum, groundwater levels should be measured and recorded prior to the daily commencement of drilling activities and upon completion of piezometer installation. Subsequent monitoring is at the discretion of the geotechnical designer. Prior to constructing an open standpipe piezometer or vibrating wire piezometer, the boring should be thoroughly purged of drill fluids using clean, potable water. The geotechnical designer should provide the depth to the vibrating wire piezometer or provide design input on the construction of the open-standpipe piezometer, specifically regarding the screened interval and seals. Following completion of the open-standpipe piezometer, it should be repeatedly surged or bailed to develop the well screen and optimize hydraulic connectivity within the formation.

Drilling Fluids

During drilling operations, it is typically preferable to contain and recirculate the drilling fluids as they return to the ground surface. This eliminates the need to haul additional water for drilling and it contains fine sediments to the drilling site for proper disposal. It should be noted that in some cases the ground is so pervious that no drill fluid returns to the surface and recirculation drill fluids is not possible. The drill water flows into the subsurface boulders, cobbles and gravels and does not return to the surface.

When recirculation occurs in less pervious subsurface materials, a couple techniques are generally used. When there are less fine sediments in the return water, the drill fluids are captured in a tub long enough to drop the sediments and then the water is siphoned off of the top of the tub and reused for drilling. When fines are prevalent in the subsurface materials, a baffled tub that allows the captured returning drill fluid to work its way through a series of baffled weirs to drop sediments and clean the returning drill fluids is utilized. As illustrated in Figure 6, the processed drill fluid return water at the end of the baffled tub can be reused for the drilling process.

At the end of the drilling process for each location, the remaining drill fluids are typically, slowly poured out over the ground in an upland area at least 150 feet from a waterway. The remaining sediment (drill cuttings) is placed back in the drill hole or is hauled off-site and disposed of by State requirements. Acceptable drill cutting disposal varies from State to State.

If drill fluid is discharging directly into a waterway, the water must be treated to less than 5 NTU, or it must be hauled off-site and disposed of.

Figure 6. Use of a baffled tub to contain returning drill fluids laden with sediment during the drilling process.

Typical Borehole Completion Work

When the boring is completed, it is backfilled with bentonite. If instrumentation is installed, a flush mount monument will be cemented in place for borings that are in asphalt or concrete, or require a flush surface. For borings that are off the road, a stand up monument is cemented in place with a two foot above ground stick up. As discussed above, the drill cuttings will be backfilled in the drill hole or transferred into sealed drums and disposed of off-site accordingly. After moving off the drill site, the area will be reclaimed to original condition, and if required seed and weed free certified straw will be spread when specified.

TYPICAL DRILLING EQUIPMENT NOISE LEVELS

Noise measurements have been collected on WFL contracted drilling equipment at the Ridgefield National Wildlife Refuge site in southwest Washington during drilling efforts in January 2014. The results are provided in the table below.

DATE	LOCATION	Equipment	Sound Level (dB)	Distance from Equip. (ft)	Weather	Notes	Vegetation
1/8/2014	Ridgefield River S Bridge Replacement	CME 850 Track-Mounted Drill Rig	70-75	50	overcast, 40s F	B&C setting, drilling with HW casing advancer in dense gravels	grass field, no trees
1/8/2014	Ridgefield River S Bridge Replacement	CME 850 Track Mounted Drill Rig	80-85	50	overcast, 40s F	B setting, penetration test w/2.5" SS, N=59, dense gravels	grass field, no trees
1/8/2014	Ridgefield River S Bridge Replacement	CME 850 Track-Mounted Drill Rig	78-83	50	overcast, 40s F	A/OSHA setting, SPT test, N=21	grass field, no trees

While WFL has taken noise level measurements, it is important to note that equipment and their respective operation noise levels measured at the Central Artery/Tunnel (CA/T) Project are listed in the table below. This information was published in the October 2009 Road Construction Noise Model User’s Guide. Typical drilling equipment is highlighted in yellow.

For each generic type of equipment listed in Table 1, the following information is provided:

- an indication as to whether or not the equipment is an impact device;

Table 1. CA/T equipment noise emissions and acoustical usage factors database.

CA/T Noise Emission Reference Levels and Usage Factors					
filename: EQUIPLST.xls					
revised: 7/26/05		Acoustical	Spec 721.560	Actual Measured	No. of Actual
	Impact	Use Factor	Lmax @ 50ft	Lmax @ 50ft	Data Samples
Equipment Description	Device ?	(%)	(dBA, slow)	(dBA, slow)	(Count)
				(samples averaged)	
All Other Equipment > 5 HP	No	50	85	-- N/A --	0
Auger Drill Rig	No	20	85	84	36
Backhoe	No	40	80	78	372
Bar Bender	No	20	80	-- N/A --	0
Blasting	Yes	-- N/A --	94	-- N/A --	0
Boring Jack Power Unit	No	50	80	83	1
Chain Saw	No	20	85	84	46
Clam Shovel (dropping)	Yes	20	93	87	4
Compactor (ground)	No	20	80	83	57
Compressor (air)	No	40	80	78	18
Concrete Batch Plant	No	15	83	-- N/A --	0
Concrete Mixer Truck	No	40	85	79	40
Concrete Pump Truck	No	20	82	81	30
Concrete Saw	No	20	90	90	55
Crane	No	16	85	81	405
Dozer	No	40	85	82	55
Drill Rig Truck	No	20	84	79	22
Drum Mixer	No	50	80	80	1
Dump Truck	No	40	84	76	31
Excavator	No	40	85	81	170
Flat Bed Truck	No	40	84	74	4
Front End Loader	No	40	80	79	96
Generator	No	50	82	81	19
Generator (<25KVA, VMS signs)	No	50	70	73	74
Gradall	No	40	85	83	70
Grader	No	40	85	-- N/A --	0
Grapple (on backhoe)	No	40	85	87	1
Horizontal Boring Hydr. Jack	No	25	80	82	6
Hydra Break Ram	Yes	10	90	-- N/A --	0
Impact Pile Driver	Yes	20	95	101	11
Jackhammer	Yes	20	85	89	133
Man Lift	No	20	85	75	23
Mounted Impact Hammer (hoe ram)	Yes	20	90	90	212
Pavement Scarafier	No	20	85	90	2
Paver	No	50	85	77	9
Pickup Truck	No	40	55	75	1
Pneumatic Tools	No	50	85	85	90
Pumps	No	50	77	81	17
Refrigerator Unit	No	100	82	73	3
Rivit Buster/chipping gun	Yes	20	85	79	19
Rock Drill	No	20	85	81	3
Roller	No	20	85	80	16
Sand Blasting (Single Nozzle)	No	20	85	96	9
Scraper	No	40	85	84	12
Shears (on backhoe)	No	40	85	96	5
Slurry Plant	No	100	78	78	1
Slurry Trenching Machine	No	50	82	80	75
Soil Mix Drill Rig	No	50	80	-- N/A --	0
Tractor	No	40	84	-- N/A --	0
Vacuum Excavator (Vac-truck)	No	40	85	85	149
Vacuum Street Sweeper	No	10	80	82	19
Ventilation Fan	No	100	85	79	13
Vibrating Hopper	No	50	85	87	1
Vibratory Concrete Mixer	No	20	80	80	1
Vibratory Pile Driver	No	20	95	101	44
Warning Horn	No	5	85	83	12
Welder / Torch	No	40	73	74	5

- the acoustical usage factor to assume for modeling purposes;
- the specification "Spec" limit for each piece of equipment expressed as an Lmax level in dBA "slow" at a reference distance of 50 feet for each piece of equipment based on hundreds of emission measurements performed on CA/T work sites; and
- the number of samples that were averaged together to compute the "Actual" emission level.