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Please contact Tony Allen at 360-705-5450 or allent@wsdot.wa.gov with comments, questions, or suggestions for improvement to the manual.

For updating printed manuals, page numbers indicating portions of the manual that are to be removed and replaced are shown below.

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Signature

Washington State
Department of Transportation

Geotechnical Design Manual

M 46-03.11

May 2015

Environmental and Regional Operations
Construction Division
Geotechnical Office

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Chapter 3 Field Investigation

3.1 Overview

This chapter addresses subsurface investigation that includes drilling and excavation of test pits as part of a geotechnical field investigation. It is organized by activities and policies involved prior to, during, and after exploration. Also addressed, through appendices included with this chapter, are best management practices for erosion and spill prevention during geotechnical field investigations, as well as other potential impacts to the natural environment in the vicinity of the geotechnical investigation site (Appendices 3-C and 3-D), and the handling, and disposing of, contaminated and potentially contaminated materials/samples obtained during the geotechnical field investigation (Appendices 3-E and 3-F).

3.2 Activities and Policies – Before Exploration

A geotechnical field exploration plan should be formulated as described in Chapter 2. The geotechnical designer assigned to the project is responsible to coordinate with the Region or Washington State Ferries (WSF) Project Office (project Office) to prepare the way for the field exploration crews to implement the field exploration program. The geotechnical designer also functions as the primary liaison between the region or WSF and the Field Exploration Manager (FEM), to keep the FEM informed as the region or WSF completes the necessary preparations to begin implementation of the field exploration plan.

Specifically, the geotechnical designer should do the following before submitting the final field exploration request to the FEM:

1. Make sure senior Geotechnical Division management agrees with the proposed exploration plan (see Section 1.4).
2. Make sure that the project office has provided adequate site data to locate test holes and key project features on paper and in the field.
3. Make sure that the project office has asked for (preferably obtained) an environmental assessment of the site to determine whether or not there is potential to encounter hazardous subsurface materials. The geotechnical designer is responsible to have a basic knowledge of previous site use as well.
4. Make sure that the project office has asked for (preferably obtained) an archeological assessment of the site to determine if there is potential to encounter Native American or other artifacts.
5. Coordinate with the project office to make sure any right-of-entry's needed are obtained for the proposed drilling.
6. Coordinate with the project office to make sure the necessary permits are obtained (especially with regard to wetlands and other environmentally sensitive areas).
7. Coordinate with the Field Exploration Supervisor (FES) who will be assigned to the project, and the project office, to conduct a joint field review to evaluate access and other issues related to setting up and finalizing the field exploration program.

8. Act as the liaison between the Field Exploration Manager (FEM) and the project office to make sure the FEM knows when all the tasks have been completed and to inform the FEM of the results so that the exploration program can be properly estimated.

Note that to obtain permits and right-of-entry, a preliminary field exploration plan will likely be needed by the region (or WSF) before the final exploration plan is completed and turned in. Therefore, the development of the field exploration plan may require a somewhat iterative process. Once enough field exploration plan details have been developed, the geotechnical designer should request that those who will be directly negotiating with local owners to obtain right-of entry (if needed) invite the FEM or FES to assist in those negotiations. This generally makes the negotiations go much smoother.

If the geotechnical designer recognizes, either through an environmental assessment or through general knowledge of the previous site use, that there is a potential to encounter hazardous materials during the geotechnical field exploration, it is important that the geotechnical designer make the FEM aware of this as soon as possible in the development of the exploration plan. This will enable the FEM to be prepared to meet the requirements as specified in Appendices 3-C and 3-D, as well as to initiate procedures provided in Appendices 3-E and 3-F. The potential to encounter hazardous subsurface materials can completely change the approach, cost, and scheduling for the site exploration activities.

A preliminary field exploration plan is also needed for use as the basis for conducting the joint field review mentioned above. This field review should be used to determine how each individual exploration site will be accessed, the type of drill equipment best suited for the site, areas for utility locates, required traffic control, and to identify any permit, right-of-entry, and environmental issues. Adjustments to the specific locations of exploration points can be made as needed during the field review to address the above issues.

During the field review, the FES will stake the borings if they have not already been located and if right-of-entry (if needed) has been obtained. The FES should also assess the traffic control needs for the exploration work at this time. The FES will coordinate directly with the Maintenance Office for traffic control. After staking borings, the FES is responsible for calling all utility locates a minimum of 48 hours prior to the start of explorations.

Once the final field exploration plan has been completed, the FEM will provide a cost estimate to the geotechnical designer to complete the field exploration plan. Once the expenditure for the field exploration has been authorized, the geotechnical designer must then notify the FEM to commence with the field exploration. Once the exploration plan has been executed, any subsequent requests to modify the plan should be provided in writing by the geotechnical designer to the FES. The FES will respond with an updated estimate and schedule for requested plan change.

If the geotechnical design is to be conducted by a geotechnical consultant, the WSDOT geotechnical designer who is overseeing the consultant task assignment or agreement is responsible to make sure that the consultant accomplishes the tasks described above and to assist in the coordination between the consultant and the

FEM. If the consultant needs changes to the field exploration plan, the geotechnical designer is responsible to provide input to the FES or FEM as to the acceptability of the changes. The FES or FEM is not to act on the requested changes to the field exploration plan without input from the geotechnical designer.

While the geotechnical designer is responsible to coordinate between the project office and the FEM or FES regarding permits, the project office is ultimately responsible to perform or provide right-of-entry, hazardous materials assessment and archeological evaluation for the site, and to provide adequate site data to locate the exploration points for exploration plan development and for location in the field.

Currently, WSDOT has a five-year blanket Hydraulic Project Approval (HPA) for both marine and fresh waters statewide. Once again the FEM or FES should be involved early in the process to define all technical questions for each project. For all barge projects, the drilling shall be in compliance with the provisions described in the general HPA from the Washington Department of Fish and Wildlife (WDF&WL).

The FEM (or as delegated to a FES) will assign the project to a drill inspector(s) and a drill crew. The drill inspector will then initiate a meeting with the geotechnical designer to discuss the objectives and any particulars of the exploration plan. Either the FES or the drill inspector should notify the geotechnical designer of the anticipated start date of the requested work.

3.3 Activities and Policies – During Exploration

The drill inspector will maintain regular contact with the geotechnical designer, especially when unanticipated conditions or difficulties are encountered, significant schedule delays are anticipated, and prior to terminating the exploration and installing instrumentation. The driller is required to complete a daily drill report at the end of each workday. This is also required of any contract driller working for WSDOT. The drilling inspector is also required to complete a daily inspector's report at the end of each workday. At the completion of each workweek these reports shall be turned in to the FES and put in the project file. Examples for both the daily drill and inspector reports that show the minimum required documentation are included in Appendix 3-A.

Exploration activities during drilling must adhere to the Geotechnical Office's Best Management Practices to mitigate for sediment/erosion control and spill prevention (see Appendix 3-C).

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

Hollow-stem augers are not to be used for assessment of liquefaction potential; wet rotary methods should be used. Further, care must be exercised during drilling with hollow-stem augers to mitigate for heave and loosening of saturated, liquefiable soils.

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

In addition to the methods described above for sampling for soft, fine-grained sediments, WSDOT utilizes a thick-walled sampler referred to as the Washington undisturbed sampler. This sampler is lined with 2-inch (I.D.) extrudible brass tubes. The sampler is intended for stiffer fine-grained deposits than what would be suitable for Shelby tubes.

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 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
- D5778-95(2000) Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils

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

Additional information on ground water investigation and monitoring is provided in Mayne, et al. (2002).

As a minimum, groundwater levels should be measured/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 a piezometer, the boring should be thoroughly purged of drill fluids using clean, potable water. The geotechnical designer should provide design input on the construction of the piezometer, specifically regarding the screened interval and seals. Piezometers shall be constructed in accordance with Washington Department of Ecology (DOE) regulations (RCW 18.104 /WAC 173.160) governing water wells. Following completion of the piezometer, the piezometer should be repeatedly surged or bailed to develop the well screen and optimize hydraulic connectivity with the formation. Furthermore, the piezometer should be sealed within the aquifer of interest, not hydraulically linking multiple aquifers.

Slope inclinometers are routinely employed for slope stability investigations. The installation and monitoring of slope inclinometers should be in accordance with the following ASTM Standard:

- D6230-98 Standard Test Method for Monitoring Ground Movement Using Probe-Type Inclinometers

Explorations using hand equipment such as augers and drive probes may also be useful for some geotechnical investigations, such as to define lateral and vertical extent of soft/loose, near-surface deposits. The WSDOT portable penetrometer consists of 1.75 inch diameter rod which tapers to a rounded 0.5 inch tip over a 4.5 inch length, and which is driven in the ground with a 35 lb weight dropped from a 25.5 inch height. Detailed procedures for portable penetrometer testing are provided in Appendix 3-B. Standard Penetration Test correlations for the WSDOT portable penetrometer (PP) are approximated as follows:

Soil Type	SPT Correlation
Clay	# PP blows/4
Silt	# PP blows/3
Sand/Gravel	# PP blows/2

The excavation of test pits can provide valuable subsurface information not determinable or well characterized by test borings. Extreme care should be exercised around open excavations, and access within them should adhere to Washington Administrative Code (WAC) sections 296-155-655 and 296-155-657.Prior to de-mobilizing, the drill inspector should ensure location information (e.g., station, offset, elevation and/or state plane coordinates) of all the explorations are recorded on the field logs. If exact location information is unavailable upon completion of field activities, a sketch of each exploration location should be made indicating relationship to observable features (i.e., bridge/structure, mile post, etc.). This information should be provided with the field logs to the geotechnical designer. In addition to providing field logs for all explorations, required documentation for test pits should include a scale drawing of the excavation and photographs of the excavated faces. Sampling methods and in situ measurement devices such as pocket penetrometers should also be documented. Detailed requirements for boring logs are provided in Chapter 4.

3.4 Activities and Policies – After Exploration

Upon completion of subsurface explorations, a finished log for each exploration is to be sent to the Department of Ecology (DOE) by the FES. In addition to subsurface conditions encountered, the log must include location (address, county, and ¼ - ¼ Section/Township/Range) and installation information (well #, type of instrumentation, seals, and screened interval).

Unless otherwise requested by the geotechnical designer, all explorations and resource protection wells (piezometers and inclinometers) shall be properly decommissioned prior to construction as per DOE requirements (WAC 173-160-381,500 and RCW 18.104.048). The construction Project Engineer is responsible for notifying the FEM at least 72 hours prior to required time for decommissioning.

Upon completion, the drilling inspector shall transmit recovered samples to the State Materials Lab and provide both the original copy of the field notes and a finished log for all explorations to the geotechnical designer. If the samples to be transmitted to the lab are known to be contaminated or are potentially contaminated, the procedures provided in Appendices 3-E and 3-F shall be followed.

3.5 Standard Penetration Test (SPT) Calibration

Calibration to determine specific hammer system efficiencies shall be developed in general accordance with ASTM D4633 for dynamic analysis of driven piles or other accepted procedure. Measured hammer efficiencies for WSDOT drilling equipment are summarized at a link found at the following web address: www.wsdot.wa.gov/biz/mats/Geotech/default.htm.

3.6 References

Mayne, P. W., Christopher, B.R., and DeJong, J., 2002, *Subsurface Investigations – Geotechnical Site Characterization*, Publication No. FHWA NHI-01-031, National Highway Institute, Federal Highway Administration, Washington, DC, 300 pp.

Appendix 3-E Geotechnical Field Investigation and Contaminated Drilling Waste Management Procedures

Requirements for handling, storage, and disposal of hazardous materials encountered during geotechnical drilling are provided at the following website:
www.wsdot.wa.gov/environment/technical/disciplines/hazardous-materials/investigation-sampling-document#Geotechnical

Appendix 3-F State Materials Laboratory Sample-Handling Policy for Contaminated and Potentially Contaminated Samples

On a project level, if any contaminated sites are brought to the attention of the Geotechnical Project Manager (GPM), he/she shall immediately notify and forward all contaminant information to the Structural Materials Testing Engineer (SMTE) of the State Materials Laboratory (SML) and the Field Exploration Manager (FEM). Similarly, if the FEM, FE Supervisor, or FE crew is made aware of or suspects the presence of contaminants on a project, they shall immediately notify the GPM and the SMTE. This information shall include the project number, project name, location, boring (if applicable), and the types and scale of the contamination.

The SMTE shall pass this information to the SML geotechnical lab employees. Three situations are anticipated with regard to contaminated or potentially contaminated samples. The sample handling and disposal protocol applicable to the situation shall be followed. These situations, and the protocols associated with those situations, are described in the sections that follow.

Situation 1: Contaminated Soils Encountered in the Field
Soils (or rock) encountered in the field known or suspected to be contaminated shall not be submitted to the lab for standard sample processing and testing. In the event suspected or known contaminated soils/rock are encountered in the field, the following protocol shall be followed:

1. The FE crew shall immediately stop drilling/sampling operations and call the FEM, Supervisor and GPM for direction.
2. The FEM and/or GPM shall then contact the Environmental Services Office (ESO) for direction.
3. Utilizing appropriate PPE, any samples suspected or known to be contaminated shall be marked as contaminated and placed in the contaminated holding area or drum, as directed by the ESO. Labeling should be in the form of a single (~4") strip of black and yellow striped tape and be placed on all samples (across the baggie, or over the cap of a Shelby tube). All drill cuttings and fluids from the boring shall also be placed in sealed drums. All samples from a suspected contaminated boring should be kept together until they have been cleared for testing.
4. If the ESO determines that a suitable secure and offsite storage area is not available or not necessary, they may direct the suspected/known contaminated materials to be transported to the SML for disposal characterization. The FEM or GPM shall then notify the SMTE that suspected/known contaminated samples are being transported to the SML.

5. The FEM shall establish a secure area outside of the main SML building, where the FE crew shall place the samples while they await disposal characterization by the ESO. The FEM shall then notify the ESO of the receipt of samples and request their direction on disposition.
6. Once analytical test results have been obtained, the ESO will direct the soil/rock samples and cuttings to be disposed of properly (protocols for what this entails shall be provided by the ESO) or make them available for geotechnical testing if contamination test(s) indicate they are suitable for geotechnical testing.
7. The samples shall not have geotechnical testing performed on them without being cleared to be tested by the ESO and Safety Office. The ESO/Safety Office shall determine the appropriate safety level for any subsequent testing/handling to be performed by SML employees. It is understood that at this time, only soils/rock not exceeding regulatory cleanup levels, and that have been cleared by the ESO Office, shall be suitable for geotechnical testing to be performed at the SML. Samples not cleared for testing at the SML should not enter the building.
8. Samples cleared for geotechnical testing by the ESO/Safety Office shall be labelled with additional green tape prior to delivery to the SML, indicating that the samples have been cleared for testing but extra precaution should be used. The black and yellow tape shall remain on the samples.

Situation 2: Screened Samples - Known Contaminants Exist in a Boring, but Samples are Screened in the Field and Deemed Safe for Geotechnical Testing

1. All samples from a contaminated boring should be kept together until they have been cleared for testing.
2. Upon direction from the ESO, samples that have been retained at a secure offsite location and confirmed to not exceed regulatory cleanup levels through analytical testing may be transmitted to the SML for geotechnical testing. Prior to transmitting the samples to the SML for geotechnical testing, the ESO shall notify the FEM, who in turn will notify the GPM and SMTE, that the soil samples are marginally contaminated and that they may be safely processed for geotechnical testing using appropriate PPE.
3. All such contaminated samples shall be properly labeled before being taken to the SML.
4. Labeling should be in the form of a single (~4”) strip of green tape placed on all samples (across the baggie, core box, or over the cap of a Shelby tube), indicating that the sample has been cleared for testing but extra precaution should be used.
5. All lab employees handling such marked samples shall use proper PPE and be at a heightened awareness for the possibility of contaminants to exist in these samples.
6. PPE for marginally contaminated materials includes latex/rubber gloves, eye protection, and other equipment or handling methods as deemed necessary by the ESO (which will vary based on the types of contaminants encountered).
7. Once cleared samples have been tested by the SML Soils Lab, at the direction of the GPM they may be disposed of in the same manner as non-contaminated soils.

Situation 3: Unexpected Contaminated Samples Discovered in the SML

If samples inadvertently make it to the SML that are suspected by lab personnel to be contaminated, lab personnel shall immediately secure all samples from the entire boring in an airtight container, label the container as having suspected contaminated samples, and notify the SMTE and the FEM, who shall then contact the ESO for direction.

If any tests have been performed on a sample and contamination is suspected after the fact, the SMTE and FEM should be notified immediately to determine how to proceed. Any equipment that came into contact with the contaminated sample should be identified and addressed (segregated, cleaned) according to ESO recommendations.

Detailing proper disposal for samples determined by ESO to be contaminated and not suitable for geotechnical testing is deemed outside the scope of this protocol. The ESO will convey the disposal requirements to the FEM or, in his absence, the FE Supervisors, and the FE personnel shall follow those disposal procedures accordingly.