CONNECTICUT DEPARTMENT OF TRANSPORTATION

GEOTECHNICAL ENGINEERING MANUAL

2005 Edition

Rev. Jan. ‘20

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Introduction

This manual has been prepared for use by in-house staff as well as consulting geotechnical engineers working for the Department. This document provides general guidance for the geotechnical design of transportation facilities for the Connecticut Department of Transportation. This manual provides an overview of the geotechnical design process, from planning through the completed construction of a project.

The manual is intended to be a guide and not a detailed geotechnical engineering text. The geotechnical engineer should use this document to understand our design process, and any special requirements of the Department. This manual contains references to other available texts that will provide guidance on the proper planning and execution of a comprehensive geotechnical investigation.

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Chapter 1

Review of Existing Data and Reconnaissance

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Chapter 1

Review of Existing Data and Reconnaissance

The first step in performing a subsurface investigation is a thorough review of the project requirements. The necessary information that should be provided by the designer to the geotechnical engineer includes the project location, roadway alignment and profile, structure locations, approximate bridge span lengths, substructure locations and estimated scour depths (if applicable). The geotechnical engineer should have access to typical sections, plan and profile sheets, and cross sections. This information allows the geotechnical engineer to properly plan and execute the subsurface exploration program.

1-1 Review of Existing Data

After gaining a thorough understanding of the project requirements, the geotechnical engineer should collect all relevant available information on the project site. Review of this information can aid the geotechnical engineer in understanding the geology, geomorphology, and topography of the area and aid in identifying potential problem areas. Use of this information allows the geotechnical engineer to development a comprehensive, cost-effective subsurface exploration. Existing data may be available from the following sources:

1-1.1 Topographic Maps

Topographic maps are prepared by the U.S. Geological Survey (USGS) and are readily available. These maps portray ground surface elevations, surface water locations, and other physical features. This data is valuable in planning a subsurface exploration, determining accessibility for field equipment and determining potential problem areas.

1-1.2 Aerial Photographs

Aerial photographs are available from the Department and other sources. They are valuable in that they can provide the basis for reconnaissance and, depending on the age of the photographs, show manmade structures, excavations, or fills that affect accessibility and the planned depth of exploration.

1-1.3 Geologic Maps and Reports

Considerable information on the geological conditions of an area can often be obtained from geologic maps and reports. These reports and maps often show the location and relative position of the different geologic strata and provide information on the general characteristics of each strata. Geologic maps and reports can be obtained from the USGS, Department of Environmental Protection-Natural Resources Section, MAGIC web site, and other sources.

1-1.4 Soils Conservation Service Surveys

Soil surveys are compiled by the U.S. Department of Agriculture are presented in the form of county soils maps. These surveys can provide valuable data on surface soils including mineralogical composition, grain size distribution, depth to rock, water table information, drainage characteristics, geologic origin, and presence of organic deposits.

1-1.5 Water Resources Inventory of Connecticut

These reports were prepared by the USGS in cooperation with the Connecticut Water Resources Commission for the major river basins in Connecticut. These reports contain surface water, groundwater information and hydrologic information. The hydrogeologic maps contain location information, which allows for the determination of the principal water-bearing units in the area of interest.

1-1.6 Previous and/or Adjacent Projects

Data may be available on nearby projects from the Department, or county or city governments. The Soils and Foundations Section may have geotechnical reports or data, pile driving records, pile load test data, and/or field data for the project. As-built drawings for completed projects are available at the Engineering Records Office at Pascone Place in Newington. This data is extremely useful in establishing preliminary boring locations and depths and in predicting problem areas. Maintenance records for existing nearby roadways and structures may provide additional insight into the subsurface conditions.

1-1.7 Aggregate Survey Maps

The Department developed these maps in the 1960's to help locate significant deposits of quality aggregate. The maps delineate the location and depth of the deposits along with an estimate of the reserves.

1-2 Field Reconnaissance

Following review of the existing data, the geotechnical engineer should visit the project site. This will enable the engineer to be aware of field conditions and correlate this information with previous data. The form included in the Appendix provides guidance to the geotechnical engineer for the site conditions or features that should be looked for. In particular, the following should be noted during the field reconnaissance:

1. Nearby structures should be inspected to determine their foundation performance and their potential damage due to vibration or settlement during the construction phase of the project.
2. On water crossings, geomorphological features of the watercourse should be noted. These include; streambed composition, scour holes adjacent to and/or near existing structures, evidence of lateral and/or vertical channel instability (e.g. cut banks, sandbars...), existing channel modifications (e.g. riprap channels, revetments...), or other conditions not previously noted.

3. Features that may affect the boring program, such as accessibility, adjacent structures, overhead utilities, signs of buried utilities, or property restrictions.
4. Feature that may assist in the engineering analysis, such as the angle of any existing slopes and the stability of any open excavations or trenches.
5. Drainage features, including signs of seasonal water tables.
6. Features that may need additional borings or probing such as organic/swamp deposits.
7. Exposed bedrock and/or existing rock cuts for type, weathering, jointing, bedding etc.

1-3 References

GEOTECHNICAL ENGINEERING CIRCULAR NO. 5, Evaluation of Soil and Rock Properties, Sabattini, Bachus, Mayne, Schnieder and Zettler, FHWA-IF-02-034, Federal Highway Administration, 2002

Appendix

This Appendix to Chapter 1 provides the following:

Existing Data and Field Reconnaissance Report

Existing Data and Field Reconnaissance Report

Project Number:
Date:
Prepared By:

Existing Information
Existing Project Plans:
Existing Soils and Foundation Project Data:
Environmental Assessment Reports:
Scour Study Reports (if applicable):
Map Data Attached:

- ☐ Topographic
- ☐ Surficial Geology
- ☐ Bedrock Geology
- ☐ Soil Conservation Survey
- ☐ Water Resources (wells or artesian conditions obs.)
- ☐ Other Mapping:

Maintenance History-Local Garage:

- ☐ Rockfall
- ☐ Icing or Frost Heave
- ☐ Drainage and/or Erosion Problems
- ☐ Pavement Distress or Settlement Problems

Bridge Safety Records:
Proposed Project Data:

- ☐ Plan & Profile Sheets
- ☐ Cross Sections
- ☐ Structure Layout

Site Reconnaissance
Date of Site Visit:
Participants:
Weather Conditions:

Date of Visit:
Prior to Visit:

Topography, Site Development and Adjacent Structures:

- ☐ photos attached

Slope Stability & Vegetative Cover:

- ☐ photos attached

Boulder/Bedrock Exposure:

- ☐ photos attached
- ☐ bedrock mapping performed

Existing Subsurface Drainage & Groundwater Observations:

- ☐ photos attached

Pavement Condition:

- ☐ photos attached

Adjacent Structures:

- ☐ photos attached

Large fills/Obstructions or Unsuitable Material Deposits:

- ☐ photos attached

Subsurface Exploration Summary:
Roadway Borings:

Type:
Min. Depth:
Sampling:

- ☐ SPT
- ☐ Undisturbed Piston

Existing Data and Field Reconnaissance Report

- ☐ Other:

Accessibility & Utilities:

- ☐ Special Equipment Required:
- ☐ Overhead or Underground Utility Conflicts:
- ☐ Permitting Requirements/Areas of Concern-EC:
- ☐ Flagging Requirements:

Structure Borings:

Type:

Min. Depth:

Sampling:

- ☐ SPT
- ☐ Undisturbed Piston
- ☐ Other:

Accessibility & Utilities:

- ☐ Special Equipment Required:
- ☐ Overhead or Underground Utility Conflicts:
- ☐ Permitting Requirements/Areas of Environmental Concern:
- ☐ Flagging Requirements:

Sheeting and Temporary Construction Borings:

Groundwater Readings & Observation Wells:

Probes or Soundings Required:

Cost Estimate and Duration: ______

Existing Data and Field Reconnaissance Report

Insert Photo
Insert Photo Commentary
Insert Photo
Insert Photo Commentary

Chapter 2

Subsurface Exploration

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Chapter 2

Subsurface Exploration Techniques

The scope of a subsurface exploration depends on many factors; including, the level of existing information and need for additional information, the variability of subsurface conditions, site accessibility, environmental considerations, and available budget. Once these factors are understood, the details of the subsurface exploration can be developed. The following is a summary of the basic tools and techniques that are used in a subsurface exploration.

2-1 Borings

Borings are probably the most common method of exploration. They can be advanced using a number of methods. Upon completion, all borings should be backfilled in accordance with applicable environmental requirements.
The most common techniques used in Connecticut are:

- Wash Borings
- Auger Borings
- Continuous Sampling

2-1.1 Wash Borings

This method typically involves the advancing of a steel casing and the washing out of the soil material that enters the casing. Either pounding or spinning is used to advance the casing into the ground. Drill rods placed within the casing are used to break up and flush the soil plug which forms within the casing. Water or drilling mud is used to stabilize the hole below the groundwater table. Soil sampling is performed through the casing into the in situ soil through the bottom of the borehole.

2-1.2 Auger Boring

2-1.2.1 Solid Flight Auger Borings

Rotating an auger while simultaneously advancing it into the ground either hydraulically or mechanically advances auger borings. The auger is advanced to the desired depth and then withdrawn without rotation to maintain cutting on the auger flight without mixing. Samples of cuttings can be removed for material identification, however, the depth of the sample can only be approximated. Feedback from the drilling equipment and the cuttings should be monitored closely to identify stratigraphy changes with depth. This method should generally not be used where split barrel samples are required.

2-1.2.2 Hollow-Stem Auger Borings

A hollow-stem auger consists of a continuous flight auger surrounding a hollow drill stem. The hollow-stem auger is advanced similar to other augers; however, removal of the hollow stem auger is not necessary for sampling. Standard Penetration Test (SPT) and undisturbed samples are obtained through the hollow drill stem, which acts like a casing to hold the hole open. Below the groundwater table, blowback may be experienced in granular soils. Drilling mud should be introduced if these conditions are experienced. In cold weather, the use of hollow-stem auger borings may be advantageous because water use may not be necessary.

2-1.3 Continuous Sampling

This method will provide a detailed, continuous column of soil or rock samples. In cohesive soils and dry granular soils continuous sampling without the use of casing may be possible. Should the borehole need to be cleaned between sampling, conventional wash boring techniques will need to be employed. This method is particularly valuable when sampling through highly variable soil stratas.

2-2 Other Exploration Techniques

2-2.1 Test Pits

The simplest methods of inspecting subsurface soils consist of excavations performed by hand or mechanical equipment. Hand excavations are often performed with shovels, pick-axes and/or posthole diggers. They offer the advantages of speed and ready access for sampling. They are limited to shallow excavations above the water table.

2-2.2 Power Soundings

In this method, the drill bit advances by power chopping with a limited amount of water in the borehole. Slurry must be periodically removed. The method is not recommended for general exploration because of the difficulty in determining stratum changes and in obtaining undisturbed samples. In materials not easily penetrated by other methods, such as those containing boulders, this method can be very useful.

2-2.3 Soundings

A sounding is a method of exploration in which either static or dynamic force is used to cause a rod tipped with a testing device to penetrate soils. Samples are not usually obtained. Small diameter groundwater observation wells can be installed in sounding holes that remain open. Typically a sounding is performed by driving a steel bar into the soil with a sledgehammer. The depth of exploration is generally less than ten feet. The depth to rock or an obstruction can easily be inferred from the resistance to penetration.

2-2.4 Bar Probes and Hand Augers

These techniques are generally used in wetland areas to determine the vertical and horizontal limits of soft, organic soil. Bar probes use small diameter steel rods that are advanced by hand. The depth of the organic soil layer is determined when refusal is reached or penetration resistance is greatly increased.

Hand augers are used in soft soils when attempts are made to obtain a disturbed soil sample. The cutter head on a hand auger comes in a variety of sizes and shapes and is typically attached to a t-handled steel rod, which can be extended to allow for explorations of greater depths.

2-3 Soil Sampling

Common methods of sampling during field explorations include those listed below. All samples should be properly preserved and carefully transported for classification and testing. Each sample attempted, regardless of recovery, shall be designated with a name and number and recorded on a field log.
All soil samples shall be visually classified by the engineer. Depending on the complexity of the project and the type of soil encountered, the engineer shall select a representative number samples for laboratory testing. After the completion of the laboratory-testing program, the engineer shall perform a final edit of the field logs. See Section 5 for details on preparation of final edited boring logs.

Soil samples not sent for laboratory testing should be retained through the design process. At the completion of the final design, generally the samples are discarded unless there are compelling reasons to retain them longer.

2-3.1 Bulk Bag Samples

These are disturbed samples obtained from auger cuttings or test pits. The quantity of the sample depends on the type of testing to be performed, but can range up to 50 lb (25 kg) or more. Testing performed on these samples includes classification, moisture-density, Atterburg limits, resilient modulus, etc. A portion of each sample should be placed in a sealed container for moisture content determination.

2-3.2 Split Barrel

These samples are obtained in conjunction with the Standard Penetration Test (SPT). In granular soils, a split barrel sample should be taken at each strata change or at a maximum interval of five feet. Each split barrel sample should be immediately examined, logged and placed in sample jar for storage. The jars used for storage shall be plastic or clear glass of sufficient size to store a four inch long sample of full diameter. Each sample jar shall be marked with the project number, boring number, sample number, depth range and blow counts. If samples are to be preserved for laboratory testing, the top of the jars should be sealed with tape or wax. Samples obtained from a split barrel are considered disturbed and are generally used only for classification and index testing.

2-3.3 Thin-Wall Tube Samples

Thin wall tube samples are taken in cohesive soils and are intended to be undisturbed. Further testing is generally required to assure the undisturbed nature of the sample. The sampling intervals of thin-wall tube samples will vary depending on the complexity of the project and the depth, thickness and variability of the cohesive soil deposit. As a minimum, at least one undisturbed sample should be taken within each distinct soil strata. If the strata is very thick, the maximum sampling interval should be twenty feet.

2-3.3.1 Shelby Tube

This is a thin-walled steel tube, usually 3 inches (O.D.) by 36 inches in length. It is pushed into the soil with a relatively rapid, smooth stroke and then retracted. This produces a relatively undisturbed sample provided the Shelby tube ends are sealed immediately upon withdrawal. This sample is suitable for strength and consolidation tests. This sampling method is unsuitable for hard materials. Refer to ASTM D 1587 (AASHTO T 207).

2-3.3.2 Piston Samplers

Stationary

This sampler has the same standard dimensions as the Shelby Tube. A piston is positioned at the bottom of the thin-wall tube while the sampler is lowered to the bottom of the hole, thus preventing disturbed materials from entering the tube. The piston is locked in place on top of the soil to be sampled. A sample is obtained by pressing the tube into the soil with a continuous, steady thrust. The stationary piston is held fixed on top of the soil while the sampling tube is advanced. This creates suction while the sampling tube is retrieved thus aiding in retention of the sample. This sampler is suitable for soft to firm clays and silts. Samples are generally less disturbed and have a better recovery ratio than those from the Shelby Tube method.

Floating

Similar to the stationary sample method, except that the piston is not fixed in position but is free to ride on the top of the sample. The soils being sampled must have adequate strength to cause the piston to remain at a fixed depth as the sampling tube is pushed downward. If the soil is too weak, the piston will tend to move downward with the tube and a sample will not be obtained. This method should therefore be limited to stiff or hard cohesive materials.

2-4 In Situ Testing

In situ tests provide field measurements that can be used to correlate to soil and rock properties. The Standard Penetration Test is the most common in situ test performed. Less frequently used tests would include the vane shear test, cone penetration test, and pressuremeter test.

2-4.1 Standard Penetration Test

The Standard Penetration test (SPT) (AASHTO T206, ASTM D 1586) is a simple and rugged test suitable for most soil types and should be included as part of any subsurface exploration. The SPT involves driving a split barrel sampler into the ground with a 140# weight, dropped from a height of 24 inches. The uncorrected SPT N value is defined as the sum of the blows required to drive the sampler for the second and third 6 inch increment. The results of the test provide correlations to soil strength and compressibility properties. Variability associated with hammer types used (i.e., donut, safety, automatic) and specific testing errors may result in poor correlations to soil design properties, especially for cohesive soils. The engineer needs to exercise proper judgement in evaluating the results of this test.

2-4.2 Vane Shear Test

The vane shear test (VST) (AASHTO T223, ASTM 2573) involves the rotation of a four bladed vane in cohesive soil to evaluate the sensitivity and peak and remolded undrained shear strength of soft to stiff clays and silts. Different sized vanes, and torque wrenches with varying capacity may be used to adjust to various soil conditions. The results of this test will generally not be consistent with strength tests performed in the laboratory; however, the test results will provide relative strength estimates. With sufficient data, correlations between the VST and laboratory tests may be developed.

2-4.3 Cone Penetration Test

The cone penetration test (CPT) involves the hydraulic push of an instrumented steel probe at constant rate to obtain continuous vertical profiles of stress, pressures, and/or other measurements. No borehole, cuttings, or spoil are produced by this test. Testing is conducted in accordance with ASTM D 5778. The cone penetration test can be conducted without the use of a pore pressure measurement (i.e., CPT) or can be conducted using a device to measure penetration pore pressure using a piezocone (i.e., CPTu). Some equipment includes the ability to measure the propagation of shear waves using a seismic piezocone; this test designated as SCPTu. The test has not been widely used in this state; refer to other texts for additional details.

2-4.4 Pressuremeter Test

The pressuremeter test (PMT) involves inflating a cylindrical probe against the sidewalls of a boring. In general, the instrument is placed in a pre-bored hole prior to expansion, although it is possible to self-bore the instrument to the test location. The pressuremeter can be used to obtain specific strength and deformation properties of various soil types, weathered rock and low to moderate strength intact rock. Menard-type pressuremeter tests are done in accordance with ASTM D4719. The test has not been widely used in this state; refer to other texts for additional details.

2-5 Rock Core Sampling

Rock cores are obtained using core barrels equipped with diamond or tungsten carbide tipped bits. There are three basic types of core barrels: Single tube, double tube, and triple tube. Single tube core barrels generally provide poor recovery and their use should be limited to non-critical applications. Double tube and triple tube core barrels are preferred. If determining rock quality or strength is required, a double tube should be considered the minimum standard.

A double tube core barrel consists of inner and outer tubes equipped with a diamond or tungsten-carbide drill bit. As coring progresses, fluid is introduced downward between the inner and outer tubes to cool the bit and to wash cuttings to the surface. The inner tube protects the core from the highly erosive action of the drilling fluid. In a rigid type core barrel, both the inner and outer tubes rotate. In a swivel type, the inner tube remains stationary while the outer tube rotates. Several series of swivel type core barrels are available. A triple tube core barrel is similar to the double tube, above, but has an additional inner liner, consisting of either a clear plastic solid tube or a thin metal split tube, in which the core is retained. This barrel best preserves fractured and poor quality rock cores.

The minimum core barrel size to be used shall be NX. Larger core barrel sizes should be considered if mechanical breakage or poor core recovery is a concern. The type of drilling bit used should be based on the driller's experience in the bedrock formation anticipated. Core run lengths should be no greater than five feet, except in unusual situations. The drilling rate during rock coring shall be monitored and recorded for each foot of penetration. Rock cores should be photographed upon removal from the borehole. A label that notes the borehole, depth interval and the core run number, should be included in the photograph. A tape measure or ruler should also be included in the photograph for scale.

Rock cores shall be stored in boxes of wood or other durable material, constructed rigidly enough to prevent flexing of the core when the box is picked up by its ends. The boxes shall be provided with hinged covers and with longitudinal spacers that will separate the core into compartments. Small blocks which fit between the spacers shall be provided to mark the beginning and end of each run or pull of core. The top of the first core run shall start at the uppermost left corner of the box [hinge side]. Any break in a core that occurs during handling should be marked with three parallel lines across the mechanical break. An indelible marker shall be used to note the project number, boring number, core run numbers, depth interval, and box # on the top, front, inside lid, and both ends of the core box. The inside lid shall also include a listing of the recovery and rqd for each core run. Each sample attempted, regardless of recovery, shall be designated with a name and number and recorded on a field log.

All rock cores shall be retained through a project's advertise-bid-award process. After this period, a determination will be made whether to retain the rock cores throughout the construction phase. If they are retained, the cores should be discarded 2 years after the date of acceptance of the construction project. Refer to ASTM D 5079 for practices of preserving and transporting rock core samples.

2-6 Geophysical Methods

These are nondestructive exploratory methods in which no samples can be taken. Geophysical methods can provide information on the general subsurface profile, the depth to bedrock, depth to groundwater, peat deposits, subsurface anomalies, or unknown dimensions of existing foundations. Geophysical explorations should be performed by an experienced professional, and preferably accompanied by conventional borings to aid in correlations. Due to the small relative size of equipment, its ability to provide continuous coverage at a fairly rapid rate, geophysical testing is an effective tool for subsurface explorations. Geophysical methods commonly used for engineering purposes include:

2-6.1 Seismic Refraction and Reflection

These methods are based on the theory that shock waves travel through different materials at different velocities. Times for an induced shock wave to travel from the energy source to a series of detectors (geophones) after being refracted or reflected by a subsurface strata change are measured. This data is then used to determine material velocities and depths to changes in strata. Material types are determined by correlations to computed velocities. These methods have been used to investigate subsurface conditions to depths of 1000 ft. For additional details regarding the seismic refraction method, refer to ASTM D 5777. Seismic investigations can be performed from the surface or from various depths using boreholes. For cross-hole seismic techniques, see ASTM D 4428.

2-6.2 Resistivity

This method is based on the differences in electrical conductivity between subsurface strata. An electric current is passed through the ground between electrodes and the resistivity of the subsurface materials is measured and correlated to material types. Several electrode arrangements have been developed, with the Wenner (4 equally spaced electrodes) being the most commonly used in the United States. Refer to ASTM G 57.

2-6.3 Ground Penetrating Radar (GPR)

The velocity of electromagnetic radiation is dependent upon the material through which it is traveling. GPR uses this principle to analyze the reflections of radar signals transmitted into the ground by a low frequency antenna. Signals are continuously transmitted and received as the antenna is towed across the area of interest, thus providing a profile of the subsurface material interfaces.

2-7 References

1. ***AASHTO Manual on Subsurface Investigations*** , Washington DC, 1988.

2. ***Subsurface Investigations***, FHWA-HI-97-021, Arman, Samtani, Castelli, and Munfakh Subsurface Investigations, FHWA-HI-97-021, 1997.

3. ***Recommended Guidelines for Sealing Geotechnical Exploratory Holes***, NCHRP Report 378, National Cooperative Highway Research Program, 1995.

Chapter 3

Subsurface Exploration Guidelines

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Chapter 3

Subsurface Exploration Guidelines

A subsurface exploration program should be performed at the site of all new structures and roadway (re)construction and widenings. The scope of the subsurface investigation will vary for each project depending on the complexity of the job, the variability of subsurface conditions, and the constraints of project funding and schedule. Engineering judgment is essential in developing a subsurface exploration that satisfies the requirements of a specific project and allows the engineer to make reasonable design assumptions. A comprehensive subsurface investigation program might include both conventional borings and other specialized field investigation or testing methods.

During the execution of the subsurface exploration program close communication between the geotechnical engineer and driller is essential. The results of each boring should be reviewed as soon as possible so that a determination for additional borings, relocation of borings and/or additional in-situ testing can be made without incurring remobilization costs and significant loss of time.

3-1 General Requirements

The extent of the exploration will vary considerably with the nature of the project. The following general guidelines should be used to estimate the scope of a subsurface exploration program.

1. Preliminary exploration depths should be estimated from data obtained during field reconnaissance, existing data, and local experience. The borings should penetrate through weak or unsuitable soil (organic soils, soft clays, etc.) and terminate in competent bearing stratum.
2. Each boring, sounding, and test pit should be given a unique identification number for easy reference.
3. The ground surface elevation (ensure that the proper datum is referenced) and actual location should be noted for each boring, sounding, and test pit.
4. Each reference exploration should be located by the Connecticut Grid System (CGS) and the line and station for the project.
5. A sufficient number of samples of the type required for the specific test should be obtained within each stratum.
6. Water table observations within each borehole should be recorded when first encountered, and wherever possible, at the end of each day and after sufficient time has elapsed for the water table to stabilize.
7. Unless serving as an observation well, each borehole, sounding, and test pit should be backfilled or grouted according to applicable environmental guidelines.

3-2 Guidelines for Subsurface Explorations

Following is a description of the recommended scope of subsurface explorations for various types of proposed construction; see Figure 3-1 for a summary. The guidelines below consider the use of conventional borings only. While this is the most common type of exploration, the geotechnical engineer may deem it appropriate on individual projects to include soundings, test pits, geophysical methods, or in-situ testing as a supplement to conventional borings.

3-2.1 Roadway Subsurface Explorations

Subsurface explorations are made along the proposed roadway alignment to characterize subsurface materials and groundwater conditions. This information is used in designing the pavement section, defining the limits of unsuitable materials and remedial measures to be taken, determining the stability of cuts and fills, determining groundwater elevations and subsurface drainage requirements, and preparing quantity estimates for earthwork related items. Minimum criteria for subsurface explorations vary substantially depending on the scope of the proposed roadway improvements and the anticipated subsurface conditions. It is important that the geotechnical engineer researches all existing information and makes a site visit before establishing the scope of the subsurface exploration program. The following information provides additional guidance not provided in **Figure 3-1.**

a. The locations of borings shall be staggered to the right and left of centerline to aid in developing an accurate soil profile. If pre-existing information indicates the presence of uniform subsurface conditions borings may be spaced further apart. In areas of highly variable soil conditions, borings shall be taken at closer intervals or the boring information shall be supplemented with other investigative techniques.
b. Where rock is encountered, cores should extend at least ten (10) feet into it to insure that it is bedrock and not a large boulder. At least one boring in each rock cut should extend through the entire depth of the cut.
c. If not addressed through other subsurface exploration requirements, borings shall be provided where temporary sheeting/support of excavation is anticipated.
d. Generally in situ soil samples should be taken at intervals of 5 ft and at strata changes.
e. Areas of unsuitable material shall be probed on a station by station basis to delineate both the vertical and the horizontal extent of the deposit.

3-2.1.1 Pipe and Tunnel Jacking

Due to the influence of subsurface conditions on jacking and tunneling operations, accurately assessing the subsurface conditions is critical. At least two borings, located at the jacking and receiving pit, should be provided. Whenever practical, additional borings shall be provided along the alignment of the pipe jacking.

3-2.1.2 Temporary/Permanent Sheeting/Cofferdams

The contractor, not the designer, generally designs temporary sheeting/support of excavation installations; however, the designer is responsible for providing sufficient subsurface information for the proper design of sheeting. Most temporary or permanent sheeting installations coincide with the other structures and with appropriate placement of borings can satisfy the subsurface information requirements for both.

3-2.1.3 Borrow Areas

Test pits, trenches, and various types of borings can be used for exploration of potential borrow areas. Samples should be obtained to permit classification, moisture, and compaction testing of each material type, as applicable. The extent of the exploration will depend on the size of the borrow area and the amount and type of borrow needed.

3-3 Structure Subsurface Explorations

Structure borings shall provide sufficient information about the subsurface conditions to allow for the proper design and construction of the proposed structure. The following general guidelines should satisfy this purpose on most projects; however, the geotechnical engineer is responsible to assure that appropriate explorations are carried out for each specific project. All structure borings shall include Standard Penetration Testing (SPT) at regular intervals unless other sampling methods and/or in-situ testing are being performed.

3-3.1 Bridges

a. At least one boring shall be performed at each substructure. Where only one boring is provided per substructure, stagger the locations between adjacent substructures. For structure widenings, the total number of borings required will vary based on the information available from the existing structure.
b. Water crossings that include a pier in the water, at least one boring should be located in the water when practical.
c. For the removal of existing substructures in open water, borings and/or probes shall be provided for the proper design of cofferdams. Due to permit restrictions during construction, subsurface information shall be obtained to determine if obstructions will impact the construction of the cofferdams.
d. Borings should be located along the toe of proposed footings and in back of of wingwalls and abutments to define the foundation material and the backfill soil conditions.
e. When using the Standard Penetration Test, split-spoon samples shall be obtained at a maximum interval of 5 ft and at the top of each stratum change.
f. When cohesive soils are encountered, undisturbed samples shall be obtained at 5 ft intervals in at least one boring. Undisturbed samples shall be obtained from more than one boring where possible.
g. When rock is encountered, a ten (10) foot NX core should be obtained, at a minimum, to insure that it is bedrock and not a boulder. Deeper rock cores are required for drilled shaft and micropiles that are socketed into rock.

h. At water crossings, samples of streambed materials and each underlying strata shall be obtained to aid in determining the median particle diameter, D_{50}, needed for scour analysis.

3-3.2 Retaining Walls

a. Generally the subsurface exploration criteria are the same as for bridges.
b. For permanent tie-back or soil-nail walls, or where tie-backs are likely required for temporary support, borings shall also be provided in the anticipated bond zone location.

3-3.3 Buildings

In general, one boring should be taken at each corner and one in the center. This may be reduced for small buildings. For extremely large buildings or highly variable site conditions, one boring should be taken at each support location. Other criteria are the same as for bridges.

3-3.4 Major Drainage Structures

a. Borings shall be taken at proposed locations of major drainage structures. It is recommended that a minimum of 2 borings be provided, one at the inlet and one at outlet of the culvert. For very long drainage structures, additional borings shall be provided along its alignment.
b. Borings should extend a minimum of fifteen (15) feet below the invert of the drainage structure. For drainage structures with large endwalls, boring depths should be consistent with those recommended for bridges and retaining walls.

3-3.5 Overhead Sign Structures

For variable message signs and tubular arch signs that use drilled shaft foundations or large spread footings, at least one boring should be provided at the proposed sign location. Should difficult soils conditions be anticipated, additional borings may be required to investigate alternate sites. Coordination with the designer is required to determine the location of possible alternate sites.

3-3.6 Drilled Shafts

a. Due to the influence of subsurface conditions on the type of equipment and/or tooling used, method of construction, and the expected productivity, obtaining accurate information at proposed drilled shaft locations is critical. Sufficient borings should be provided to depict the grain size distribution of soil deposits (including cobbles and boulders); the horizontal and vertical limits of miscellaneous fill stratas where obstructions may be anticipated; any unstable soil deposits (running conditions); groundwater levels and any unusual piezometric conditions; and bedrock type, quality and hardness along with any unusual rock surface slope conditions.
b. One boring per shaft should be provided when a drilled shaft is used as a single column.

c. One boring for every two shafts should be provided when the drilled shaft is 6-feet diameter or greater and is incorporated into a footing.
d. One boring should be provided for every three to four shafts for shafts less than 6-foot diameter and incorporated into a footing.
e. For rock socketed drilled shafts, borings should extend at least ten (10) feet below the bottom of the rock socket. For large diameter drilled shafts, greater depths may be required.
f. When it is not practical to perform all of the required borings during the design phase, the borings may be performed during the construction phase, prior to the actual construction of the drilled shaft. The number of borings provided during the design phase should be sufficient to accurately depict subsurface conditions.

Proposed Construction	***Boring Layout***	***Minimum Boring Depth Requirements***
Bridge Foundations, Overhead Sign Foundation	*For substructures less than 100' wide, provide a minimum of 1 boring. For substructures over 100' wide provide a minimum of two (2) borings. Additional borings should be provided in variable subsurface conditions.*	*For spread footings, the borings should extend a minium 30' below the footing elevation. For deep foundations the boring shall extend at least 20' beyond the anticipated pile/shaft tip elevation or at least 10' into bedrock.*
Retaining Walls	*A minimum of 1 boring should be provided for each retaining wall. The maximum spacing between borings should generally not exceed 150'. The location of borings should be staggered between the toe of the wall and area behind the wall to define the soil conditions at the foundation and within the backfill of the wall.*	*Use criteria for bridge borings.*
Roadways	*The spacing of borings for roadway improvements should generally not exceed 300'. In establishing the spacing of borings, the complexity or continuity of soil and rock conditions within the project area and their impacts on the project design should be considered.*	*Borings should extend a minimum of 5' below proposed subgrade level or invert of proposed roadway drainage.*
Deep Cuts/High Fills	*The spacing of borings should be decreased where slope stability or sloping limits may be a concern. Borings may be required in longitudinal and transverse direction to aid in defining geologic conditions.*	*For deep cuts, boring should extend a minimum of 15' below the bottom of cut, deeper if stability is a concrern. For high fills, the borings shall have a minimum depth of twice the fill height, deeper if stability or settlement is a concern.*
Culverts	*Provide a minimum of one boring at each major culvert. Additional borings may be warranted for long culverts of variable gologic conditons.*	*Borings should extend at least 10' below the invert of a major drainage structure. Boring depths may be increased in variable geologic conditions or where temporary sheeting is required for its construction.*
Jacked Pipes and Structures	*A minimum of 2 borings, located within the limits of the jacking and receiving pits, shall be provided. Borings should also be provided along the alignment of the jacking. The number and location of borings along the alignment shall be based on the length of the structure and the geologic conditions.*	*Borings for the jacking and receiving pits shall extend deep enough to address the design of the temporary sheeting. Borings along the alignment of the jacking shall extend a minimum of 10' below the proposed invert.*
Sheet Piling	*At least one boring should be provided in the area of proposed temporary sheeting.*	*Borings should extend a minimum of 15' below the depth of cut. Deeper borings may be required based on the depth of the cut or geologic conditions.*

Figure 3-1
Subsurface Exploration Guideline

3-4 Test Boring Program Administrative Requirements

3-4.1 Procurement Procedures

When state forces or existing drilling contracts are not being used, the following rules generally govern the acquisition of services. For contracts that are less than 10,000 dollars, the contract may be formally advertised for bids or 3 oral competitive bids can be obtained to establish a low bidder.

For subsurface explorations which have an estimated cost which exceeds 10, 000 dollars, a formal advertise-bid-award process shall be followed. If services are required for an in-house design, the solicitation will be done through the Purchasing and Materials Management Division.

The Department maintains a list of test-boring contractors who have expressed an interest in bidding on test-boring services (see Appendix). Each vendor on that list shall be contacted via e-mail and provided with a bid package in electronic (.pdf) format.

Should only one (1) bid be received from a solicitation, the geotechnical engineer shall evaluate the bids to determine if an award should be made or if the project should be readvertised with a revised exploration program.

3-4.2 Sample Contract

See Appendix

3-4.3 Entry Permits

Section 13a-60 of the Connecticut General Statutes, authorizes the Commissioner of Transportation or his agents to enter private and or public property for the purpose of surveying or examining such property for the location or relocation of any highway. The same law protects the owner against damage to the property as a result of such entry.

Before entering any property for the purpose of making subsurface explorations, the geotechnical engineer shall inform the property owner of the proposed work and obtain their permission. This includes all municipalities when working on a town owned street. No property entry is permitted without the owner's consent. If the property owner can not be located or will not grant consent, a request should be sent to the Project Manager for them to obtain the entry permit.

The geotechnical engineer is responsible to see that inconvenience to the property owner is kept to a minimum and that any damage to property incidental to subsurface exploration is promptly repaired. All property entered shall be restored to conditions similar to what existed prior to the exploration. Included shall be the removal of equipment, materials and debris, repair of damaged driveways, fences and gates, proper backfilling of all test pits and boreholes to avoid any immediate or future hazard, resodding of lawn where grass is damaged and restoration of shrubbery, etc.

The geotechnical engineer shall insure that both his personnel and that of the drilling contractor treat property owners and the general public courteously to maintain the best possible public relations.

The Appendix contains a copy of the Entry Permit form used by the Soils and Foundations Section to obtain consent from the property owner**.** Consulting Engineers working for the Department should request an entry permit letter that has been authored by the liaison group**.**

3-4.5 Environmental Permits

Environmental permits may be required if open-water work is performed or drilling operations involve the filling or cutting in a wetland. Should there be any questions whether a permit is required, contact the designer or the Environmental Planning Section for clarification.

3-4.6 Notice to Utilities

Public Act 87-71requires individuals who use power or mechanized equipment for the purpose of disturbing the subsurface of earth to provide advance notice of at least two full working days to the "Call Before You Dig" central clearinghouse prior to commencing proposed excavations. The purpose of "Call Before You Dig" is to function as a statewide, one-call notification system that provides excavators and the general public with the ability to inform multiple owners and operators of underground facilities of a proposed excavation. The phone number of "Call Before You Dig" is 1-800-922-4455. "Call Before You Dig" can also be found on the world wide web at www.cbyd.com. The internet site has an e-mail service that can be used in lieu of the call in service.

The Department's Incident Management System is not covered by CBYD. Should a proposed subsurface exploration fall within the Incident Management System, the Highway Operations Section should be contacted to clear the proposed excavation. When working on town-owned streets, the municipality should also be contacted since certain municipally owned facilities are also not covered by CBYD.

The responsibility for clearing excavations with CBYD lies with the excavator doing the work. If a contract driller is doing the work, the geotechnical engineer should obtain the CBYD number from the contractor prior to the start of work.

3-4.7 Work Zones and Maintenance and Protection of Traffic

The sample test boring contract in the Appendix to this chapter contains traffic control guidelines to be followed when a subsurface investigation is performed on any part of the roadway. If a lane closure is required to perform the work, the *Daytime Lane Closure Guide* prepared by the Division of Traffic should be used to determine the allowable work periods. In certain locations, the time for a daytime closure is very restrictive or not permitted at all. For these locations, a nighttime closure may be necessary to accomplish the work.

Whenever a subsurface investigation involves working on an expressway or a high-volume roadway, the engineer should consult with the District Traffic Engineer or the Division of Traffic to determine the appropriate maintenance and protection of traffic plan.

If a lane closure is planned, the Department’s Communications Office will issue a press release in advance to inform the traveling public. The engineer should provide this office with the relevant information at least three (3) days in advance of the scheduled closure.

While working on the roadway, the engineer shall insure the contractor has provided the correct traffic control and that impact to the traveling public is kept to a minimum. If impacts to the traveling public are severe, the operation may need to be temporarily shut down or rescheduled to off-peak hours.

3-5 References

1. ***AASHTO Manual on Subsurface Investigations***, AASHTO, 1988.

2. ***Subsurface Investigations***, Arman, Samtani, Castelli, and Munfakh Subsurface Investigations, FHWA-HI-97-021, Federal Highway Administration, 1997.

3. "Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications", Federal Highway Administration, 2004.

Appendix

The Appendix to Chapter 3 presents the following

1. Sample Test Boring Contract
2. Work Zone Safety Guidelines for Maintenance Operations
3. Sample ConnDOT Boring Log
4. List of Boring Contractors Interested in Submitting Bids
5. Sample Entry-Permit Form

SAMPLE BIDDING AND CONTRACT DOCUMENTS
FOR FIELD SUBSURFACE INVESTIGATIONS
BY BORING CONTRACTORS

Prepared by the Connecticut Department of Transportation
Bureau of Engineering and Construction
Office of Geotechnical Engineering

(Revised October 2019)

Contract Components

Note: These Contract documents, including specifications, were prepared for informational purposes and is furnished solely as a guide. The State assumes no liability for use of the contents herein.

INVITATION TO BID

Sealed proposals for the performance of subsurface explorations, including the makings of borings in soil and rock; securing samples and other work incidental thereto in the Town(s) of _______________*(Town)*______________________________, Connecticut, will be received by ____________________*(Consultant)*_____________________________, Consulting Engineer, until 12:00 noon, Eastern (Daylight) (Standard) Time, __________*(date)*______________, 20__.

Plans, specifications, boring schedule, proposal form and form of contract are attached hereto.

If available, preliminary soils information obtained by subsurface explorations already completed at the site are attached. It shall be understood by all bidders that the preliminary data presented is no intended as a warranty of the subsurface conditions to be encountered, but is furnished for information only.

Proposals must be made upon the form provided. The blank places in the form must be filled in as noted, and no change shall be made in the phraseology of the proposal or in the items mentioned herein. Proposals that contain any omissions, alternations, additions, or items not called for in the itemized proposal, or that contain irregularities of any kind, may be rejected as non-responsive.

A certified check for the sum of ten percent (10%) of the amount of the bid, made payable to ______________*(Consultant)*______________________________ must accompany the bid, as a guarantee that the contract will be entered into, if awarded.

In lieu of a certified check, a proposal guaranty in the form of a bond furnished by a surety company in the amount of 10% of the amount of the bid will be accepted. The surety must be a corporate surety licensed to sign surety bonds in the State of Connecticut.

A performance contract bond and payment bond, each in the sum of one hundred percent (100%) of the contract price, will be required on execution of the contract.

___________*(Consultant)*________________ reserves the right to reject any or all bids.

BID FORMS FOR SUBSURFACE EXPLORATIONS

________________*(description of project – use as many lines as needed)*________________

TO: *(Contractor)*

In submitting this bid, the undersigned declares that he/she is the only person or persons interested in the said bid; that it is made without any connection to any person making another bid for the same contract; and that the bid is, in all respects, fair and without collusion, fraud, or mental reservation.

The undersigned also declares that he has carefully examined the plans, specifications and form of contract and that he has personally inspected the actual location of the work, together with the local sources of supply; has satisfied himself as to all the quantities and conditions; and understands that in signing this proposal, he waives all right to plead any misunderstanding regarding same.

The undersigned further understands and agrees that he is to furnish and provide for the respective unit bid price, all the necessary material, machinery, implements, tools, labor, services, etc., and to do and perform all the necessary work under the aforesaid conditions, to complete the work in accordance with the plans and specifications, which plans and specifications it is agreed are a part of this proposal. The list of bid items, together with the estimated quantities thereof, is set forth in the Bid Sheet, which accompanies and forms a part of this proposal. The undersigned further agrees that his total bid prices, which shall be evaluated in comparison with the total bid prices of other bidders, shall be completed as the summation of the products of the approximate quantities shown on the Bid Sheet multiplied by the gross sum bid. In case of discrepancy between the words and the numerals giving the unit bid prices, the words shall govern.

Furthermore, the undersigned fully understands that the quantities of the items set forth in the Bid Sheet are only approximate and agrees to accept the unit price as full compensation for the actual quantities of such items required to complete the work to the satisfaction of the Engineer, be the quantities more or less than those set forth in the Bid Sheet.

The undersigned agrees to submit a schedule of progress or time chart for the work concerned if so requested by the Engineer after the opening of the bids, and to do so within three (3) days of such request. The schedule or chart will be used in consideration of the bids and after award of the contract by the Engineer in the field as a check on the actual progress.

On acceptance of this proposal for said work, the undersigned does hereby bind himself to enter into written contract with ________________*(Consultant)*____________________ within three (3) days of the date of notice of award and to comply in all respects with the terms of said contract. The undersigned agrees that this proposal shall be valid for thirty (30) calendar days from the date of this proposal.

Accompanying this proposal is a guarantee, payable to the order of ___*(Consultant)*___, in the sum of 10% of the amount of the Gross Sum Bid, which deposit is to be forfeited as liquidated damages in case this proposal is accepted and the undersigned shall fail to execute a contract under the conditions of this proposal within three (3) days after date of official notice of the award of the contract. Otherwise, said deposit is to be returned to the undersigned.

All proposal guarantees will be returned within three (3) calendar days following the award of the contract. When the award is deferred for a period of time longer than ten (10) calendar days after the opening of the proposals, all guarantees, except those of the three lowest bidders, will be returned. Should no award be made within 30 calendar days after the opening of proposals, all proposals will be rejected and the proposal guarantee returned, except that with the approval of the Bidder and the Surety, the Engineer may retain the proposal and proposal guaranty of the low bidder for as long as may be agreed upon by the Engineer, Bidder and Surety.

The Bid Sheet submitted with these bid documents will become part of the Contract documents in Exhibit B of the Contract.

Dated ___________________________________, 20___

____
(Legal name of person, firm, or corporation)

By_______________________________________
(Name of person submitting form)

The P. O. Address of the bidder is:

____
(Street)

____
(City and State)

If a Corporation:

Name	Address
__________________________________	______________________________
(President)	______________________________
__________________________________	______________________________
(Secretary)	______________________________
__________________________________	______________________________
(Treasurer)	______________________________

If a Firm:

Names of Members	Address
__________________________________	______________________________
(Member name)	______________________________
_________________________________	______________________________
(Member name)	______________________________
_________________________________	______________________________
(Member name)	______________________________

BID SHEET

Item No.	Description of Commodity	Unit	Approximate Quantities	Unit Price Dollars/Cents	Total Amount of Bid Dollars/Cents
1.01	Soil Boring – Type A (0-75 feet)	L.F.			
1.02	Soil Boring – Type A (Over 75 feet)	L.F.			
1.03	Soil Boring – Type B	L.F.			
1.04	Cement Grout Backfill	L.F.			
2.01	Auger Boring. 4” Diameter	L.F.			
3.01	Split Tube Sample	Each			
4.01	Stationary Piston Samples	Each			
5.01	Rock Coring – NX	L.F.			
5.02	Structural Coring – NX	L.F.			
6.01	Pavement Core – 4 inch	Each			
7.01	Test Pits	Each			
8.01	Bar Soundings	L.F.			
9.01	Drill Rod Probe	L.F.			
10.01	Observation Wells	L.F.			
11.01	Piezometers	L.F.			
12.01	Inclinometers	L.F.			
13.01	Trafficperson – Uniformed	Hour			
13.02	Trafficperson – Police Officer (Municipal)	Hour			
13.03	Trafficperson – Police Officer (State Police)	Hour			
14.01	Mobilization and Dismantling - Land	Ea. Rig			
14.02	Mobilization and Dismantling - Railroad	Ea. Rig			
15.01	Mobilization and Dismantling - Water	Ea. Rig			
16.01	Mobilization and Dismantling – Tracked Rig or Skid Rig on Land	Ea. Rig			
17.01	Standby Time	Hour			
18.01	Truck Mounted Impact Attenuator Vehicles (TMAs)	Day			
19.01	Light Plant	Day			
				Total Bid	

Contract Table of Contents

Article 1 - Contract Agreement

This Contract (the "Contract") is made and entered into on ________*(date)*____________, by and between, ____________*(Consultant)*________________, hereinafter referred to as the Engineer and ____________*(Contractor)*_______________, hereinafter referred to as the Contractor.

The Contractor shall furnish all labor, materials, equipment, supplies and other facilities, and shall perform all work necessary or proper for or incidental to the making of subsurface explorations at the locations on the plans at the site of ____ at ______________________, Connecticut, in strict accordance with the Specifications found herewith and the accompanying Contract Plans, and to the satisfaction and approval of the Engineer; and shall perform all other obligations and assume all liability imposed upon him by the Contract and Specifications.

In full consideration thereof, the Engineer will pay the Contractor, at the times and in the manner hereinafter provided, an amount determined by the prices named on the Bid Sheet in Exhibit B, hereof entitled "Contract Unit Prices," and, except as otherwise provided herein, such amounts only. The prices for items named therein include full compensation to the Contractor for all labor, materials, and other things incidental to the completion of the entire work. Such payment shall be computed upon the basis of the actual quantities in the completed work, whether such quantities be more or less than those shown in the Bid Sheet.

Article 2 – Extra Work

Unforeseen work made necessary by changes in plans or work necessary to complete the subsurface investigations, for which no price is provided in the contract, shall be classified as extra work and done in accordance with the requirements of the specifications and as directed by the Engineer.

The Engineer shall notify the Contractor of the necessity for extra work, stipulating its character and extent. Upon receipt of such notification, the Contractor shall notify the Engineer, in writing, of the compensation, either unit price or lump sum as requested, for which he proposes to perform the extra work required. The Engineer may accept or reject the compensation proposed by the Contractor. If the extra work is rejected by the Engineer no extra work will be done or paid for. If the Engineer considers the prices submitted to be excessive, he may order the work done on a "Cost Plus" basis as specified hereinafter. In any case, the character and extent of extra work, together with the accepted basis of compensation shall be communicated to the Contractor in writing.

If the Engineer orders extra work performed on a "Cost Plus" basis, the Contractor shall perform the same and shall receive in payment there for an amount equal to the actual net cost in money to him of the materials, wages of applied labor, other direct expense and insurance required for labor, plus 20 percent of the above items and plus such rental for plant and other equipment (other than small tool) as the Engineer deems reasonable, and that amount only.

No work shall be considered Extra Work unless it has been ordered in writing as such by the Engineer before the said work started, or unless the Contractor shall file a written claim for Extra work with the Engineer within two (2) days from the date of instructions from the Engineer or his representative to proceed with such work.

Article 3 – Payment

Partial Payment(s): On or about the first day of each calendar month, the Engineer will request the Contractor to furnish information necessary to estimate the value of the work satisfactorily done up to that time. Within three (3) days after receipt of this information, the
Engineer will request the State to pay him 90% of the value of the work thus estimated, less any previous payments made; and the Engineer, within three (3) days after receipt of such payment from the State, will pay to the Contractor the amount thus received.

Final Payment: Upon the satisfactory completion of all work whatsoever required, the Contractor shall furnish to the Engineer satisfactory evidence that all just liens, claims and demands for rental of equipment, labor and material, arising out of such work, are fully satisfied, and that all of the work is fully released from liens, claims and demands, whether just or otherwise. Within three (3) days after receipt of such evidence, the Engineer will request the State to pay him the total value of all work satisfactorily done, less any payments previously made, and within three (3) days of receipt of this Final Payment from the State, the Engineer will pay to the Contractor all amounts still outstanding and due him. All prior estimates and payments shall be subject to correction in this payment, which is throughout this Contract called the Final Payment.

The acceptance by the Contractor of the Final Payment shall be and shall operate as a release to the Engineer of all claims and all liability to the Contractor for all things done or unfinished for or relating to the work, and for every act of the Engineer, his representatives, agents and employees, or other relating to or arising out of the work.

Article 4 – Contract Not To Be Assigned

The Contractor shall give his personal attention constantly to the faithful prosecution of the work. He shall not assign or otherwise dispose of the Contract, or his right, title or interest in or to the same or any part thereof.

Article 5 - Modification of Contract

No modification of or change in this Contract shall be valid or enforceable against either of the parties unless it is in writing and signed by the parties or their duly authorized representatives.

Article 6 - Default of Contract

When, in the opinion of the Engineer, the project or any part thereof has been abandoned, or the Contractor is willfully violating any of the covenants of this Contract, then the

Engineer may declare the Contractor in default of the Contract and notify him to discontinue the project. The Engineer may then call on the Surety to complete the project.

Article 7 - Commencement of Work

The Contractor agrees to mobilize and actually start work on the Contract within nine (9) consecutive calendar days from the date of the written notice to proceed.

Article 8 - Performance Contract Bond and Payment Bond

The successful Bidder, at the time of the execution of the contract, may deposit with the Engineer, a surety company bond for the satisfactory completion of the work and a surety company bond for the payment of all debts pertaining to materials, rental of equipment, and labor used or employed in the execution of the Contract. These bonds shall each be in an amount equal to the amount of the contract award and in a form acceptable to the Engineer.

The Surety must be a corporate surety licensed to sign surety bonds in the State of Connecticut.

Article 9 - Insurance

The Bidder, to whom the Contract has been awarded, shall furnish to the Engineer, prior to the commencement of any work, satisfactory proof that all provisions, herewith specified, relating to the Contractor's insurance have been fully complied with.

Article 10 – Waiver of Responsibility

It shall be understood that preliminary data obtained by subsurface explorations prior to this Contract and presented for examination by prospective bidders is not intended as a warranty of actual subsurface conditions to be encountered. The Engineer will bear no responsibility for the accuracy or suitability of subsurface information made available for examination and the conditions indicated by such information shall not be used by the Contractor as possible cause for subsequent revisions or waivers in the Contract.

Article 11 – Non-Liability of the State and Engineer's Representatives

No agents or employees of the Engineer (Consulting Engineer), the State of Connecticut, all officers, agents and servants of the State of Connecticut, Commissioner of Transportation and his successors, shall be charged personally by the Contractor with any liability or held liable to him, under any terms or provisions of this Contract or because of its execution or attempted execution, or because of any breach thereof.

Article 12 – Contractor's Warranties

The Contractor represents and warrants:

That he is financially solvent; that he is experienced in and competent to perform the type of work contemplated by this Contract.

That he has carefully examined the specifications, plans, and the site of the work, the general and local conditions, and other matters which may in any way affect the work or its performance.

IN WITNESS WHEREOF, the parties have caused these presents to be signed and sealed the day and year first above written.

Witness

______________________________	______________________________
(Signature)	*(Date)*
______________________________	______________________________
(Name)	*(Contractor Company Name)*

Witness

______________________________	______________________________
(Signature)	*(Date)*
______________________________	______________________________
(Name)	*(Engineer Company Name)*

SPECIFICATIONS FOR SUBSURFACE EXPLORATIONS

Article 13 – General Conditions

Definitions:

"Engineer" shall mean the firm of ________________*(Consultant)*____________________, or their authorized representative, or the Commissioner of Transportation or his authorized representative.

"Commissioner of Transportation" shall mean the Commissioner of Transportation for the State of Connecticut, acting directly or through his duly authorized representative.

"Contractor" shall mean the person, persons, or corporation, which has executed the Contract with the Engineer for the proposed work.

"Inspector" shall mean the authorized representative of the Engineer assigned to the inspection of work and materials.

"State" shall mean the State of Connecticut.

Authority and Duties of the Engineer:

All work shall be performed to the satisfaction of the Engineer and at such times and places, by such methods and in such manner and sequence as he may require, and shall at all stages be subject to his inspection.

Upon request of the Contractor, the Engineer will confirm in writing any oral order, direction or requirement.

Injury to Persons or Property:

The Contractor shall be responsible for all injury to persons or damage to property, either directly or indirectly, that may result from his operations.

Insurance:

With respect to the operations performed by the contractor under the terms of this contract and also those performed for the contractor by its subcontractors, the contractor will be required to obtain at its own cost and for the duration of this contract, and any supplements thereto, for and in the name of the State of Connecticut in conjunction with paragraph (A) below, and with the State being named as an additional insured party for paragraphs (B), (C), (E), (F), (G), and (H) is specified, the following minimum liability insurance coverage at no direct cost to the State.

Changes to the types and dollar amounts of coverage, if required, will be specified in the individual bid package.

Insurance Provisions

The State of Connecticut, its officers, officials, employees, agents, Boards and Commissions shall be named as additional insured. The coverage shall contain no special limitations on the scope of protection afforded to the State.

Contractor shall assume any and all deductibles in the described insurance policies.

The contractor's insurers shall have no right of recovery or subrogation against the State and the described insurance shall be primary coverage.

Any failure to comply with the claim reporting provisions of the policy shall not affect coverage provided to the State.

Each required insurance policy shall not be suspended, voided, cancelled or reduced except after 30 days prior written notice by certified mail has been given to the State.

"Claims Made" coverage is unacceptable, with the exception of Professional Liability.

Contractor agrees that he/she will not use the defense of Governmental immunity in the adjustment of claims or in the defense of any suit, unless requested by the State.

(A) Owner's And Contractors Protective Liability**:**

The contractor shall purchase Owner's and Contractor's Protective Liability Insurance for and in the name of the State of Connecticut. This insurance will provide a total limit of one million dollars ($1,000,000.00) per occurrence for all damages arising out of injury to or death of all person and out of injury to or destruction of property in any one accident or occurrence and, subject to that limit per occurrence, a total (or aggregate) limit of two million dollars ($2,000,000.00) for all damages arising out of bodily injury to or death of all persons in all accidents or occurrences and out of injury to or destruction of property during the policy period.

(B) Commercial General Liability**:**

The Contractor shall carry Commercial General Liability Insurance, including Contractual Liability Insurance, providing for a Combined Single Limit of one million dollars ($1,000,000.00) for all damages arising out of bodily injury to or death of all persons in any one

accident or occurrence, and for all damages arising out of injury to or destruction of property in any one accident or occurrence, and, subject to that limit per occurrence, a total (or aggregate) limit of two million dollars ($2,000,000.00) for all damages arising out of bodily injury to or death of all persons and out of injury to or destruction of property during the policy period.
Total/aggregate coverage shall be per project, purchase order or contract aggregate. Coverage shall include Premises and Operations, Independent Contractors, Products and Completed Operations, Contractual Liability and Broad Form Property Damage. The policy shall have coverage for and exclusions removed for “Explosion, Collapse and Underground” (“XCU”).

(C) Automobile Liability**:**
The operation of all motor vehicles, including those hired or borrowed, used in connection with the contract shall be covered by Automobile Liability Insurance providing for a total limit of one million dollars ($1,000,000.00) Combined Single Limit per occurrence for all damages arising out of bodily injury to or death of all persons in any one accident or occurrence, and for all damages arising out of injury to or destruction of property in any one accident or occurrence. In cases where an insurance policy shows an aggregate limit as part of the automobile liability coverage, the aggregate limit must be at least two million dollars ($2,000,000.00). Coverage extends to owned, hired and non-owned automobiles. If the vendor/contractor does not own an automobile, but one is used in the execution of the contract, then only hired and non-owned coverage is required. When it is clearly established that no vehicle is used in the execution of the contract, then automobile coverage is not required. Contractor operations on airports that use vehicles on the air side require five million dollars ($5,000,000.00) automotive coverage unless specifically modified by the State, and may require additional special vehicle coverage depending on the types of vehicles employed.

(D) Worker's Compensation:

With respect to all operations the contractor performs and all those performed for the contractor by subcontractor(s), the contractor and subcontractor(s) if used, shall carry Workers’ Compensation Insurance at statutory coverage limits and, as applicable, insurance required in accordance with the U.S. Longshoremen and Harbor Workers’ Compensation Act, in accordance with the requirements of the laws of the State of Connecticut, and of the laws of the United States respectively.

<u>Additional Coverage</u>

Other types of coverage may be offered by the vendor or required by the terms of a particular bid.

(E) Railroad Requirements:

When the Contract requires work on, over or under the right of way of any railroad company, the Contractor shall provide, with respect to the operations that it or its subcontractors perform under the contract the following additional insurance requirements apply:

The Contractor is warned that entrance to the railroad property will not be allowed by the Railroad Company if there are outstanding charges remaining against the Contractor for Railroad Services rendered on prior projects. No request for an extension of time will be considered as a result of any delay to the Contractor's operations caused by the Contractor's indebtedness to the railroad. It is agreed that providing of any conductors, flagmen, or other employees shall not relieve the Contractor from liability or payment for any damages previously caused by its operations.

If any of the railroad insurances specified in this section is provided on a claims-made basis, then in addition to coverage requirements, such policy shall provide that:

1) The policy retroactive date must coincide with or precede the Contractor's start of work (including subsequent policies purchased as renewals or replacements),
2) The Contractor shall maintain insurance for at least two years following Project completion,
3) If insurance is terminated for any reason, the Contractor agrees to purchase an extended reporting provision of at least two years to report claims arising from Work performed in connection with this Contract, and,
4) The policy must allow for reporting of circumstances or incidents that might give rise to future claims.

1 - Worker's Compensation Insurance:
Workers compensation insurance must provide a minimum coverage of $100,000 per accident and $100,000 per employee for any projects on, over or under the railroad.

"Employer’s Liability insurance shall be provided in amounts not less than $2,000,000 which limit may be met by a combination of primary and excess insurance meeting the statutory limits of the laws of the state in which the work is performed, whichever is greater."

2 – Commercial General Liability Insurance:
For projects involving work on, over or under the railroad the "Contractual Liability, Products and Completed Operations, Broad Form Property Damage and Independent Contractors coverages,” shall have all railroad exclusions deleted. The “named as an additional insured” shall be as noted on the Request for Quotation." Any Umbrella/Excess Policy used to meet the minimum contract requirements must follow form of the underlying policy and be extended to “drop down” to become primary in the event the primary policy is exhausted.”

For projects involving work on, over or under the railroad use the following “Limits of Coverage” chart for Commercial General Liability Insurance:

Contract Amount ($)	Minimum Single Occurrence Limit ($)	Minimum Annual Aggregate Limit ($)
0-10,000,000	3,000,000	3,000,000
>10,000,000	4,000,000	8,000,000

3 - Owner's and Contractor's Protective Liability Insurance for and in the Name of The State:

For projects involving work on, over or under the railroad use the following "Limits of Coverage" chart for Owners, Contractor's Protective Liability Insurance:

Contract Amount ($)	Minimum Single Occurrence Limit ($)	Minimum Annual Aggregate Limit ($)
0-50,000,000	3,000,000	3,000,000
>50,000,000	4,000,000	4,000,000

Each policy shall waive right of recovery (waiver of subrogation) against the State of Connecticut or the Railroad and the described insurance shall be primary coverage.

For projects on Metro-North rights-of-way the Contractor is required to file certificates of insurance with Metro-North Commuter Railroad at least 30 days prior to commencing any work within the Railroad right-of-way. Certificates are to be sent to:

Ms. Sharon Sebro, Risk Analyst
Metro-North Railroad Risk and Insurance Management Department
2 Broadway, 21st floor, New York, NY, 10004
Phone: 646-252-1429 Email: ssebro@mtahq.org

Ms. Priscilla Yen may also be contacted for questions at 646-252-1437 or Pyen@mtahq.org.

Note: For projects with limits of construction that cross the Connecticut/New York State Line into New York, "American Premier Underwriters" shall also be shown as an additional insured.

For coverage provided under the Article "Railroad Protective Liability Insurance", the names of the "Additional Insured" shall be as indicated on the Request for Quotation.

(F) Protection and Indemnity Insurance for Marine Operations in Navigable Waters

If a vessel of any nature or kind is involved, the Contractor shall obtain the following insurance coverage:

If a vessel of any nature or kind is involved, the Contractor shall obtain the following insurance coverage:

A. Protection and Indemnity Coverage of $300,000 per vessel or a limit equal to the value of hull and machinery, whichever is greater.

B. If there is any limitation or exclusion with regard to crew or employees under the protection and indemnity form, there must be a worker's compensation policy in effect, including coverage for operations under admiralty jurisdiction with a limit of liability of $300,000 per accident or to a limit equal to the hull and machinery, whichever is greater, or as otherwise required by statute.

(G) Umbrella Liability:

In the event the contractor secures excess/umbrella liability insurance to meet the minimum requirements specified as items B, C, E, F, G, and H (if required), the State of Connecticut must be named as Additional Insured. The State of Connecticut must be the Named Insured if a separate umbrella policy is obtained to supplement the coverage specified for item A.

(H) Other Insurance:

Certain contracts require higher levels of coverage and/or specialized types of coverage that are unique to that contract. When required, the additional type(s) of insurance and specific coverage dollar levels will be specified in the terms and conditions of the individual bid. If additional specialized coverage is required by the bid, the State must be named as additional insured for each policy unless otherwise specified.

Certificate of Insurance

The contractor agrees to furnish to the Engineer a Certificate of Insurance in conjunction with Items A, B, C, D, E, F, G, and H above, fully executed by an insurance company or companies satisfactory to the State, for the insurance policy or policies herein above, which policy or policies shall be in accordance with the terms of said Accord form. For the Workers' Compensation Insurance and, if applicable, the U.S. Longshoremen and Harbor Workers' Compensation Act coverage, the policy number (s) and term of the policy(ies) shall be indicated on the Certificate of Insurance. Each insurance policy shall state that the insurance company agrees to investigate and defend the insured against all claims for damage, even if groundless.

Laws To Be Enforced:

The Contractor, at all times, shall observe and comply with all federal and state laws and local bylaws, ordinances, and regulations n any manner affecting the conduct of the work or applying to employees on the project, as well as all orders or decrees which have been promulgated or enacted, by any legal bodies or tribunals having authority or jurisdiction over the work, materials, employees for contract.

Article 14 - Contract Requirements

General:
The work will consist of, but not be limited to, various types of soil borings, installation of instrumentation, and testing of soil and rock. Contractors shall also provide traffic control when stated in the contract documents.

Basis of Payment:
The Engineer will pay the Contractor at the contract unit prices stated in Article 2 of the contract agreement for work completed to the satisfaction of the Engineer. Payment includes full compensation for all materials, equipment, tools, labor, obtaining, recording and submitting data as well as the procuring of any required permits or licenses and any incidental work necessary to complete the services.

Equipment Regulations:
Contractors shall have the equipment or vehicles properly equipped as necessary to perform the services. Equipment is to be maintained in compliance with all applicable Federal, State of Connecticut Department of Motor Vehicle (DMV) and local regulations in effect at all times during the contract. All Contractor operators of specialized equipment shall be properly trained, insured and licensed.

Contractors must comply with all applicable provisions and regulations of Title 14, Motor Vehicles, Use of the Highway by Vehicles, of the Connecticut General Statutes.

Under Connecticut law, a commercial vehicle used by Contractors and vendors in conjunction with the Contract may be subject to Connecticut registration requirement. Section 14-12a of the Connecticut General Statutes required such registration for any vehicle with is most frequently garaged in this State, or most frequently leaves from, and returns to one or more points within this State in the normal course of operations. In addition, a vehicle must obtain a Connecticut registration if it continuously receives and discharges cargo in the State.

For work on water, the barge, boat, or other float shall be securely anchored and at all times be free of the casing. Drill rigs for rock coring on water shall be mounted on the casing, where required.

Equipment Inspection:
Equipment supplied by the Contractor must be in safe operating condition at all times. The Engineer reserves the right to inspect the Contractor's equipment at any time and to confirm that equipment is in good operating condition. Contractors having equipment unavailable for inspection or for the performance of the Services will be considered in breach.

Work Day:
No work shall be performed by the Contractor without prior approval of the Engineer. Normal on site working hours are ____(Time)___ to ____(Time)___, Monday through Friday. Normal on site work hours may vary slightly by season. On Site work hours may vary, or be restricted for work on Interstates, Expressways, Railroads and Airports; on site work deviating from normal

work hours will be as directed by the Engineer. No additional premium or Standby Time will be paid.

Contractors will not be permitted to work on the following Legal Holidays; New Year's Day, Washington's Birthday, Good Friday, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, Christmas Day, Martin Luther King Day, Lincoln's Birthday, Columbus Day, and Veteran's Day.

Contractors will not be permitted to work on the day before and the day after any of the above Legal Holidays on Interstate Highways or Expressways. This applies also to the Friday immediately preceding any of the above Legal Holidays celebrated on a Monday and the Monday immediately following any of the above Legal Holidays celebrated on a Friday.

Traffic Control:
When traffic control is required for the project, the Contractor or its authorized subcontractor for traffic control shall supply and be responsible for all equipment, signs, supports, cones, and any other materials and equipment necessary. When traffic control personnel are required, they will be paid at the contract unit prices stated in Article 2 of the contract agreement. Traffic control personnel must be uniformed, trained and equipped for the proper performance of their duty. Traffic control personnel must comply with the Manual of Uniform Traffic Control Devices (MUTCD), revised 2009 edition, and the "Work Zone Safety Guidelines for Maintenance Operations 2013" booklet including the general notes. The booklet is attached to this document and is incorporated herein. Contractor shall provide the installation and removal of all signs, sign supports, barricades, traffic cones, traffic delineators, and any other equipment and material necessary as set forth in the provisions of the Work Zone Safety Guidelines for Maintenance Operations 2013.

Quality Control:
Quality control of the Services will be the responsibility of the Contractor. Services will be performed in conformance with the attached technical provisions, general procedures and specifications for items, traffic control patterns and any related specifications.

Use of Site:
The Contractor shall confine operations, equipment and materials to the designated work area. The work area and site access must be maintained free and clear of any obstructions or hazards by the Contractor. The Contractor shall take particular care in the Performance of work in order to prevent injury or defacement to property. Any damage caused by the Contractor in the Performance of work must be remedied at the Contractor's own expense.

The Engineer will have access to the work area whenever it is in preparation or progress and the Contractor shall provide proper accommodations for access and inspection.

Health and Safety Plan:
The Contractor shall have a General Health and Safety Plan (HASP) for the work to be performed and assumes full responsibility for site safety of the Contractor’s personnel. The Engineer may request a copy of the HASP. The purpose of this requirement is to assure proper and safe conduct

of drilling operations. Items to be covered in the General Health and Safety Plan include, but are not limited to general safety practices of drill rig movement and operation:

- Protective clothing and gear
- Buried and overhead utilities
- Traffic Safety
- First Aid
- Location of and directions to the nearest urgent care center or hospital
- Emergency contact information

Extenuating circumstances which affect work performed and payments:
No payment will be made to the Contractor where the Contractor has been given reasonable notification of any temporary shutdown of work for work that could not be performed due to extenuating circumstances or adverse weather conditions declared by the State.

Should the Engineer direct the Contractor to standby at a project site, the standby time rate at the contract unit prices stated in Article 2 of the contract agreement, will be used to assess charges per rig/crew required to standby.

Supervision:
The Services will be performed under the supervision and direction of the Engineer. The Engineer will check the drillers logs of the explorations to determine that the information designated herein is being obtained and see that all samples are properly preserved, protected against damage, boxed and stored in a suitable place or immediately turned over to the Engineer.

Call before you dig (CBYD) – existing conditions:
Before any subsurface exploration is Performed, the Contractor shall contact CBYD at 811 or 1-800-922-4455 or by e-mail to obtain and maintain a request number and the names of the utility companies that are being notified. The Contractor, shall supply the Engineer with the request number(s) and shall update them as needed. Upon request the Contractor shall supply to the Engineer a complete list of utilities that CBYD will contact for each request. Any relocation of borings or other subsurface explorations will be cleared with CBYD at least two (2) days prior to drilling. The relocation of borings, including those due to utility conflict, must be approved by the Engineer. The Contractor shall locate all known utilities prior to work and repair/replace all damage done to known utilities at no cost to the State. Contractor may be held responsible for any damage done to unknown utilities if Contractor suspected that a utility may have existed due to drilling resistance or other evidence encountered during the Performance of the Services and did not immediately take steps to ensure that no damage was done to the unknown utility.

Boring Stakeout:
Work locations are to be laid out in the field by the Engineer prior to authorizing the Contractor to begin work.

Contractor's Equipment:
All equipment and methods to be used by the Contractor will be subject to approval by the Engineer at any time during the performance of the Services. Contractor shall maintain all

equipment in good and safe operating condition. Engineer approval of the use of any equipment will not be construed as including the approval of the equipment's performance. Additional equipment and methods will be provided where ordered by the Engineer if required to perform the work satisfactorily according to the specifications.

The Contractor may be required to provide more than one (1) rig at a time on a project. The Contractor shall have access to sufficient personnel, equipment and materials to provide two (2) manned drill rigs throughout the Contract term. The Contractor must have one (1) drill that has been rated by its manufacturer to have at least 6500 ft-lbs of torque. All other drill rigs listed must be rated by their manufacturer to have at least 3500 ft-lbs of torque.

Cooperation by Contractor:
The Contractor will at all times provide a competent lead driller, thoroughly experienced in the type of Services being performed, who will receive instructions from the Engineer. The lead driller will have full authority to execute the orders or directions of the Engineer, without delay and to supply promptly such materials, equipment, tools, labor and incidentals as may be required. The Contractor shall employ only workers that are careful and competent. The Engineer may demand the dismissal of any person or persons employed by the Contractor who misconduct themselves or are incompetent or negligent in the performance of their duties or neglects or refuses to comply with directions given by the Engineer. Should the Contractor continue to employ or again employ such person or persons, the Engineer may withhold all payments, which are due or become due, or the Engineer may suspend the work until such orders are complied with.

Qualification of Personnel:
An experienced lead driller will have a minimum of five (5) years' experience in performing geotechnical borings, or a minimum of two (2) years' experience as a lead driller for a geotechnical boring contractor.

Records:
The Contractor shall keep complete, neat, accurate and legible field records of each boring (based in part on the driller's field logs as described herein) and other subsurface exploration and these records will show the Contractor's interpretation of the results of the explorations as to the nature of the subsurface conditions. The records will be made at the site and will be furnished to the Engineer as the work progresses. With the exception of the following items; CT grid coordinates, station, offset and elevation the records will contain complete boring logs that include all information specified in the latest version of the Connecticut DOT Geotechnical Engineering Manual.

Submission of Reports and Samples:
One copy of the driller's field log will be given to the Engineer at the site at the end of each working day.

Complete data files and typed boring logs referenced to ground surface with stratum classified as described above, together with all notes, remarks and pertinent information required by the Contract will be e-mailed to the Engineer (____________________) by the Contractor no later than five (5) days after the completion of exploration program. The boring logs and data files shall be submitted in gINT (*.gpj) format.

All samples except as otherwise specified below will be stored at or near the site as directed by the Engineer. All soil and rock samples will be given to the Engineer on completion of the last hole or as directed by the Engineer. If samples are not turned over by the Contractor, the Engineer will consider that the hole or holes were not drilled and no payment will be made for those borings.

After sealing by the Contractor, all stationary piston tube samples will be immediately transferred to the custody of the Engineer at the site.

Rights-of-Way and Damage to Property:
The Contractor shall obtain all necessary permits and licenses at his how expense from the authorities having jurisdiction. He shall comply with all federal laws, state statutes and local ordinances of the city, town or village in which the work is being done.

The Contractor shall be responsible for carrying out the work in accordance with the provisions of all permits.

The Contractor may occupy during his operations only those portions of streets or public places at the boring locations for which the required permits have been obtained by him. If the Contractor desires to use additional areas outside of those required for the borings, he shall arrange for such areas at his own expense.

The Contractor shall take every precaution against injuring pavement, utilities, or private properties and shall promptly repair at his own expense any damage to such pavement, utilities, or private property, to the satisfaction of the Engineer. The requirement includes the filling of all drill holes and the resodding of any areas where the grass is damaged. Property, which is damaged as the result of the Contractor's operations, shall be repaired at the Contractor's expense, to the satisfaction of the Engineer.

The location of all stationary and mobile equipment shall be subject to the approval of the Engineer and upon the completion of the Contractor's operations at each site, he shall remove equipment therefrom and shall clear the area of all debris and restore it to the condition existing before the start of his operations. All casings shall be withdrawn from the drill holes.

The Contractor shall carry on his operations without interference or delay to traffic. He shall furnish all labor, material, watchmen, barricades, signs, and lights necessary to maintain traffic, to protect his work and the public during the operations, and to comply with all orders of the Engineer, of the Corps of Engineers, U. S. Army, and of the U. S. Coast Guard pertaining to navigation, and of all other agencies having jurisdiction when applicable.

The Contractor is cautioned that there shall be no entry of his equipment or personnel upon private property until the Engineer first notifies him that such entry is permissible in accordance with state statutes and state policy and until he, the Contractor, then informs the property owner that entry is being made pursuant to said notification. He shall, at all times, carry out his operations so as to inconvenience no resident at or near the working area. The Contractor shall make clear to all his personnel, the importance of proper public relations. The Engineer will not condone any rude or inconsiderate treatment of any citizens of the State by personnel employed on this project. The

Engineer reserves the right to require the removal from the work of any persons or persons employed by the Contractor who has violated this section of the specifications, and such person or persons shall not be employed again thereon without the written consent of the Engineer.

Cleaning up:
After completing the work, the Contractor shall promptly remove all plant and other materials brought by him to the site and restore the site to its original condition.

Progress and Time of Completion:
The work under this Contract shall be commenced within (__) consecutive calendar days from the date of written notice to proceed and shall be prosecuted continuously to completion within (__) calendar days from the date of written notice to proceed.

If the quantities stated in the proposal are increased, as hereinafter provided, the number of calendar days allowed for completion will be similarly increased. This increase will be in the same proportion as the increase in the total payments to the Contractor above the amount of the executed Contract.

Liquidated Damages:
In case the Contractor shall fail to complete the work hereunder in accordance with the Contract within the time limit specified, he shall pay to the Engineer the sum of ____ for each and every calendar day that the time consumed in said completion exceeds the above-mentioned time allowed for that purpose. This sum shall not be considered as a penalty, but as the liquidated damages that the State will suffer by reason of said delay. The Engineer shall deduct the amount of such liquidated damages from the moneys, which may be due or become due to the Contractor under this Contract.

Exhibit A - Technical Requirements

Note – All "Item" designations refer to the "Item" designation for payment of each item as herein described and as shown on the Bid Sheet included with the request for quotation.

Item 1.01 Soil Boring, Type A (0-75 feet)
Item 1.02 Soil Boring, Type A (over 75 feet)
Item 1.03 Soil Boring, Type B
Item 1.04 Cement Grout Backfill

General Boring Procedures: Sequence of borings and the type or types of samples to be taken at each hole will be as directed by the Engineer. In general, borings will be carried out as follows:

(a) For determination of soil strata, borings will normally be 3 inch minimum diameter holes in which 2 inch outer diameter split tube samples will be taken. The 2 inch sampler will be used regardless of the size of casing being employed if, in the opinion of the Engineer, such sampler will recover a representative sample. Undisturbed samples may also be taken. For taking undisturbed samples, a 3 inch stationary piston sampler will be required.
(b) For determination of depth to and soundness of bedrock, borings will be 3 inch minimum diameter holes through which NX type rock cores can be recovered.
(c) If pilot borings are shown on the plans, such boring or borings at a site of a bridge or highway cut or fill will be completed not less than three (3) working days prior to commencing the other borings at that site.
(d) Borings designated as soil borings, Type A (0-75 feet) or soil borings, Type A (over 75 feet) will be cased holes performed in accordance with the requirements of these specifications for such work.

For borings designated as soil borings - Type B the Contractor, at its option, may employ drilling methods involving uncased holes or use of hollow-stem augers or use of the methods required for soil borings - Type A or any combination of these methods, provided it can also perform split tube sampling, stationary piston sampling and rock coring as required in the bore hole.

In boring methods using a heavy drilling fluid, casing will be driven to such depths below ground surface as required to maintain the top of bore holes. Thereafter, heavy drilling fluid may be used to maintain the holes. At the completion of such holes, the heavy drilling fluid will be removed by flushing or bailing in order that the true water level may be accurately determined.

In soil borings using hollow-stem auger methods, holes will be advanced using hollow-stem auger flights capable of accommodating 2 inch outer diameter samplers at locations where 3 inch borings are specified. The inner rod-center plug assembly will be used to prevent disturbed soil from entering the stem.

Hollow-stem auger borings or uncased borings which fail to penetrate to the specified depth will be continued by other methods which may include use of the cased methods described herein. Payment for borings specified as "soil borings - Type B" will be made at the Contract unit price for this item regardless of the method or combination of methods necessary to achieve the required depth.

(e) No soil samples will be obtained by driving and removing casing.

(f) After completion of the boring the hole must be completely backfilled as directed by the Engineer. Usually cuttings from the borings will be used as backfill, however, the Engineer may require the hole to be backfilled with other materials such as sand, crushed stone or cement grout. All borings located in the roadway and any borings that include structural coring will be backfilled with cement grout. The bid documents will specify which borings, if any, will require cement grout backfill. Borings drilled in fine grained soil that is below the water table may require backfilling with sand or crushed stone. The Contractor should always have sand or crushed stone on-site in sufficient quantity to backfill borings in case it is necessary to use. Soil backfill will be placed in hole and be thoroughly compacted as the hole is filled. Spoils that remain after the hole is completely backfilled will be handled as directed by the Engineer. On some sites the spoils may be evenly dispersed on-site upon the ground surface, but on some sites, such as urban areas the spoils may need to be taken off-site. Disposal of spoils that are to be taken off-site will be the responsibility of the Contractor. All holes drilled through the pavement will be topped with a minimum of 3 inches of bituminous cold patch material.

Casing:

(a) Sinking: Casing will be driven vertically through earth or other materials to such depth below the surface of the ground as required to maintain the sides of bore holes or as directed by the Engineer. The blows per foot required for the penetration of the casing will be recorded and included in the Contractor's drill record. Simultaneous washing and driving of the casing will not be permitted except by order of the Engineer and where so permitted the elevations between which water was used in driving the casing must be recorded on the Contractor's logs.

It is the Contractor's responsibility when boulders or other obstacles are encountered to carry the drilling through or past such obstacles.

Blasting with small charges will not be permitted.

(b) Size: Casing will be of a size that will permit the specified soil sample, soil test, rock core, or monitoring device to be installed or to allow for the telescoping and spinning of casing.

(c) Weight of hammer for casing: The weight of hammer for driving the casing will be 300 pounds and the drop will be 24 inches.

(d) Removal: The casing will be removed on completion of the work and it will remain the property of the Contractor.
However, no casing will be removed until measurements of the water level have been made and the Engineer has approved such removal. In addition, water level measurements will be made at twenty-four (24) hours and forty-eight (48) hours after the casing has been removed, provided the hole has not collapsed. Bore holes will not be backfilled until the final water level measurement has been made unless ordered by the Engineer. Casing may be removed upon completion of soil borings at which the Engineer directs that observation wells be installed.

Should the casing or apparatus be removed from a bore hole or should the hole be abandoned, without the permission of the Engineer or should a boring re-started and for any reason not carried to the depth required by the Engineer or should the Contractor fail to keep complete records of materials encountered or furnish the Engineer the required samples and cores, the Contractor will make an additional soil boring at a location selected by the Engineer and no payment will be made for either the abandoned hole or any samples or cores obtained therein. However, the Contractor will make a record of abandoned bore holes and note thereon the reasons for the abandonment.

Method of Measurement: Soil borings when completed as such will be measured by the actual number of vertical linear feet bored for each accepted boring between the ground surface at the boring and the bottom of the accepted bore hole or the bottom of the last soil sample taken, whichever is deeper. This measurement will include the portion(s) of the boring in boulder(s), if any, as well as structural coring regardless of their thickness, but will not include the portion of the hole in bedrock, if any.

Soil boring, Type A (0-75 feet) will be the accepted linear feet of soil boring less than 75 feet deep, or the first 75 feet in soil borings that extend deeper than 75 feet. Soil boring, Type A (over 75 feet) will be the accepted linear feet of soil boring that extends deeper than 75 feet. Soil boring, Type B will be the accepted linear feet of soil boring. The cost for soil backfill material and disposal of spoils, if required, is considered incidental to this item and will not be measured for payment.

Cement grout backfill will be the accepted linear feet of cement grout backfill installed.

Item 2.01 Auger Boring – 4 Inch Diameter

Auger borings must be made with earth augers ranging in size from 4 inches to 8 inches in diameter, depending upon the type of soil encountered and the amount of soil required for a disturbed sample. Earth augers may be hand or power operated. Unless otherwise permitted in writing by the Engineer, a power auger, if used, will be a type which does not mix the soil in advancing the hole, such as a short flight section single flight auger which is withdrawn without rotation from the hole after each new advancement of the auger into undisturbed material. The augers will be turned under a downward pressure, but in no case will the augers be pushed or driven below the soil layers encountered by the twist of the auger in turning the auger into the soil. The auger will be removed when it is filled and a disturbed sample obtained of each soil type and for every 5 feet in depth of the auger hole if there is no change in soil type. Auger borings will be carried to such depths below the ground surface as are directed by the Engineer.

An accurate log will be made for each auger boring with the location of each boring noted, as well as elevations of the top and bottom of the hole and each change of material, as well as the water level when encountered. Materials will be carefully described and identified in the log of every hole. This item will include the procurement of split tube samples. Samples from auger holes will be preserved and submitted as specified for split tube samples unless otherwise directed.

Payment will not be made for any auger holes from which, in the opinion of the Engineer satisfactory soil samples are not obtained.

If gravel or cobbles or other obstacles are encountered, the Contractor will make all reasonable efforts to carry the auger boring past such obstacles. However, if such efforts fail and the hole must be abandoned before adequate information is obtained, another auger boring will be tried nearby where directed by the Engineer.

Method of Measurement: This work will be measured for payment by the actual number of vertical linear feet between the ground surface and the deepest point penetrated by the auger for each Engineer accepted auger boring. Abandoned auger holes will be accepted and measured for payment from the ground surface to the top of the obstacle which caused abandonment of the hole, provided the Contractor made all reasonable efforts to advance the hole before abandoning it.

Item 3.01 Split Tube Sample

While performing soil or auger borings, the Contractor will take split tube samples at approximately 1 foot below the ground surface and at the beginning of every change of stratum and at intervals not to exceed 5 feet, unless otherwise directed by the Engineer. At these points, advancement of the bore hole will be stopped and all material removed from inside the casing or bore hole. The sampler will be driven in accordance with equipment and procedures outlined in ASTM D-1586-84 or American Association of State Highway and Transportation Officials ("AASHTO") T 206-87, Standard Penetration Test ("SPT") which are both incorporated herein as they may be amended, updated or supplemented from time to time. A fully automatic hammer system will be used to conduct the SPT. The automatic hammer system will lift a 140 pound drive weight and completely release the weight for a 30 inch free fall. The drive weight will not have a cable or rope attached that may impede the fall. The Engineer has the option to waive the required use of the automatic hammer system and allow the use of rope and cable systems. The use of water for cleaning out between samples will generally be allowed and approved chopping bits, augers or sampling spoons may be used for cleaning the casing or bore hole preparatory to taking split tube samples. The reuse of wash water will not be permitted except in unusual cases and then only with the written approval of the Engineer. The pump used for wash water will have sufficient capacity to adequately clean the bore holes before sampling the material which has been loosened. The samples will be obtained by driving a split tube sampler 24 inches into the undisturbed material below the bottom of the casing or bore hole.

When sampling in granular materials, the casing will be kept full of water at all times, unless otherwise directed by the Engineer. The casing will be filled with water and covered at the end of the working day and the drop recorded when work is resumed.

Split tube samplers will be equipped at the top with a reliable check valve and will have a minimum inside sampling length of 24 inches. They will have minimum inside diameter of 1 1/2 inches. If difficulty is experienced in the first attempt to recover a sample, the split tube sampler for the second attempt will be equipped at the bottom with a basket shoe or other spring type sample retainer. Flap (trap) valves will be allowed only with the approval of the Engineer. If the earth is very compact and cannot be sampled using the split tube sampling methods required herein, the Contractor will resort to coring methods to obtain a sample.

To facilitate determination of the relative resistance of the various strata, the 2 inch split tube samplers will be driven by a hammer weighing 140 pounds and having a 30 inch drop. The number of blows for each 6 inches of penetration will be recorded.

Representative specimens of each sample will be preserved. The containers for preserving drive samples will be large-mouth, round, screw top, air tight, clear glass jars. Size of jars will be 8 ounce for all drive samples. The specimens will be placed in the jars and tightly capped with gasket sealed caps as soon as they are taken in order to preserve the original moisture in the material. Samples which retain their form upon removal from the sampling spoon will not be jammed or forced into the jar. The jars will be suitably boxed in cardboard boxes, twelve (12) to a box, marked and identified with legible labels. These labels will show the date, town, project name, route number, road name, project number, boring number, sample number, depth at which the sample was taken, number of blows for each 6 inches of penetration. The samples will be protected against freezing and the jars protected against breaking. When a split tube sample contains material from more than one (1) distinct soil stratum, a representative specimen from each stratum will be placed in separate jars. Additional identification will be as required by the Engineer.

Method of Measurement: Split tube samples will be paid at the contract unit price each. The quantity of split tube samples will be the actual number of completed samples actually taken and accepted. The use of an automatic hammer, where required by the Engineer, will be included in the cost of the split spoon samples and will not be measured for payment.

Item 4.01 Stationary Piston Sample

While performing soil borings, it may be necessary to obtain stationary piston samples. Stationary piston samples will be taken with a sampler containing a close fitting piston operated by a separate piston, rod and a sampler head with appropriate spring and piston rod check. The sampler will meet AASHTO T 207-87 which is incorporated herein as it may be amended, updated or supplemented from time to time. The sampler tube will have a No. 16 wall thickness, (as described in AASHTO T 207-87) will be 30 to 36 inches long and 3.0 inches outer diameter, will be provided with a sharp cutting edge and positive inside clearance and will be bright, clean and free from rust. The end of the tube will be drawn in so the inner diameter of the cutting edge will be 1/64 inch less than the inner diameter of the sampler tube.

Samples will be taken in a "piston clamped flush position," unless otherwise directed by the Engineer to produce samples 24 inches long.

Before each sample is taken, the casing or bore hole will be thoroughly cleaned with a cleanout jet auger.

The sampler will be jacked or forced into the ground without rotation in one continuous operation under steady pressure at a rate of from 1/2 to 1 foot per second.

The sampler tube with sample will be detached from the head of the mechanism in a manner so as to cause as little disturbance as possible to the sample.

Samples having less than 50 percent recovery of undisturbed soil will not be accepted for payment under this item.

All samples will be preserved. In preserving samples, a maximum of 1 inch of material will be removed from the bottom of the tube and used to make up a jar sample. All disturbed material will be removed from the top of the tube. A 1 inch wax seal will be placed at the top and bottom of the remaining undisturbed material and allowed to harden. Empty portions of the tube will then be filled with firmly pressed damp sand and the tube ends will be sealed with a metal or plastic cap, friction tape and wax.

Stationary piston samples will be marked upon removal from the ground to indicate the upper end of the sample and will be transported and stored in the same relative position as they existed in the ground.

The weights of all stationary piston samples will be determined and recorded immediately after they are sealed and ready for transfer to the custody of the Engineer. The utmost care will be used in protecting the stationary piston samples from freezing, jarring or disturbance of any kind.

Method of Measurement: Stationary piston samples will be paid at the Contract unit price each. The quantity of stationary piston samples will be the actual number of completed samples actually taken and Engineer accepted.

Item 5.01 Rock Coring – NX

Wherever bedrock is encountered, the Contractor will take continuous core samples to a depth directed by the Engineer. Each core run will be drilled by means of a rotary method and diamond bit of such size as will yield cores not less than 2 1/8 inch in diameter (NX).

The diamond core bit will be started in the hole and the bedrock will be drilled until the required depth is reached. When the core is broken off, it will be withdrawn, labeled and stored before the drilling is continued. The holes will be carried into the bedrock to a depth sufficient to permit the Engineer to determine to its satisfaction the character of the bedrock penetrated. In general, it is expected that the depth of the core holes in bedrock will be 5 feet, but it may be required in some cases to penetrate the bedrock as much as 45 feet or as directed by the Engineer. The maximum length of each coring run will be 5 feet. However, the Engineer reserves the right to reduce the length of core run as necessary to affect maximum recovery.

Rock cores will be carefully handled to insure their proper identification and placed in the order in which they are removed from the hole. Care will be taken to recover as large a percentage of core as possible. The Contractor will regulate the speed of the drill and remove the core as often as necessary to insure the maximum percentage of recovery. The drilling time for each successive foot of rock drilling will be recorded.

Should the recovered length of core be less than 50 percent of the depth cored for any run, the Contractor will adopt such measures as may be necessary to improve the percentage of recovery. These measures may include, but will not necessarily be limited to changes in type of diamond bit, feed rate, speed of rotation, volume of circulation, use of a triple tube core barrel, length of run per removal and change in machine operator. In those cases where, in the opinion of the Engineer, the competency, structure and condition of the bedrock are critical to the design, the Engineer reserves the right to direct that a triple tube core barrel be used.

All rock cores will be stored in wooden boxes, constructed rigidly enough to prevent flexing of the core when the box is picked up by its ends. The boxes will be provided with hinged covers and with longitudinal spacers that will separate the core into compartments. Small blocks which fit between the spacers will be provided to mark the beginning and end of each run or pull of core. The top of the first core run will start at the uppermost left corner of the box (hinge side). Any break in a core that occurs during handling should be marked with three parallel lines across the mechanical break.

An indelible marker will be used to note the project number, boring number, core run numbers, depth interval, and box number on the top, front, inside lid, and both ends of the core box. The inside lid will also include a listing of the recovery and Rock Quality Designation (RQD) as determined per ASTM D6032 for each core run. Each sample attempted, regardless of recovery, will be designated with a name and number and recorded on a drillers field log.

Method of Measurement: This work will be measured for payment by the actual number of vertical linear feet of Engineer accepted drilled hole in bedrock and in individual boulders 2 feet or more in thickness.

Item 5.02 Structural Coring – NX

Structural coring will be specified when it is necessary to core into or through an existing structure. Material encountered, may include concrete, steel reinforced concrete, stone masonry, etc. Each core run will be drilled by means of a rotary method and diamond bit of such size as will yield cores not less than 2 1/8 inch in diameter ('NX").

The diamond core bit will be started in the hole and the structure will be drilled until the required depth is reached. When the core is broken off, it will be withdrawn, labeled and stored before the drilling is continued. Structure cores will be carefully handled to insure their proper identification and placed in the order in which they are removed from the hole. Care will be taken to recover as large a percentage of core as possible. The Contractor will regulate the speed of the drill and remove the core as often as necessary to insure the maximum percentage of recovery. The drilling time for each successive foot of rock drilling will be recorded.

Should the recovered length of core be less than 50 percent of the depth cored for any run, the Contractor will adopt such measures as may be necessary to improve the percentage of recovery.

All structure cores will be stored in wooden boxes or other durable material, constructed rigidly enough to prevent flexing of the core when the box is picked up by its ends. The boxes will be provided with hinged covers and with longitudinal spacers that will separate the core into compartments. Small blocks which fit between the spacers will be provided to mark the beginning and end of each run or pull of core. The top of the first core run will start at the uppermost left corner of the box (hinge side). Any break in a core that occurs during handling should be marked with three parallel lines across the mechanical break.

An indelible marker will be used to note the project number, boring number, core run numbers, depth interval, and box number on the top, front, inside lid, and both ends of the core box. The inside lid will also include a listing of the recovery for each core run. Each sample attempted, regardless of recovery, will be designated with a name and number and recorded on a field log.

Method of Measurement: Structural coring will be the actual number of linear feet of Engineer accepted drilled borehole through a structure.

Item 6.01 Pavement Core-4 inch Diameter
Item 6.02 Pavement Core-8 inch Diameter
At each location indicated on the plans, the Contractor will take continuous core samples of the pavement to a depth directed by the Engineer by means of a rotary method and a bit of such size as to yield a core not less than 4 inches in diameter for a pavement core-4 inch diameter and 7 3/4 inches in diameter for a pavement core-8 inch diameter.

The core bit will be started at the pavement surface and the pavement will be drilled until the required depth is reached. When the core is broken off, it will be withdrawn, labeled and stored before drilling is continued. The holes will be carried to the bottom of the pavement.

However, the Engineer reserves the right to reduce the length of core run as necessary to affect maximum recovery. Upon removal of core, the hole will be backfilled with a suitable patch.

Cores will be carefully handled to insure their proper identification and placed in the order in which they are removed from the hole. Care will be taken to recover as large a percentage of core as possible. The Contractor will regulate the speed of the drill and remove the core as often as necessary to insure the maximum percentage of recovery.

Should the recovered length of core be less than 80 percent of the depth cored for any run, the Contractor will adopt such measures as may be necessary to improve the percentage of recovery. These measures may include, but will not be limited to changes in type of bit, feed rate, speed of rotation, volume of circulation, length of run per removal and change in machine operator.

Each pavement core will be placed in suitable cardboard box. Pavement cores will be suitably labeled and arranged neatly in the boxes in the sequence in which the material was removed from the hole. The boxes will be properly labeled showing the date the core was taken, town, project name, road name, project number, station and offset, boring number, depth of core and driller's names.

Method of Measurement: Pavement cores, of the size specified, will be paid at the contract unit price each. The quantity of pavement cores will be the actual number completed and accepted.

Item 7.01 Test Pits
Test pits, 3 feet by 5 feet minimum horizontal dimensions at the bottom and as specified below or ordered by the Engineer, will be dug at locations as directed by the Engineer. Test pits will be dug

to a maximum depth of 5 feet. Test pits will be properly sheathed to protect the workers and will be large enough to allow easy inspection of soil conditions and procurement of soil samples, if necessary. A detailed log of soil and water conditions will be made for each test pit, including the location of each pit and elevation of the top and bottom of each pit and the elevation at each change of material therein. This item will include the procurement of samples which will be preserved and submitted as directed.

When the test pit is approved and accepted by the Engineer and the necessary samples taken, it will be backfilled.

Method of Measurement: This work will be measured for payment by the actual number of completed and accepted test pits.

Item 8.01 Bar Soundings
Bar soundings will be taken where and to such depths as directed by the Engineer. The estimated maximum depth of bar soundings is 15 feet.

If boulders or other obstacles are encountered, the Contractor will make all reasonable efforts to drive the bar past such obstacles. However, if such efforts fail and the sounding must be abandoned before adequate information is obtained, another sounding will be made nearby where directed by the Engineer. An accurate log will be made for each bar sounding with the location of each sounding and elevations noted for the ground surface at the sounding location and for the bottom of the sounding.

Method of Measurement: This work will be measured for payment by the actual number of vertical linear feet sounded for each accepted bar sounding between the ground surface, bottom of test pit, bottom of auger boring or bottom of other boring at the sounding and the bottom of the bar sounding. Abandoned bar soundings will be accepted and measured for payment from the ground surface or other starting elevation, if lower, to the top of the obstacle which caused abandonment of the sounding, provided the Contractor made all reasonable effort to drive the bar and the bar met refusal before the sounding was abandoned.

Item 9.01 Drill Rod Probe
Drill rod probes will be made to determine the depth and lateral extent of organic material in swamps or marshes. A drill rod or appropriate equal will be used in such areas to obtain the extent of the organic material. These probing's will extend to firm-bearing soil. An accurate log will be made for each probing, including the elevation at the ground surface and at the bottom of the probing.

Method of Measurement: This work will be measured for payment by the actual number of vertical linear feet probed for each accepted drill rod probe between the ground surface and the bottom of the probe.

Item 10.01 Observation Wells
Observation wells, consisting of schedule 40 Polyvinyl Chloride (PVC) monitoring well casing and slotted screen of 3/4 to 2 inch outside diameter, will be installed in borings designated by the Engineer. Soil Borings in which observation wells are to be installed will be determined as the work proceeds. Notice to install an observation well will be given prior to time of completion of the borings selected. The total length of casing required for any observation well will not exceed 60 feet.

If the casing is to be left above ground, a riser pipe consisting of 5 feet of 3 inch nominal inner diameter steel casing with a locking cap will be required at the ground surface for protection. If the well is to remain flush with the ground, it will be encased in a bolt down, locking, water tight curb box or manhole. The curb boxes will be supplied by the Contractor and clearly labeled as a monitoring well. Curb boxes will be 8 inches to 12 inches in diameter and meet or exceed AASHTO standard for "HL-93" truck loadings. The curb boxes will be encased in a concrete pad 12 inches X 12 inches X 12 inches to prevent the destruction of the unit. The Contractor will supply the Engineer with a key or wrench that is designed to open the curb box.

The PVC will be new, clean 3/4 inch to 2 inch outside diameter and made of Type I, Schedule 40, flush joint threaded PVC with an o-ring seal. The bottom 5 feet or greater as determined by the Engineer, will be factory slotted with 0.010 or 0.020 high capacity slots. A suitable PVC threaded point and o-ring seal will close the bottom of the well screen.

Filter material will consist of fine aggregate used for Portland cement concrete or Number 0 New Jersey sands.

The boring will be filled with filter material to the elevation directed by the Engineer at which the bottom of well will be located. Dependent upon the depth of boring, there will be at least 2 feet of filter material below the bottom of PVC. The assembled well will be lowered into the cased boring and additional filter material will be placed around the PVC as the casing is withdrawn from the hole. The well will be kept centered in the boring during the backfilling operation. The filter material will be placed up to an elevation approximately 5 feet below the ground surface and the remaining depth of boring will be backfilled with firmly-tamped suitable impervious material, unless otherwise directed by the Engineer. The 5 foot length of casing and the PVC will be set flush with or extended above the ground surface to such height as the Engineer may direct.

Method of Measurement: This work will be measured for payment by the actual number of linear feet from the observation well bottom to the top of the riser pipe, but not more than 2 feet above the ground surface or to the top of the curb box, for each accepted well installed in accordance with these specifications, or as directed by the Engineer.

Item 11.01 Piezometer
Piezometers may be required to be installed in soil borings, type A. The borings, which will require the installation of a piezometer, will be specified in the bid documents. The piezometer unit to be installed will be supplied by the Contractor.

The piezometer will be installed in accordance with the manufacturer's specifications and AASHTO specification T252-96.

To protect the piezometer from damage, a riser pipe consisting of 5 feet of 3 inch nominal inner diameter steel casing with a locking cap, will be required at the ground surface.

Method of Measurement: This work will be measured for payment by the actual number of linear feet from the piezometer tip to the top of the riser pipe, but not more than 2 feet above the ground surface for each accepted piezometer installed in accordance with these specifications, or as directed by the Engineer.

Item 12.01 Inclinometer

The Contractor is to install grooved inclinometer casing and appurtenances. The casing will be comprised of 2.75 inch outer diameter x 2.32 inch inner diameter acrylonitrile butadiene styrene (ABS) plastic telescoping coupling. The casing will have two (2) vertical, perpendicular sets of grooves on the inside surface to guide the inclinometer monitoring unit. The casing will have recessed ends to allow the coupling to freely slide for a minimum of 3 inches per 10 foot casing section. The casing will have screws set at the 1/4 points and mid-point between groove centers.

The inclinometer will be installed in accordance with AASHTO specification T 254-80 and the manufacturer's specifications.

For protection, the inclinometer is to be cut flush with the ground and encased in a bolt down locking, water tight curb box or manhole. The curb boxes will be supplied by the Contractor and clearly labeled as monitoring wells. Curb boxes will be 8 inches to 12 inches in diameter and meet or exceed AASHTO standard for "HL-93" truck loadings. The curb boxes will remain flush to the ground and be encased in a concrete pad 12 inches X 12 inches X 12 inches to prevent the destruction of the unit.

Method of Measurement: This work will be measured for payment by the actual number of linear feet from the bottom of the inclinometer casing to the ground surface for each accepted inclinometer installed in accordance with these specifications, or as directed by the Engineer.

Item 13.01 Uniformed Trafficperson

The Contractor will provide the services of uniformed traffic-persons as the Engineer determines and approves for the control and direction of vehicular traffic and pedestrians.

The Contractor will inform the Engineer of their scheduled operations and the number and type of uniformed traffic-persons required. A uniformed traffic-person when scheduled, will be on site during installation and removal of all traffic control devices (signs, etc.).

If the Contractor changes or cancels any scheduled operations without prior notice of same as required by the agency providing the uniformed traffic-person and such services are no longer required, the Contractor will be responsible for payment at no cost to Conn DOT of any cost for any traffic-person-uniformed not used because of the change. Exceptions, as approved by the

Engineer in writing, may be granted at Engineer's discretion for adverse weather conditions and unforeseeable causes beyond the control and without the fault or negligence of the Contractor.

Uniformed traffic-persons assigned to a work site are to only take direction from the Engineer.

Uniformed traffic-persons will wear a high visibility safety garment that complies with OSHA, MUTCD and ASTM Standards

Method of Measurement: Only uniformed traffic-persons services approved by the Engineer will be measured for payment. Services of uniformed trafficpersons will be measured for payment by the actual number of hours for each person rendering services in accordance with these specifications. Services of uniformed trafficpersons utilized by the Contractor, for which the Engineer did not approve, will not be measured for payment. In cases where the uniformed trafficpersons is an employee on the Contractor's payroll, payment for the uniformed trafficpersons will be made only for those hours when the Contractor's employee is performing uniformed traffic-persons duties.

Safety garments and STOP/SLOW paddles will not be measured for payment.

Item 13.02 Trafficperson(s) – Police Officer (Municipal)

Municipal police officers used as trafficperson(s) will be sworn municipal police officers or uniformed constables who perform criminal law enforcement duties from the municipality in which the project is located. Their services will also include an official police vehicle. Municipal police officers used as trafficperson(s), when available in a municipality will be used on non-limited access highways and local roads. When municipal police officers used as trafficperson(s) are unavailable, other uniformed traffic persons may be used when authorized in writing by the Engineer.

Municipal police officers used as trafficperson(s) will be used at such locations and for such periods as the Engineer deems necessary to control traffic operations and promote increased safety to motorists through the work site.

Municipal police officers used as trafficperson(s) may conduct motor vehicle enforcement operations in and around work areas as directed and approved by the Engineer.

Municipal police officers used as trafficperson(s) will wear the high visibility safety garment provide by their law enforcement agency. If no high visibility safety garment is provided, the Contractor will provide the law enforcement personnel with a garment meeting the requirements of OSHA, MUTCD and ASTM Standards for the municipal police officers used as trafficperson(s). The Contractor will also provide STOP/SLOW paddles if needed.

Method of Measurement: Only municipal police officer traffic person services approved by the Engineer will be measured for payment. Services of trafficpersons will be measured for payment by the actual number of hours for each municipal police officer rendering services in accordance with these specifications. The Contractor will also provide STOP/SLOW paddles if needed.

The minimum hours of payment for each municipal police traffic-person supplied by a law enforcement agency in any one day will be four hours.

No travel time will be allowed or paid for municipal police officers.

Safety garments and STOP/SLOW paddles will not be measured for payment.

Item 13.03 Trafficperson(s) – Police Officers (State)

Municipal police officers used as trafficperson(s) will be sworn State of CT police officers or uniformed constables who perform criminal law enforcement duties from the municipality in which the project is located. Their services will also include an official police vehicle. Municipal police officers used as trafficperson(s), when available in a municipality will be used on non-limited access highways and local roads. When municipal police officers used as trafficperson(s) are unavailable, other uniformed traffic persons may be used when authorized in writing by the Engineer.

State police officers used as trafficperson(s) will be used at such locations and for such periods as the Engineer deems necessary to control traffic operations and promote increased safety to motorists through the work site.

State police officers used as trafficperson(s) may conduct motor vehicle enforcement operations in and around work areas as directed and approved by the Engineer.

State police officers used as trafficperson(s) will wear the high visibility safety garment provide by their law enforcement agency. If no high visibility safety garment is provided, the Contractor will provide the law enforcement personnel with a garment meeting the requirements of OSHA, MUTCD and ASTM Standards for the state police officers used as trafficperson(s). The Contractor will also provide STOP/SLOW paddles if needed.

Method of Measurement: Only state police officer trafficperson services approved by the Engineer will be measured for payment. Services of trafficpersons will be measured for payment by the actual number of hours for each person rendering services in accordance with these specifications. Services of trafficpersons utilized by the Contractor, for which the Engineer did not approve, will not be measured for payment.

The minimum hours of payment for each state police trafficperson supplied by a law enforcement agency in any one day will be four hours.

One hour of travel time will be paid for each state police officer per day. If an officer splits the work shift with another officer the travel time will be cut in half for each of the officers.

Safety garments and STOP/SLOW paddles will not be measured for payment.

Item 14.01 Mobilization and Dismantling-Land
This item will include the initial mobilization of the drill rig at the project site and the final dismantling after all borings are complete. The Contractor is required to furnish the drill rig and tools, in good condition and all other equipment necessary to carry on and complete the work properly. The Contractor may be required to mobilize and dismantle its equipment at existing highway structures, highway embankments, highway rights of way, off the traveled way, wooded areas and other difficult sites. Standard site preparation includes activities such as minor tree or brush removal, temporary dismantling and reassembling guide rail, minor earth leveling work performed with hand tools and other minor site preparation activities, as determined by the Engineer. The Contractor will have the necessary equipment and personnel to assemble its drilling equipment at the desired locations.

The mobilization and dismantling-land item will include full compensation for all traffic control devices, cones, signs, etc. When the Contractors operations obtrude onto any part of the roadway, the Contractor is to adhere to ConnDOT's publication "Work Zone Safety Guidelines for Maintenance Operations" revised 2013. Traffic control will not include crash trucks, arrow boards or message signs.

All material and equipment furnished under this item will remain the property of the Contractor and will be maintained and disposed of by it. This item will carry all charges incidental to such plant setup and removal, in order that the charges need not be distributed among the more variable items of the Contract.

Method of Measurement: This item will be measured for payment by the actual number of boring rigs and/or crews specified in the bid documents or as directed by the Engineer. This item will be due for payment at the time of final payment after removal of all materials and equipment from the project.

Item 14.02 Mobilization and Dismantling-Railroad
This item will include the initial mobilization of the drill rig at the project site and the final dismantling after all borings are complete. The Contractor is required to furnish the drill rig and tools in good condition and all other equipment necessary to carry on and complete the work properly.

The Contractor may be required to mobilize and dismantle his equipment at existing railroad structures, railroad embankments, railroad rights-of-way, and other areas under railroad ownership. The Contractor shall have the necessary equipment and personnel to assemble his drilling equipment at the desired locations. ***The Contractor may be required to provide the drill rig on a high rail vehicle.***

The backfilling and casing, hand excavation in the top few feet of ballast, or any other requirements made by a railroad or public transportation authority for entering on their property shall be complied with by the Contractor and any costs shall be considered as part on the unit price of Mobilization and Dismantling-Railroad and no additional compensation will be allowed. The cost of the entry permit required by the railroad or public transportation authority will be reimbursed to the Contractor as a direct cost. No additional compensation will be made to the Contractor for preparation of the entry permit. Should Railroad flagmen and/or Groundmen be required, the

Department will establish a force account with the railroad for their payment. If there are limitations of operations imposed by the railroad that reduce the work day to less than 8 hours then standby time will apply and will be measured and paid for under Item 18.01 Standby Time.

The Mobilization and Dismantling item shall include full compensation for all traffic control devices, cones, signs, etc. When the Contractors operations obtrude onto any part of the roadway, the Contractor is to adhere to the Department's publication "Work Zone Safety Guidelines" revised 2013.

All material and equipment furnished under this item will remain the property of the Contractor and will be maintained and disposed of by it. This item will carry all charges incidental to such plant setup and removal, in order that the charges need not be distributed among the more variable items of the Contract.

Method of Measurement: This item will be measured for payment by the actual number of boring rigs and/or crews specified in the Request for Quotation or as directed by the Engineer. This item will be due for payment at the time of final payment after removal of all materials and equipment from the project. There will be no separate payment for Contractor's employees to receive training required by the railroad to work on rail property because that training is considered incidental to this item.

Item 15.01 Mobilization and Dismantling-Water

This item will include the initial mobilization of the drill rig at the project site, the launching, positioning and moving of rafts and other equipment necessary for making borings over water and the final dismantling after all borings are complete. The Contractor is required to furnish the drill rig and tools, in good condition and all other equipment necessary to carry on and complete the work properly. The Contractor will have the necessary equipment and personnel to assemble its drilling equipment at the desired locations.

For work on water, the Contractor shall provide and set a water level gauge as directed by the Engineer, the use of a boat or float, and boatmen, laborers and material to constitute a part of the usual equipment and crew, as may be required in supervising the work.

The mobilization and dismantling-water item will include full compensation for all traffic control devices, cones, signs, etc. When the Contractors operations obtrude onto any part of the roadway, the Contractor is to adhere to ConnDOT's publication "Work Zone Safety Guidelines" revised 2013. Traffic control will not include crash trucks, arrow boards or message signs.

All material and equipment furnished under this item will remain the property of the Contractor and will be maintained and disposed of by it. This item will carry all charges incidental to such plant setup and removal, in order that the charges need not be distributed among the more variable items of the Contract.

Method of Measurement: This item will be measured for payment by the actual number of boring rigs and/or crews specified in the bid documents or as directed by the Engineer. This item will be due for payment at the time of final payment after removal of all materials and equipment from the project. The cost for a water level gauge is considered incidental to this item and will not be measured for payment.

Item 16.01 Mobilization and Dismantling-Tracked Rig or Skid Rig on Land
This item will include the set up and breakdown of a tracked rig or skid rig on borings that require such a setup, as determined by the Engineer. If after examination of the site the Contractor feels a boring location warrants use of a tracked rig or skid rig, the Contractor will confirm approval for use of a tracked rig or skid rig under this item with the Engineer. The Contractor is required to furnish the tracked or skid rid rig, and tools, in good condition and all other equipment necessary to carry on and complete the work properly. The Contractor may be required to mobilize and dismantle its equipment at existing highway embankments, highway rights of way, off the traveled way, wooded areas and other difficult sites. Standard site preparation includes activities such as minor tree or brush removal, temporary dismantling and reassembling of guide rail, minor earth leveling work performed with hand tools and other minor site preparation activities, as determined by the Engineer. The Contractor will have the necessary equipment and personnel to assemble its drilling equipment at the desired locations.

Method of Measurement: This item will be measured for payment by the actual number of boring rigs and/or crews specified in the bid documents or as directed by the Engineer. This item will be due for payment at the time of final payment after removal of all materials and equipment from the project.

Item 17.01 Standby Time
Certain projects may require the Contractor to curtail operations from the workday specified in the contact documents due to working hour restrictions imposed by Connecticut DOT or for other reasons such as traffic control including highway, air and rail traffic, tides or other conditions. Construction projects may require that the Contractor stop the test boring operations.

When standby time occurs for any purpose it will be determined by the Engineer.

No standby time will be paid when work cannot be performed due to adverse weather conditions as determined by the Engineer, State police or municipal police, breakdowns, etc. Should the State deem any Contractor equipment or workers to be unsafe no standby time will be paid for the Contractor to furnish replacement workers or equipment.

Standby time will not be paid for time after all productive work as determined by the Engineer has been completed at a site.

Standby time will not be paid to assemble or remove a traffic control pattern.

If more than one (1) drill rig is being used on a project this item will be paid per hour per drill rig when applicable, as determined by the Engineer.

Method of Measurement: The item standby time will be measured for payment by the actual number of hours each drill rig is required by the Engineer to standby. Standby time will be measured to the nearest 15 minute interval.

Item 18.01 Truck Mounted Impact Attenuator Vehicles (TMAs) Operations on limited access, high volume roadways which require the use of a TMA (commonly referred to as a crash truck) will be provided in accordance with this item. The TMA will be placed prior to the first work area in the traffic control pattern. If there are multiple drill rigs working within the same pattern then each drill rig will have a TMA positioned at a sufficient distance (25 to 100 feet), as directed by the Engineer, to protect the workers and traveling public.
Any TMA/crash system manufactured before 12/31/2019 can be used throughout its service life must conform either to NCHRP 350 (TL-3) or AASHTO MASH (TL-3). Any TMA/crash system that is manufactured on or after 12/31/19 must meet AASHTO MASH (TL-3) requirements. Prior to using a TMA the Contractor shall submit to the Engineer a materials certificate for each attenuator supplies along with a copy of the federal aid eligibility letter issued to the manufacturer documenting that the device complies with the requirements stated here.

The truck will have a minimum weight (mass) of 15,000 pounds (6,800 kilograms) and a maximum weight (mass) in accordance with the manufacturer's recommendations. Any ballast used to obtain the minimum weight requirement, or any other object that is placed on the vehicle will be anchored so that it will be retained on the vehicle during an impact.

The truck will be equipped with an internally illuminated flashing arrow visible from the rear. The bottom of the illuminated arrow sign will be installed a minimum of 7 feet above the ground. The illuminated arrow will conform to the requirements of Part VI MUTCD, Advance Warning Flashing Sequencing Arrow panels, Type C.

The truck will be equipped with a minimum of two (2) amber strobe type flashers mounted above the internally illuminated flashing arrow.

The TMA unit will have a chevron pattern that covers the rear face of the unit. The standard chevron pattern will consist of stripes, alternating non-reflective black and Type III retro-reflective yellow sheeting, slanted at 45 degrees in an inverted "V" pattern, centered on the rear of the unit. The width of the stripes will be between 4 and 8 inches.

The disposal of crushed or damaged systems is the responsibility of the Contractor. The disposal method employed will be approved by the Engineer.

Method of Measurement: This item will be measured for payment by the actual number of TMA(s) that are used on a daily basis when determined necessary by the Engineer. This item will be due for payment at the time of the final payment.

Item 19.01 Light Plant
Operations which will be performed during hours of darkness will require either equipment mounted or standalone illumination. Illumination will include a minimum of two (2) flood/wide

lights and two (2) narrow/spot lights. The lighting will be UL listed as suitable for wet locations and be either 250 watt metal halide lamps with integral ballast or 1000 watt quartz PAR64, or approved lighting fixtures of equivalent light output characteristics.

All mounts will provide a secure connection that allows for adjustable positioning and aiming of the light fixture. Lighting must be capable of maximizing the illumination on each task, while minimizing glare to the passing traffic.

Lighting will be provided continuously during the entire operation and a sufficient number of spare lamps will be available on site in the event of failures.

Method of Measurement: Lighting will be measured for payment by the actual number of days that each drill rig requires illumination during the hours of darkness.

EXHIBIT B - BID SHEET

Item No.	Description of Commodity	Unit	Approximate Quantities	Unit Price Dollars/Cents	Total Amount of Bid Dollars/Cents
1.01	Soil Boring – Type A (0-75 feet)	L.F.			
1.02	Soil Boring – Type A (Over 75 feet)	L.F.			
1.03	Soil Boring – Type B	L.F.			
1.04	Cement Grout Backfill	L.F.			
2.01	Auger Boring. 4” Diameter	L.F.			
3.01	Split Tube Sample	Each			
4.01	Stationary Piston Samples	Each			
5.01	Rock Coring – NX	L.F.			
5.02	Structural Coring – NX	L.F.			
6.01	Pavement Core – 4 inch	Each			
7.01	Test Pits	Each			
8.01	Bar Soundings	L.F.			
9.01	Drill Rod Probe	L.F.			
10.01	Observation Wells	L.F.			
11.01	Piezometers	L.F.			
12.01	Inclinometers	L.F.			
13.01	Trafficperson – Uniformed	Hour			
13.02	Trafficperson – Police Officer (Municipal)	Hour			
13.03	Trafficperson – Police Officer (State Police)	Hour			
14.01	Mobilization and Dismantling - Land	Ea. Rig			
14.02	Mobilization and Dismantling - Railroad	Ea. Rig			
15.01	Mobilization and Dismantling - Water	Ea. Rig			
16.01	Mobilization and Dismantling – Tracked Rig or Skid Rig on Land	Ea. Rig			
17.01	Standby Time	Hour			
18.01	Truck Mounted Impact Attenuator Vehicles (TMAs)	Day			
19.01	Light Plant	Day			
				Total Bid	

WORK ZONE SAFETY GUIDELINES

FOR MAINTENANCE OPERATIONS

2013

Table of Contents

Introduction

The purpose of this handbook is to present basic guidelines for work zone traffic control. It presents the requirements of Part 6 of the Manual on Uniform Traffic Control Devices (MUTCD) with particular emphasis on the short-term work sites typical to maintenance operations. The purpose of temporary traffic control is to protect motorists, pedestrians, and workers from hazards associated with construction, maintenance, and utility operations.

The handbook presents information and gives examples of traffic control applications for two-lane, multilane, and moving pattern work zones. It is intended to illustrate the principles of proper work zone traffic control, but is not a standard.

Signs

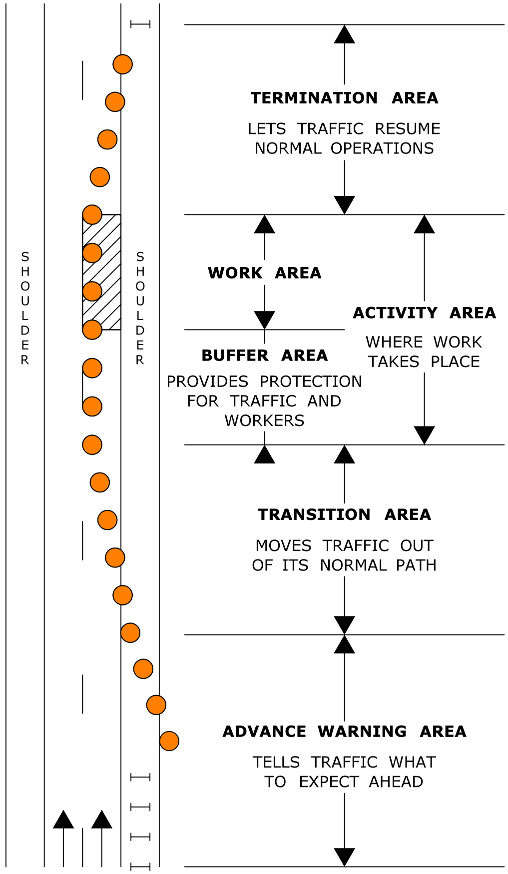
Signs used in work zone traffic control are classified as regulatory, warning, or guide. Regulatory signs impose legal restrictions and may not be used without permission. Warning signs give notice of conditions that are potentially hazardous to traffic. Guide signs commonly show destinations, directions, and distances.

Short Duration

Short duration activities are generally considered to be those for which it takes longer to set up and remove the traffic control devices than to perform the work. According to the MUTCD, short duration work occupies a location for 1 hour or less.

During short duration work, there are hazards involved for the crew in setting up and taking down the traffic control devices. Also, since the work time is short, the time during which motorists are affected is significantly increased as the traffic control is expanded. Considering these factors, it is generally held that simplified traffic control procedures may be warranted for short duration work. Such shortcomings may be offset by the use of other, more dominant devices, such as special lighting units (arrow boards, strobe lights) on work vehicles in conjunction with traffic cones to delineate the work vehicle and/or work area. Conditions will vary; flag persons and advance warning "worker ahead" signs or symbols may also be needed. **Good Judgment** should always prevail in placement of the devices.

FIVE PARTS OF A TRAFFIC CONTROL ZONE



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

FIVE PARTS

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

Traffic Control during Maintenance Operations

The following guidelines shall assist field personnel in determining when and what type of traffic control patterns to use for various situations. These guidelines shall provide for the safe and efficient movement of traffic through work zones and enhance the safety of work forces in the work area.

Traffic control patterns: Traffic control patterns shall be used when a work operation requires that all or part of any vehicle protrudes onto any part of a travel lane or shoulder. For each situation, the installation of traffic control devices shall be based on the following:

1. Speed and volume of traffic.
2. Duration of operation.
3. Exposure to hazards.

Traffic control patterns shall be uniform, neat, and orderly, so as to command respect from the motorist.

In the case of a horizontal or vertical sight restriction in advance of the work area, the traffic control pattern shall be extended to provide adequate sight distance for approaching traffic.

If a lane reduction taper is required to shift traffic, the entire length of the taper should be installed on a tangent section of roadway so that the entire taper area can be seen by the motorist.

Any existing signs that are in conflict with the traffic control patterns shall be removed, covered, or turned so that they are not readable by oncoming traffic.

When installing a traffic control pattern, a buffer area should be provided, and this area shall be free of equipment, workers, materials, and parked vehicles.

Typical traffic control plans 19 through 25 may be used for moving operations such as painting, pothole patching, mowing, or sweeping, when it is necessary for equipment to occupy a travel lane.

Traffic control patterns will not be required when vehicles are on an emergency patrol type activity or when a short duration stop is made and the equipment can be contained within the shoulder. Flashing lights and a trafficperson shall be used when required.

Although each situation must be dealt with individually, conformity with the typical traffic control plans contained herein is required. In a situation not adequately covered by the typical traffic control plans, the Engineer or Supervisor must contact both the District Traffic Representative and the District Safety Advisor for assistance prior to setting up a traffic control pattern.

Placement of signs: Signs must be placed in such a position to allow motorists the opportunity to reduce their speed prior to the work area. Signs shall be installed on the same side of the roadway as the work area. On multilane divided highways, advance warning signs may be installed on both sides of the highway if sight line is restricted. On directional roadways (on-ramps, off-ramps, one-way roads), where the sight distance to signs is restricted, these signs should be installed on both sides of the roadway.

Allowable Adjustment of Signs and Devices Shown on the Traffic Control Plans

The traffic control plans contained herein show the location and spacing of signs and devices under ideal conditions. Signs and devices should be installed as shown on these plans whenever possible.

The proper application of the traffic control plans and installation of traffic control devices depends on actual field conditions.

Adjustments to the traffic control plans shall be made only at the direction of the Engineer or Supervisor to improve the visibility of the signs and devices and to better control traffic operations. Adjustments to the traffic control plans shall be based on safety of work forces and motorists, abutting property requirements, driveways, side roads, and the vertical and horizontal curvature of the roadway.

The Engineer or Supervisor may require that the signing pattern be located significantly in advance of the work area to provide a better sight line to the signing and safer traffic operations through the work zone.

Table 1 indicates the minimum taper length required for a lane closure based on the posted speed limit of the roadway. These taper lengths shall only be used when the recommended taper lengths shown on the traffic control plans cannot be achieved.

TABLE 1 - MINIMUM TAPER LENGTHS

POSTED SPEED LIMIT	MINIMUM TAPER LENGTH FOR A SINGLE LANE CLOSURE
30 MPH OR LESS	180 FEET
35 MPH	250 FEET
40 MPH	320 FEET
45 MPH	540 FEET
50 MPH	600 FEET
55 MPH	660 FEET
65 MPH	780 FEET

Paving Operations on Highways - Work by Contractors

The Engineer or Supervisor will be assigned to each project to coordinate the traffic control for paving operations and determine the number of traffic control personnel required.

The District Traffic Representative will determine the hours of the paving operations and will coordinate the paving operations with other construction activities in the immediate area. The District Traffic Representative will be available to assist field forces on traffic control issues and may contact the Division of Traffic Engineering for additional assistance.

When work hours on a particular project have been established, an on-site meeting between the Department and the Contractor will be held two weeks prior to the starting date. If the District Traffic Representative determines that it is necessary, a news release will be prepared and distributed to the local papers, radio stations, state police, and municipalities.

Moving Operations - Work by State Forces

The Engineer or Supervisor will be assigned to each project and will direct the entire moving operation. If the Engineer or Supervisor must leave the operation, a substitute shall be assigned to continue the operation.

All personnel involved in this work will be instructed by the Engineer or Supervisor regarding the proper application of traffic control patterns that will be used to complete the work.

The first advance warning to the motorist shall be Vehicle 1, which shall be located to maximize visibility for approaching motorists, considering ramps, grades, curves, volumes, and speed of traffic. This vehicle shall not restrict any portion of the travelway on multilane highways, except as noted on the plans.

All vehicles shall have the appropriate illuminated warning devices.

Installing and Removing Traffic Control Patterns

Lane closures shall be installed beginning with the advanced warning signs and proceeding forward toward the work area.

Lane closures shall be removed in the reverse order: beginning at the work area or end of the traffic control pattern, and proceeding back toward the advanced warning signs.

Use of Truck Mounted Impact Attenuator Vehicles (TMAs)

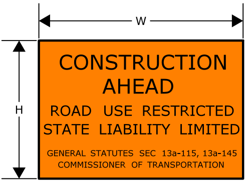
On limited access, high volume roadways, a TMA shall be placed prior to the first work area in the traffic control pattern. If there are multiple work areas within the same pattern, then additional TMAs may be positioned at each additional work area in the pattern as needed.

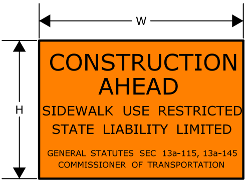
TMAs shall be positioned a sufficient distance prior to the workers or equipment being protected to allow for appropriate vehicle roll-ahead in the event that the TMA is hit, but not so far that an errant vehicle could travel around the TMA and into the work area.

Traffic Cones

Traffic cones shall be fluorescent orange PVC with 6" and 4" white retroreflective collars. Traffic cones shall be 36" minimum in height and 12 lbs minimum in weight with the following approximate dimensions: 14" square base, 2¼" top O.D., 10½" bottom O.D. All cones used within a pattern shall be the same size; mixing of sizes is not permitted.

SERIES 16 SIGNS





		W H
16-E	80-1605	84" x 60"
16-H	80-1608	60" x 42"
16-M	80-1613	30" x 24"

		W H
16-S	80-1619	48" x 30"

THE 16-S SIGN SHALL BE USED ON ALL PROJECTS THAT REQUIRE SIDEWALK RECONSTRUCTION OR RESTRICT PEDESTRIAN TRAVEL ON AN EXISTING SIDEWALK.

SERIES 16 SIGNS SHALL BE INSTALLED IN ADVANCE OF THE TRAFFIC CONTROL PATTERNS TO ALLOW MOTORISTS THE OPPORTUNITY TO AVOID A WORK ZONE. SERIES 16 SIGNS SHALL BE INSTALLED ON ANY MAJOR INTERSECTING ROADWAYS THAT APPROACH THE WORK ZONE. ON LIMITED-ACCESS HIGHWAYS, THESE SIGNS SHALL BE LOCATED IN ADVANCE OF THE NEAREST UPSTREAM EXIT RAMP AND ON ANY ENTRANCE RAMPS PRIOR TO OR WITHIN THE WORK ZONE LIMITS.

THE LOCATION OF SERIES 16 SIGNS CAN BE FOUND ELSEWHERE IN THE PLANS, OR INSTALLED AS DIRECTED BY THE ENGINEER OR SUPERVISOR.

IF SIGNS ARE TO BE POST-MOUNTED, THEN:
- SIGN 16-E OR 16-H SHALL BE USED ON ALL EXPRESSWAYS.
- SIGN 16-H OR 16-M SHALL BE USED ON ALL RAMPS, OTHER STATE ROADWAYS, AND MAJOR TOWN / CITY ROADWAYS.
- SIGN 16-M SHALL BE USED ON OTHER TOWN ROADWAYS.

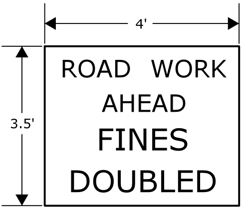
IF SIGNS ARE TO BE MOUNTED ON PORTABLE SUPPORTS, THEN SIGN 16-M SHALL BE USED.

REGULATORY SIGN "ROAD WORK AHEAD, FINES DOUBLED"

THE REGULATORY SIGN "ROAD WORK AHEAD, FINES DOUBLED" SHALL BE INSTALLED FOR ALL WORK ZONES THAT OCCUR ON ANY STATE HIGHWAY IN CONNECTICUT WHERE THERE ARE WORKERS ON THE HIGHWAY OR WHEN THERE IS OTHER THAN EXISTING TRAFFIC OPERATIONS.

THE REGULATORY SIGN "ROAD WORK AHEAD, FINES DOUBLED" SHALL NOT BE INSTALLED ON TOWN ROADS.

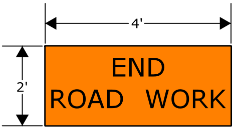
THE REGULATORY SIGN "ROAD WORK AHEAD, FINES DOUBLED" SHALL BE PLACED AFTER THE SERIES 16 SIGN AND IN ADVANCE OF THE "ROAD WORK AHEAD" SIGN.



31-1906

"END ROAD WORK" SIGN

THE LAST SIGN IN THE PATTERN MUST BE THE "END ROAD WORK" SIGN.



80-9612

SCALE: NONE

MAINTENANCE TRAFFIC CONTROL PLAN

REQUIRED SIGNS

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

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PRINCIPAL ENGINEER

NOTES FOR TRAFFIC CONTROL PLANS

1. IF A TRAFFIC STOPPAGE OCCURS IN ADVANCE OF SIGN A, THEN AN ADDITIONAL SIGN A SHALL BE INSTALLED IN ADVANCE OF THE STOPPAGE.
2. SIGNS AA, A, AND D SHOULD BE OMITTED WHEN THESE SIGNS HAVE ALREADY BEEN INSTALLED TO DESIGNATE A LARGER WORK ZONE THAN THE WORK ZONE THAT IS ENCOMPASSED ON THIS PLAN.
3. SEE TABLE 1 FOR ADJUSTMENT OF TAPERS IF NECESSARY.
4. IF THIS PLAN REMAINS IN CONTINUOUS OPERATION FOR MORE THAN 36 HOURS, THEN TRAFFIC DRUMS SHALL BE USED IN PLACE OF TRAFFIC CONES.
5. IF THIS PLAN REMAINS IN CONTINUOUS OPERATION FOR MORE THAN 36 HOURS, THEN ANY LEGAL SPEED LIMIT SIGNS WITHIN THE LIMITS OF A ROADWAY / LANE CLOSURE AREA SHALL BE COVERED WITH AN OPAQUE MATERIAL WHILE THE CLOSURE IS IN EFFECT, AND UNCOVERED WHEN THE ROADWAY / LANE CLOSURE IS RE-OPENED TO ALL LANES OF TRAFFIC.
6. IF THIS PLAN REMAINS IN CONTINUOUS OPERATION FOR MORE THAN 36 HOURS, THEN ANY EXISTING CONFLICTING PAVEMENT MARKINGS SHALL BE ERADICATED OR COVERED, AND TEMPORARY PAVEMENT MARKINGS THAT DELINEATE THE PROPER TRAVEL PATHS SHALL BE INSTALLED.
7. DISTANCES BETWEEN SIGNS IN THE ADVANCE WARNING AREA MAY BE REDUCED TO 100' ON LOW-SPEED URBAN ROADS (SPEED LIMIT $<$ 40 MPH).
8. IF THIS PLAN IS TO REMAIN IN OPERATION DURING THE HOURS OF DARKNESS, INSTALL BARRICADE WARNING LIGHTS - HIGH INTENSITY ON ALL POST-MOUNTED DIAMOND SIGNS IN THE ADVANCE WARNING AREA.
9. FOR SHORT DURATION OPERATIONS, 4 TRUCK MOUNTED ATTENUATOR UNITS MAY BE USED TO CREATE THE TAPER IN LIEU OF TRAFFIC CONES/DRUMS.

10 FOR THE INSTALLATION OF PAVEMENT MARKINGS, VEHICLE 1 SHALL HAVE A SIGN WITH THE LEGEND "LINE PAINTING."

11 SIGN P SHALL BE MOUNTED A MINIMUM OF 7 FEET FROM THE PAVEMENT SURFACE TO THE BOTTOM OF THE SIGN.

12 IF THIS PLAN REMAINS IN CONTINUOUS OPERATION FOR MORE THAN 8 HOURS, THEN DRUMS SHALL BE USED FOR ANY LANE CLOSURE TAPER, AND ALL SIGNS MARKED "OPTIONAL" ARE REQUIRED.

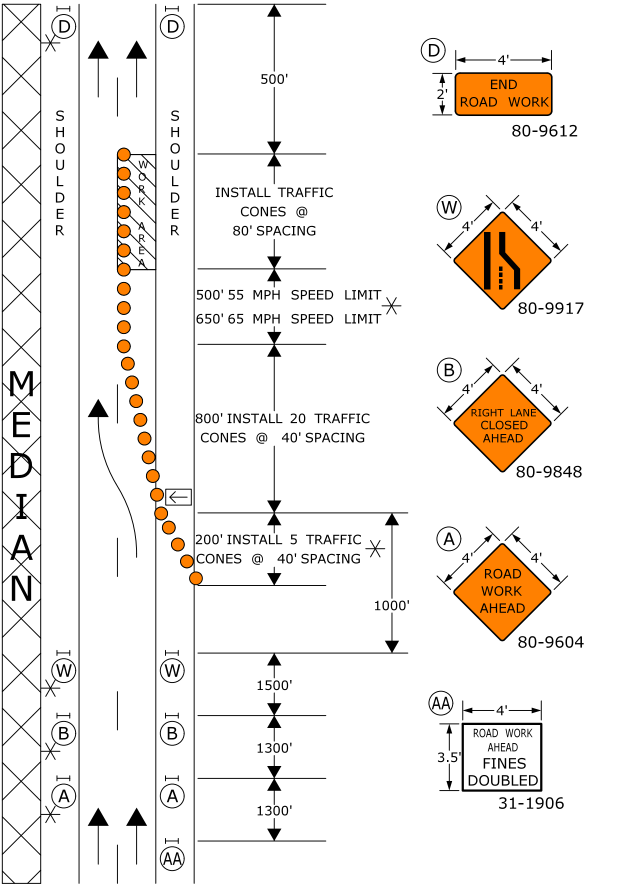
SCALE: NONE

MAINTENANCE TRAFFIC CONTROL PLAN

NOTES

WORK IN RIGHT LANE - MULTILANE HIGHWAY

SIGN FACE
70 SQ. FT (MIN)



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 3, 4, 5, 6, 8, 9, 12

PLAN 1

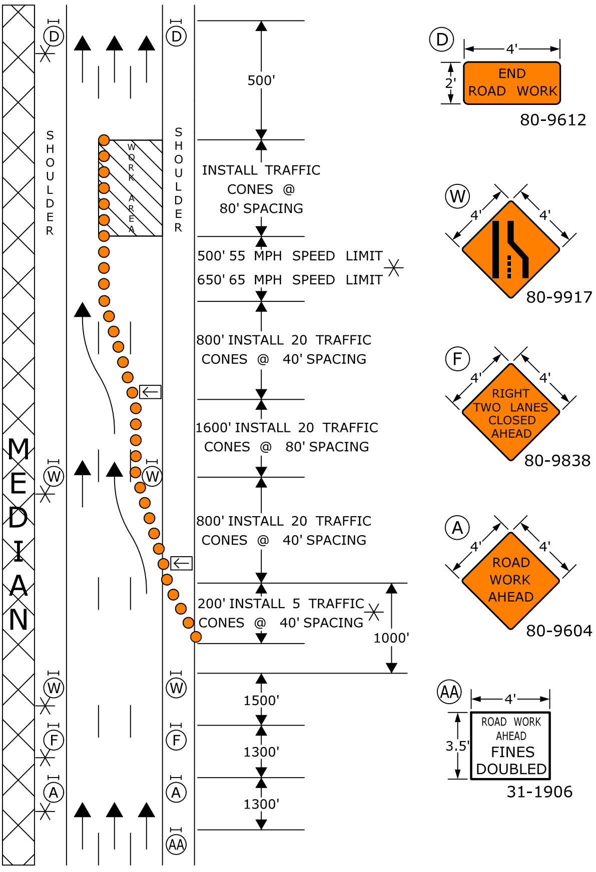
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN RIGHT TWO LANES - MULTILANE HIGHWAY

SIGN FACE
86 SQ. FT (MIN)



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 3, 4, 5, 6, 8, 9, 12

PLAN 2

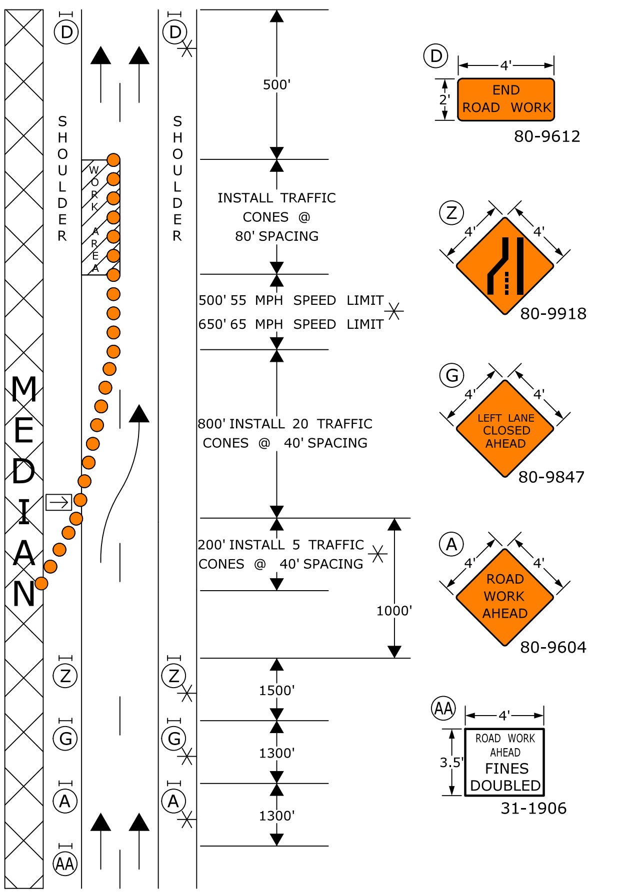
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN LEFT LANE - MULTILANE HIGHWAY

SIGN FACE 70 SQ. FT (MIN)



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 3, 4, 5, 6, 8, 9, 12

PLAN 3

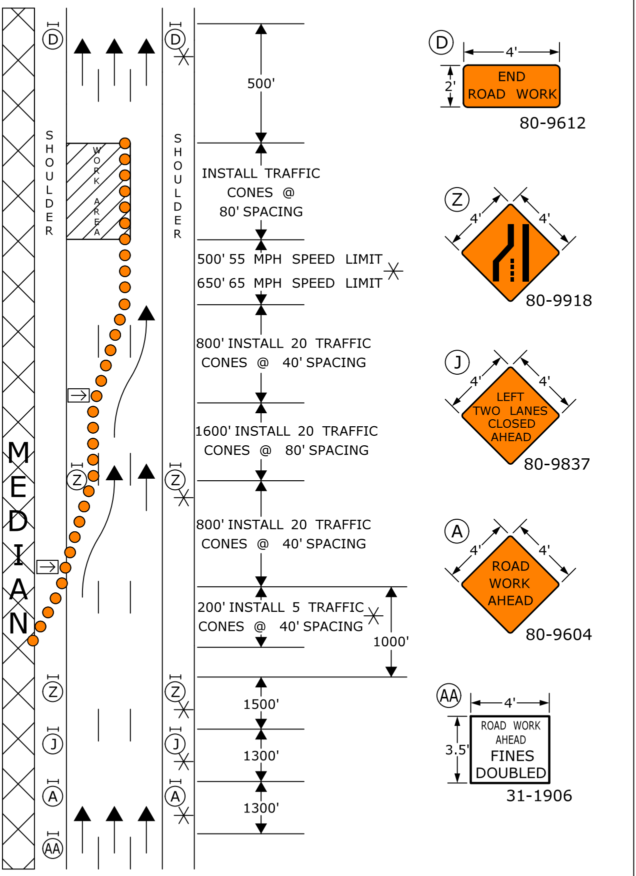
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN LEFT TWO LANES - MULTILANE HIGHWAY

SIGN FACE
86 SQ. FT (MIN)



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 3, 4, 5, 6, 8, 9, 12

PLAN 4

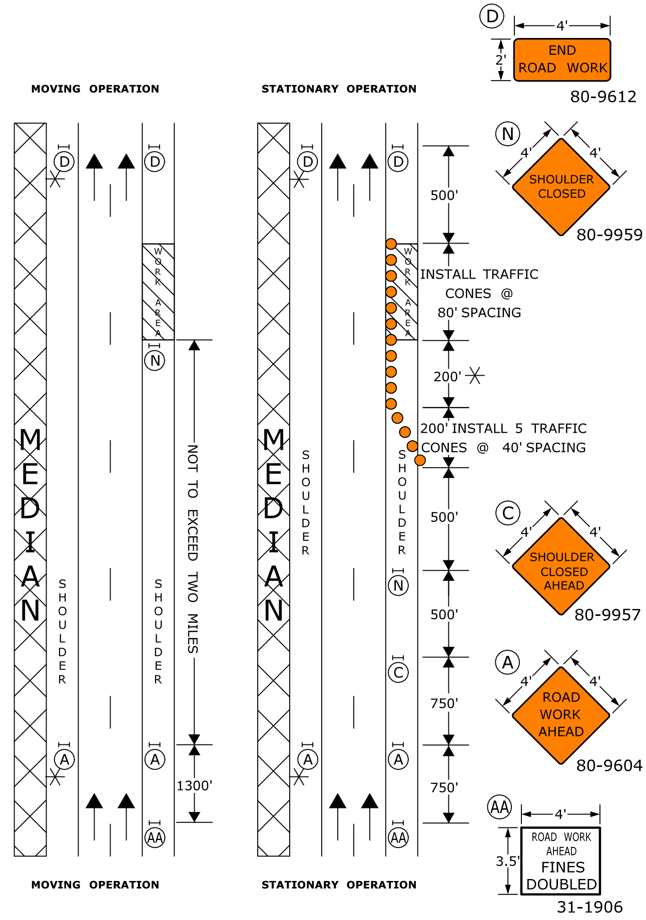
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN SHOULDER AREA - MULTILANE HIGHWAY

SIGN FACE
54/70 SQ. FT (MIN)



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 8, 9, 12

PLAN 6

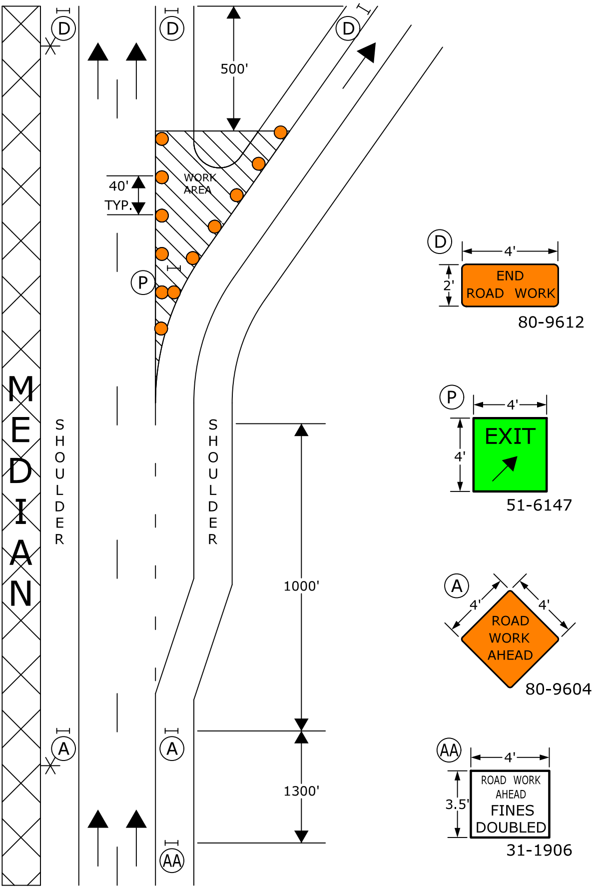
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN RAMP GORE AREA

SIGN FACE
62 SQ. FT (MIN)



SCALE: NONE

OPTIONAL	TRAFFIC CONE **OR** TRAFFIC DRUM
PORTABLE SIGN SUPPORT	HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 8, 11, 12

PLAN 7

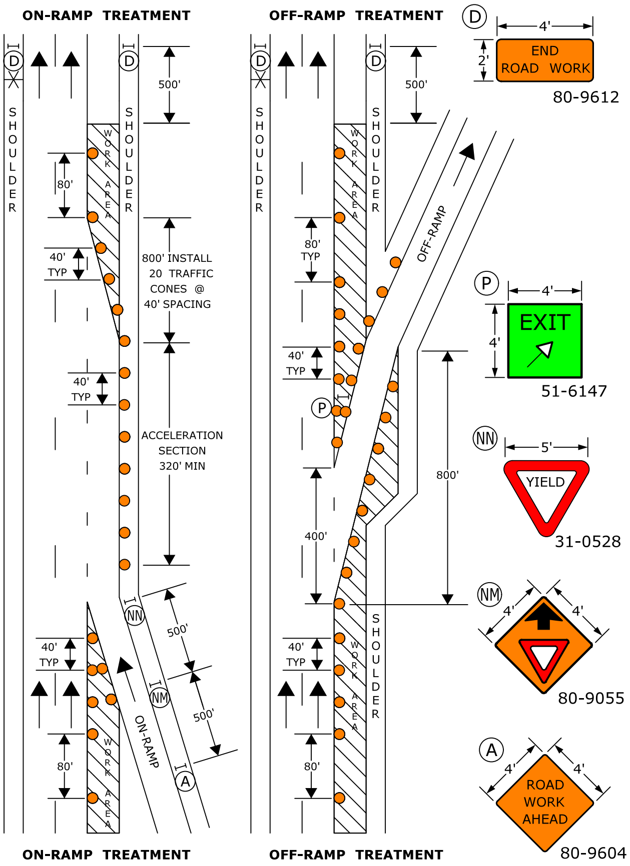
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

TYPICAL RAMP TREATMENTS FOR MAIN LINE CLOSURE - MULTILANE HIGHWAY

SIGN FACE SQ. FT VARIES



USE TRAFFIC CONTROL PLAN 1 TO CLOSE THE RIGHT LANE

SCALE: NONE

OPTIONAL	TRAFFIC CONE **OR** TRAFFIC DRUM
PORTABLE SIGN SUPPORT	HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 3, 4, 5, 6, 8, 9, 11, 12

PLAN 8

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

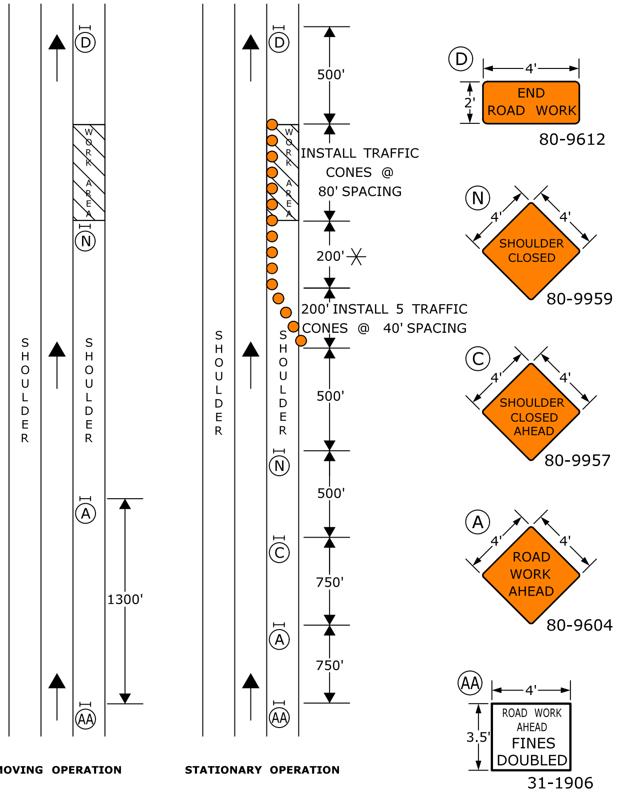
APPROVED

PRINCIPAL ENGINEER

WORK IN SHOULDER AREA - TURNING ROADWAYS / RAMPS

SIGN FACE
54/70 SQ. FT (MIN)

MOVING OPERATION **STATIONARY OPERATION**



MOVING OPERATION **STATIONARY OPERATION**

SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 8, 9, 12

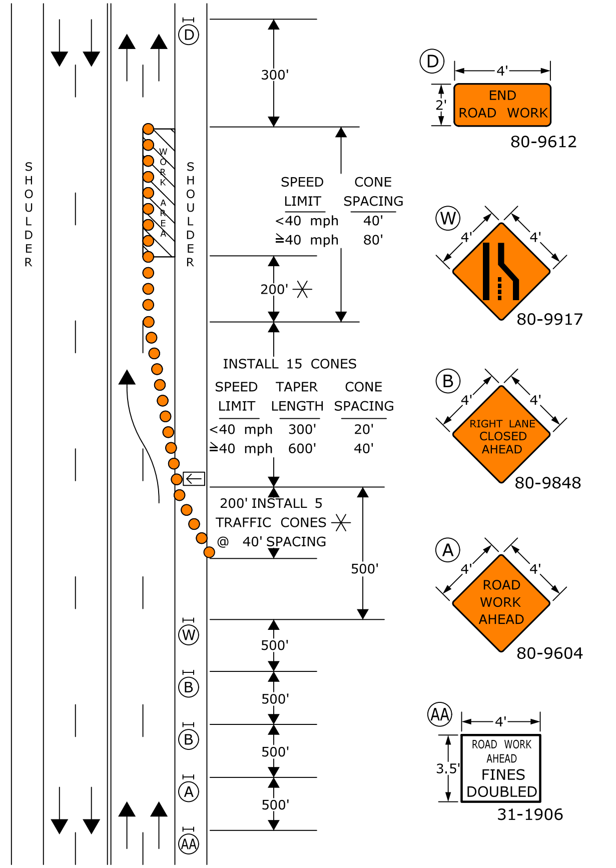
PLAN 9

APPROVED

PRINCIPAL ENGINEER

WORK IN RIGHT LANE - 4 LANE UNDIVIDED HIGHWAY

SIGN FACE
86 SQ. FT (MIN)



SCALE: NONE

✳ OPTIONAL

⊢⊣ PORTABLE SIGN SUPPORT

● TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 3, 4, 5, 6, 7, 8

PLAN 10

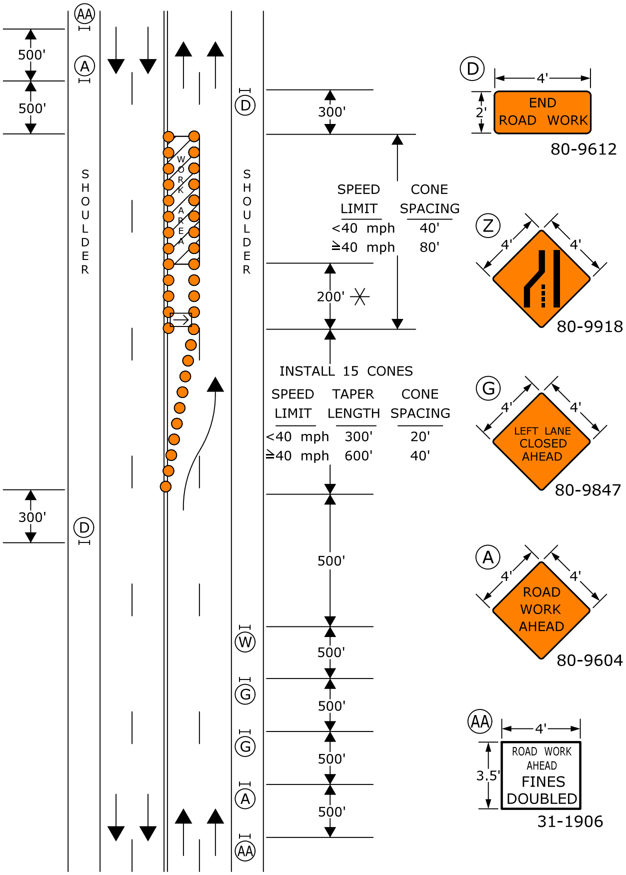
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN LEFT LANE - 4 LANE UNDIVIDED HIGHWAY

SIGN FACE
124 SQ. FT (MIN)



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 3, 4, 5, 6, 7, 8

PLAN 11

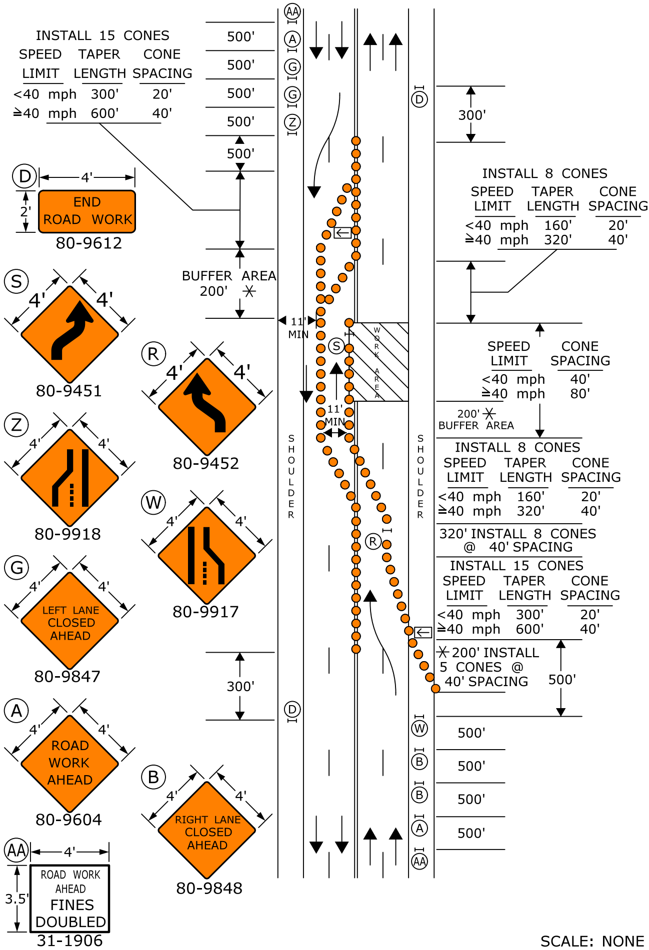
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN BOTH LANES - 4 LANE UNDIVIDED HIGHWAY

SIGN FACE
204 SQ. FT (MIN)



SCALE: NONE

OPTIONAL — TRAFFIC CONE **OR** TRAFFIC DRUM

PORTABLE SIGN SUPPORT — HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 3, 4, 5, 6, 7, 8

PLAN 12

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

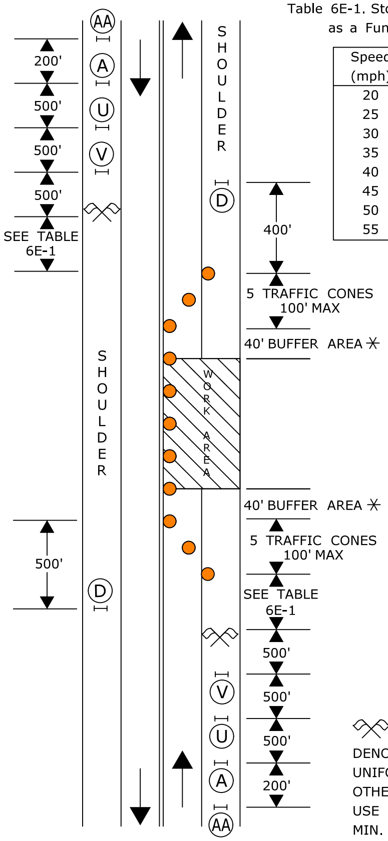
WORK IN TRAVEL LANE AND SHOULDER - TWO LANE HIGHWAY ALTERNATING ONE-WAY TRAFFIC OPERATIONS

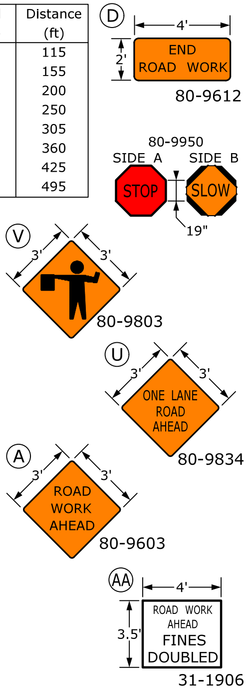
SIGN FACE
108 SQ. FT (MIN)

FROM THE MUTCD
(2009 EDITION)

Table 6E-1. Stopping Sight Distance as a Function of Speed.

Speed (mph)	Distance (ft)
20	115
25	155
30	200
35	250
40	305
45	360
50	425
55	495





DENOTES APPROXIMATE LOCATION OF UNIFORMED FLAGGER. TRAFFICPERSON OTHER THAN POLICE OFFICERS SHALL USE SIGN 80-9950 MOUNTED ON A 6' MIN. STAFF.

SCALE: NONE

OPTIONAL
PORTABLE SIGN SUPPORT
TRAFFIC CONE **OR** TRAFFIC DRUM
HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 6, 7, 8

PLAN 13

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN TRAVEL LANE AND SHOULDER - TWO LANE HIGHWAY ALTERNATING ONE-WAY TRAFFIC OPERATIONS

SIGN FACE
108 SQ. FT (MIN)

HAND SIGNAL METHODS TO BE USED BY UNIFORMED FLAGGERS

THE FOLLOWING METHODS FROM SECTION 6E.07, FLAGGER PROCEDURES, IN THE "MANUAL ON UNIFORM TRAFFIC CONTROL DEVICES," SHALL BE USED BY UNIFORMED FLAGGERS WHEN DIRECTING TRAFFIC THROUGH A WORK AREA. THE STOP/SLOW SIGN PADDLE (SIGN NO. 80-9950) SHOWN ON THE TRAFFIC STANDARD SHEET TR-1220 01 ENTITLED, "SIGNS FOR CONSTRUCTION AND PERMIT OPERATIONS" SHALL BE USED.

A. TO STOP TRAFFIC

TO STOP ROAD USERS, THE FLAGGER SHALL FACE ROAD USERS AND AIM THE STOP PADDLE FACE TOWARD ROAD USERS IN A STATIONARY POSITION WITH THE ARM EXTENDED HORIZONTALLY AWAY FROM THE BODY. THE FREE ARM SHALL BE HELD WITH THE PALM OF THE HAND ABOVE SHOULDER LEVEL TOWARD APPROACHING TRAFFIC.

B. TO DIRECT TRAFFIC TO PROCEED

TO DIRECT STOPPED ROAD USERS TO PROCEED, THE FLAGGER SHALL FACE ROAD USERS WITH THE SLOW PADDLE FACE AIMED TOWARD ROAD USERS IN A STATIONARY POSITION WITH THE ARM EXTENDED HORIZONTALLY AWAY FROM THE BODY. THE FLAGGER SHALL MOTION WITH THE FREE HAND FOR ROAD USERS TO PROCEED.

C. TO ALERT OR SLOW TRAFFIC

TO ALERT OR SLOW TRAFFIC, THE FLAGGER SHALL FACE ROAD USERS WITH THE SLOW PADDLE FACE AIMED TOWARD ROAD USERS IN A STATIONARY POSITION WITH THE ARM EXTENDED HORIZONTALLY AWAY FROM THE BODY. TO FURTHER ALERT OR SLOW TRAFFIC, THE FLAGGER HOLDING THE SLOW PADDLE FACE TOWARD ROAD USERS MAY MOTION UP AND DOWN WITH THE FREE HAND, PALM DOWN.

SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 6, 7, 8

PLAN 13

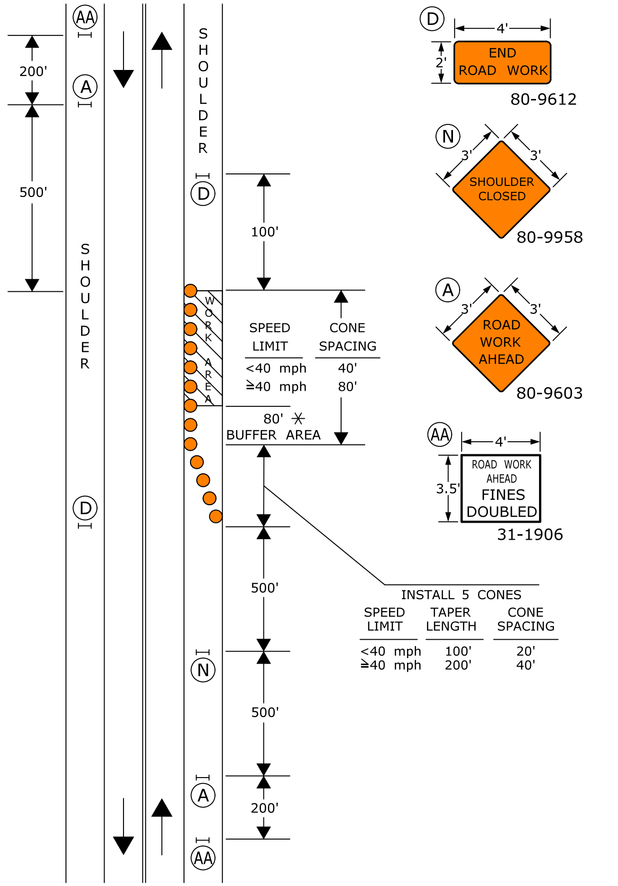
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN SHOULDER AREA - TWO LANE HIGHWAY

SIGN FACE
71 SQ. FT (MIN)



SCALE: NONE

✳ OPTIONAL

⊢⊣ PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 7, 8

PLAN 14

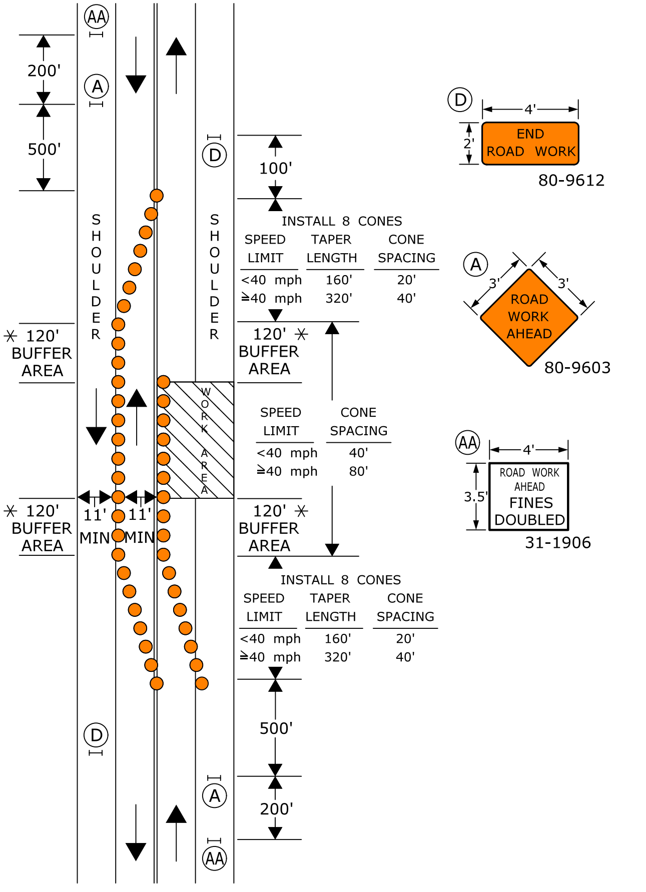
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN TRAVEL LANE AND SHOULDER - TWO LANE HIGHWAY

SIGN FACE
62 SQ. FT (MIN)



SCALE: NONE

✳ OPTIONAL

⊢⊣ PORTABLE SIGN SUPPORT

● TRAFFIC CONE **OR** TRAFFIC DRUM

⇐ HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 6, 7, 8

PLAN 15

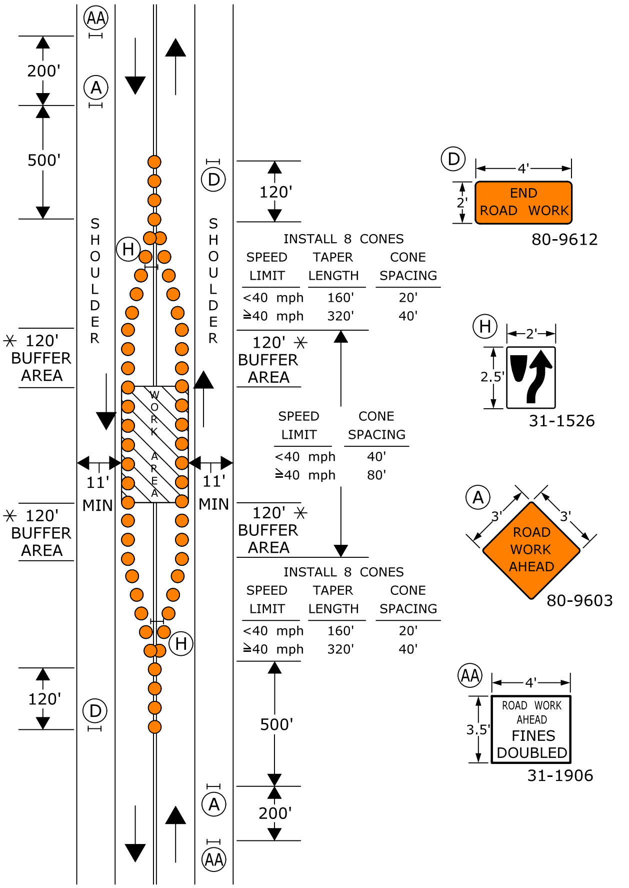
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN MIDDLE OF ROADWAY - TWO LANE HIGHWAY

SIGN FACE
74 SQ. FT (MIN)



SCALE: NONE

✻ OPTIONAL

⊢ PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 6, 7, 8

PLAN 16

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

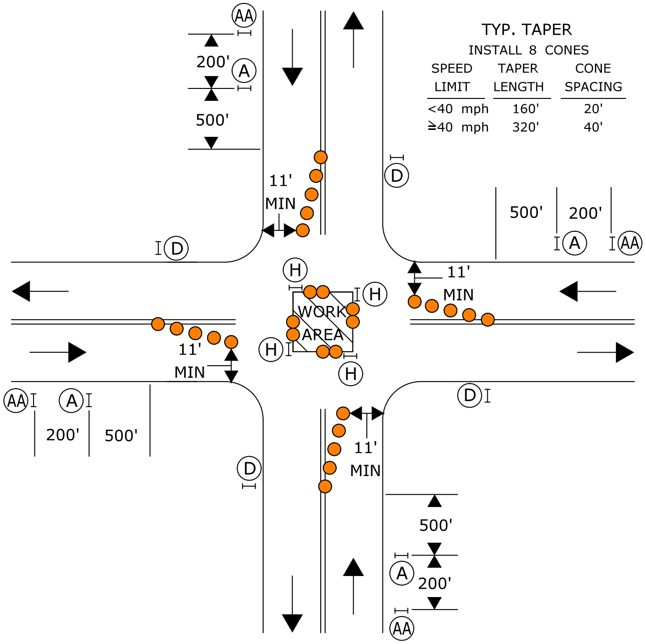
PRINCIPAL ENGINEER

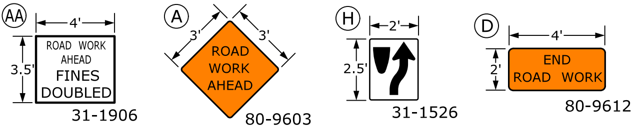
WORK IN MIDDLE OF ROADWAY AT INTERSECTION

SIGN FACE
144 SQ. FT (MIN)

TYP. TAPER
INSTALL 8 CONES

SPEED LIMIT	TAPER LENGTH	CONE SPACING
<40 mph	160'	20'
≥40 mph	320'	40'





SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 6, 7, 8

PLAN 17

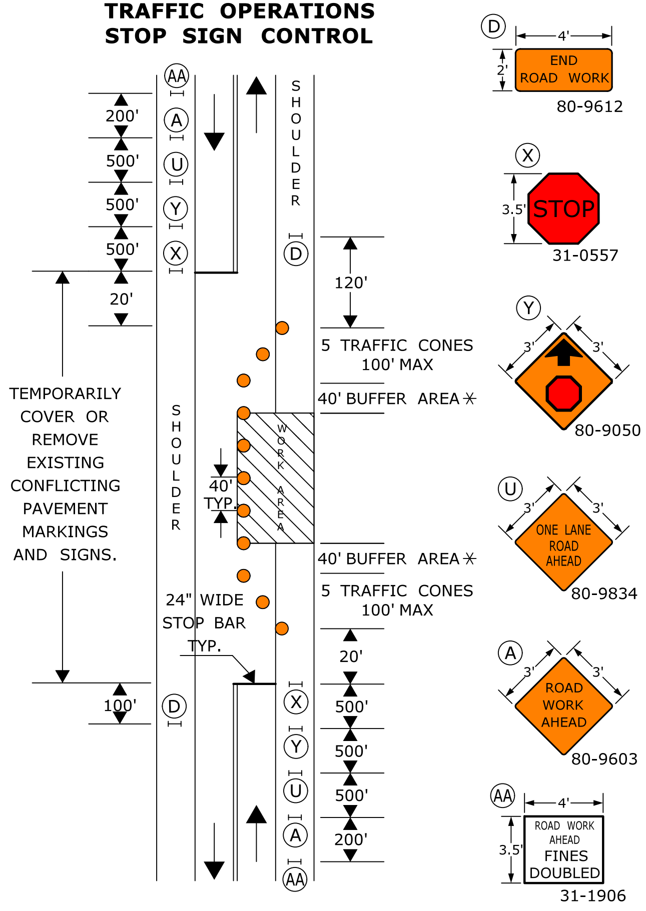
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN TRAVEL LANE AND SHOULDER - TWO LANE HIGHWAY ALTERNATING ONE-WAY TRAFFIC OPERATIONS STOP SIGN CONTROL

SIGN FACE
125 SQ. FT (MIN)



SCALE: NONE

✳ OPTIONAL

⊢⊣ PORTABLE SIGN SUPPORT

● TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 7, 8

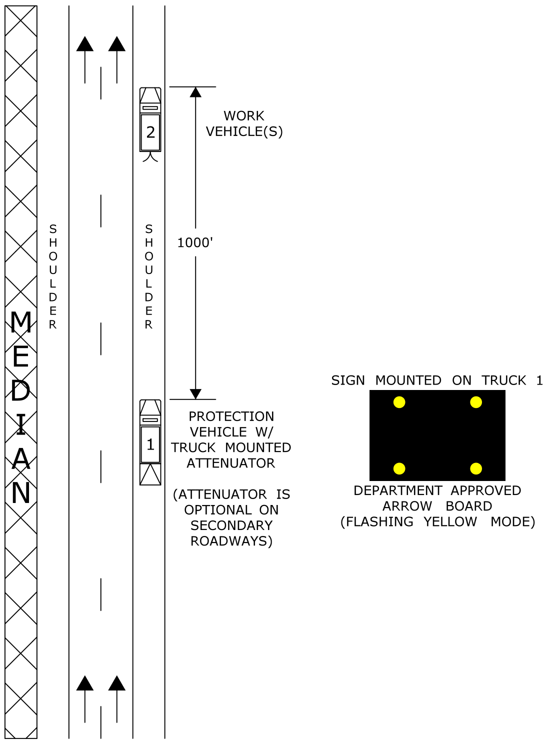
PLAN 18

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

MOVING OPERATION ON RIGHT SHOULDER - MULTILANE HIGHWAY & SECONDARY ROADWAYS



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

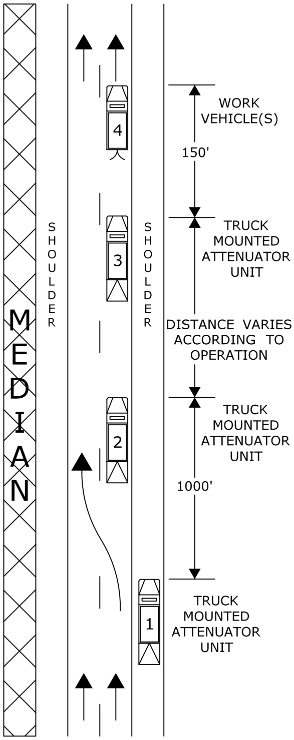
PLAN 19

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

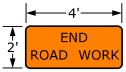
APPROVED

PRINCIPAL ENGINEER

MOVING OPERATION IN RIGHT LANE AND OUTSIDE SHOULDER AT THE SAME TIME MULTILANE HIGHWAY

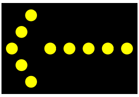


SIGN MOUNTED ON VEHICLE 4



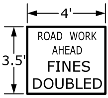
80-9612

SIGN MOUNTED ON TRUCKS 1, 2, & 3



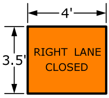
DEPARTMENT APPROVED ARROW BOARD

SIGN MOUNTED ON VEHICLE 2



31-1906

SIGN MOUNTED ON VEHICLE 1



THIS SIGN SHOULD BE COVERED WHEN NOT IN USE.

ON NON-LIMITED ACCESS HIGHWAYS AND THE MERRITT PARKWAY, VEHICLE 3 MAY BE ELIMINATED AND VEHICLE 2 WILL TAKE THE POSITION OF VEHICLE 3. WHERE ADEQUATE SHOULDER WIDTH IS NOT AVAILABLE, VEHICLE 1 MAY DRIVE PARTIALLY IN THE LANE.

SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTE 10

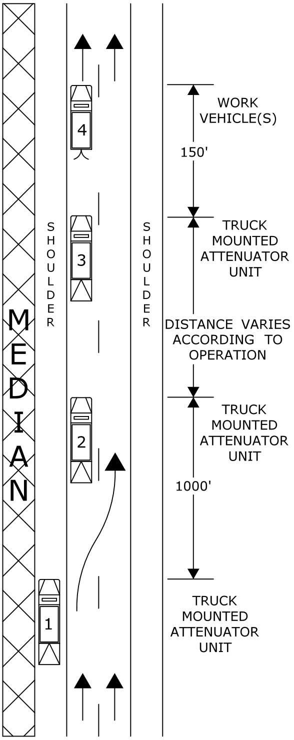
PLAN 20

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

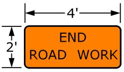
APPROVED

PRINCIPAL ENGINEER

MOVING OPERATION IN LEFT LANE AND INSIDE SHOULDER AT THE SAME TIME MULTILANE HIGHWAY

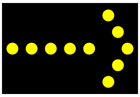


SIGN MOUNTED ON VEHICLE 4



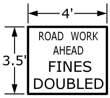
80-9612

SIGN MOUNTED ON TRUCKS 1, 2, & 3



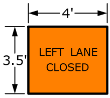
DEPARTMENT APPROVED ARROW BOARD

SIGN MOUNTED ON VEHICLE 2



31-1906

SIGN MOUNTED ON VEHICLE 1



THIS SIGN SHOULD BE COVERED WHEN NOT IN USE.

ON NON-LIMITED ACCESS HIGHWAYS AND THE MERRITT PARKWAY, VEHICLE 3 MAY BE ELIMINATED AND VEHICLE 2 WILL TAKE THE POSITION OF VEHICLE 3.
WHERE ADEQUATE SHOULDER WIDTH IS NOT AVAILABLE, VEHICLE 1 MAY DRIVE PARTIALLY IN THE LANE.

SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTE 10

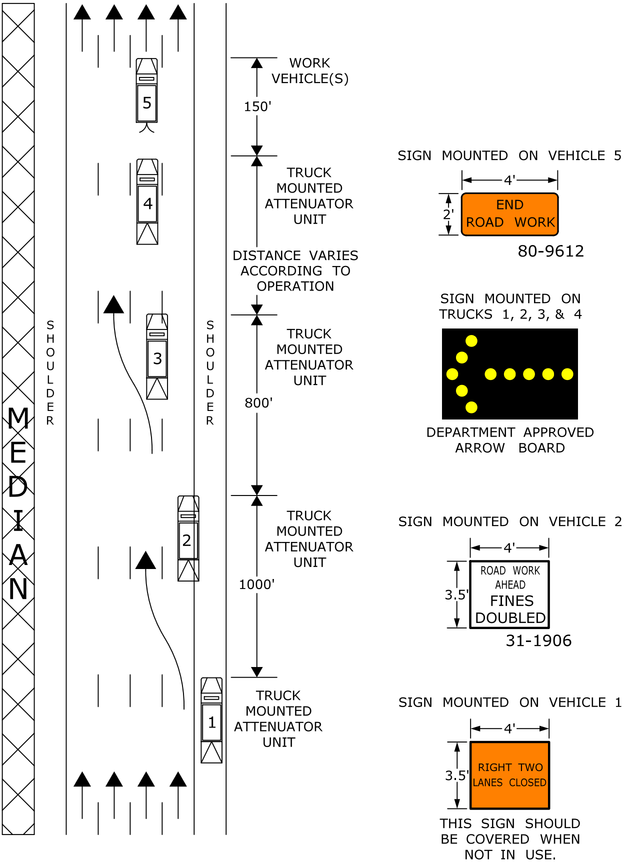
PLAN 21

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

MOVING OPERATION IN CENTER LANE MULTILANE HIGHWAY



WHERE ADEQUATE SHOULDER WIDTH IS NOT AVAILABLE, VEHICLE 1 MAY DRIVE PARTIALLY IN THE LANE.

SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTE 10

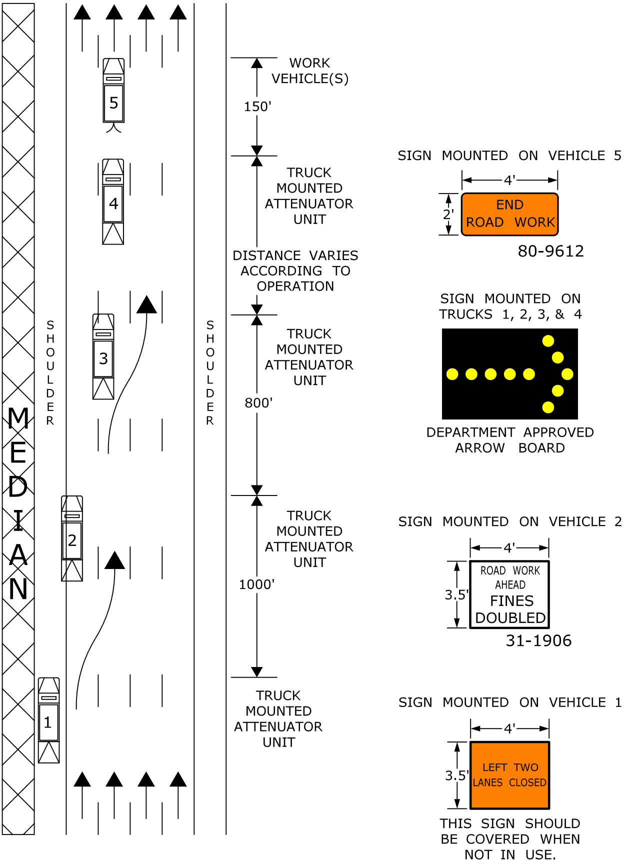
PLAN 22

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

MOVING OPERATION IN CENTER LANE
MULTILANE HIGHWAY



WHERE ADEQUATE SHOULDER WIDTH IS NOT AVAILABLE, VEHICLE 1 MAY DRIVE PARTIALLY IN THE LANE.

SCALE: NONE

OPTIONAL	TRAFFIC CONE **OR** TRAFFIC DRUM
PORTABLE SIGN SUPPORT	HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTE 10

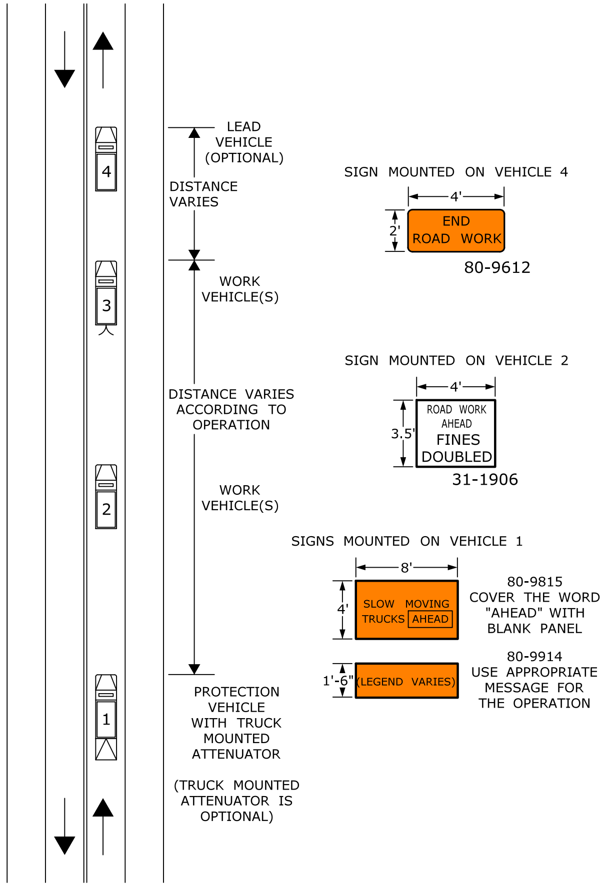
PLAN 23

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

MOVING OPERATION
TWO LANE HIGHWAY



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTE 10

PLAN 24

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

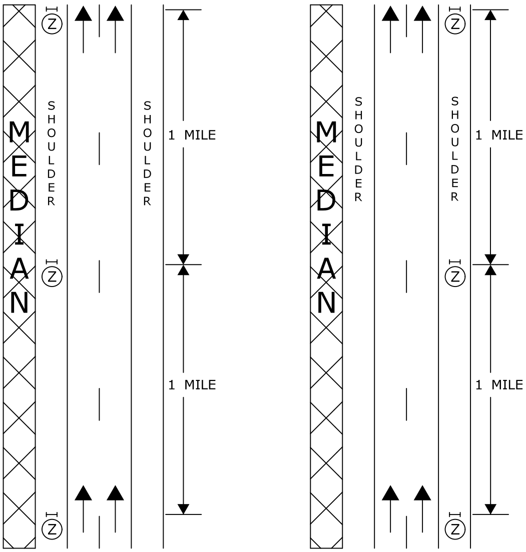
APPROVED

PRINCIPAL ENGINEER

MOWING OPERATION - MULTILANE HIGHWAY

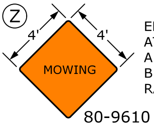
FOR EQUIPMENT ON THE ROADWAY, ROADSIDE,
OR ON THE MEDIAN COMPLETELY OFF THE ROADWAY.

MOWING IN MEDIAN **MOWING OFF RIGHT SHOULDER**



MOWING IN MEDIAN
INSTALL "MOWING" SIGNS ON OPPOSITE TRAVELWAY MEDIAN SHOULDER AS SHOWN ABOVE.

MOWING OFF RIGHT SHOULDER



ERECT "MOWING" SIGNS AT 1-MILE INTERVALS AND IMMEDIATELY BEYOND ANY ENTRANCE RAMP.

WHEN MOWING FROM A TRAVEL LANE, USE BACK-UP VEHICLES 1, 2, & 3 AS SHOWN ON PLANS 20 & 21 TO PROTECT MOWING OPERATIONS. WHEN MOWING EQUIPMENT MUST USE THE TRAVELWAY TO GET AROUND AN OBSTACLE, USE BACK-UP VEHICLES 2 & 3 ONLY. THE BACK-UP VEHICLES MUST REMAIN OFF THE ROADWAY UNTIL MOWING EQUIPMENT IS READY TO GET OUT ONTO THE TRAVELWAY. THE DISTANCE BETWEEN VEHICLE 3 AND THE MOWING EQUIPMENT SHOULD BE 200 FEET.

SCALE: NONE

OPTIONAL
PORTABLE SIGN SUPPORT
TRAFFIC CONE **OR** TRAFFIC DRUM
HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

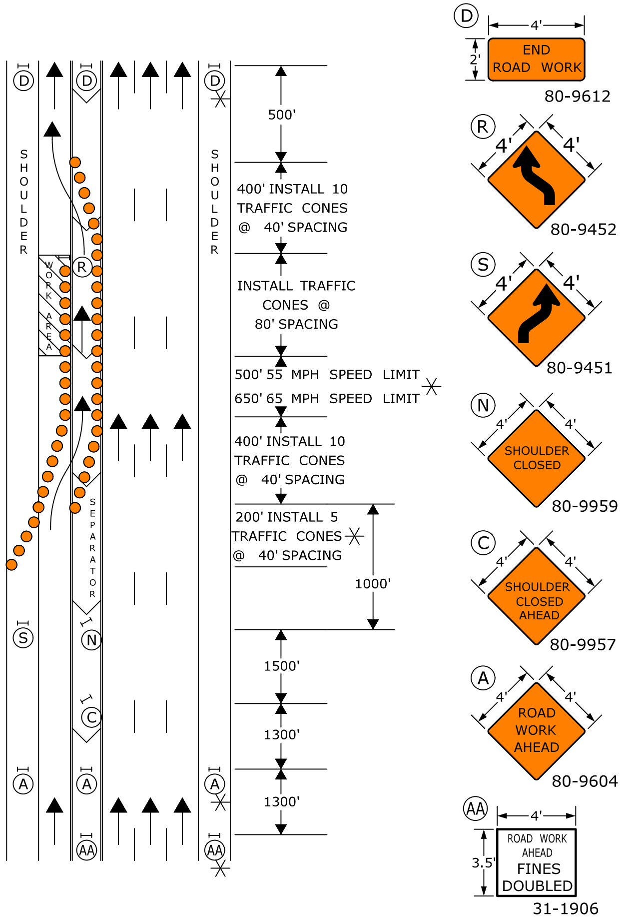
PLAN 25

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED
PRINCIPAL ENGINEER

WORK IN RESTRICTED LANE (STATIONARY CLOSURE)

SIGN FACE
126 SQ. FT (MIN)



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 3, 4, 5, 6, 8, 12

PLAN H1

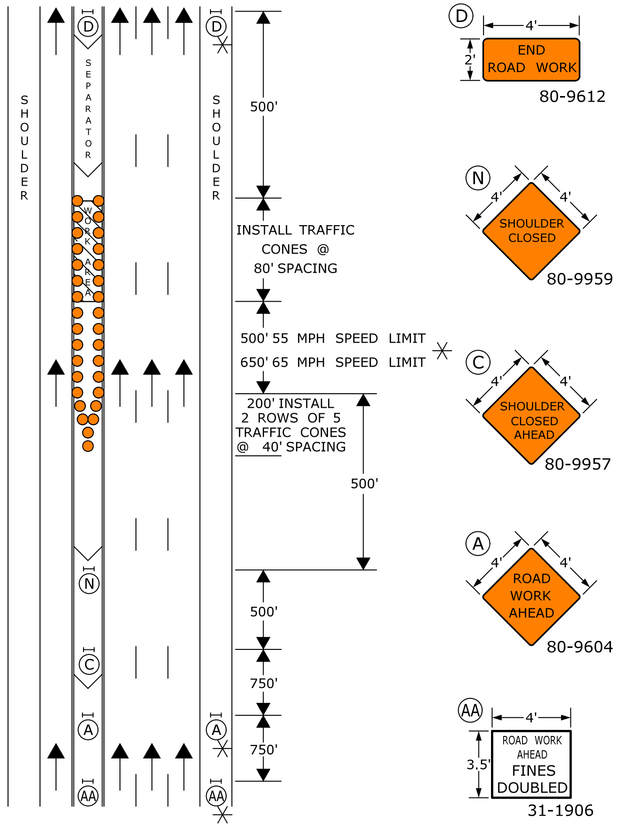
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN RESTRICTED LANE SEPARATOR (STATIONARY CLOSURE)

SIGN FACE
70 SQ. FT (MIN)



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTES 1, 2, 4, 8, 12

PLAN H2

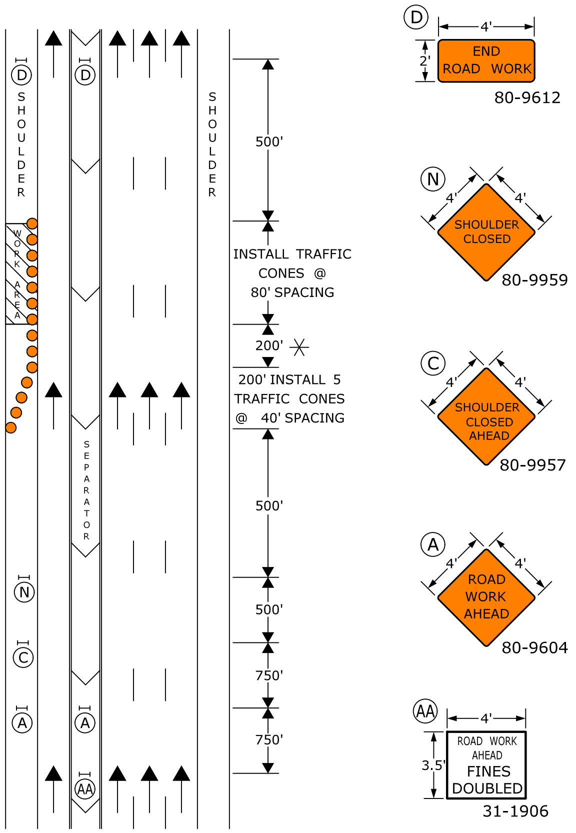
CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

WORK IN LEFT SHOULDER OF RESTRICTED LANE (STATIONARY CLOSURE)

SIGN FACE
94 SQ. FT (MIN)



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

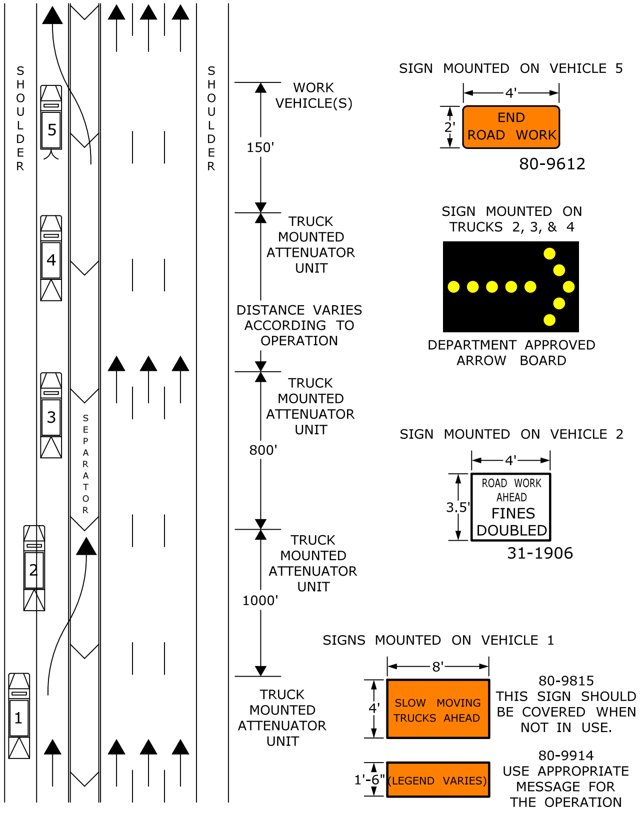
SEE NOTES 1, 2, 4, 8, 12

PLAN H3

APPROVED

PRINCIPAL ENGINEER

MOVING OPERATION IN RESTRICTED LANE



SCALE: NONE

OPTIONAL

PORTABLE SIGN SUPPORT

TRAFFIC CONE **OR** TRAFFIC DRUM

HIGH MOUNTED INTERNALLY ILLUMINATED FLASHING ARROW

MAINTENANCE TRAFFIC CONTROL PLAN

SEE NOTE 10

PLAN H4

CONNECTICUT DEPARTMENT OF TRANSPORTATION
BUREAU OF ENGINEERING AND CONSTRUCTION

APPROVED

PRINCIPAL ENGINEER

Supervisor's Checklist

Every work zone situation is different, so several items must be considered in determining the traffic control needed. Every supervisor should consider the following information:

Have a plan before going to the work site.
What kind of signing will be required?
Remove the devices in a timely manner.
Ask yourself, "what is the driver's view?"
Frequently inspect the work zone.

Acknowledgements

These guidelines were developed to meet the needs of the Connecticut Department of Transportation (CONNDOT) and are intended to be consistent with current practices of CONNDOT.

The following parties and publications provided input and information toward the completion of this handbook:

Part 6 of the Manual on Uniform Traffic Control Devices (MUTCD), 2009 Edition

CONNDOT Bureau of Maintenance and Highway Operations

CONNDOT Office of Engineering

CONNDOT Office of Construction

CONNDOT Office of Highway Safety

This handbook was produced by Nicholas Mandler, CONNDOT Division of Traffic Engineering, in May, 2013.


END
ROAD WORK

Sample CDOT Boring Log

Driller: C. Knight	**Connecticut DOT Boring Report**	Hole No.: B-2
Inspector: G. Arzt	Town: Stafford	Stat./Offset: 51+07/30.0' Lft
Engineer: R. Pion	Project No.: 0134-0147	Northing: 915062
Start Date: 7-26-17	Route No.: 190 & 319	Easting: 1112614
Finish Date: 7-26-17	Bridge No.:	Surface Elevation: 507.05
Project Description: Roundabout Installation		
Casing Size/Type: 3" HFJ	Sampler Type/Size: 1 3/8" ID SS	Core Barrel Type: NQ2
Hammer Wt.: Fall: in.	Hammer Wt.: 140 Fall: 30in.	
Groundwater Observations: @3.5 after 0 hours		

Depth (ft)	Sample Type/No.	Blows on Sampler per 6 inches				Pen. (in.)	Rec. (in.)	RQD %	Generalized Strata Description	Material Description and Notes	Elevation (ft)
0	S-1	2	2	1	70	20	3		GRAVELLY SAND	Gray c-f GRAVEL, and c-f SAND, trace silt	505
5	S-2	8	7	7	10	24	10			Brown f-c SAND, some c-f gravel, trace silt	500
10	S-3	17	19	26	26	24	12			Gray-Brown c-f SAND, and c-f GRAVEL, trace silt	495
15	S-4	38	13	29	19	24	14			Gray c-f SAND, trace f gravel, trace silt	490
20	S-5	76				6				Gray-Brown c-f SAND, and c-f GRAVEL, trace silt	485
25	C-1					60	55.5	82	BEDROCK	Gray medium grained, massive bedded, slightly fractured, slightly weathered gneiss Core times in min/ft: 2.0, 1.5, 1.0, 1.5, 1.5	480
30	C-2					60	56	73		Gray medium grained, massive bedded, unfractured, fresh gneiss Core times in min/ft: 1.0, 1.0, 1.0, 1.0, 2.0	475
35										END OF BORING 31.5ft	470
40											465
45											460
50											

Sample Type: S = Split Spoon C = Core UP = Undisturbed Piston V = Vane Shear Test

Proportions Used: Trace = 1 - 10%, Little = 10 - 20%, Some = 20 - 35%, And = 35 - 50%

Total Penetration in Earth: 21.5ft Rock: 10ft	NOTES: Encountered 24" of blowback at 15 foot sample	Sheet 1 of 1
No. of Soil Samples: 4 No. of Core Runs: 2		SM-001-M REV. 1/02

List of Boring Contractors
Who Are Interested In Submitting Bids
On Boring Work for CT DOT Projects
(Revised Date 8/27/18)

Company Name

A & A Test Boring, LLC
681 John Fitch Boulevard
South Windsor, CT 06074
860-282-0757/860-290-1745
Contact Person: Alan Augustine
E-mail: AAtestboring@aol.com

Allstate Drilling Company
227 Wampanoag Trail
Riverside, RI 02915
401-434-7458/FAX (no fax number)
Contact Person: George Geisser
E-mail: ggeisser@aol.com

Aquifer Drilling & Testing, Inc.
109 West Dudleytown Road, Unit K
Bloomfield, CT 06002
860-243-0352/ FAX 860-243-8570
E-mail: adtdrill@aol.com

Associated Borings Company, Inc.
119 Margaret Circle
Naugatuck, CT 06770
203 729-5435/FAX 203729-5116
Contact Person: Jaime Lloret
E-mail: jlloret64@yahoo.com

Atlantic Testing Laboratories, Limited
6431 U. S. Highway 11
P.O. Box 29
Canton, NY 13617-0029
315-386-4578
Contact Person: Timothy Gavin
E-mail: TGavin@atlantictesting.com

Clarence Welti Associates, Inc.
227 Williams Street
P.O.Box 397
Glastonbury, CT 06033
860-633-4623/FAX 860-657-2514
Contact Person: Max Welti
E-mail: mcwelti@weltiassoc.com

Connecticut Test Borings, LLC
28 Rimmondale Street
Seymour, CT 06483
203-888-3857; FAX 203 888-0655
Contact Person: Christian Deangelis
E-mail: ctbllc@sbcglobal.net

General Borings, Inc.
201 Straightsville Road
Prospect, CT 06712 (Delivery)
P.O.Box 7135 (Mail)
Prospect, CT 06712
203-758-5817/FAX 203-758-0822
Contact Person: Daniel R. Tuccillo Jr.
E-mail: office@generalborings.com

Glenn Drilling
532 New London Road
Colchester, Ct 06415
(860) 537-3601
Contact Person: Roy Glenn
E-mail: rglenn14@sbcglobal.net

Hardiman Company & Associates, Inc.
10 Fox Hunt Road
Shelton, CT 06484
203-926-0106/FAX 203-926-0131
Contact Person: Tom Hardiman Jr.
E-mail: thomas.hardiman@snet.net

New England Boring Contractors of CT, Inc.
129 Krieger Lane
Glastonbury, CT 06033
860-633-4649/FAX 860-657-8046
Contact Person: Steve Preli
E-mail: steve.preli@NEboring.com

Seaboard Drilling, Inc.
649 Meadow Street
Chicopee, MA 01013 (Delivery Only)
P.O. Box 3026 (Mail)
Springfield, Ma 01101
1800-595-1114/FAX 413-592-0191
Contact Person: Jeff Campbell
E-mail: campbell.j@verizon.net

Soil Exploration Corporation
148 Pioneer Drive
Leominster, MA 01453
978-840-0391/FAX 978-537-9918
Contact Person: Marilou Bonetti/ Dave Doyle-v.pres.
E-mail: mbonettie@soilexcorp.com

Soil Testing, Inc.
90 Donovan Road
Oxford, CT 06478
203-888-4531/FAX 203-264-3414
Contact Person: James Deangelis
E-mail: james@soiltestinginc.net

Special Testing Laboratories, Inc.
21 Henry Street
Bethel, CT 06801
203-743-7281/FAX 203-791-2451
Contact Person: Virginia Speciale
E-mail: virginias@specialtesting.net or Richards@specialtesting.net

Warren George, Inc.
P.O. Box 413
Jersey City, NJ 07303
201-433-9797/FAX 201-433-9139
Contact Person: Tony Tirro
E-mail: wgidrill@aol.com

STATE OF CONNECTICUT
DEPARTMENT OF TRANSPORTATION

2800 BERLIN TURNPIKE, P.O. BOX 317546
NEWINGTON, CONNECTICUT 06131-7546
Phone: 860-594-3180

Town ____________________________
Project __________________________

Name ____________________________________
Address __________________________________
____

Dear Property Owner:

Section 13a-60 of the General Statutes of Connecticut, as revised, provides that the Transportation Commissioner or his agent may enter upon private property for the purpose of conducting surveys, inspections or geological investigations for the location, relocation, construction or reconstruction of any proposed or existing highways.

In the course of performing a survey, inspection or geological investigation, it may be necessary to set markers of various types adjacent to or on your property. The placement of these markers does not necessarily indicate the location of a proposed highway or other facility to be constructed or reconstructed by the Department of Transportation.

Section 13a-60 provides that the Transportation Commissioner or his agent shall use care that no unnecessary damage shall result and that the State shall pay damage to the owner for any damage or injury he causes such owner by such entrance or use.

Your consent to the Transportation Commissioner or his agent to enter upon your property for the purpose of carrying out the provisions of this statute is requested.

A signature to authorize entrance upon your property does not indicate your approval or disapproval of the above-noted project.

Please sign in the space provided below and return to the attention of Mr. Leo L. Fontaine , Transportation Principal Engineer, in the enclosed self-addressed stamped envelope. Thank you for your cooperation.

Very truly yours,

Mark D. Rolfe, P.E.
Chief Engineer
Bureau of Engineering and Construction

I hereby give my consent to the Transportation Commissioner or his agent to enter upon my property in order to carry out the provisions of Sec. 13a-60 of the 1969 Supplement to the General Statutes and for the purposes as checked.

___Survey
___Borings, Soundings or Other Tests

Owner ____ Date ______________________

Interviewer ____________________________________ Date ______________________

Chapter 4

Laboratory Testing of Soil and Rock

Table of Contents

Chapter 4

Laboratory Testing of Soil and Rock

After the completion of a project's subsurface exploration, laboratory testing of representative samples is generally performed. A careful review of all data obtained during the field investigation is essential to developing an appropriately scoped laboratory-testing program. Unless specialized testing is required, all testing should be performed in accordance with the AASHTO and/or ASTM specifications. Figure 4-1 provides a listing of commonly performed laboratory tests. Figures 4-2 and 4-3 provides an overview of typical soil index and performance tests, respectively.

In establishing the type and number of tests to be part of the laboratory testing program, the geotechnical engineer shall consider:

- Project Scope (new bridge, major roadway reconstruction, vertical construction, etc.)
- Potential problem soils within the project limits (soft clays, organics, loose silty soils, etc)
- Variability of site soils
- Proposed foundation types and magnitude of loads
- Seismicity
- Settlement constraints, both total and differential
- Height and slope rate of proposed cuts and fills (global instability concerns)

The selection of samples for testing can be as important as selecting the test itself. Selected samples must be representative of the formation or deposit being investigated. The geotechnical engineer should study the drilling logs, understand the geology of the site, and visually examine the samples before selecting the test specimens. Samples should be selected on the basis of their color, physical appearance, and structural features. Specimens should be selected to represent all types of materials present at the site, not just the worst or the best.

4-1 Laboratory Index Tests for Soils

Data generated from laboratory index tests provide an inexpensive way to assess soil consistency and variability of a site. Information obtained from index tests is used to select samples for engineering property testing as well as to provide an indicator of general engineering behavior. Common index tests discussed in this section include moisture content, unit weight (wet density), Atterberg limits, particle size distribution, visual classification, specific gravity, and organic content. When samples have been collected during a subsurface exploration, some amount of Index testing should be performed. Information from these tests should be assessed prior to a final decision regarding the specimens selected for subsequent performance testing.

Figure 4-1
Common Soil Laboratory Tests

Test Category	Name of Test	Test Designation AASHTO	Test Designation ASTM
Visual Identification	Practice for Description and Identification of Soils (Visual-Manual Procedure)	-	D 2488
	Practice for Description of Frozen Soils (Visual-Manual Procedure)	-	D 4083
Index Properties	Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating Method	T 265	D 2216
	Test Method for Specific Gravity of Soils	T 100	D 854; D 5550
	Method for Particle-Size Analysis of Soils	T 88	D 422
	Test Method for Classification of Soils for Engineering Purposes	M 145	D 2487; D 3282
	Test Method for Amount of Material in Soils Finer than the No. 200 (75-μm) Sieve		D 1140
	Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils	T 89; T 90	D 4318
Compaction	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort	T 99	D 698
	Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort	T 180	D 1557
Strength Properties	Test Method for Unconfined Compressive Strength of Cohesive Soil	T 208	D 2166
	Test Method for Unconsolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression	T 296	D 2850
	Test Method for Consolidated, Undrained Compressive Strength of Cohesive Soils in Triaxial Compression	T 297	D 4767
	Method for Direct Shear Test of Soils under Consolidated Drained Conditions	T 236	D 3080
	Test Methods for Modulus and Damping of Soils by the Resonant-Column Method	-	D 4015
	Test Method for Laboratory Miniature Vane Shear Test for Saturated Fine-Grained Clayey Soil	-	D 4648
	Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils	-	D 1883
	Test Method for Resilient Modulus of Soils	T 294	-
	Test Method for Resistance R-Value and Expansion Pressure of Compacted Soils	T 190	D 2844
Consolidation And Swelling Properties	Test Method for One-Dimensional Consolidation Properties of Soils	T 216	D 2435
	Test Method for One-Dimensional Consolidation Properties of Soils Using Controlled-Strain Loading	-	D 4186
	Test Methods for One-Dimensional Swell or Settlement Potential of Cohesive Soils	T 258	D 4546
	Test Method for Measurement of Collapse Potential of Soils	-	D 5333

Figure 4-1 (continued)
Common Soil Laboratory Tests

Test Category	Name of Test	Test Designation	
		AASHTO	ASTM
Permeability	Test Method for Permeability of Granular Soils (Constant Head)	T 215	D 2434
	Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter	-	D 5084
Corrosivity	Test Method for pH for Peat Materials	-	D 2976
	Test Method for pH of Soils	-	D 4972
	Test Method for pH of Soil for Use in Corrosion Testing	T 289	G 51
	Test Method for Sulfate Content	T 290	D 4230
	Test Method for Resistivity	T 288	D 1125; G57
	Test Method for Chloride Content	T 291	D 512
Organic Content	Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils	T 194	D 2974

Figure 4-2
Methods for Index Testing of Soils.

Test	Procedure	Applicable Soil Types	Applicable Soil Properties	Limitations / Remarks
Moisture Content, w_n	Dry soil in oven at 230 ºF (100 ºC)	Gravel, sand, silt, clay, peat	e_o, γ	Simple index test for all materials
Unit Weight and Density	Extract a tube sample; measure dimensions and weight;	Soils where undisturbed samples can be taken, i.e., silt, clay, peat	γ_{tot}, γ_{dry}, ρ_{tot}, ρ_{dry}, σ_{vo}	Not appropriate for clean granular materials where undisturbed sampling is not possible. Very useful index test.
Atterberg Limits, LL, PL, PI, SL, LI	LL – Moisture content associated with failure at 25 blows of specimen in Casagrande cup PL – Moisture content associated with crumbling of rolled soil at 1/8" (3.2 mm)	Clays, silts, peat; silty and clayey sands to determine whether SM or SC	Soil classification	Not appropriate in non-plastic granular soil. Recommended for all plastic materials.
Mechanical Sieve	Place air dry material on a series of successively smaller screens of known opening size and vibrate to separate particles of a specific equivalent diameter	Gravel, sand, silt	Soil classification	Not appropriate for clay soils. Useful, particularly in clean and dirty granular materials
Wash Sieve	Flush fine particles through a U.S. No. 200 sieve with water;	Sand, silt, clay	Soil classification	Needed to assess fines content in dirty granular materials
Hydrometer	Allow particles to settle, and measure specific gravity of the solution with time.	Fine sand, silt, clay	Soil classification	Helpful to assess relative quantity of silt and clay
Specific Gravity	The volume of a known mass of soil is compared to the known volume of water in a calibrated pyncnometer	Sand, silt, clay, peat	Used in calculation of e_o	Particularly helpful in cases where unusual solid minerals are encountered
Organic Content	After performing a moisture content test at 230 ºF (100 ºC)the sample is ignited in a muffle furnace at 833 ºF (445 ºC) to measure the ash content.	All soil types where organic matter is suspected to be a concern	Not related to any specific performance parameters, but samples high in organic content will likely have high compressibility	Recommended on all soils suspected to contain organic materials

Symbols used in Figure 4-2

e_o: in-situ void ratio
γ: unit weight
γ_{tot}: total unit weight
γ_{dry}: dry unit weight

ρ_{tot}: total density
ρ_{dry}: dry density
σ_{vo}: total vertical stress
w_n: natural water content

Figure 4-3
Methods for Performance Testing of Soils.

Test	Procedure	Applicable Soil Types	Soil Properties	Limitations / Remarks
1-D Oedometer	Incremental loads are applied to a soil specimen confined by a rigid ring; deformation values are recorded with time; loads are typically doubled for each increment and applied for 24 hours each.	Primarily clays and silts; Granular soils can be tested, but typically are not.	σ_p', OCR, C_c, $C_{c\varepsilon}$, C_r, $C_{r\varepsilon}$, C_α, $C_{\alpha\varepsilon}$, c_v, k	Recommended for fine grained soils. Results can be useful index to other critical parameters
Constant rate of Strain Oedometer	Loads are applied such that Δu is between 3 and 30 percent of the applied vertical stress during testing	Clays and silts; Not applicable to free draining granular soils.	σ_p', C_c, $C_{c\varepsilon}$, C_r, $C_{r\varepsilon}$, c_v, k	Requires special testing equipment, but can reduce testing time significantly
Unconfined Compression (UC)	A specimen is placed in a loading apparatus and sheared under axial compression with no confinement.	Clays and silts; cannot be performed on granular soils or fissured and varved materials	$s_{u,\ UC}$	Provides rapid means to approximate undrained shear strength, but disturbance effects, test rate, and moisture migration will effect results
Unconsolidated Undrained (UU) Triaxial Shear	The specimen is not allowed to consolidate under the confining stress, and the specimen is loaded at a quick enough rate to prevent drainage	Clays and silts	$s_{u,\ UU}$	Sample must be nearly saturated. Sample disturbance and rate effects will affect measured strength.
Isotropic Consolidated Drained Compression (CD) Triaxial Shear	The specimen is allowed to consolidate under the confining stress, and then is sheared at a rate slow enough to prevent build-up of porewater pressures	Sands, silts, clays	ϕ', c', E	Can be run on clay specimen, but time consuming. Best triaxial test to obtain deformation properties
Isotropic Consolidated Undrained Compression (CU) Triaxial Shear	The specimen is allowed to consolidate under the confining stress with drainage allowed, and then is sheared with no drainage allowed, but porewater pressures measured	Sands, silts, clays, peats	ϕ', c', $s_{u,CIUC}$, E	Recommended to measure pore pressures during test. Useful test to assess effective stress strength parameters. Not for measuring deformation properties
Direct Shear	The specimen is sheared on a forced failure plane at a constant rate, which is a function of the hydraulic conductivity of the specimen	Compacted fill materials; sands, silts, and clays	ϕ', ϕ'_r	Requires assumption of drainage conditions. Relatively easy strength test.
Flexible Wall Permeameter	The specimen is encased in a membrane, consolidated, backpressure saturated, and measurements of flow with time are recorded for a specific gradient	Relatively low permeability materials ($k \leq 1 \times 10^{-5}$ cm/s); clays & silts	k	Recommended for fine grained materials. Backpressure saturation required. Confining stress needs to be provided. System permeability must be at least an order of magnitude greater than that of the specimen. Time needed to allow inflow and outflow to stabilize.
Rigid Wall Permeameter	The specimen is placed in a rigid wall cell, vertical confinement is applied, and flow measurements are recorded with time under constant head or falling head conditions	Relatively high permeability materials; sands, gravels, and silts	k	Need to control gradient. Not for use in fine grained soils. Monitor for sidewall leakage.

Figure 4-3 (continued)
Methods for Performance Testing of Soils.

Symbols used in Table IV-3.

ϕ':	peak effective stress friction angle	OCR:	Overconsolidation ratio	$C_{c\varepsilon}$:	Modified compression index
ϕ'_r	residual effective stress friction angle	c_v:	Vertical coefficient of consolidation	C_r:	Recompression index
c':	effective stress cohesion intercept	E:	Young's modulus	$C_{r\varepsilon}$:	Modified recompression index
s_u:	undrained shear strength	k:	Hydraulic conductivity	C_α:	Secondary compression index
σ_p':	preconsolidation stress	C_c:	Compression index	$C_{\alpha\varepsilon}$:	Modified secondary compression index

4-1.1 Moisture Content

The moisture (or water) content test is one of the simplest and least expensive laboratory tests to perform. Moisture content is defined as the ratio of the mass of the water in a soil specimen to the dry mass of the specimen. Moisture content can be tested in a number of different ways including: (1) a drying oven (ASTM D 2216); (2) a microwave oven (ASTM D 4643); or (3) a field stove or blowtorch (ASTM D 4959). While the microwave or field stove (or blowtorch) methods provide a rapid evaluation of moisture content, potential errors inherent with these methods require confirmation of results using ASTM D 2216. The radiation heating induced by the microwave oven and the excessive temperature induced by the field stove may release water entrapped in the soil structure that would normally not be released at 230 ^{o}F (100 ^{o}C), yielding higher moisture content values than would occur from ASTM D 2216.

Improper sampling, handling, and storage may alter the in-situ moisture content tests. If a sample is not properly sealed, drying of the sample and moisture loss will likely occur.

4-1.2 Unit Weight

In the laboratory, soil unit weight and mass density are easily measured on tube samples of natural soils. The moist (total) mass density is $\rho_t = M_t/V_t$, whereas the dry mass density is given by $\rho_d = M_s/V_t$. The moist (total) unit weight is $\gamma_t = W_t/V_t$, whereas the dry unit weight is defined as $\gamma_d = W_s/V_t$. The interrelationship between the total and dry mass density and unit weight is given by:

$$\rho_d = \rho_t/(1+w_n)$$

and the relationship between total and dry unit weight is given by:

$$\gamma_d = \gamma_t/(1+w_n)$$

4-1.3 Atterberg Limits

The Atterberg limits of a fine grained (i.e., clayey or silty) soil represent the moisture content at which the behavior of the soil changes. The tests for the Atterberg limits (ASTM D4318) are referred to as index tests because they serve as an indication of several physical properties of the soil, including strength, permeability, compressibility, and shrink/swell potential. These limits also provide a relative indication of the plasticity of the soil, where plasticity refers to the ability of a silt or clay to retain water without changing state from a semi-solid to a viscous liquid. In geotechnical engineering practice, the Atterberg limits generally refers to the liquid limit (LL), and plastic limit (PL). These limits are defined below.

4-1.3.1 Liquid Limit (LL)

This upper limit represents the moisture content at which any increase in moisture content will cause a plastic soil to behave as a liquid. The LL is defined as the moisture content at which a standard groove cut in a remolded sample will close over a distance of ½ inch at 25 blows of the liquid limit device

4-1.3.2 Plastic Limit (PL)

This limit represents the moisture content at which the transition between the plastic and semisolid state of a soil. The PL is defined as the moisture content at which a thread of soil just crumbles when it is carefully rolled out to a diameter of 1/8" (3.2 mm).

4-1.3.3 Plasticity Index (PI)

A measure of a soils plasticity is the plasticity index (PI) which as calculated as PI = LL – PL. relating PI to clay soil properties, including undrained and drained strength and compression index. Results are typically presented on Casagrande's Plasticity chart . On this chart, the equation for the A-line and U-line are, respectively:

$$A-line: PI=0.73(LL-20)$$

$$U-line: PI=0.9(LL-8)$$

4-1.4 Particle Size Distribution

Particle size distribution by mechanical sieve and hydrometer are useful for soil classification purposes. Procedures for grain size analyses are contained in ASTM D 422 and AASHTO T88. Testing is accomplished by placing air-dried material on a series of screens of known opening size. U.S. standard sieve sizes are noted in Table 4-4 below. Each successive screen has a smaller opening to capture progressively smaller particles. Testing of the finer grained particles is accomplished by suspending the chemically dispersed particles in water column and measuring the specific gravity of the liquid as the particles fall from suspension.

Figure 4-4
U.S. Standard Sieve Sizes and Corresponding Opening Dimension.

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Opening (in.)
3	6.35	0.25
4	4.75	0.187
6	3.35	0.132
8	2.38	0.0937
10	2.00	0.0787
12	1.68	0.0661
16	1.20	0.0469
20	0.85	0.0331

U.S. Standard Sieve No.	Sieve Opening (mm)	Sieve Opening (in.)
30	0.60	0.0232
40	0.425	0.0165
50	0.30	0.0117
60	0.25	0.0098
70	0.21	0.0083
100	0.15	0.0059
140	0.106	0.0041
200	0.075	0.0029
270	0.053	0.0021
400	0.0375	0.0015

Representative samples with fines (particles with diameter less than 0.075 mm or the U.S. No. 200 sieve) should not be oven dried prior to testing because some particles may cement together leading to a calculated lower fines content from mechanical sieve analyses than is actually present. When fine-grained particles are a concern, a wash sieve (ASTM D 1140) should be performed to assess the fines content. Additionally, if the clay content is an important parameter, hydrometer analyses need to be performed. It should be noted that the hydrometer test provides approximate analysis results due to oversimplified assumptions, but the obtained results can be used as a general index of silt and clay content.

4-1.5 Specific Gravity

The specific gravity of solids (G_s) is a measure of solid particle density and is referenced to an equivalent volume of water. Specific gravity of solids is defined as $G_s = M_s/(V_s \times \gamma_w)$ where M_s is the mass of the soil solids and V_s is the volume of the soil solids. It is common to assume a reasonable G_s value, although laboratory testing by AASHTO T100 or ASTM D 854 or D 5550 can be used to verify and confirm the G_s value

4-1.6 Organic Content

A visual assessment of organic materials may be very misleading in terms of engineering analysis. Laboratory test method AASHTO T194 or ASTM D 2974 should be used to evaluate the percentage of organic material in a specimen where the presence of organic material is suspected based on field information or from previous experience at a site. The test involves heating a sample to temperatures of 833^{o}F (455^{o}C) and holding this temperature until no further change in mass occurs. At this temperature, the sample turns to ash. Therefore, the percentage of organic matter is (100% - % ash) where the % ash is the ratio of the weight of the ash to the weight of the original dried sample. The sample used for the test is a previously dried sample from a moisture content evaluation. Usually organic soils can be distinguished from inorganic soils by their characteristic odor and their dark gray to black color. In doubtful cases, the liquid limit should be determined for an oven-dried sample (i.e., dry preparation method) and for a sample that is not pre-dried before testing (i.e., wet preparation method). If drying decreases the value of the liquid limit by about 30 percent or more, the soil may usually be classified as organic (Terzaghi, Peck, and Mesri, 1996).

Soils with relatively high organic content have the ability to retain water, resulting in high moisture content, high primary and secondary compressibility, and potentially high corrosion potential.

4-1.7 Electro Chemical Classification Tests

Electro chemical classification tests provide quantitative information related to the aggressiveness of the soil conditions and the potential for deterioration of a foundation material. Electro chemical tests include (1) pH; (2) resistivity; (3) sulfate ion content; and (4) chloride ion content. If the pH of the soil is below 4.5 or the resistivity is less than 1000 ohms/cm, the soil should be treated as an aggressive environment. If the soil resistivity is between 3000 ohms/cm and 5000 ohms/cm, chloride ion content and sulfate ion content tests should be performed. If results from these tests indicate chloride ion content greater than 100 ppm or sulfate ion content greater than 200 ppm, then the soil should be considered as aggressive. Tests to characterize the aggressiveness of a soil environment are important for design applications that include metallic elements, especially for ground anchors comprised of high strength steel and for metallic reinforcements in mechanically stabilized earth walls.

4-2 Laboratory Performance Tests for Soils

Design soil properties for deformation, shear strength, and permeability characteristics are evaluated using laboratory-testing methods. To contrast most index tests, performance tests are usually more costly and time consuming. The results, however, provide specific data regarding engineering performance. This section provides information on equipment and testing procedures for consolidation, shear strength, and permeability testing.

4-2.1 Consolidation

Results from oedometer tests can be used to assess the magnitude of settlement (both primary and secondary), time rate of settlement, and stress history. A consolidation test is typically performed on undisturbed samples to evaluate settlement potential of in-situ foundation soils, however recompacted materials can also be tested to assess the settlement performance of compacted fills. The oedometer (or one-dimensional consolidometer) is the primary laboratory equipment used to evaluate consolidation and settlement potential of cohesive soils. The equipment for a consolidation test includes: (1) a loading device that applies a vertical load to the soil specimen; (2) a metal ring (fixed or free) that laterally confines the soil specimen and restricts deformation to the vertical direction only; (3) porous plates placed on the top and bottom of the sample; (4) a dial indicator or linear variable differential transducer (LVDT); (5) a timer; and (6) a surrounding container to permit the specimen to remain submerged during the test.

Consolidation properties of clay soils are evaluated in the laboratory using the one-dimensional consolidation test. The most common laboratory method is the incremental load (IL) oedometer (ASTM D 2435). High-quality undisturbed samples obtained using thin-walled tubes (ASTM D 1587), piston samplers, or other special samplers are required for laboratory consolidation tests. The consolidation test is relatively expensive and time consuming as compared to simpler index type tests. This test is one of the most valuable tests for fine grained soil as it provides valuable data regarding stress history, as well as compressibility. It is important to carefully consider all laboratory testing variables and their potential effects on computed properties.

A loading schedule will need to be provided to a laboratory to perform a consolidation test (i.e., loads and duration of loads). The loading schedule for a consolidation test will depend on the type of soil being tested, the depth where the soil was obtained, and the particular application (e.g., embankment, shallow foundation) being considered for the project. The engineer needs to carefully evaluate the loading schedule to be used and should not leave the decision to the discretion of the laboratory′.

The range of applied loads for the test should well exceed the effective stresses that are required for settlement analyses. This range should cover the smallest and largest effective stresses anticipated in the field. The anticipated preconsolidation stress should be exceeded by at least a factor of four during the laboratory test. If the preconsolidation stress is not significantly exceeded during the loading schedule, σ_p', and C_c (or $C_{c\varepsilon}$) may be underestimated due to specimen disturbance effects. A load-increment-ratio (LIR) of 1 defined as $\Delta\sigma_V/\sigma_V' = 1$, is commonly used for most tests corresponding to a doubling of the vertical stress applied to the specimen during each successive increment. As the stress approaches the value of σ_p', smaller LIR increments are recommended to facilitate an accurate estimate of σ_p'.

An unload-reload cycle should be performed, especially for cases where accurate settlement predictions are required, specifically to obtain a value for C_r. Since most samples will inevitably be somewhat disturbed, a C_r value based on the initial loading of a consolidation test sample will be higher than that for an undisturbed sample, resulting in an overestimation of settlements in the overconsolidated region. A C_r value based on an unload-reload cycle is likely to be more representative of the actual modulus in the overconsolidated region. It is recommended that the unload-reload cycle be performed at a stress slightly less than σ_p'.

The duration of each load increment should be selected to ensure that the sample is approximately 100 percent consolidated prior to application of the next load. For relatively low to moderate plasticity silts and clays, durations of 3 to 12 hours will be appropriate for loads in the normally consolidated range. For fibrous organic materials, primary consolidation may be completed in 15 minutes. For high plasticity materials, the duration for each load may need to be 24 hours or more to ensure complete primary consolidation and to evaluate secondary compression behavior. Conversely, primary consolidation may occur in less than 3 hours for loads less than σ_p'. If the time period is too short for a given load increment (i.e., the sample is not allowed to achieve approximately 100 percent consolidation before the next load increment is applied), then values of C_c (or $C_{c\varepsilon}$) may be underestimated and values of C_v may be overestimated.

Secondary compression should be assessed on the basis of the deformation versus a log-time response. The consolidation test for each load increment should be run long enough to establish a log-linear trend between time and deformation.

The constant rate of strain (CRS) version of the consolidation test (ASTM D 4186) applies the loading continuously and measures stress and pore pressures by transducers in real time, thereby reducing testing times from approximately 1 week by IL oedometer to about 1 day by a CRS consolidometer. While expediting the testing time duration, the CRS consolidation test requires special instrumentation and equipment.

4-2.2 Soil Strength

Soil shear strength is influenced by many factors including the effective stress state, mineralogy, packing arrangement of the soil particles, soil hydraulic conductivity, rate of loading, stress history, sensitivity, and other variables. As a result, shear strength of soil is not a unique property. Laboratory measured shear strength values will also vary because of boundary conditions, loading rates, and direction of loads. Typical laboratory strength tests including unconfined compression (AASHTO T208; ASTM D 2166), triaxial (AASHTO T234; ASTM D 4767), and direct shear (AASHTO T236; ASTM D 3080). A detailed discussion on testing equipment and procedures is beyond the scope of this document, the AASHTO and ASTM standards provide for detailed information on these tests. This section describes information that must be conveyed to a laboratory-testing firm to ensure that the strength testing performed is consistent with the requirements imposed by the design (e.g., selection of confining pressures consistent with the imposed loads).

4-2.3 Unconfined Compression (UC) Tests

The unconfined compression test is a quick, relatively inexpensive means to estimate the undrained shear strength of cohesive specimens. This test is commonly used in practice because of its simplicity and low cost; however, in most cases, the undrained strength results from an unconfined compression test are conservative. The maximum stress, q_u, measured at failure is equal to two times the undrained strength (s_u). In this test a cylindrical specimen of the soil is loaded axially, without any lateral confinement to the specimen, at a sufficiently high rate to prevent drainage. Since there is no confinement, residual negative pore pressures that may exist in the sample following sample preparation control the state of effective stress. This test cannot be performed on granular soils, dry or crumbly soils, silts, peat, or fissured or varved materials. Because there is no control on the effective stress state of the specimen, this test is not recommended for evaluating strength properties for compressible clay soils when a rigorous analysis of embankment or structural foundation loads is required. The reliability of this test decreases with respect to increasing sampling depth because the sample tends to swell after sampling resulting in greater particle separation and reduced shear strength. Testing the full diameter extruded specimen as soon as possible after removal from the tube can minimize swelling. This reduces disturbance and preserves natural moisture content.

4-2.4 Triaxial Tests

4-2.4.1 Unconsolidated-Undrained (UU) Test

In this test, no drainage or consolidation is allowed during either the application of the confining stress or the shear stress. This test models the response of a soil that has been subject to a rapid application of confining pressure and shearing load. It is difficult to obtain repeatable results for UU testing due to sample disturbance effects. Like the UC tests, the accuracy of the UU test is also dependent on the soil sample retaining its original structure until testing occurs. The undrained strength of the soil, s_u, is measured in this test.

4-2.4.2 Consolidated-Drained (CD) Test

In this test, the specimen is allowed to completely consolidate under the confining pressure prior to performing the shearing portion of the test. During shearing, load is applied at a rate slow enough to allow drainage of pore water and no buildup of pore water pressures. The time required to conduct this test in low permeability soil may be as long as several months; therefore it is not common to conduct this test on low permeability soils. This test models the long-term (drained) condition in soil. Effective stress strength parameters (i.e., ϕ' and c') are evaluated in this test.

4-2.4.3 Consolidated-Undrained (CU) Test

The initial part of this test is similar to the CD test in that the specimen is allowed to consolidate under the confining pressure. Shearing occurs, however, with the drainage lines closed, thus during shearing there is continual pore water pressure development. The rate of shearing for this test is more rapid than that for a CD test. Pore pressures should be measured during shearing so that both total stress and effective stress strength parameters can be obtained. The effective stress parameters evaluated for most soils based on CU testing with pore pressure measurements is similar to that obtained for CD testing, thus making CD tests unnecessary for typical applications.

4-2.5 Direct Shear Tests

In the direct shear test, the soil is first consolidated under an applied normal stress. The soil is then sheared at a constant rate after consolidation is completed (which will be instantaneous in cohesionless soils), which should be selected as a function of the hydraulic conductivity of the specimen. Direct shear testing is commonly performed on compacted materials used for embankment fills and retaining structures. In addition to peak effective stress friction angle (ϕ'), the direct shear test can be used for the evaluation of effective stress residual strengths ($c'_r \approx 0$; ϕ'_r). A reversing direct shear test can be used to evaluate residual shear strengths. In this test, the direction of shearing in the test is reversed several times thereby causing the accumulation of displacements at the slip surface.

For designs involving geosynthetics, the strength of the interface between the soil and geosynthetic or geosynthetic and geosynthetic are often necessary parameters. Direct shear machines have been modified to test the shear strength of various interfaces, as described in ASTM D 5321.

4-2.6 Factors Affecting Strength Test Results

4-2.6.1 Sample Disturbance

The degree of disturbance affecting samples will vary according to the type of soil, sampling method, and skill of the driller. All samples will experience some degree of disturbance due to the removal of in-situ stresses during sampling and laboratory preparation for testing. Due to disturbance-induced alteration of the in-situ soil structure, internal migration of pore water, and reduction in the effective stress state of the sample, shear strength values obtained from UC and UU tests will be unrepeatable and may be higher or lower than corresponding field strengths. Recompression of a sample during the consolidation phase of a CIU test will reduce the void ratio of the specimen that may lead to higher laboratory strengths relative to the in-situ condition, but destruction of natural bonding during sampling will typically more than offset this strength increase. Shear strengths from samples likely to be very disturbed should be used with caution for design calculations.

4-2.6.2 Mode of Shearing

Experience has shown the undrained soil shear strength also depends on the direction of shearing. That is, a soil loaded in compression will likely have a shear strength that is different than if the soil is loaded in extension. The effects are not as recognized for drained (effective stress) strength in compression and extension, or partially drained conditions. Most triaxial tests will be performed with isotropic consolidation and vertical compression, as most commercial laboratories are not equipped to perform various modes of shearing. The engineer must consider how the actual strength mobilized under field conditions differs from that measured using laboratory (or in-situ) methods. For most typical projects the use of alternative loading paths is not practical. However, information and existing correlations relating undrained strength from isotropically consolidated (CU) triaxial tests to other loading paths can be used to adjust the CU strength to a value more appropriate for the loading condition imposed by the structure to be built.

4-2.6.3 Confining Pressures

Soil shear strength is governed by the effective stresses in the soil. Therefore, it is important to carefully consider the range of effective stresses that a soil will be subjected to during the design life of a structure. These stresses will be affected by changes in the level of the ground water table, effects of capillary rise, design loads of potential structures, as well as many other possibilities. For laboratory testing considerations, this means that for each sample tested, the in-situ (or current) effective stress condition and that which will exist after the design feature (e.g., shallow foundation, embankment, retaining wall, cut slope) has been constructed needs to be calculated.

For laboratory strength testing, three different confining stresses are generally used for each sample at a unique depth, thus requiring three specimens from the same undisturbed sample. For each specimen, the shear strength is measured and a shear strength envelope is developed.

Loading ranges typically include the effective overburden stress at the sample depth, one half the effective overburden stress at the sample depth, and a third stress condition superceding the anticipated design load or two to four times the effective overburden stress at the depth sampled, whichever is greater. To calculate the range of effective stresses, the final effective stress at the elevation of the sample should be plotted as a function of depth. For surface loadings such as that due to embankments and shallow foundations, stress distributions with depth should be calculated using appropriate methods.

For UU tests, the soil specimen is not re-consolidated to the effective stress in the ground. In selecting confining pressures, the total stress at the elevation of the soil sample in the ground is reapplied to the specimen with the test apparatus drain lines closed. If it is assumed that the water content of the specimen just prior to testing is the same as that in the ground and if the sample is saturated, the reapplication of total stresses equal in magnitude to those which were in the ground, should theoretically restore the sample to its in-situ effective stress condition. Because of inevitable sample disturbance, more pressure is transferred to the porewater resulting in a lower effective stress as compared to that in the ground. The lower preshear effective stress results in lower than actual shear strength. UU test results are considered unreliable at depths greater than 20 ft for normally consolidated samples and over 40 ft for overconsolidated soils because of this reduction in effective stress.

4-2.6.4 Specimen Size

The specimen size for testing must be provided to the laboratory. Triaxial testing specimens are cylindrical with a minimum diameter of 1.3 in (33 mm), and a length to diameter (L:D) ratio between 2 and 2.5. Undisturbed samples from tubes, which are typically 3 in (76 mm) in diameter, need to be trimmed to fit the caps and bases of the triaxial device. A specimen trimmed with care to 1.4 in (35.6 mm) diameter is generally the best practice for triaxial test specimen preparation for CU or CD testing to minimize the disturbance related to the side walls of the samples. If UU tests are performed, specimens should be extruded directly from the sampling tube and tested untrimmed at full diameter to minimize disturbance effects.

Laboratory testing for undrained strength of heavily overconsolidated, fissured soils is difficult since typical sample diameters may not be sufficient to capture the affects of fissures and cracks on strength. In many cases, the actual strength of the soil can be up to 50 percent less than that measured in the laboratory.

4-2.6.5 Saturation

Backpressure saturation procedures are typically used to saturate soil samples for triaxial testing. A backpressure of at least 1 atm (100 kPa) should be applied, but 2 to 3 atm (200 to 300 kPa) of backpressure are recommended. Samples need to be saturated for drained tests to permit volume change measurements to be made and, for undrained tests, to permit pore pressures during shearing to be measured. Saturation by backpressure methods involves raising the pressure inside the specimen to dissolve gas into the pore fluid. Since the cell pressure is raised an equal value along with the internal specimen pressure, the effective stress of the sample remains constant. The pore pressure parameter, $B=\Delta u/\Delta\sigma_3$, should be equal to at least 0.95 for the specimen to be considered saturated. If the B-value remains constant as the back pressure is increased, the specimen can be considered essentially saturated.

4-2.6.6 Displacement at Failure

The engineer should estimate the amount of deformation or strain necessary to achieve the ultimate strength of the material in a laboratory strength test. The purpose of this is to ensure that the full stress-strain curve of the sample is recorded during the test. For example, large-displacement (or residual) shear strength values may be required to perform stability analyses for a preexisting slip plane, such as the case for a landslide. The engineer should provide the laboratory with a minimum strain (or displacement) value to ensure that the laboratory does not prematurely stop a test. In most cases, UC and triaxial tests run to 15 percent axial strain will be sufficient. For truly normally consolidated samples tested in compression, strains on the order of 20 to 25 percent may be required to reach the peak soil strength.

4-2.6.7 Rate of Shearing

The rate of shearing needs to be carefully considered before beginning either a triaxial or direct shear test, especially for fine grained soils. The selection of shearing rates for undrained shearing tests on clays needs to be slow enough to ensure equalization of pore pressures within the sample. For drained tests on clays, the shearing rate must be slow enough to allow for excess pore pressures to dissipate through the pervious boundaries. For both CU and CD tests, the time to failure, t_f, is estimated using Figure 4-5. This table also shows the affect of using side drains. Typical triaxial tests incorporate porous stones on the top and bottom of the specimen. The use of filter strips along the side of the specimen (i.e., side drains) serves to reduce the time required to dissipate excess pore pressures in the specimen by allowing drainage in the radial direction. The t_{100} value in Figure 4-5 is the time to complete primary consolidation, which can be evaluated using time rate versus deformation data from the consolidation portion of the strength test. Since most laboratories do not record time rate consolidation data during the consolidation phase of a CIU test, this data will need to be requested from the testing laboratory prior to testing. Next, the axial strain to reach peak strength, ε_p, is estimated. Strains required to reach peak conditions depend on the type of clay, OCR of the clay, and the imposed loading during shear (i.e., compression, extension, etc.). Typical values for compression loading of an isotropically consolidated specimen are 20 to 25 percent at OCR = 1 and decreasing to a few percent at high OCR (>20). A maximum rate of displacement, $\dot{\delta}$, can then be calculated so that ε_p is reached after t_f for a specimen with an initial height H_o as:

$$\dot{\delta} = \varepsilon_p H_o/(12.7\ t_{100})$$

Figure 4-5
Time t_f to Reach Failure

Type of test	Without side drains	With side drains
CU	0.51 t_{100}	1.8 t_{100}
CD	8.5 t_{100}	14 t_{100}

Although not commonly performed on fine-grained soils, in the case of consolidated drained (CD) direct shear tests, the shearing rate can be selected based on ASTM 3080 wherein the minimum time required to fail a sample, t_f, is calculated as:

$$t_f = 50 \cdot t_{50} = 11.7 \cdot t_9$$

where t_{50} and t_{90} are the times required to complete 50 percent and 90 percent primary compression, respectively. The times t_{50} and t_{90} may be evaluated using the square root of time or logarithm of time method to assess the vertical displacements measured with time under the constant normal load prior to shearing. Once t_f is calculated, the displacement required to achieve the peak strength of the soil (using a conventional size direct shear box), δ_f, can be estimated as 1 to 2 mm for hard clays, 2 to 5 mm for stiff clays, and 8 to 10 mm for plastic clay (Bardet, 1997). The maximum shear rate for the CD test is then selected so that the test takes at least as long as t_f to reach the displacement δ_f.

4-2.7 Permeability

Laboratory permeability testing is performed to determine the hydraulic conductivity of a soil specimen. For natural soils, tests are conducted on specimens from tube samples and for fill and borrow soils, tests are made on recompacted materials. Two types of tests are commonly performed, the rigid wall test (AASHTO T215; ASTM D 2434) and the flexible wall test (ASTM D 5084). Rigid wall permeameters are not recommended for low permeability (i.e., $k \leq 10^{-6}$ cm/s) soils due to the potential for sidewall leakage. The equipment for the rigid wall test includes a rigid wall permeameter, water tank, vacuum pump, and manometer tubes. Constant head and falling head tests can be performed using a flexible wall permeameter cell, cell reservoir, headwater reservoir, tailwater reservoir, top and base caps, flexible membrane, porous stones, and filter paper.

4-3 Sample Storage and Handling

Undisturbed soil samples should be transported and stored so that that the moisture content is maintained as close as possible to the natural conditions (AASHTO T 207, ASTM D 4220 and 5079). Samples should not be placed, even temporarily, in direct sunlight. Undisturbed soil samples should be stored in an upright position with the top side of the sample up. Samples should always be handled by experienced personnel in a manner that ensures that the sample maintains structural integrity and natural moisture condition. The potential for disturbance and moisture migration within the sample will increase with time, and samples tested after 30 days should be noted on the laboratory data sheet. Excessive storage time can lead to additional sample disturbance that will affect strength and compressibility properties. Long-term storage of soil samples in sampling tubes is not recommended.

X-ray photographs of soil specimens can be used to assess sample quality. Radiography (ASTM D 4452) utilizes X-ray photographs to assess density variation or consistency of a sample, and thus identify potential areas of defects and disturbance. X-ray photographs may be taken on samples within tubes or liners, or on extruded samples. Radiography can be used to identify:

- variation in soil types;
- macrofabric features such as bedding planes, varves, fissures, and shear planes;
- presence of intrusions such as gravel, shells, calcareous soils, peat, and drilling mud;
- presence of voids and cracks; and
- variation in the degree of disturbance that may range from curvature of soil layers near the tube edges to extreme disturbance noted by large voids and cracks (typically at the end of the tubes).

Since these features are often within the sample and not apparent from visual identification, radiography provides a non-destructive means for selecting representative samples for laboratory performance testing. Radiography is particularly useful where a limited number of samples are available for testing or complexities in sampling are likely to induce disturbance. Radiographic testing requires special testing equipment (usually from an outside laboratory) but the testing is not expensive. The radiographic images provide information to ensure that high quality samples are used for laboratory performance tests.

4-4 Laboratory rock tests

Figure 4-6 provides a list of commonly performed laboratory tests for rock associated with typical projects for highway applications. Although other laboratory test methods for rock are available including triaxial strength testing, rock tensile strength testing, and durability testing related to rock soundness, most design procedures for structural foundations and slopes on or in rock are developed based on empirical rules related to RQD, degree of fracturing, and to the unconfined compressive strength of the rock. The use of more sophisticated rock laboratory testing is usually limited to the most critical projects. Details on other laboratory rock testing procedures are provided in FHWA- HI-97-021 (1997). Figure 4-7 provides summary information on typical rock index and performance tests.

Figure 4-6
Common Rock Laboratory Tests

Test Category	Name of Test	ASTM Test Designation
Point Load Strength	Suggested method for evaluating point load strength	D 5731
Compressive Strength	Compressive strength of intact rock core specimen (in unconfined compression)	D 2938
Direct Shear Strength	Laboratory direct shear strength tests for rock specimens under constant normal stress	D 5607
Durability	Slake durability of shales and similar weak rocks	D 4644
Strength-Deformation	Elastic moduli of intact rock core specimens in uniaxial compression	D 3148

Figure 4-7
Summary Information on Rock Laboratory Test Methods.

Test	Procedure	Applicable Rock Types	Applicable Rock Properties	Limitations / Remarks
Point-Load Strength Test	Rock specimens in the form of core, cut blocks, or irregular lumps are broken by application of concentrated load through a pair of spherically truncated, conical platens.	Generally not appropriate for rock with uniaxial compressive strength less than 3500psi (25 Mpa)	Provides an index of uniaxial compressive strength	Can be performed in the field with portable equipment or in the laboratory; in soft or weak rock, test results need to be adjusted to account for platen indentation
Unconfined Compressive Strength of Intact Rock Core	A cylindrical rock specimen is placed in a loading apparatus and sheared under axial compression with no confinement until peak load and failure are obtained.	Intact rock core	Uniaxial compressive strength	Simplest and fastest test to evaluate rock strength; fissures or other anomalies will often cause premature failure
Laboratory Direct Shear Test	A rock specimen is placed in the lower half of the shear box and encapsulated in either synthetic resin or mortar. The specimen must be positioned so that the line of shear force lies in the plane of the discontinuity to be investigated. The specimen is then mounted in the upper shear box and the normal load and shear force are applied.	Used to assess peak and residual shear strength of discontinuity	Peak and residual shear strength	May need to perform in-situ direct shear test if design is controlled by potential slip along a discontinuity filled with very weak material
Elastic Moduli of Intact Rock Core	Procedure is similar to that for unconfined compressive strength of intact rock. Lateral strains are also measured	Intact rock core	Modulus and Poisson's ratio	Modulus values (and Poisson's ratio) vary due to nonlinearity of stress-strain curve.
Slake Durability	Dried fragments of rock are placed in a drum made of wire mesh that is partially submerged in distilled water. The drum is rotated, the sample dried, and the sample is weighed. After two cycles of rotating and drying, the weight loss and the shape of size of the remaining rock fragments are recorded.	Shale or other soft or weak rocks	Index of degradation potential of rock	

4-4.1 Point-Load Strength Test

The point load strength test is an appropriate method used to estimate the unconfined compressive strength of rock in which both core samples and fractured rock samples can be tested. The test is conducted by compressing a piece of the rock between two points on cone-shaped platens until the rock specimen breaks in tension between these two points. Each of the cone points has a 5-mm radius of curvature and the cone bodies themselves include a 60° apex angle. The equipment is portable, and tests can be carried out quickly and inexpensively in the field. Because the point load test provides an index value for the strength, usual practice is to calibrate the results with a limited number of uniaxial compressive tests on prepared core samples. Point load test results are not acceptable if the failure plane lies partially along a pre-existing fracture in the rock, or is not coincident with the line between the platens. For tests in weak rock where the platens indent the rock, the test results should be adjusted by measuring the amount of indentation and correcting the distance D (Wyllie, 1999).

4-4.2 Unconfined Compressive Strength of Intact Rock Core

The unconfined compressive strength of intact rock core can be evaluated reasonably accurately using ASTM D 2938. In this test, rock specimens of regular geometry, generally rock cores, are used. The rock core specimen is cut to length so that the length to diameter ratio is 2.5 to 3.0 and the ends of the specimen are machined flat. The ASTM test standard provides tolerance requirements related to the flatness of the ends of the specimen, the perpendicularity of the ends of the specimens, and the smoothness of the length of the specimen. The specimen is placed in a loading frame. Axial load is then continuously applied to the specimen until peak load and failure are obtained. The unconfined (or uniaxial) compressive strength of the specimen is calculated by dividing the maximum load carried by the specimen during the test by the initial cross-sectional area of the specimen.

4-4.3 Elastic Moduli of Intact Rock Core

This test is performed similarly to the unconfined compressive test discussed above, except that deformation is monitored as a function of load. This test is performed when it is necessary to estimate both elastic modulus and Poisson's ratio of intact rock core. Because of this, it is common to measure both axial (or vertical) and lateral (or diametral) strain during compression. It is preferable to use strain gauges glued directly to the rock surface as compared to LVDT mounted on the platens since slight imperfections at the contact between the platens and the rock may lead to movements that are not related to strain in the rock (Wyllie, 1999).

4-4.4 Laboratory Direct Shear Test

The apparatus and procedures for direct shear testing are discussed in ASTM D 5607. This test is typically used to evaluate the shear strength of a rock discontinuity. Overall, the equipment for the direct shear test on rock is similar to that for soil including a direct shear testing machine, a device for applying normal pressure, and displacement monitoring devices. For testing of rock specimens, an encapsulating material such as a high strength gypsum cement is poured around the specimen in the upper and lower holding ring. The specimen is sheared as one holding ring is displaced horizontally with respect to the other such that the discontinuity surface is exactly parallel to the direction of the shear load. Load cells are used to monitor the shear force and LVDTs or dial gauges are used to monitor both horizontal and vertical deformation. Multiple LVDTs should be used to monitor vertical deformation and potential overturning of the specimen.

In this test, plots of shear stress versus shear displacement and normal displacement and shear displacement are prepared. Normal stresses should be adjusted to account for potential decreases in the shear contact area. After the sample is sheared, the sample is then reset to its original position, the normal load is increased, and another test is performed. Each test will produce a pair of shear stress and normal stress values for both peak and residual conditions. From this, the friction angle of the discontinuity surface can be

4-5 References

1. ***GEOTECHNICAL ENGINEERING CIRCULAR NO. 5, Evaluation of Soil and Rock Properties***, Sabattini, Bachus, Mayne, Schnieder and Zettler, FHWA-IF-02-034, 2002.

2. ***Subsurface Investigations***, Arman, Samtani, Castelli, and Munfakh Subsurface Investigations, FHWA-HI-97-021, Federal Highway Administration, 1997.

Chapter 5

Boring Log Preparation

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Chapter 5

Boring Log Preparation

For every subsurface exploration performed, a log of the results shall be produced. An inspector, as well as the driller performing the work, shall prepare a field log for each investigation. The geotechnical engineer will prepare a final edited logs based on the field log, visual classification of the soil samples, and the results of the laboratory testing program.

The material encountered in the subsurface investigation must be described in a consistent format. The following sections provide the basis of the terms and descriptions used to describe soil, bedrock, stratigraphy, and drilling details on a boring log.

5-1 Data Entry Requirements

The Department maintains a subsurface database to store geotechnical data and project related geotechnical information. Each borehole requires a unique name and spatial location to be integrated into the database system. The following convention shall be used on each log:

Within every project, each borehole will have its own, unique name.

a. Bridge borings shall start with the letter “B.” If there is more than one bridge a project, the boring should include an intermediate number that denotes the structure no., i.e. “B-1-1.”
b. Retaining wall borings shall start with the letters “RW.” If there is more than one retaining wall on a project, the boring shall include an intermediate number that denotes the structure no., i.e. “RW-101-1
c. Roadway borings and other miscellaneous structures shall start with the letter “R.”

If the construction project number will be different than the PE project number, reference the construction project number on the boring log.

All logs shall include a northing and easting coordinate.

All logs shall include the town the project is located in.

If the boring is being taken for a bridge structure, the NBIS Bridge number shall be referenced on the log.

The Department uses gINT software produced by Bentley to generate boring logs. A standard field log template generated by gINT is included as an appendix to this chapter. The Department has developed a computer application that is used with gINT to streamline data entry and to populate the subsurface database.

Consulting engineers shall use gINT software, unless written approval is obtained to use another software application. Condition of approval for **other** types of log generating software will be based on the ability of the application to export information to a database or excel workbook that is compatible in format to our subsurface database. See the Appendix of this chapter for the standard formatting of tables and fields used in our database.

5-2 Soil Classification

Due to the complex and variable nature of soils deposits in Connecticut, identification of soils must be accurate and detailed. The Department's method for soil description has its basis in the Burmister Method. The system is divided in two broad categories: granular soils, in which the proportion and gradation of the components are most significant, and cohesive soils, in which the degree of plasticity is the controlling factor. Frequently granular and cohesive soils will occur in combination.

5-2.1 Granular Soils

Granular soils are cohesionless soils consisting of boulders, cobbles, gravel, sand, and silt, which may be present separately or in combination. Granular soil components are defined on the basis of particle size as indicated in Figure 5-1.

Figure 5-1
Granular Soil Component Based on Grain Size Distribution

<table>
<tr><th colspan="2" rowspan="2">Soil Component</th><th colspan="2">Sieve Size</th></tr>
<tr><th>From</th><th>To</th></tr>
<tr><td colspan="2">Boulder*</td><td>8 in.</td><td>---</td></tr>
<tr><td colspan="2">Cobbles*</td><td>3 in.</td><td>8 in.</td></tr>
<tr><td rowspan="3">Gravel</td><td>coarse</td><td>1 in.</td><td>3 in.</td></tr>
<tr><td>medium</td><td>3/8 in.</td><td>1 in.</td></tr>
<tr><td>fine</td><td>#10</td><td>3/8 in.</td></tr>
<tr><td rowspan="2">Sand</td><td>coarse</td><td>#40</td><td>#10</td></tr>
<tr><td>fine</td><td>#200</td><td>#40</td></tr>
<tr><td colspan="2">Silt</td><td>---</td><td>#200</td></tr>
</table>

*Boulders and Cobbles are not included when determining the soil’s classification and shall be preceded by the word "with."

Figure 5-2 includes the terminology to be used in describing percentage of the minor soil component present.

Figure 5-2
Description of Minor Soil Component Percentage

Term	Percent Range
trace	1-10%
little	10-20%
some	20-35%
and	35-50%

Figure 5-3 demonstrates the method of describing the fractional components of sands and gravels.

Figure 5-3
Description of Sand and Gravel Fractional Component

Fraction	Written Fraction	Proportion
coarse to fine	c-f	All sizes
coarse to medium	c-m	Less than 10% fine gradation
medium to fine	m-f	Less than 10% coarse gradation
coarse	c	Less than 10% medium and/or fine gradation
medium	m	Less than 10% coarse and fine gradation
fine	f	Less than 10% medium and/or coarse gradation

In describing the soil, the primary component will be spelled with all capitals, while the remaining components will be in small case letters. A color description should also be included with the soil description. The following is a typical description of a granular soil: ***Yellow-brown c-f SAND, some m-f gravel, trace silt***.

5-2.2 Cohesive Soils

Cohesive soils are those which contain a high percentage of fines. They may be granular soils with the addition of fine-grained components which cause cohesion and plasticity, or they may be fine-grained soils with no coarse components. For predominately granular size soils that exhibit plastic properties, it will be necessary to combine the methods used to describe granular and cohesive soils to provide an accurate description.

Plasticity is the most distinct characteristic of cohesive soils and colloidal organic soils. Figure 5-4 provides the descriptive term for fine-grained soils based on the degree of plasticity and plasticity index.

Figure 5-4
Fine-Grained Soil Description

Descriptive Term	Degree of Plasticity	Plasticity Index
SILT	None	Non-plastic
Silt, trace Clay	Slight	1-5
ORGANIC SILT	Slight	1-5
clayey SILT	Medium	5-20
ORGANIC clayey SILT	Medium	5-20
silty CLAY	High	20-40
ORGANIC silty CLAY	High	20-40
CLAY	Very High	over 40
ORGANIC CLAY	Very High	over 40

The following are typical descriptions of cohesive soils:

a. Gray silty CLAY, some f sand; trace gravel
b. Red-brown CLAY varved with gray clayey SILT
c. ***Dark gray ORGANIC SILT; many roots and fibers***.

5-2.3 Highly Organic Soils

Fine-grained soils, where the organic content appear to be more than 50 percent of the volume (about 22 percent by weight), should be described as peat. Fine-grained soils, where the organic content is less than 50 percent of the volume should be described as soils with organic material or organic soils. The following terms can be used to describe the organics.

1. Peat: Organic soils with a high percentage of vegetable material, without living fibers.
2. Marsh, Meadow or Root Mat: Organic soils that have a pronounced structure of living root fibers.
3. Humus: Completely decomposed organic matter
4. Forest Litter: Surficial deposits of decaying vegetation/wood/leaves or other organic matter which is distinguishable as to the original form or is partly decomposed into humus.
5. Lignite: Immature coals having a woody appearance and brown in color.

A typical description of a highly organic soil is a follows: ***Dark brown compressed PEAT, some gray c-f sand*.**

5-3 Bedrock Description

The level of detail for bedrock description should be based on the purpose of the exploration and the intended user of the information. Although the same basic information should be presented for all bedrock core descriptions, the appropriate level of detail should be determined by the geotechnical engineer based on the project needs. The description of bedrock cores may include some or all of the following items:

5-3.1 Bedrock type

Bedrock are classified according to origin into three major divisions: igneous, sedimentary, and metamorphic. Some of the more common bedrock types found in this state are included in Figure 5-5.

Figure 5-5
Common Bedrock Types

IGNEOUS		**SEDIMENTARY**		**METAMORPHIC**	
Basalt	Diabase	Shale	Limestone	Slate	Quartzite
Gabbro	Diorite	Sandstone	Dolomite	Schist	Marble
Pegmatite	Granite	Conglomerate		Gneiss	Amphibolite

5-3.2 Color

A color chart should be used to assigned colors consistently. When appropriate, color for both wet and dry conditions shall be recorded.

5-3.3 Grain size

The grain size description should be classified using Figure 5-6.

Figure 5-6
Bedrock Grain Size Description

Description	**Diameter (mm)**	**Characteristic**
coarse grained	>2.0	Individual grains can be easily distinguished by eye
medium grained	0.42-2.0	Individual grains can be distinguished by eye
fine grained	<0.42	Individual grains cannot be distinguished by unaided eye

5-3.4 Bedrock Structure

5-3.4.1 Bedding

The bedding description should be in accordance with Figure 5-7.

Figure 5-7
Bedrock Bedding Description

Description	Thickness (ft)
massive	>3
thickly bedded	1 – 3
medium bedded	0.3 – 1.0
laminated	<0.3

5-3.4.2 Degree of Fracturing (jointing)

The jointing description should be in accordance with the following Figure 5-8.

Figure 5-8
Bedrock Degree of Fracturing Description

Description	Thickness (ft)
unfractured	> 6
slightly fractured	3 – 6
moderately fractured	1 – 3
highly fractured	0.3 – 1
intensely fractured	< 0.3

5-3.4.3 Weathering

The weathering description should be in accordance with the Figure 5-9:

Figure 5-9
Bedrock Weathering Description

Description	Characteristic
residual soil	Original mineral of bedrock have been entirely decomposed and original bedrock fabric is not apparent; mineral can be easily broken by hand.
completely weathered	Original minerals of bedrock have been almost entirely decomposed, although original fabric may be intact; material can be granulated by hand.

Figure 5-9 (continued)
Bedrock Weathering Description

Description	Characteristic
highly weathered	More than half of the bedrock is decomposed; bedrock is so weakened that a minimum 2 inch diameter sample can be broken readily by hand across bedrock fabric.
moderately weathered	Bedrock is discolored and noticeably weakened, but less than half is decomposed; a minimum 2 inch diameter sample cannot be broken readily by hand across bedrock fabric.
slightly weathered	Bedrock is slightly discolored, but not noticeably lower in strength than fresh bedrock.
fresh	Bedrock shows no discoloration, loss of strength, or other effect of weathering alteration.

5-3.5 Strength

Figure 5-10 present guidelines for a qualitative assessment of rock strength. Field estimates should be confirmed with selected laboratory tests, where appropriate.

Figure 5-10
Bedrock Strength Description

Description	Characteristic	App. Uniaxial Comp. Strength (psi)
extremely weak	Can be indented by thumbnail	35 – 150
very weak	Can be peeled by knife	150 - 700
weak	Can be peeled with difficulty by knife	700 – 3500
medium strong	Can be indented ¼” with sharp end of hammer	3500 - 7200
strong	Requires one hammer blow to fracture	7200 – 14,500
very strong	Requires many hammer blows to fracture	14,500 – 35,000
extremely strong	Can only be chipped with hammer blows	>35,000

5-3.6 Mineral Composition

For some common bedrock types (e.g. basalt, arkose), mineral composition need not be specified. When included in the bedrock description, the most abundant mineral should be listed first, followed by minerals in decreasing order of abundance.

5-4 Stratification Identification

In addition to the information contained in the “Material Description” column, a boring log should contain information that describes the various strata that are encountered. The strata information should denote where the geological origin of the material changes and should be shown in the “Generalized Strata Description.” Individual strata should be marked midway between samples unless the boundary is encountered in a sample or other measurements are available to better define the boundary. The stratigraphy observations should include identification of the pavement structure, topsoil, existing fill, native soil and bedrock.

Figure 5-11 is a set of keywords that should be used when describing generalized soil stratas.

Figure 5-11
Strata Keyword List

Keyword	General Description
Topsoil	Uppermost strata of soil which contains a mixture granular and cohesive soils and organic material
Pavement Structure	Includes the wearing surface and bound and unbound base courses
Miscellaneous Fill	Man-made deposit of soil, rock, debris, etc. May or may not have been placed under controlled conditions.
Peat	Highly organic material with a somewhat fibrous aggregate of decayed and decaying vegetative matter.
Clay	Fine-grained soil with a very high degree of plasticity.
Silty Clay	Fine-grained soil with a high degree of plasticity.
Varved Silt and Clay	Fine-grained soil deposit of interbedded layers of silt, silty clay, and/or clay.
Organic Silty Clay	Plastic, fine-grained soil which contains organic matter

Figure 5-11 (continued)
Strata Keyword List

Keyword	General Description
Silt	Fine-grained soil that is non-plastic to slightly plastic
Clayey Silt	Fine-grained soils which exhibits moderate plasticity
Organic Silt	Non-plastic to slightly plastic fine grained soil which contains organic matter
Organic Clayey Silt	Moderately plastic fine-grained soil which contains organic matter
Sandy Silt	Non-plastic fine grained soil with a lesser sand constituent
Sand	Clean sandy soil, predominately sand but may contain lesser amounts of gravel, generally little or no fines
Silty Sand	Sandy soil which contains a lesser silt constituent
Gravelly Sand	Predominately sandy soil which contains a lesser gravel constituent
Stratified Sand and Gravel	Interbedded layers of sands, gravels, and sand-gravel mixtures.
Gravel	Predominately clean gravel, but may contain lesser amounts of sand, generally little of no fines
Sandy Gravel	Predominately gravel with lesser amounts of sand, generally little or no fines
Glacial Till	Unstratified deposit of material of all sizes in various proportions from boulders to clay
Boulder	Large size boulder which is cored and has a significant core recovery
Weathered Bedrock	Bedrock which exhibits a moderate to high degree of weathering
Bedrock	Bedrock which is fresh or slightly weathered.

5-5 Driller Notes & Other Information

The subsurface conditions observed in the soil samples and drill cutting or feedback from the drilling machine operation should be included in the “Material Description” column on the standard boring log report form.

5-6 References

1. ***GEOTECHNICAL ENGINEERING CIRCULAR NO. 5, Evaluation of Soil and Rock Properties***, Sabattini, Bachus, Mayne, Schnieder and Zettler, FHWA-IF-02-034, Federal Highway Administration, 2002.

2. ***Subsurface Investigations***, Arman, Samtani, Castelli, and Munfakh Subsurface Investigations, FHWA-HI-97-021, Federal Highway Administration, 1997.

3. ***Rock Foundations***, ACOE EM 1110-1-2908, U.S. Army Corps of Engineers, 1994.

4. ***Soil Mechanics,*** Donald Burmister, Columbia University, 1952.

Appendix

The Appendix to Chapter 5 contains the following:

1. Sample Boring Log
2. Schema for Subsurface Database

Driller: C. Purdell	**Connecticut DOT Boring Report**	Hole No.: B-1
Inspector: E. T. Budney	Town: WILTON	Stat./Offset: 57+09 22 RT
Engineer: Olmstead	Project No.: 0161-0135	Northing: 125225
Start Date: 7/28/2003	Route No.:	Easting: 422713
Finish Date: 7/28/2003	Bridge No.:	Surface Elevation 265.1

Project Description: Reconstruction of Route 33 @ Route 53

Casing Size/Type:	Sampler Type/Size: Split Spoon 2 in	Core Barrel Type: NWM
Hammer Wt.: Fall:	Hammer Wt.: 140 lbs Fall: 30 in	

Groundwater Observations @Dry after 0 hours, @ after hours, @ after hours

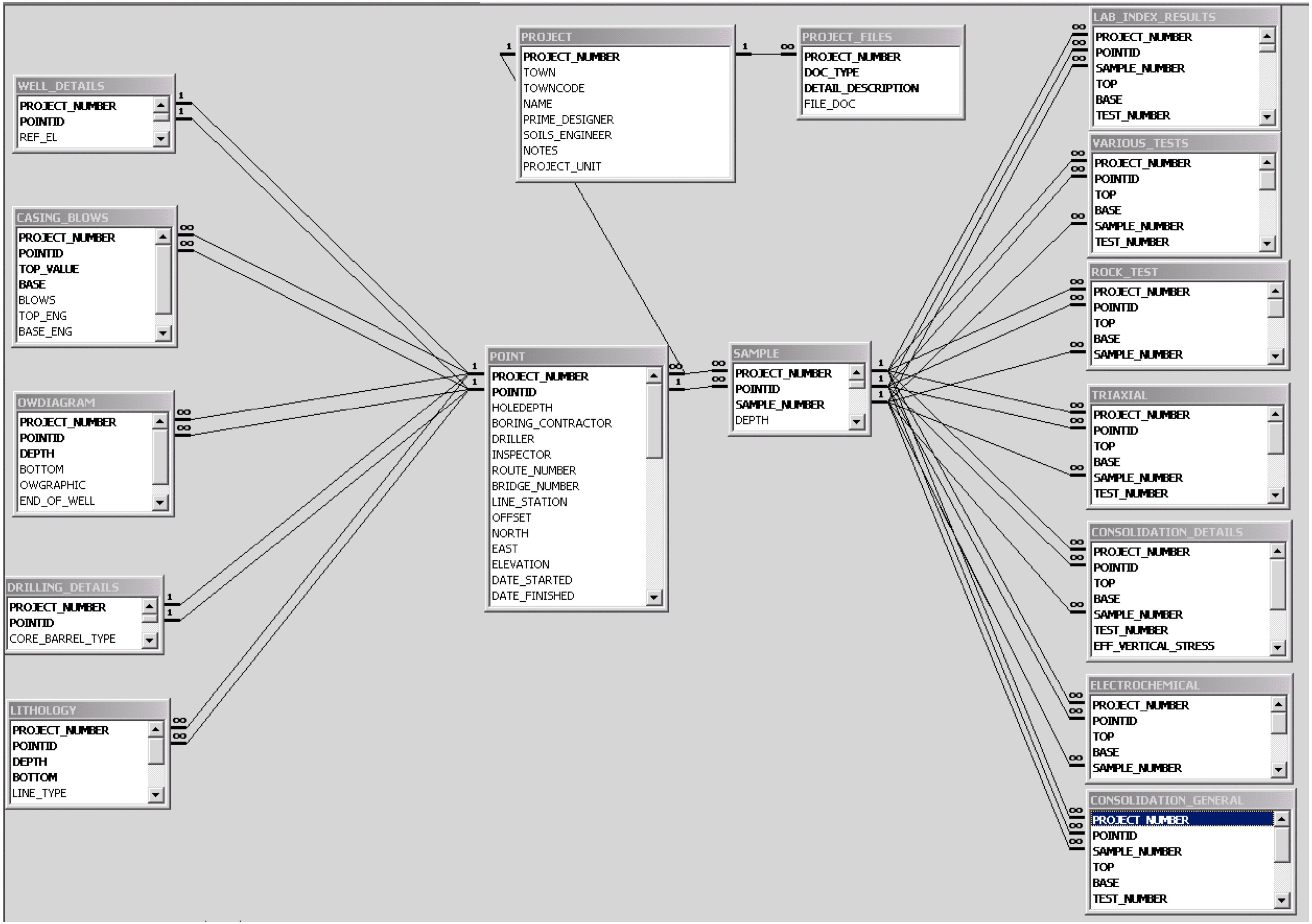
Depth (ft)	SAMPLES: Sample Type/No.	SAMPLES: Blows on Sampler per 6 inches	SAMPLES: Pen. (in.)	SAMPLES: Rec. (in.)	SAMPLES: RQD %	Generalized Strata Description	Material Description and Notes	Elevation (ft)
0						ASPHALT		265
						GRAVEL AND SAND		
5	S-1	7 18 23 20	24	6			Brown C-F GRAVEL, some c-f Sand, trace Silt	260
10	S-2	68	6	6			Brown C-F GRAVEL, some c-f Sand, trace Silt w/ cobbles and boulders	255
15								250
							Bottom of Boring	
20								

Sample Type: S=Split Spoon C=Core UP = Undisturbed Piston V = Vane Shear Test

Proportions Used: Trace = 1 - 10%, Little = 10 - 20%, Some = 20 - 35%, And = 35 - 50%

Total Penetration in Earth: 18 Rock:	NOTES: Auger Refusal at 11 feet Drilled ahead with core barrel from 11 to 18 feet	Sheet 1 of 1
No. of Samples: 2	Cobbles and Boulders 3 to 5, 7 to 8 and 11 to 12	SM-001-M REV. 1/02

Subsurface Database Schema



Subsurface Database Schema

WELL_DETAILS
- **PROJECT_NUMBER**
- **POINTID**
- REF_EL
- PRO_COVER
- PRO_CSG_HEIGHT
- RISER_TOP
- PRO_CSG_TYPE
- PRO_CSG_LENGTH
- PRO_CSG_DIAM
- SEAL_TYPE1
- SEAL_TOP1
- SEAL_THICKNESS1
- SEAL_TYPE2
- SEAL_TOP2
- SEAL_THICKNESS2
- SEAL_TYPE3
- SEAL_TOP3
- SEAL_THICKNESS3
- RISER_TYPE
- RISER_DIAM
- RISER_BACKFILL
- BOREDIA
- SCREEN_TYPE
- GUAGE
- SCREEN_DIAM
- SCREEN_BACKFILL
- SILT_TRAP
- REFERENCE_NUMBER

DRILLING_DETAILS
- **PROJECT_NUMBER**
- **POINTID**
- CORE_BARREL_TYPE
- MUD_TYPE
- SAMPLER_SS
- SAMPLER_TYPE_SIZE
- CASING_SIZE_TYPE
- HAMMER_WT_CASING
- HAMMER_FALL_CASING
- HAMMER_WT_SAMPLER
- HAMMER_FALL_SAMPLER
- REFERENCE_NUMBER

CASING_BLOWS
- **PROJECT_NUMBER**
- **POINTID**
- **TOP_VALUE**
- **BASE**
- BLOWS
- TOP_ENG
- BASE_ENG
- REFERENCE_NUMBER

OWDIAGRAM
- **PROJECT_NUMBER**
- **POINTID**
- **DEPTH**
- BOTTOM
- OWGRAPHIC
- END_OF_WELL
- REFERENCE_NUMBER

LITHOLOGY
- **PROJECT_NUMBER**
- **POINTID**
- **DEPTH**
- **BOTTOM**
- LINE_TYPE
- STRATA_DESCRIPTION
- REFERENCE_NUMBER
- DEPTH_ENG
- BOTTOM_ENG

1

1

POINT
- **PROJECT_NUMBER**
- **POINTID**
- HOLEDEPTH
- BORING_CONTRACTOR
- DRILLER
- INSPECTOR
- ROUTE_NUMBER
- BRIDGE_NUMBER
- LINE_STATION
- OFFSET
- NORTH
- EAST
- ELEVATION
- DATE_STARTED
- DATE_FINISHED
- WATER_DEPTH_1
- WATER_HOURS_1
- WATER_DEPTH_2
- WATER_HOURS_2
- WATER_DEPTH_3
- WATER_HOURS_3
- THICKNESS_EARTH
- THICKNESS_ROCK
- NUMBER_SAMPLES
- NUMBER_ROCK_SAMPLES
- NOTE1
- NOTE2
- NOTE3
- PLUNGE
- HOLEDEPTH_ENG
- NORTH_ENG
- EAST_ENG
- ELEVATION_ENG
- WATER_DEPTH_1_ENG
- WATER_DEPTH_2_ENG
- WATER_DEPTH_3_ENG
- THICKNESS_EARTH_ENG
- THICKNESS_ROCK_ENG
- REFERENCE_NUMBER
- DAT_FILE
- IMAGE_FILE

PROJECT
- **PROJECT_NUMBER**
- TOWN
- TOWNCODE
- NAME
- PRIME_DESIGNER
- SOILS_ENGINEER
- NOTES
- PROJECT_UNIT

SAMPLE
- **PROJECT_NUMBER**
- **POINTID**
- **SAMPLE_NUMBER**
- DEPTH
- NUMBER_FIELD
- PENETRATION
- RECOVERY
- TYPE
- BLOWS_1ST_INCH
- BLOWS_2ND_INCH
- BLOWS_3RD_INCH
- BLOWS_4TH_INCH
- RQD
- CORING_TIME
- KEYWORD
- DESCRIPTION
- REFERENCE_NUMBER
- DEPTH_ENG
- PENETRATION_ENG
- RECOVERY_ENG

PROJECT_FILES
- **PROJECT_NUMBER**
- **DOC_TYPE**
- **DETAIL_DESCRIPTION**
- FILE_DOC

LAB_INDEX_RESULTS
- **PROJECT_NUMBER**
- **POINTID**
- **SAMPLE_NUMBER**
- **TOP**
- **BASE**
- **TEST_NUMBER**
- SPECIFIC_GRAVITY
- MOISTURE_CONTENT
- DESCRIPTION
- PERCENT_FINER_5_IN
- PERCENT_FINER_3_IN
- PERCENT_FINER_5/2_IN
- PERCENT_FINER_2_IN
- PERCENT_FINER_3/2_IN
- PERCENT_FINER_1_IN
- PERCENT_FINER_3/4_IN
- PERCENT_FINER_1/2_IN
- PERCENT_FINER_3/8_IN
- PERCENT_FINER_1/4_IN
- PERCENT_FINER_4_IN
- PERCENT_FINER_10_IN
- PERCENT_FINER_40_IN
- PERCENT_FINER_100_IN
- PERCENT_FINER_200_IN
- MINSIZE1
- MINFINER1
- MINSIZE2
- MINFINER2
- MINSIZE5
- MINFINER5
- MINSIZE15
- MINFINER15
- MINSIZE30
- MINFINER30
- MINSIZE60
- MINFINER60
- MINSIZE250
- MINFINER250
- MINSIZE1440
- MINFINER1440
- LIQUID_LIMIT
- PLASTIC_LIMIT
- PLASTICITY_INDEX
- PERCENT_ORGANIC
- REFERENCE_NUMBER

VARIOUS_TESTS
- **PROJECT_NUMBER**
- **POINTID**
- **TOP**
- **BASE**
- **SAMPLE_NUMBER**
- **TEST_NUMBER**
- HYDRAULIC_CONDUCTIVITY
- DS_COHESION_CALC
- DS_FRICTION_ANGLE_CALC
- VS_SHEAR_STRENGTH_PEAK
- VS_SHEAR_STR_REMOLDED
- CBR_DRY_DENSITY
- CBR_MOISTURE_CONTENT
- CBR_SWELL
- CBR
- UC_STRENGTH
- UC_STRAIN_FAILURE
- MR_GRANULAR_COHESIVE
- MR_REGRESSION_EQUATION
- MR

ROCK_TEST
- **PROJECT_NUMBER**
- **POINTID**
- **TOP**
- **BASE**
- **SAMPLE_NUMBER**
- **ROCK_TYPE**
- LOADING_DIR
- LS
- LS_50
- UNIAXIAL_COMP_STR
- YOUNGS_MODULUS
- POISSONS_RATIO
- TOTAL_HARDNESS

TRIAXIAL
- **PROJECT_NUMBER**
- **POINTID**
- **TOP**
- **BASE**
- **SAMPLE_NUMBER**
- **TEST_NUMBER**
- INITIAL_UNIT_WT_DRY
- WATER_CONTENT
- FAILURE_MINOR_STRESS
- FAILURE_MAJOR_STRESS
- DEVIATOR_STRESS
- CONSOLIDATION_PRESSURE

CONSOLIDATION_GENERAL
- **PROJECT_NUMBER**
- **POINTID**
- **SAMPLE_NUMBER**
- **TOP**
- **BASE**
- **TEST_NUMBER**
- INITIAL_VOID_RATIO
- INITIAL_WATER_CONTENT
- CR
- CC
- MAX_PAST_VER_EFF_STRESS

CONSOLIDATION_DETAILS
- **PROJECT_NUMBER**
- **POINTID**
- **TOP**
- **BASE**
- **SAMPLE_NUMBER**
- **TEST_NUMBER**
- **EFF_VERTICAL_STRESS**
- **REFERENCE_NUMBER**
- CV
- CV_METHOD_USED
- C_ALPHA

ELECTROCHEMICAL
- **PROJECT_NUMBER**
- **POINTID**
- **TOP**
- **BASE**
- **SAMPLE_NUMBER**
- **TEST_NUMBER**
- PH
- PH_H2O_CACL
- SOIL_RESISTIVITY
- CHLORIDE_CONTENT
- SULFATE_CONTENT

Chapter 6

Analysis and Design

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Chapter 6

Analysis and Design

The analysis of the data from the subsurface investigation and laboratory testing program and design effort will vary based on the complexity of the project and the type of soil and rock encountered. The following contains a listing of the issues that are typically addressed and the reference documents that are used in the design of a project.

6-1 Roadway Embankment and Subgrade

The characterization of the in-situ materials by the engineer is based on an analysis of the subsurface investigation and laboratory testing program. The engineer shall use this information to perform the necessary geotechnical analyses and studies for the roadway design. A listing of issues typically addressed for the geotechnical roadway design include:

6-1.1 Classification of Excavated Materials

The engineers shall classify on a station-by-station basis, the type of material to be excavated for the construction of roadways, structures, trenches, channels, etc. The classification will be based on the various excavation types noted in the ***Standard Specifications for Roads, Bridges and Incidental Construction***.

In cases where there is a potential for a significant volume of payment-size boulders, the engineer shall provide a percent estimate for the required excavation.

The engineer shall also determine which excavated materials (if any) will not be suitable for unrestricted use in embankments and fills. A determination shall be made if these materials may be used in restricted locations and/or with special construction considerations.

6-1.2 Shrink or Swell Factors

For use in determining the quantity of excavated material available on a project, the engineer shall determine the shrinkage or swell factors for the predominate material types to be encountered.

6-1.3 Embankment Stability and Maximum Rate of Slope

Typical roadway sections are presented in the ConnDOT ***Highway Design Manual***. At times, geotechnical constraints may require a modification to these typicals or special construction considerations to allow for their construction. Where the presence of problematic soils or unfavorable bedrock structure is known early in a project's development, the designer should be made aware of these possible constraints so that an evaluation of alternate horizontal and/or vertical alignment can be made.

Geotechnical issues that may influence the roadway design include, weak/unstable subgrade soils, adverse subsurface groundwater conditions, unfavorable bedrock conditions, significant rockfall potential, etc. Recommendations for maximum earth and/or rock slope rates shall be provided for each project. Where multiple recommendations are provided, they shall be done on a station-by-station basis.

6-1.3.1 Slope Stability

In evaluating the slope stability of an earth cut or fill slope, a minimum factor of safety of 1.25 for the static case is generally acceptable. A higher factor of safety may be warranted for approach fills to major structures where a slope failure would result in significant damage to the structure. In evaluating the acceptability of the factor of safety of slope stability, the engineer shall consider the method of analysis used, the reliability of the subsurface data, and the consequences of slope failure. To mitigate the problem of slope instability, the engineer should evaluate the feasibility of flatter slopes, alternate horizontal or vertical alignment, soil reinforcement with geosynthetics, partial/total removal of weak soils, controlled filling, counterweight berms, shear keys, lightweight fill, ground improvement, installation of subsurface drainage, etc. When controlled filling is proposed, the type and frequency of geotechnical monitoring shall also be evaluated.

6-1.3.2 Embankment Settlement

When compressible soils are encountered, the engineer shall estimate the total embankment settlement along with the time-rate of settlement. Coordination with the designer is necessary to determine what time is available for construction waiting periods to allow for settlement to occur. When large settlements are anticipated, slope instability may also likely be a problem. The majority of the solutions to slope instability also apply to embankment settlement. The engineer should evaluate both issues at the same time to determine the most feasible solution. The type and frequency of geotechnical monitoring needed to determine the magnitude and rate of settlement actually experienced in the field shall be evaluated.

6-1.3.3 Unsuitable Materials

The engineer shall determine the limits of all subgrade soils considered unsuitable for embankment or roadway construction. The strength and compressibility of these deposits shall be evaluated and their effect on the proposed construction assessed. The engineer shall provide a recommendation based on an evaluation that considers in part the immediate cost of the proposed treatment and any long term maintenance considerations. Solution may include, complete removal, partial removal and stabilization, stabilization in place.

6-1.3.4 Slope Treatment

Where the potential exists for significant erosion on cut or fill earth slopes the engineer shall design a slope treatment to mitigate the problem for that specific location. DEP's ***Connecticut Guidelines for Soil Erosion and Sediment Control*** includes a number of requirements for tall and/or steep slopes. The designer should be consulted to determine if there are any special treatments or analyses required to satisfy these requirements.

6-1.4 Steepened Slopes

When steepened slopes (steeper than 1V:1.5H) are considered in lieu of other retaining structures, the slopes are to be evaluated for external stability including all failure possibilities; sliding, deep-seated overall instability, bearing capacity failure, and excessive settlement. Reinforcement requirements must be designed to account for the internal stability of the slope. Slope face treatments must be properly designed to minimize erosion. The FHWA publication ***Geotechnical Engineering Circular No. 11 – Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Vol. I and Vol. II*** provides the most current reference for design and construction of steepened slopes.

6-1.5 Subsurface Drainage

The engineer, based on the results of the subsurface investigation, shall evaluate the need for subsurface drainage within the roadway section, toe of slope cut, mid-slope, or other locations. The engineer shall take into consideration seasonal variations in groundwater elevations. The engineer shall work with the pavement designer to determine if subsurface drainage will be required where impervious subgrade soils or rock are present at the bottom of the pavement section.

6-2 Foundation Analysis and Design

Spread footings, driven piles, micropiles or drilled shaft are considered viable foundation types. The engineer shall evaluate the anticipated subsurface conditions, type of structure proposed, tolerable differential settlement, allowable total settlement, and design loading to establish the most economically viable, constructible foundation type(s). Generally only one type of foundation is recommended for a structure, however, in some cases, multiple types of foundations may be specified. The evaluation of the proposed foundation type shall be included in the structure geotechnical report and shall also include the other foundation types considered, and the reasons and/or analysis for the selection or exclusion of a particular foundation type.

The analysis of the various foundation types shall be in conformance with the governing design code (AASHTO, AREMA, BOCA, etc.) and the latest ***Connecticut Bridge Design Manual (BDM)*** and any other reference document cited herein. The Department has developed guidelines for scour and seismic design, the engineer should refer to these guidelines to insure the appropriate design of foundations. Should a conflict exist between the design code and the ***BDM***, the requirements of the ***BDM*** will govern.

6-2.1 Spread Footings

Spread footings that can be constructed at a relatively shallow depth will generally be the most economical foundation type. To design a spread footing, the engineer shall first determine the maximum allowable bearing capacity and check that a reasonable sized footing can support the design loads. The engineer shall estimate the magnitude of settlement (total and differential) and its time of occurrence for the foundation loads and insure the settlement is within acceptable limits. Refer to FHWA publication, FHWA-SA-02-05, ***Geotechnical Engineering Circular No. 6 Shallow Foundations*** and the structural design codes for the current practice for the design of spread footings.

The minimum depth of a spread footing on soil for a new roadway structure is four (4) feet. The minimum depth of a spread footing on soil for a building shall be three and one half (3.5) feet. Shallow foundation placed on compacted granular fill is an acceptable option, provided there are competent underlying soils. For structures over waterways, refer to the ***BDM*** and ***Connecticut Drainage Design Manual*** for the design requirements and acceptability of shallow foundations.

6-2.2 Driven Piles

The design of a pile foundation involves an evaluation of a number of different design and constructibility issues. Some of the items to be considered include:

1. Design loads (axial and lateral)
2. Predicted scour depth
3. Pile types (displacement or non-displacement, friction/end-bearing) and pile availability
4. Pile driveability, hammer types
5. Test piles and load testing requirements
6. The presence of obstructions/boulders
7. Corrosion (steel piles)
8. Site constraints-horizontal and vertical clearance, access, etc.
9. Impact to adjacent structures
    - Settlement
    - Vibration damage
    - Noise

For end bearing piles on bedrock, obtaining enough subsurface information so that pile order lengths can be established in the design phase is preferable to establishing order lengths in the construction phase. When considering the use of a test pile to establish order lengths, the engineer should carefully weigh the time required to obtain the production piles against the benefit of a refined order length. Test piles are recommended when the borings indicate large differences in rock elevations or penetration to the rock surface is not predictable. When pile order lengths can not be established until after test piles, readily available pile types should be recommended. When order lengths are established in the design phase, test piles with dynamic monitoring (pda testing w/CAPWAP) may still be necessary to determine pile capacity. Static load tests may be needed for end bearing piles when the axial resistance factor must be maximized.

Test piles are generally required to establish pile order lengths and to validate ultimate capacity for friction piles. If pile driving records and pile load test data are available for a site (e.g. a bridge widening where the same pile type is proposed), specifying the pile order length on the design plans may be considered. A test pile with dynamic monitoring (pda testing w/CAPWAP) is the preferred method to establish the ultimate pile capacity of friction piles. When pile freeze is anticipated, the engineer shall determine the minimum time-wait requirement between initial drive and restrike of the test pile. Static pile load tests may also be required when there is a need to maximize the resistance factor and pile capacity.

The length of a test pile for friction piles should be at least ten (10) feet longer than the estimated length and for end-bearing piles should be at least five (5) feet longer than the estimated length. Pile order lengths should be given in five (5) foot increments. An order length should be specified for each pile cutoff elevation. For large substructures, where the bedrock profile varies significantly, more than one order length may be specified for a cutoff elevation. Separate lengths may be specified for plumb and batter piles.

Various static methods are available to the engineer to estimate pile axial resistance in soil. The Department maintains a file of pile load tests performed throughout the state and the engineer should compare their computations against load tests performed in similar subsurface conditions. The estimated axial pile resistance can be increased or decreased based on this comparison.

Historically with working stress designs of piles driven to bedrock, the structural capacity of a Grade 36 pile, not the geotechnical limit, controls the pile axial design. With LRFD designs, the assumption that the structural capacity, not the geotechnical capacity, controls the axial design has not been validated. The majority of load tests performed across the state have not exceeded a unit toe resistance of 24 ksi. At that maximum toe stress a geotechnical axial limit was observed in some tests. If the controlling design load results in an ultimate pile capacity (factored design load/ φ) approaching or exceeding these historical limits, a static load test should be performed to validate the design.

For LRFD designs, the resistance factors shown below are recommended for the geotechnical axial resistance of a single pile at the strength limit state. The resistance factors contained in the AASHTO-LRFD specification should be used for all other cases.

Construction Control	Resistance Factor
Dynamic Monitoring(PDA w/CAPWAP)	0.65[1]
Static Load Test	0.8[2]

[1] A minimum of one test pile with dynamic monitoring at each substructure is required. An additional test per substructure should be considered for very large substructure units.
[2] A minimum of one static load test per structure is required. An additional load test should be considered if there is a change in bedrock type or soil type.

The contract plans shall contain the computed ultimate pile capacity, which is defined as:

Ultimate Pile Capacity = (Factored Design Load/ φ) + Scour + Downdrag

Scour= The estimated skin friction resistance of the soil above the predicted scour depths.

Downdrag= The estimated side friction resistance of a compressible soil above the neutral point (determined when computing the downdrag load (DD) due to settlement).

The Contractor will use the ultimate pile capacity to properly size pile driving equipment and load testing apparatus. The Engineer will use the ultimate pile capacity to establish the required driving resistance and to validate load test results.

Refer to FHWA publication, FHWA-NHI-16-009, ***Geotechnical Engineering Circular No. 12 Design and Construction of Driven Pile Foundations, Volumes 1 and 2,*** and the structural design codes for the current design practice of driven pile foundations.

6.2.3 Drilled Shafts

Drilled shafts are generally used where design loads (axial and/or lateral) are very large, where the use of drilled shafts eliminates the need for a cap, or where the use of driven piles is not viable. Diameters from two and one half feet up to ten feet may be considered when evaluating the use of drilled shafts. When very large diameter drilled shafts are being considered, especially those with rock-sockets, industry groups (ADSC) should be contacted to determine the constructibility of the proposed foundation.

Due to the possible influence on design assumptions, the engineer must consider the possible construction methods to be used for drilled shafts. Construction techniques that negatively influence the design assumptions must be restricted from use and specified in the contract documents.

Based on load test data, the Department has found the design approach outlined in current AASHTO codes to be extremely conservative and does not adequately utilize the combined end-bearing/side shear axial load capacity of rock socketed drilled shafts. The Department's design approach is to use the end-bearing and side shear components in combination. To quantify these components and economize the overall design, load test(s) are typically performed. The type of load test performed may be Osterberg Cell, Statnamic, or a static load test(s). Refer to FHWA publication, FHWA-NHI-18-024, ***Geotechnical Engineering Circular No. 10, Drilled Shafts: Construction Procedures and Design Methods,*** and the structural design codes for current design practice information.

To insure that production shafts will be constructed properly, a method shaft is typically included in a project. All drilled shafts should be constructed with steel access tubes to allow for cross-hole sonic logging. The percentage of shafts that are tested will vary from project to project, however, the contract documents should include a minimum quantity equal to 1/3 the total number of shafts.

6-2.4 Micropiles

In areas of limited or difficult access, close proximity to settlement-sensitive existing structures, or difficult geology, or other areas where deep foundations are required, micropiles should be considered when determining the recommended foundation type. Micropiles used by the Department are typically CASE 1, type A; which are individual, reinforced pile elements where the grout is placed under gravity head, or CASE 1, type B micropiles which are individual, reinforced pile elements where the grout is placed under low pressure. The geotechnical engineer typically performs a preliminary design of the micropile element to estimate capacities and minimum size requirements. The final micropiles shown on the contract drawings is a partial design build item. The contract drawings, prepared by the designer, will show the footing layout, design loads and the minimum micropile material properties needed to resist lateral demands on the micropiles. The Contractor will be responsible for installation methods and the final design build of the micropile elements to assure that the pile will resist axial load demands and meet the minimum micropile criteria shown on the contract drawings.

Lateral load demand on a micropile foundation is typically resisted by the horizontal component of battered piles. The lateral resistance provided by the soil-pile interaction is small and preference is to not rely on it for the design.

6-3 Earth Retaining Structures

All retaining walls must be designed with adequate soil resistance against bearing, sliding, overturning, and overall stability as specified by the governing design code. Retaining walls are typically semi-gravity cantilever or gravity type retaining walls. In certain cut applications, nongravity cantilever, anchored walls or soil nail walls may be considered as an option.

The Department's practice for retaining walls includes the use of various proprietary retaining wall systems. Low height, non-critical applications are typically a mechanically stabilized earth (mse) wall with a dry-cast block facing.

Taller walls, walls that support roadways, and other critical applications are generally mse walls with precast concrete facing panels or prefabricated modular walls. The design of proprietary walls are in conformance with the latest AASHTO LRFD Bridge Design Specifications. The geotechnical design responsibility for a proprietary wall involves the determination of the factored bearing resistance, minimum lateral pressure (or maximum ϕ to be used for determination), minimum foundation depths, and overall stability. The Department has developed special provisions and typical details for these wall systems and should be referred to for additional information.

The ***BDM*** and the governing design code should be referred to for the current design practice associated with the particular type of retaining wall. Additional information regarding the design of anchored walls can be found in the FHWA Publication, IF-99-015, ***Geotechnical Engineering Circular No. 4 - Ground Anchors and Anchored Systems.*** The design codes do not include provisions for the design of soil nail wall; refer to FHWA publication, IF-03-017, ***Geotechnical Engineering Circular No. 7 - Soil Nail Walls*** for the current design practice

6-4 References

1. ***Standard Specifications for Roads, Bridges and Incidental Construction,*** Connecticut Department of Transportation

2. ***Connecticut Highway Design Manual,*** Connecticut Department of Transportation

3. ***Geotechnical Engineering Circular No. 11 – Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Vol. I and Vol. II,*** Berg, Christopher and Samtani, FHWA-NHI-10-024, Federal Highway Administration, 2009.

4. ***Bridge Design Manual,*** Connecticut Department of Transportation

5. ***GEOTECHNICAL ENGINEERING CIRCULAR NO. 6 Shallow Foundations***, Robert Kimmerling, FHWA-SA-02-05, Federal Highway Administration, 2002.

6. ***ConnDOT Drainage Manual,*** Connecticut Department of Transportation

7. ***2002 Connecticut Guidelines for Soil Erosion and Sediment Control***, DEP Bulletin 34, Connecticut Department of Environmental Protection, 2001.

8. ***Geotechnical Engineering Circular No. 12 Design and Construction of Driven Pile Foundations, Volumes 1 and 2***, Hannigan, Rausche, Likins, Robinson and Becker, FHWA-NHI-16-009, Federal Highway Administration, 2016.

9. ***Geotechnical Engineering Circular No. 10 - Drilled Shafts: Construction Procedures and Design Methods,*** Brown, Turner, Loehr and Castelli, FHWA-NHI-18-024, Federal Highway Administration, 2018.

10. ***Micropile Design and Construction Reference Manual,*** Sabatini, Tanyu, Armour, Groneck and Keely, FHWA-NHI-05-039, 2005

11. ***Geotechnical Engineering Circular No. 4 - Ground Anchors and Anchored Systems***, Sabatini, Pass, and Bachus, FHWA-IF-99-015, Federal Highway Administration, 1999.

12. ***Geotechnical Engineering Circular No. 7 - Soil Nail Walls,*** Lazarte, Elias, Espinoza, and Sabatini, FHWA-IF-03-017, Federal Highway Administration, 2003.

13. ***AASHTO LRFD Bridge Design Specifications,*** AASHTO

Chapter 7

Geotechnical Reports

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Chapter 7

Geotechnical Reports

Unless otherwise agreed upon early in the design process, a geotechnical report shall be prepared for each project. For smaller roadway projects where the scope is limited to reconstruction at grade, minor widening or realignment, and there are no significant geotechnical issues, a transmittal memo or letter response may be used in lieu of a formal geotechnical report. Geotechnical reports will typically be completed early in the final design phase of a project. The reports are initially provided with the semi-final roadway and/or the structure layout for design submissions. For complex projects, where geotechnical constraints may have a significant impact on the design of a project, a preliminary geotechnical report may be required.

The purpose of a geotechnical report is to present the subsurface data collected in clear and concise manner, to provide an evaluation of the data, and to provide recommendations for use by highway designers, structural engineers and construction inspectors. While every project has its own specific site conditions and design requirements, each geotechnical report needs to include certain basic elements, including; a summary of the subsurface data, an interpretation of the subsurface data, design recommendations, and a discussion of the impacts of the subsurface conditions on the proposed construction. The geotechnical report will serve as the permanent record of the geotechnical design prepared for a specific project, with its use spanning the design, construction and post-construction phases of a project.

While each project will be unique in its site conditions and design constraints; however, the following should be used as a guide for the preparation of a geotechnical report.

7-1 Roadway Geotechnical Report

A roadway geotechnical report should present conclusions and recommendations concerning the suitability of in-situ materials for re-use; slope stability or excessive settlement; subsurface drainage requirements; suitability of subgrade soils for support of pavement structure, and any constructibility issues. The following is a general outline of the topics, which should be included.

7-1.1 General Information

1. Description of the project, including location, scope, and any design assumptions or constraints.
2. Description of existing roadways and structures.
3. Summary of information provided to the geotechnical engineer (plans, cross sections, alignment, structure type studies, hydraulic report, etc.).

7-1.2 Geology and Existing Geotechnical Information

1. Description of the regional surficial and bedrock geology based on USGS, SCS, or other mapping.
2. Description of significant geologic, hydrogeologic and topographic features of the site.
3. Description of any observed geotechnical-related problems at site (slope instability, rockfall history, observed settlement, etc.)
4. Description of any significant historical data (existing boring data, maintenance history, subsurface drainage installations, rockfall data, etc.)

7-1.3 Subsurface Exploration

1. Description of field investigation performed. Include in the description the scope and purpose of the investigation, the methods used, when performed, instrumentation installed, where the information is summarized, etc.
2. Description of laboratory testing program. Include the tests performed (include testing standard, and where departed from), the purpose of the testing, who performed the testing, and where the information is summarized.

7-1.4 Evaluation and Recommendations

7-1.4.1 Subsurface Conditions

a. Description of stratification of in situ materials. A graphic soil profile along the roadway alignment and at critical cross sections may be required depending on the complexity of the geology and project.
b. Summary of groundwater observations.
c. Summary of existing pavement structure or pavement thickness where required.
d. Summary of soil properties assumed for design.

7-1.4.2 Cut Slopes

a. Discussions on suitability of in situ material for re-use.
b. Shrink or swell value for material.
c. Recommendations for location and types of subsurface drainage.
d. Proposed maximum cut slope rates and discussion on global stability.
e. Proposed treatments for slope surface to minimize erosion.
f. Suitability of subgrade soils for pavement structure.
g. An estimation of the presence of payment-size boulders within the excavated material.
h. The treatment of rock slopes: slope rates, depth of burden, top of slope bench, fall zone, etc.

7-1.4.3 Embankments

a. Limits of unsuitable material removal and determination of areas within the project limits where material may be used, if any.
b. Discussion on global stability (short and long term) and proposed maximum fill slope rates.
c. Proposed treatments for slope surface.
d. Discussion on time-rate and magnitude of settlement
e. Limitations or requirements for constructing embankment.

7-1.4.4 Reinforced Soil Slopes

a. Estimated factor of safety for internal and external stability.
b. Spacings and lengths of reinforcement to provide a stable slope.
c. Design parameters for reinforcement (allowable strength, durability criteria, and soil-reinforcement interaction)
d. Facing details
e. Recommended fill material properties.
f. Special drainage considerations for temporary and permanent condition (subsurface and surface water runoff control).
g. A special provision is required; a guide specification is contained in the FHWA publication *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design and Construction Guidelines*, NHI-00-043.

7-1.5 Construction Considerations

1. Recommendations for temporary excavation, including maximum slopes and suitable types of temporary support.
2. Recommendations on method of blasting and monitoring where there is concern relative to its impact on adjacent structures and the maintenance and protection of traffic.
3. Recommendations for types and locations of instrumentation for monitoring settlement.
4. Recommendations for any special construction method not addressed by the Standard Specification.

7-1.6 Appendix Information

5. Edited Boring Logs
6. Laboratory Testing Data
7. Special Provisions
8. Figures: Boring location plan, soil profile/cross-sections, details, etc.

7-2 Structure Geotechnical Report

A structure geotechnical report should present conclusions and recommendations concerning the type of foundation(s) to be used, type of earth retaining structure or acceptable retaining wall types, the design parameters to be used by the structural engineer, and any constructibility issues associated with the proposed construction. The following is a general outline of the topics, which should be included.

7-2.1 General Information

1. Description of the project, including location, scope, and any design assumptions or constraints. The report should reference the design specification (AREMA, BOCA, AASHTO-LRFD, etc.) used, and any Department based criteria which supercedes or supplements the national design code.
2. Description of existing structure(s).
3. Summary of information provided to the engineer (plans, cross sections, structure type studies, hydraulic report, etc.).

7-2.2 Geology and Existing Geotechnical Information

1. Description of the regional surficial and bedrock geology based on USGS, SCS, or other mapping.
2. Description of significant geologic, hydrogeologic and topographic features of the site.
3. Description of any observed geotechnical-related problems at site.
4. Description of any significant historical data (existing boring data, load test data, maintenance history, etc.).

7-2.3 Subsurface Exploration

1. Description of field investigation performed. Include in the description the scope and purpose of the investigation, the methods used, when performed, instrumentation installed, where the information is summarized, etc.
2. Description of laboratory testing program. Include the tests performed (include testing standard, and where departed from), the purpose of the testing, testing company used, and where the information is summarized.

7-2.4 Subsurface Conditions

1. Description of stratification of in-situ materials.
2. A soil profile provided on an elevation view of the structure, along with soil profiles at each substructure unit (if more than one boring is performed).
3. Summary of groundwater observations.
4. Summary of soil properties assumed for design. If seismic design is required, include a discussion of the soil types and site coefficients.

7-2.5 Evaluation and Recommendations

For each structure, a discussion should be provided regarding the type of foundations considered; spread footings or deep foundations utilizing driven piles, drilled shafts, or micropiles are acceptable types. A recommended foundation type should be provided along with a summary of the advantages and disadvantages of each foundation type considered. The summary should include any design assumptions/constraints (loading conditions-static and seismic, settlement, scour, impacts on adjacent structures, etc.) that control the selection of the foundation type.

7-2.5.1 Earth Retaining Structures

a. Recommended wall type. For retaining walls, include recommended proprietary wall types.
b. Static and dynamic lateral earth pressures (if required), based on soil and foundation type.
c. Recommendations for placement of pervious structure backfill and backwall drainage.
d. Global stability analysis of the retaining structure.
e. Foundation recommendations (see section below).
f. Special design/construction requirement for non-standard elements such as tiebacks, soil nails, vertical anchors, etc., if applicable.
g. Minimum reinforcement lengths for MSE walls and/or minimum base width required for external stability of prefabricated concrete modular walls.

7-2.5.2 Foundations

7-2.5.2a Spread Footings

- Minimum embedment depth, elevation of bottom of footing, depth to competent bearing material, or depth required by structure/geometric design.
- Factored bearing resistance based on settlement and bearing capacity.
- Recommended design coefficient of friction or soil friction angle for determination of sliding resistance.
- Settlement potential (total and differential).
- Subgrade preparation and/or overexcavation requirements.

7-2.5.2b Driven Piles

- Recommended pile type(s) and size(s).
- Method of support-end bearing (soil or rock) or friction, including recommendations of minimum pile length or estimated bearing elevation. An estimated pile length shall be provided based on footing cutoff elevation.
- Nominal axial pile resistance for the strength and service limit state design, including resistance factors (or safety factors).
- An estimate of the lateral soil resistance provided by single pile and/or pile group based on limiting deflections defined by structural engineer,

accounting for predicted scour and construction methods. Provide soil parameters to be used by structural engineer for foundation analysis using software such as COM624P, LPile, Group, FB-PIER, etc.

- Recommendations regarding use of batter piles for lateral resistance
- Recommended minimum pile spacing.
- Estimated pile settlement or pile group settlement, if significant.
- Effects of scour, downdrag, or liquefaction, if applicable.
- Corrosion potential of driven piles.
- Pile tip reinforcement requirements.
- Determination of minimum hammer energy required to drive piles to the estimated bearing elevation. Provide a special provision when the minimum hammer energy exceeds those specified in the *Standard Specification.*
- Recommended locations of test piles.
- Recommendations for static or dynamic load tests (number, location and ultimate pile capacity)

7.2.5.2c Drilled Shafts

- Recommendations for axial capacity and resistance (or safety) factors to be used. Recommendations should be provided for end bearing, skin friction/side shear and total resistance. Load testing done to date indicates significant contribution from end bearing in rock sockets, which should not be discounted.
- Recommendations for minimum shaft length or bearing elevation, and recommended shaft diameter.
- Minimum shaft spacing and group effects on capacity.
- Recommended soil parameters for use by the structural engineer in lateral load analysis. Parameters selected must reflect anticipated construction techniques, scour, liquefaction, etc.
- Effects of scour and downdrag, if any.
- Estimated drilled shaft settlement.
- Recommendations for method shaft. Where there are a significant number of shafts to be constructed or difficulties in constructing the shaft are anticipated, a non-production, method shaft should be considered.
- Recommended location and type of load tests. Load Test(s) should be considered where the axial load is determined to control the length of the shaft or rock socket and there can be a significant cost savings in shaft length reduction by using a higher resistance factor and the load test based design values. In developing the load test special provision, the equipment used for a drilled shaft load test in rock should be capable of developing a load significantly greater than the estimated design values.
- Recommendations for shaft construction methods if required to meet design assumptions or site or permitting constraints. For all other

cases, the contractor should be allowed to choose the installation method. A special provision is required with the use of drilled shafts.

7.2.5.2d Micropiles

- Recommended minimum corrosion protection
- Maximum Service Limit (SVL), Maximum Strength Limit (STL) and Ultimate Pile Capacity (UPC) loads
- Recommendations for verification and performance testing
- Restricted or required construction methods for installation (include justification for recommendation; preference is to leave construction method up to the Contractor).
- Minimum micropile property requirements, to be shown on the contract drawings, to assure that the micropiles meet service and strength limit requirements for lateral load demands. These property requirements include;
  - Recommended minimum micropile spacing
  - Recommended minimum length/grade/diameter/thickness of permanent casing
  - Recommended minimum grade/size of central reinforcement bar
  - Recommended minimum strength of grout
  - Recommended minimum length of bond zone required for lateral resistance (if applicable, i.e. lateral demands are not sufficiently resisted through the permanent casing length alone).

7.2.6 Construction Considerations

1. Dewatering and/or cofferdam requirements for foundation excavation.
2. Requirements for tremie seals.
3. Recommendations for temporary excavation, including maximum slopes and suitable types of temporary support.
4. Recommendations for special construction techniques, monitoring, underpinning, sequencing, etc., that are needed to minimize the effects of foundation installation on adjacent structures. A special provision that incorporates these recommendations is required.

7.2.7 Approach Embankment Considerations

7.2.7.1 Settlement

a. Estimated magnitude and rate of settlement. Recommendations for time-waiting periods to be included in a project's "Sequence and Limitations of Operations."
b. Evaluation of possible ground improvement or structure alternatives if the magnitude or time required for settlement is excessive. A recommended alternate should be provided along with a summary of the advantages and disadvantages each alternate considered.

c. Recommended instrumentation and/or monitoring. A special provision that summarizes the requirements will be prepared.

7.2.7.2 Stability

a. Computed global stability.
b. Evaluation of possible ground improvement or structure alternatives to improve overall factor of safety. Recommended treatment based on economic analysis, time and environmental constraints.

7.2.7.3 Construction Considerations

a. Special fill or ground improvement requirements at earth retaining structures.
b. Recommended construction-monitoring program with limiting threshold values, if applicable.
c. Recommendations for special provisions for embankment construction.

7-2.8 Appendix

1. Edited Boring Logs
2. Laboratory Testing Data
3. Special Provisions
4. Figures: Boring location plan, soil profile/cross-sections, details, etc.

7-3 Final Geotechnical Report

At the end of the Final Design Phase, a Final Geotechnical Report shall be prepared. The Final Geotechnical Report is a single comprehensive report that contains the Roadway Geotechnical Report and the Structure Geotechnical Report(s) and all Appendix Information listed below.

7-4 Appendix Information

7-4.1 Edited Boring Logs

All geotechnical reports should include edited boring logs. See Appendix to Chapter 5 for the template to be used for preparation of boring logs.

7-4.2 Laboratory Testing Data

A table that provides a summary of the testing done for each borehole shall be provided. In addition to the summary table, the data sheets used to present the results of each individual test performed shall be included.

7-4.3 Special Provisions

Where the Standard Specification and its Supplementals are found to be inadequate, or where no specification exists for a geotechnical related item, a special provision shall prepared and included with the geotechnical report. The special provision shall be prepared in the format required by the Department. Formatting information is available on the Department website at the following URL:

www.ct.gov/dot/cwp/view.asp?a=2288&q=259474

7-4.4 Figures

1. Boring Location Plan
2. Soil Profiles & Cross Sections
3. Typical Details
4. Soil Pressure Diagrams

7-5 DESIGN COMPUTATIONS

Design computations performed as part of the preparation of a geotechnical report shall compiled into a stand alone document retained as part of the project record.

Appendix

The Appendix to Chapter 7 presents the following:

Geotechnical Report, Plan and Specification Checklist

Project No.________________
Prime Designer:____________
Geotechnical Consultant:__________
Geotechnical Engineer_____________

Item	**Yes**	**No**	**N/A**	**Comments**
Geotechnical Report				
General Information				
Location of investigation described and/or location plan included				
Scope and purpose of investigation provided • Proposed construction • Plan information used for investigation • Applicable design criteria listed				
Description of geology and site condition provided • Surficial geology • Bedrock geology • Site topography • Geomorpholoy • Existing conditions/site constraints ○ Observed settlement ○ Slope instability ○ Sloughing slopes ○ Rockfall History ○ Observed wet areas, existing subsurface drainage				
Subsurface Exploration Data				
Narrative summary of subsurface exploration and				

laboratory testing provided				
Subsurface exploration program • Minimum number of borings provided • Location of borings appropriate for proposed construction (including information for temprorary work) • Depth of borings adequate for proposed construction				
Edited logs of field explorations provided (Appendix) • Coordinate and station & offset locations • Elevations provided (correct datum) • Edited soil and rock descriptions use standard convention • Drilling notes included • Groundwater observations provided				
Boring location plan provided				
Soil profile and/or critical cross sections provided				
Tabular summary of laboratory testing provided • Minimum testing performed for each soil and rock strata • Test data consistent with soil types described, consistent with log description • Laboratory test data provided in appendix				
Evaluation and Recommendations-Roadway				

Fill slope recommendations provided
• Maximum slope rate provided
• Compressible soil recommendations provided
    ○ Limitations on placement of fill
    ○ Requirements for monitoring or instrumentation
    ○ Requirements for ground improvement/surcharge/waiting periods				

○ Estimate of total settlement				
Cut slope recommendations provided (permanent and temporary)				
Slopes design evaluated for minimum factor or safety				
Slope protection recommendations provided				
Recommendations for subsurface drainage provided				
Excavated soils evaluated for re-use on project				
Preparation/stabilization of subgrade soil addressed				
Shrink/swell factors provided				
Limits of unsuitable material removal provided				
Rock slope design addresses stability and rockfall potential				
Rock removal • Vibration limits for blasting provided • Impact on adjacent structures addressed				
<u>Evaluation and Recommendations-Structures</u>				
Foundation type acceptable. If spread footings are not recommended, evaluation of other foundation types provided.				
Recommendations for alternate wall types provided				
Recommended lateral earth pressure provided ○ Static ○ Seismic				
Seismic site coefficient based on soil type provided				
Loose soils evaluated for liquifaction				
Backfill and subsurface drainage requirements provided				
<u>Spread Footings</u> • Bearing pressure ○ Static ○ Seismic • Estimate of foundation settlement (magnitude &				

time) provided • Recommended footing elevation or minimum embedment provided • Sliding coefficient • Subgrade preparation requirements provided				

Pile Foundations
• Recommended pile type provided
• Estimated pile length or minimum tip elevation provided
• Pile capacity provided (based on end-bearing, friction, or combination)
  ○ Static
  ○ Seismic
• Pile lateral loads or p-y curves provided (single pile and pile group analysis)
• Other design considerations addressed (scour, corrosion, downdrag
• Recommendations for test piles, dynamic monitoring, and pile load tests provided
• Driveabilty study performed
  ○ Wave equation analysis
  ○ Obstruction considerations
  ○ Pile tip reinforcement requirements
  ○ Effect on existing structures				

Drilled Shaft Foundations
• Recommended shaft diameter(s) provided
• Estimated shaft lengths provided
  ○ Minimum tip elevation or
  ○ Top of sound rock defined
• Shaft capacity provided (based on end-bearing, friction/side shear, or combination at limiting settlement)
  ○ Static				

○ Seismic • Shaft lateral loads or p-y curves provided (single shaft and group analysis) • Other design considerations addressed (scour, downdrag) • Recommendations for test shafts and load tests provided • Construction method requirements (temp. or permanent casing, slurry) and impact on design assumptions. • Obstruction considerations				

Design Plan & Specification Review-Roadway				
Boring location plan provided				
Boring locations are appropriate and sufficient for proposed work. Minimum information provided for all work including; drainage structures, pipe jacking, overhead signs, temporary sheeting				
Boring logs are provided				
Shrink/swell estimates are consistent with geotechnical report				
Typical sections for earth cuts and fills match recommendations in geotechnical report				
Slope protection details for steep slopes provided				
Typical sections provided for rock cuts (minimum bench, cut slope and catchment area)				
Special provisions provided for controlled blasting/vibration monitoring				
Limits of unsuitable material removal noted on cross sections (quantity of free draining material provided where no rock excavation is anticipated)				
Limits (and quantity estimates) of proposed subsurface drainage shown on plans				
Locations of proposed instrumentation shown on plans • Special provisions included for items • Time waiting periods included in the spec. package-Limitations and Sequence of Operations section • Fill placement limitations provided in spec. package				

Design Plan and Specification –Structures (SL for D submission)				
Boring locations shown on plan				
Boring locations are appropriate and sufficient for proposed work. Minimum information provided for all work including; temporary sheeting, cofferdams, and ground anchors.				
Boring logs are provided				
Limits of temporary sheeting or cofferdams provided				
Foundation Details-footing elevations provided • Spread footing elevation (and subgrade preparation) provided on plan matches geotechnical report • Pile foundation-pile type shown on plan • Drilled Shaft-shaft diameter shown on plans (multiple diameters are not used w/o justification)				

Design Plan and Specification –Structures (Semi-Final submission)				
Boring locations shown on plan				
Boring locations are appropriate and sufficient for proposed work. Minimum information provided for all work including; temporary sheeting, cofferdams, and ground anchors.				
Boring logs are provided				
Limits of temporary sheeting or cofferdams provided				
Foundation Details-Spread footing • Spread footing elevation matches geotechnical report • Granular fill/CGF placement-depth and horizontal limits shown on plans • Maximum design bearing pressure shown on plans • Loose soils present, sheeting piling material left in place item provided				
Foundation Details-Pile foundation • Pile size and type specified properly • Estimated pile length provided • Test pile and pile load test locations shown • maximum design pile load & associated group number provided • Items included for pile (size & type), test piles (size,type, & length), pile load tests, splices, point reinforcement • Batter piles will not conflict with adjacent structures, sheeting or utilities • Pile Notes				
Foundation Details-Drilled Shaft • Recommended shaft diameter(s) provided • A drilled shaft schedule provided which includes: ○ Minimum rock socket length or tip elevation				

○ Estimate of top of sound rock ○ Design shaft loads provided • Method shaft provided • Load test shaft provided • Casing requirements detailed on plans (or in specification) • Standard items from guide specification are included • If additional borings are required during construction, is the item included				
Alternate Retaining Wall Details • Maximum allowable bearing pressure provided on plans • For sloping backfill conditions, a design phi angle provided for lateral pressure determination • Minimum embedment depth detailed . • Plan, elevation, and typical section provided in accordance with Bridge Design Manual • Backwall drainage requirements included in typical section. • Outlet for backwall drainage included on plan view				

Chapter 8

Geotechnical Engineering by Consulting Engineers

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Chapter 8

Geotechnical Engineering by Consulting Engineers

For any project that requires geotechnical engineering, the Department will determine whether it has the resources to do it in-house or to assign the work to a consulting engineer. If assigned to a consulting engineer, they shall use a qualified geotechnical engineer who is licensed to practice in the State of Connecticut. The geotechnical engineer may be an employee of the firm, or that of a specialty geotechnical subconsultant. The consulting engineer shall submit the qualifications of the geotechnical engineer to the Department for review and approval. If the geotechnical engineer has the proper facilities and qualified personnel to perform laboratory testing of soil and rock, they may request approval to do the laboratory testing with their facilities. The submittals for the geotechnical engineer and laboratory testing services shall be made prior to the development of the scope of work for the project.

If at any time during the design of a project, a change to the designated geotechnical engineer is necessary, the consulting engineer shall submit to the Department for review and approval the qualifications of the new geotechnical engineer.

8-1 Assignment of Work and Development of Scope

The consulting engineer shall be responsible to develop a detailed scope of work for the geotechnical portion of the assignment. For most projects this will involve a Preliminary Design phase and a Final Design phase; for larger or more complex projects, a Preliminary Engineering phase may also be included. At the project Assignment Meeting, the consulting engineer will be provided with all relevant existing geotechnical data for the project. This information shall be used in developing the scope of work along with the man-hour and direct cost estimate for the geotechnical engineering portion of the project. The preceding sections of this Manual provide a framework for the geotechnical engineering scope of work for a project.

The Appendix to this chapter includes the Department’s standard man-hour proposal form for geotechnical engineering. This form should not be changed without prior Department approval. To aid in the development of the fee proposal, an outline of the general tasks associated with each line item in proposal form is included in the Appendix. For more information relative to administrative and design development processes, refer to the Department's *Consulting Engineers Manual*.

8-2 Preliminary Design Phase

The major tasks associated with this design phase involve collecting and reviewing all the existing subsurface and site data to establish preliminary design assumptions for the subsurface conditions to be encountered at the site. The designer will use these assumptions to develop their Preliminary Design and the

Structure Type Studies (if applicable) and proposed subsurface exploration program.

As part of the Preliminary Design Submission, the consulting engineer will submit for review and approval a Subsurface Exploration Program Proposal. The proposal shall include:

- A brief narrative which describes the overall program, the types of explorations to be performed, and any unusual requirements in the proposal (i.e., access issues, mpt issues, scheduling/timing constraints, permitting requirements, etc).
- The proposed contract specifications including invitation to bid, proposal, bid sheet and contracts agreement. The Department maintains a sample contract and listing of boring contractors for use by consulting engineers see appendix to Chapter 3.
- Forty (40) scale plan sheets denoting the location of proposed explorations.
- Detailed quantity and cost estimate.

When subsurface information is necessary for the consulting engineer to prepare the Preliminary Design or Structure Type Study(s), a pilot boring program shall be part of the scope of work. The pilot boring program shall be submitted for review and approval by the Department as early as possible in the Preliminary Design Phase and shall include the items listed above.

After receiving Department approval of the subsurface exploration program, each contractor on the Department's list of interested test boring contractors should be sent, via email, an invitation to bid and all related contract documents. Response time to return bids should be a minimum of 3 weeks.

After bids are opened, the consulting engineer shall evaluate and prepare a tabular list of all bids received. The consultant may proceed with contract award to the low bidder provided the following conditions are met:

- More than one bid is received,
- No irregularities are noted in the bid prices of the low bidder,
- The total cost of the program is within the negotiated direct-cost estimate.

The consulting engineer shall document this process and provide the Department with a copy of their evaluation. If the above conditions are not met, or if rejection of the low bidder is recommended, the consulting engineer will forward to the Department their evaluation of the bids and a recommendation for award. The Department may either approve the award, or require the contract be re-advertised for bid.

The geotechnical engineer will be responsible to supervise the execution of the pilot boring program and as necessary modify the program based on field conditions. Should the field conditions require a significant change to the pilot boring program, the geotechnical engineer should immediately contact the Department and advise them of the necessary changes.

8-3 Final Design Phase

Once the consulting engineer has received authorization to proceed with Final Design, the geotechnical engineer shall initiate the subsurface exploration program. The procurement process for the final subsurface exploration program will be the same as the pilot boring program previously described. Standard procurement procedures will be followed for the laboratory testing program unless, as agreed upon in the scope of work, the geotechnical engineer will be performing the laboratory testing in-house. The geotechnical engineer shall follow the procedures described herein for the classification of soil and rock and the presentation of field and laboratory data used in the geotechnical reports.

Based on the guidelines contained in this document and the approved scope of work, the geotechnical engineer will prepare the roadway and structure geotechnical report(s). These reports shall be completed well in advance of the Semi-Final Design and Structure Layout for Design (SLD) Submissions so that all geotechnical recommendations can be incorporated into the project. Prior to submitting the geotechnical report(s) to the Department, the geotechnical engineer shall review the project plans to insure that recommendations have been appropriately incorporated and to provide quality control for the geotechnical aspects of the design. The geotechnical reports will be included with the Semi-Final and SLD submissions for Department review and comment.

Revised geotechnical reports, that incorporate the Department's comments and design plan revisions from the previous submission, shall be included with the roadway and structure Final Plan for Review Submissions. Should a comment not be incorporated, a written response shall be provided by the geotechnical engineer. Prior to this submittal, the geotechnical engineer shall again review the plans and specifications to insure the proper incorporation of geotechnical recommendations.

A final geotechnical report that is signed and stamped by the geotechnical engineer shall be included with the Final Plan Submission. The final geotechnical report shall incorporate the roadway and all the structure reports into one single comprehensive document. In addition to a hard copy of the final geotechnical report, an electronic (.pdf) copy of the report shall be submitted. A file containing the field and laboratory testing data in an approved database or workbook format shall also be submitted with the final report.

If the Department determines that rock cores need to be retained beyond the Design Phase, the geotechnical engineer shall forward to the Department all rock cores obtained during the subsurface exploration program(s). The geotechnical engineer shall prepare in spreadsheet format an inventory of all the boxes that will be transferred. Any missing rock cores, including those sent out for testing, shall be noted. To insure that cores will be available during the bidding process, transfer of rock cores should coincide with the Final Plan Submission.

8-4 Construction Phase

The geotechnical engineer's involvement in the construction phase of a project will vary depending on the complexity of the project. When there is geotechnical involvement in the construction phase, the geotechnical engineer shall be available to address issues as they arise. Responses shall be provided as promptly as possible to insure that any delays to construction are kept to a minimum.

For deep foundations and other geotechnical related structural elements, the geotechnical engineer will be involved with the review of working drawing submittals regarding construction equipment, construction procedures, contractor designed items, load test data, etc. For these types working drawing submittals, the geotechnical engineer will be requested to review and provide comments through the prime designer. Refer to the *Standard Specifications for Roads, Bridges and Incidental Construction* and the *Department's Bridge Design Manual* for additional details regarding working drawing submittals.

When monitoring during construction is required by the geotechnical design, the geotechnical engineer shall be responsible to review the associated data. The geotechnical engineer shall coordinate with construction personnel, through the appropriate channels, regarding the reading levels, their significance to the related construction activities and what, if any, actions need to be taken.

The geotechnical engineer may also be required to provide input relative to changed subsurface conditions that materially affect the design resulting in significant change orders or differing site conditions claims by the contractor.

8-5 References

Consulting Engineers Manual, Connecticut Department of Transportation, 1998.

Appendix

The Appendix to Chapter 8 presents the following:

Standard Man-Hour Matrix and Terms

Soils Man-Hour Matrix

PRELIMINARY DESIGN SOILS	CLASSIFICATIONS						
OPERATION							TOTAL
ANALYZE EXISTING SOILS DATA							0
STRUCTURE TYPE STUDIES							0
PREPARE FINAL SUBSURFACE EXPLORATION PROGRAM							0
PRELIM.ROADWAY REPORT							0
COORDINATION & MEETINGS							0
							0
							0
							0
							0
							0
							0
							0
TOTAL HOURS	0	0	0	0	0	0	**0**
RATE OF PAY	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	
INFLATED RATE OF PAY	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
DIRECT SALARY COST	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	**$0.00**

FINAL DESIGN SOILS	CLASSIFICATIONS						
OPERATION							TOTAL
SUPERVISE & COORDINATE FINAL S.S.E. PROG. IN FIELD							0
INSPECTION OF FINAL S.S.E.							0
PREPARE & ANALYZE FIELD & LAB DATA							0
STRUCTURE REPORTS							0
ROADWAY REPORTS							0
REVIEW PLANS							0
FINAL SOILS REPORT							0
COORDINATION AND MEETINGS							0
							0
							0
							0
TOTAL HOURS	0	0	0	0	0	0	**0**
RATE OF PAY	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	**$0.00**	
INFLATED RATE OF PAY	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	
DIRECT SALARY COST	$0	$0	$0	$0	$0	$0	**$0**

Soils & Foundations
Preliminary Design-Matrix Details

Analyze Existing Data

(reference ConnDOT Geotechnical Engineering Manual (GEM), Chapter 1)

- Site visit/reconnaissance of project site noting bedrock exposures, wetland areas, groundwater seepage, slope instability, pavement distress, etc.
- Review of previous subsurface investigations, geotechnical reports and environmental assessments available from ConnDOT, towns or other sources.
- Review of as-built plans and construction records, including existing foundation types, test pile and load test data, settlement data, limits of unstable subgrade, etc.
- Review of available topographic and geologic mapping available from USGS, DEP, SCS, etc.

Structure Type Study

(reference GEM 8.2)

- Summarize available information (or results of Pilot Boring Program) into a separate report (if requested by the Dept.) or include as part of the comprehensive Structure Type Study Report. Information should include a preliminary recommendation(s) for foundation type.
- Foundation recommendations should be consistent with the scope of the proposed subsurface exploration.

Prepare Final Subsurface Exploration

(reference GEM 3 & 8)

- Establish type, spacing and depth of proposed explorations.
- Obtain entry permits (if necessary) from private property owners.
- Obtain DEP, ACOE and/or Coast Guard permits (if necessary).
- Determine accessibility and schedule restrictions if working on a railroad or freeway.
- Coordinate with Environmental Compliance (if necessary) for additional environmental sampling/requirements to be included in the subsurface exploration.
- Develop subsurface exploration contract and forward with the Preliminary Design submission for the Department review.

Preliminary Roadway Report (if required by the Department)

(reference GEM 7.1 & 8.2)

- Typically only prepared when a pilot boring program has been performed, or there is sufficient existing geotechnical information to prepare a report.
- Report should provide a summary of the geotechnical information available and the geotechnical constraints and/or recommendations that will have a significant impact on the proposed roadway alignment.

Coordination and Meetings

- Attend Structure Type Study Meeting if structure has significant/complex foundation issues.
- Attend PD Meeting if a Preliminary Roadway Report was prepared,
- If railroad entry for the subsurface exploration is anticipated, a railroad coordination meeting may be necessary.

Soils & Foundations
Final Design-Matrix Details

SUPERVISE AND COORDINATE FINAL SSE PROGRAM IN FIELD
(reference GEM 3.4 & 8)
- Solicit bids from boring contractors and award contract.
- Coordination with field inspector(s), monitor progress and modify SSE Program, as necessary.
- Make field visits, as necessary, by Project Engineer

INSPECT SSE PROGRAM
(reference GEM 8)
- Assume one inspector per two drill rigs unless there are circumstances where it is impractical to monitor 2 operations; such as, barge work, railroad sites, etc.
- Coordination with Project Engineer.
- Preparation of inspection reports and field boring logs.
- Coordination with environmental sampling, as necessary.

PREPARE AND ANALYZE FIELD AND LAB DATA
(reference GEM 4, 5 & 8.3)
- Handle and store soil samples and rock samples from SSE Program.
- Examine soil samples and rock cores to identify representative samples to be tested.
- Develop and administer laboratory testing program.
- Analyze laboratory testing results and establish engineering properties
- Prepare edited boring logs.

Prepare Geotechnical Structure Report
(reference GEM 6, 7 & 8.3)
- Establish preliminary design parameters and recommendations.
- Coordinate with prime designer to insure recommendations are consistent with the project objectives.
- Prepare report. Incorporate geotechnical design recommendations, figures, and details needed for project.

Prepare Geotechnical Roadway Report
(reference GEM 6, 7 & 8.3)
- Establish preliminary design parameters and recommendations.
- Coordinate with prime designer to insure recommendations are consistent with the project objectives.
- Prepare report. Incorporate geotechnical design recommendations, figures, and details needed for project.

Review Plans
(reference GEM 7 & 8.3)

- Review plans to insure recommendations in Geotechnical Roadway and Structure Reports have been incorporated correctly and are clearly presented on the contract drawings.

Final Soils Report
(reference 7 & 8.3)
- Revise Geotechnical Structure and Roadway Reports based on Department review comments.
- Develop special provisions, as necessary.
- Transfer rock cores to the Department, if necessary.

Coordination and Meetings
- Coordination and meeting with Department personnel. There are no scheduled meetings identified for the Final Design phase.