VERMONT
VTrans

**Materials & Research Engineering Instructions** **MREI 11-01**

**Distribution:** Structures, Director PDD, Assistant Director PDD, PDD Section Managers, Chief of Contract Admin., Director Ops., Assistant Director Ops., Consultants

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**Subject:** Geotechnical Guidelines to Standardize VTrans' Subsurface Investigation Process

**Administrative Information:**

**Effective Date:** This Materials & Research Engineering Instruction (MREI) shall be considered effective from the date of approval.

**Superseded MREI:** None

**Disposition of MREI Content:** The content of this MREI will be incorporated into a future VTrans Soils & Foundations Engineering Manual.

## 1.0 Purpose:

The purpose of this MREI is to standardize VTrans' subsurface investigation procedures.

## 2.0 Technical Information:

In general, guidance outlined in FHWA's *GEC No. 5* should be followed. Unless otherwise noted, the procedures to be performed in the field shall be in accordance with the current edition of the *AASHTO Standard Specifications for Transportation Materials and ASTM Standards.*

## 3.0 Overview:

The subsurface investigation typically occurs in the preliminary design phase of an Agency project; however investigations may occur at any stage of design or construction. The scope of the subsurface investigation will vary for each project depending on the type of project, variability of soil conditions, site access, and possible constraints of the projects funding and schedule. Outlined herein is referenced guidance as well as the Agency's common practices for conducting a subsurface investigation.

## 4.0 Procedure:

During the subsurface investigation there should be close communication between the geotechnical engineer or geologist, and the drillers. The following are general guidelines to estimate the scope of the subsurface investigation program depending on the type of project. The geotechnical engineer or geologist may deem it appropriate on individual projects to supplement these general guidelines with additional instruction for investigations.

### 4.1 Geotechnical Services Request Form and Field Work Order

A *Geotechnical Services Request Form* shall be submitted to the VTrans Soils and Foundations Engineer. This request is mainly used to request borings by the Structures, Roadway, Rail or Pavement Management Sections, as well as consultant designers. A *Field Work Order* will then be generated by a Geotechnical Project Engineer for use by the drilling unit. The field work order includes the anticipated layout of the proposed borings, sampling and testing requirements, project contact information, and any special considerations or instructions. Routine communication is expected between the Geotechnical Project Engineer and the Drillers. The Geotechnical Project Engineer shall contact the Agency's Project Manager or Project Design Engineer before the drillers leave the site once the investigation is complete.

### 4.2 Existing Site Information

Knowledge gained about the subsurface conditions before performing an investigation can be very useful. The Agency uses several resources, both in-house developed and from the internet. The following resources shall be used to investigate any existing subsurface information in the project area.

1. VTrans Subsurface Investigation Boring Map*
2. Agency of Natural Resources Well Locator
3. USDA Web Soil Survey
4. VTrans Record Plans*
5. VTrans Route Logs
6. USGS and VGS published and Open File Maps and Reports
7. Agency of Natural Resources Environmental Interest Locator
8. Soils & Foundation Files*
9. Test Boring data, Vermont Highway Department – Bridge Department Boring Log Archive (Available in AOT Geologist office)*

* Available to those outside AOT network upon request

### 4.3 Site Visit

A visit to the site is required by the Geotechnical Project Engineer and the Drilling Supervisor or the Drilling Crew Chief. Some features to note and document with photographs while on the site visit are as follows:

1. Verify boring locations (have they been staked?)
2. Limits of a future survey (if not already completed) - noting location of existing benchmarks
3. Drill rig and water accessibility (property owner permissions, specialty equipment necessities)
4. Potential safety and health hazards (overhead power, etc.)
5. Existing instrumentation (e.g., monitoring wells or inclinometers)
6. Visible and potential utilities or past DigSafe markings
7. Surficial soil conditions ( e.g., boulders, bedrock outcrops
8. Surface water conditions (presence of cobbles/boulders, etc.)
9. Temporary or permanent traffic control requirements
10. Dig Safe Limits
11. Visual indicators of environmental or cultural resources

## 4.4 Safety Prior to Drilling

A Dig Safe clearance permit shall be obtained before the investigation program commences. The permit number, date, and utilities on site shall be documented and kept in the Soils and Foundations project folder. Additional utilities (sewer, water, non-DigSafe member utilities) may need to be contacted and met with by the Drilling Supervisor. If the proposed boring is on private land, the landowners must be contacted and asked for permission prior to drilling and should be asked to identify any underground utilities, septic or other known obstructions. The safety of the site must be assessed by the Drillers and the Geotechnical Project Engineer at the start of the project. The Drillers are responsible for re-assessing the safety of the site each day prior to drilling, especially if near an unstable slope.

Traffic control is the responsibility of the Drilling Supervisor and/or the drillers to determine when it is necessary, and to organize with the VTrans District personnel or at times with non-agency traffic control companies to schedule assistance when needed. Due to changing traffic and weather conditions, the Drillers are responsible for re-assessing and maintaining the safety of the traffic control operations. Considerations must always be taken to ensure the safety of the drill crew.

### 4.4.1 Hazardous Materials

a. The Geotechnical Project Engineer should investigate the site for potential environmental hazards prior to the site visit. The Agency of Natural Resources *Environmental Interest Locator* should be utilized in this effort.

b. Field personnel should always be on the alert for any deposits of material or for sites that could be potentially hazardous. These deposits or sites might show any of the following:

   1. Soil discoloration
   2. Liquid breakouts

3. Odors
4. Abnormalities in vegetation
5. Dead animals or vegetation

c. Upon encountering an area that appears to contain hazardous materials, crews shall immediately halt all drilling in the affected area and call the Soils and Foundations Engineer. If the Soils and Foundations Engineer is not available, contact should be made to any management personnel in the Materials and Research Lab.

d. In the event of a spill of more than 1 gallon of hazardous material or if a hazardous substance reaches a waterway, take all reasonable measures to contain the spill. Immediately after those actions, the field personnel shall call the Soils and Foundation Engineer and report the following information:
   1. Size of spill in gallons, area, and extent
   2. Location of the spill
   3. Time spill occurred
   4. Nature of the spill
   5. Actions taken

e. Upon receiving information from the field personnel, the Soils and Foundations Engineer shall contact the Hazardous Material and Waste Coordinator at 828-2797 or the VTrans Safety Coordinator at 828-2585 or other appropriate authorities.

## 4.5 Boring Locations

Each boring should be located either by survey or the Agency's Global Positioning System (GPS) unit. The method of locating the borings should be identified on the field work order. The station and offset from centerline of road, northing and easting coordinates or other necessary ties should be acquired in the field and recorded on the boring log. A minimum of three ties is required. Ties should be measured from features that have a high probability of remaining in-place and undisturbed. Ground surface elevations for all borings shall be recorded using a project appropriate datum. This requirement may be waived for paving projects. Ground surface elevations should be obtained prior to completion of drilling activities.

## 4.6 Subsurface Investigations

Refer to *GEC No. 5* Table 3 for guidance on minimum number of borings (investigation points) and depths. This table covers retaining walls, embankment foundations, cut slopes, and shallow and deep foundations. The depth of borings will differ depending on whether a shallow or deep foundation is expected. However, the foundation type is often not known at the time of drilling. Therefore, it is important that borings be deep enough to evaluate both types of foundations. Below are common practices utilized by the Agency to supplement *GEC No. 5* Table 3. This table, as well as the guidelines below is to be used as a starting point; the final subsurface

investigation program shall be adjusted based on predicted and actual variability of the subsurface conditions.

### 4.6.1 Bridge Subsurface Investigations

a. For a single span bridge, perform a minimum of one boring on opposite corners of the bridge (two total).
b. For a multiple span bridge, perform at least one boring per substructure. If the foundation is known to be drilled shaft, perform one boring at each shaft location.
c. If a wingwall has a length greater than 20 feet, perform an additional boring along the wall away from the abutment.
d. When bedrock is encountered within 15 feet of bottom of footing elevation, perform additional borings along the abutment to determine the bedrock profile.
e. Any additions or changes to the boring plan as provided by the Project Manager must be discussed with the Project Manager or the Project Design Engineer.
f. Borings generally should be drilled 10 feet into rock, unless an exception is noted on the field work order.
g. The presence of soft soils may require additional borings similar to part d above.

### 4.6.2 Roadway Subsurface Investigations

a. For realignment roadway projects, refer to the Cut Slopes Section in the *GEC No. 5*, Table No. 3.
b. For reclaiming projects, perform one roadway boring or core every 0.2 miles in alternating lanes. The offset to centerline should vary so that the borings are performed in the center of the lane, at the extreme edges of the travel lane, and in the wheel path. To increase efficiency, core pavement first, followed by rotary drilling with a five (5) foot solid stem auger flight, which should be advanced in one continuous corkscrew motion if possible. The strata depths and disturbed samples can be attained from the auger flight as it is pulled straight up out of the ground without rotating. It may be necessary to scrape the outer half inch of material off the auger flights to see behind the material that has been smeared when pulling the auger out of the ground.
c. For reclaiming projects that include roadway widening, perform a roadway boring or core on alternating shoulders of the road every 0.2 miles in addition to the borings in the lanes. Therefore there will be a boring every 0.1 miles either in the road or the shoulder.
d. If the soils are highly variable, additional borings should be performed to characterize the variation.
e. When bedrock or unsuitable soils are present, perform additional borings to gauge the horizontal and vertical extent.

### 4.6.3 Slope Stability Subsurface Investigations

a. As a minimum, a boring should be performed at the top and bottom of the slope safely near the deformed or failed slope, and if possible, a boring performed in the middle of the slide area (TRB, Landslides).
b. For slides longer than 50 feet additional borings should be spaced at an interval ranging between 50 and 100 feet along a line perpendicular to the direction of the slide movement.
c. For large areas of potential slide movement, a grid of borings should be placed within the suspected area to delineate the landslide. The grid spacing shall depend on the area of interest, but as a rule of thumb, the area to be studied should be two to three times wider or longer than the area suspected [6].
d. Typically, instrumentation such as monitoring wells and inclinometers will be installed in one or more of the borings as determined by the Geotechnical Project Engineer.

### 4.6.4 Culvert Subsurface Investigations

a. For an exploration of suspected voids, perform roadway borings or cores in approximate locations of visual pavement deformation. See Section 4.6.6 for alternatives available for investigation using non destructive test methods.
b. For explorations conducted for projects involving pipe-jacking, pipe ramming and other trenchless technologies, a minimum of two borings should be drilled one at the outlet and inlet of each pipe. Borings should be performed at a maximum spacing of fifty (50) feet along the alignment of the pipe. The depth of the borings should reach a minimum of ten (10) feet below the proposed culvert elevation. Variable conditions may warrant additional borings.

### 4.6.5 Mast Arm/Sign Support Subsurface Explorations

a. Perform one boring per foundation element.
b. Borings should be advanced and samples taken as outlined in MREI 10-01, *Geotechnical Design Procedures for Mast Arm and Overhead Sign Support Foundations*.

### 4.6.6 Characterization of Voids and Subsidence Subsurface Explorations

a. There are several geophysical and nondestructive tests that can be performed to supplement subsurface borings, test pits, and hand steel soundings. These tests offer accurate and timely information and are always ground proofed with borings. FHWA's *Application of Geophysical Methods to Highway Related Problems* provides a broad range of practical methods, including almost all traditional geophysical methods.

b. Refer to Application of Geophysical Methods to Highway Related Problems *Chapter 5* for information regarding roadway subsidence and methods used to map voids, sinkholes, and other cavities.
c. Refer to Application of Geophysical Methods to Highway Related Problems *Chapter 6* for information regarding site characterization, including the use of subsurface geophysical mapping to determine of depth of bedrock, find weak zones within bedrock, map lithology, shallow sand and gravel deposits, and groundwater surface and flow.

## 4.7 Boring Methods

Refer to *GEC No. 5* Table 5(a) for information regarding various boring procedures, applications and limitations. Descriptions of each type of boring can be found in the above reference also. VTrans subsurface drill rigs are capable of wash bore, hollow stem, solid stem auger drilling and pavement coring.

### 4.7.1 Hand Steel Soundings

Hand steel soundings shall be performed if the surficial soils are easily penetrable and where a shallow depth to boulders or bedrock is anticipated. Refer to AASHTO's 1988 Manual on Subsurface Investigation, Section 7.5.3.1 for further information regarding exploratory probing.

### 4.7.2 Test Pits

Test pits may be performed when full-depth shallow bedrock or surficial subsurface information is desired. Test pits are typically excavated using conventional construction equipment and allow for the visual observation and recording of shallow soil or bedrock layers. Test pits are often performed where sampling is difficult to allow for hand samples to be extracted from the test pit floor or walls.

A competent person is required to be on-site at all times. Classification of the trench or test pit soils in accordance with the OSHA manual is to be performed prior to entering the pit. All personnel shall adhere to the trench safety guidelines specified in Section V, Chapter 2 of the *OSHA Technical Manual*, *Excavations: Hazard Recognition in Trenching and Shoring.*

## 4.8 Sampling Methods

Sampling methods should be performed according to *GEC No. 5*, Chapter 4. The Agency's common practice is to perform continuous Standard Penetration Testing (SPT) and sampling to twenty five (25) feet followed by SPT interval sampling of 5 feet for the first boring of the investigation. Additional borings after that are performed with SPT testing and sampling at five (5) foot intervals for the full depth of the boring. The sampling method and frequency should be determined by the Geotechnical Project Engineer and included on the field work order.

1. Standard Penetration Tests (SPTs) shall be performed according to *AASHTO T 206*. A 2-inch (OD) diameter split barrel sampler shall be used unless the Drilling Supervisor determines that it is necessary to use the 3-inch sampling barrel. The use of the larger sample barrel often occurs where large gravel deposits exist.
2. Prior to sampling, the disturbed materials at the bottom of the hole shall be removed, so that the split spoon is driven through the underlying undisturbed material.
3. During SPT testing, the sampler must be driven with a 140 lb hammer, and the number of blows must be counted for each 6-inch increment until one of the following occurs:
    a. A total of 50 blows have been applied during any one of the 6-inch drive increments.
    b. A total of 100 blows have been applied.
    c. There is no observed advance of the sampler during 25 consecutive blows of the hammer.
    d. The sampler is advanced the complete 24 inches.
4. Material must be collected from each split-spoon sampler. Multiple samples shall be collected per split-barrel if a change in material exists. All the material from the split spoon sampler shall be put in an airtight durable plastic bag and a VTrans sample tag shall be filled out and attached to the bag. As a minimum the following information shall be included on the tag:
    a. Project name & number
    b. Borehole number
    c. Station and offset
    d. Depth of sample
    e. Sample description
    f. Method sampled
    g. Date sampled
5. An SPT test is considered acceptable if the amount of material recovered in the split-barrel sampler measures at least 25 percent of the driven distance. Undisturbed, or Shelby tube samples, are considered acceptable if at least 75 percent of the sample depth has been recovered. Sampling should be attempted directly below any unacceptable recoveries.
6. When cohesive soils are encountered, undisturbed samples shall be obtained by either a 3-inch diameter Shelby tube or a stationary piston tube sampler in accordance with *AASHTO T 207.* Post extraction, tubes shall be filled with micro-crystalline wax, and then sealed with a cap and electrical tape. An approved alternative to using wax is the use of heat shrink to seal the ends of the tube followed by electric tape. A VTrans sample card shall be filled out and attached to the tube with tape. The top of the tube must be identified on the tube. See *GEC No. 5*, Table 7 for detailed information on various undisturbed sampling methods.
7. The most common in-situ test performed by the Agency in cohesive soils is the Vane Shear Test (VST), which shall be performed according to

*AASHTO T 223*. This test is performed to measure the undrained shear strength. It is sometimes alternated with Shelby tubes if desired by the Geotechnical Project Engineer. A split spoon sampler can be driven through material tested to obtain a sample for laboratory testing post vane shear testing.

**8.** Cone penetrometer testing is a viable option of investigation to attain fast and reliable soil information as well as shear wave velocities if a seismic analysis is needed. CPT testing shall be performed in accordance with *ASTM D5778*, and the penetrometer used shall be capable of registering pore water pressure induced during the CPT test.

**9.** When bedrock is encountered, a 10-foot core into sound bedrock should be obtained, at a minimum, to insure that it is bedrock and not a boulder. Coring shall be performed according to *AASHTO T 225*. When soft or broken bedrock overlies sound bedrock, coring operations shall proceed through soft or broken bedrock into sound bedrock. The Geologist should be consulted in these instances so as to determine the maximum drill depth for the hole. NX size cores must be taken when there is a need for testing the bedrock when the bedrock will be used to support a drilled shaft or micro-pile foundation. BX size cores are acceptable for those conditions when the bedrock will only be classified. Refer to *GEC No. 5*, Table 5(b) for rock coring methods.

**10.** The ground water level observed within each borehole should be recorded when first encountered, and at the end of each day after the water level stabilizes. Water levels shall be measured to an accuracy of 0.10 feet. When drilling mud is used during boring operations, the drill hole shall be thoroughly flushed with clean water on completion of drilling to allow observation of the ground water level.

**11.** Unless serving as an observation well, each borehole should be backfilled or grouted. When grouting is required, it shall be completed according to *NCHRP Report 378*, *Recommended Guidelines for Sealing Geotechnical Exploratory Holes*.

## 4.9 Sample Disposition

Soil samples should be collected and stored in durable air tight bags as to maintain the in-situ moisture content. Samples should be transported to the VTrans' Soils Laboratory in Berlin, VT. Tube samples shall be transported to the lab within 3 days of sampling in an upright position and protected from vibration, shock, and extreme temperatures. The *VTrans Laboratory Test Request Form* must be filled out when the samples are deposited at the lab. Rock core samples shall be collected and stored in core boxes consistent with procedures detailed in AASHTO's 1988 *Manual on Subsurface Investigation*, Section 7.9.3.

## 4.10 Field Log Recording

VTrans or other consultant drillers are responsible for keeping a legible field log during drilling operations. Information recorded during drilling, at a minimum, should be as follows:

1. Title of project, boring number, location of site by name
2. Date of starting and completing each boring, personnel names, drill rig and casing information, boring station, offset, and elevation.
3. Hammer correction factor to account for the efficiency of the hammer on the drill rig, if known.
4. Weight, fall-height, and type of hammer used.
5. Record of sample depths and recoveries.
6. Number of blows of sampling hammer required to drive sampling device a total of twenty-four (24) inches, recorded as four (4) 6-inch increments. Refusal shall be defined as in Section 4.7. Record the number of blows and actual distance driven if refusal is encountered during the sampling interval, (e.g., 100 @ 11”).
7. Description of material in each sample based upon visual examination, including material type, color, moisture, etc.
8. Water level observations; a minimum of once daily. If possible, leave hole open for an extended period of time to record stabilized water level.
9. All observations during drilling should be recorded on the field log. If cobbles/boulders are encountered and cored through, record depth and extent of layer. Record all types of equipment used on the field log and at what depths.
10. For rock cores, record number of runs, rate of drilling, and drilling breaks encountered. Place cores in wooden core box and assemble core the way it was extracted from the ground. Wooden blocks shall be placed in the box to show the length of core not recovered and to separate individual runs. Record core recovery and run information on a VTrans rock core tag and staple that directly to the box.
11. Record on the field log if any instrumentation was installed in borehole.
12. Complete VTrans groundwater monitoring well installation log recording size of well material used and all depths (top and bottom of well casing/screen, sand pack, bentonite seal, backfill and grouting). Record ground surface elevation and elevation of top of well PVC.

## 4.11 Instrumentation Installation

Inclinometers and monitoring wells are the two most common types of geotechnical instrumentation the Agency installs. A future MREI entitled Geotechnical Instrumentation will cover this area of the subsurface investigation.

## 5.0 References:


1. AASHTO (2010 Edition) Standard Specifications for Transportation and Methods of Sampling and Testing, 30th Edition, American Association State Highway Transportation Officials, Washington, D.C.

2. AASHTO (1988) Manual on Subsurface Investigations, American Association of State Highway Transportation Officials, Washington, D.C.

3. FHWA (2002a) Geotechnical Engineering Circular No. 5 (GEC5) Evaluation of Soil and Rock Properties. Report No. FHWA-IF-02-034. Authors: Sabatini, P.J., Bachus, R.C., Mayne, P.W., Schneider, J.A., Zettler, T.E., Federal Highway Administration, U.S. Department of Transportation.

4. NCHRP (1995) Recommended Guidelines for Sealing Geotechnical Exploratory Holes, Report 378, National Cooperative Highway Research Program.

5. Vermont Agency of Transportation (2010) MREI 10-01, Geotechnical Design Procedures for Mast Arm and Overhead Sign Support Foundations.

6. TRB (1996) Landslides: Investigation and Mitigation. A. Keith Turner and Robert L. Schuster, eds., Special Report 247, Transportation Research Board, National Research Council, Washington, D.C.

7. FHWA (2004) Application of Geophysical Methods to Highway Related Problems. Publication No. FHWA-IF-04-021. Authors: Wightman, W.E., Jalinoos, F., Sirles, P., Hanna, K., Federal Highway Administration, U.S. Department of Transportation.


## 6.0 Implementation:

The content of this MREI will be implemented immediately for all subsurface investigations performed.

## 7.0 Transmitted/Enclosed Materials:

1. VTrans Geotechnical Services Request Form

2. VTrans Geotechnical Field Work Order

3. VTrans Soil Laboratory Testing Request Form