Section 34 - Geotechnical Engineering

34.1 General Plan Preparation

A. Location of borings and identification numbers shall be shown on both preliminary and final General Plan and Elevation sheets for each bridge and structure.

B. Subsurface soil profiles and boring log information shall not be shown on the contract plans. Copies of boring logs and other test data are available to bidders as separate documents. Upon submission of final construction documents (PS&E), the Designer shall submit one set of compact disc (CD) consisting of PDF format of boring logs, and other subsurface investigation data (CTP, etc.) and lab test data and one hard copy of aforementioned logs and data to the Geotechnical Engineering Unit and Project Manager.

34.2 Subsurface Exploration Program

The Designer is to prepare a subsurface exploration program for the project. Prior to developing this program, the Designer should initiate a search for all existing subsurface information within the project limits. Generally, design test boring requests should be initiated as soon as sufficient information is available concerning horizontal/vertical geometry and structure locations. Preliminary test borings may be requested at any time prior to this. To assist in the preparation of a program, the Designer should refer to Subsections 34.2., Item 6, Suggested Methods and Procedures for Test Borings and 34.2., Item 7, Guidelines for Spacing and Depths of Test Borings of this Manual for guidance.

34.2.1 Gather Subsurface Information

A. The Designer is responsible for providing the field layout of the proposed test borings. The stakeout shall consist of a hub driven flush, and a lath with the boring number and the elevation of existing ground shown on it. In heavily wooded and shrubby areas, additional markings should be provided to direct boring crews to the sites. For water boring locations, a suitable range pole system may be required. In tidal streams, a tide gauge should be provided.

   A tabulation of the as-staked data including station, offset, reference line, and existing ground elevation, should be provided to the Geotechnical Engineering Unit prior to the commencement of drilling operations. In addition, a tabulation of boring locations referenced to the New Jersey Plane Coordinate System, and GI compatible, should also be provided. The location data must be referenced to a baseline which is shown on the appropriate construction plans for the project.

B. All completed borings are to be plotted and labeled on the construction plans, or on the plan sheet index, if available. In addition, if the borings are for structural design, they should also be plotted and labeled on the General Plan and Elevation sheet for each structure in the bridge plans.

C. Preliminary laboratory testing programs, if deemed necessary, should be submitted to the Geotechnical Engineering Unit with the boring request. When cohesive soils are encountered during the boring operations, the Designer should recommend any immediate revisions or additions to the program to obtain additional samples suitable for appropriate laboratory testing (i.e. undisturbed samples). Requests for field tests, such as in-situ vane shears, should be submitted with the original boring request, or as soon as possible thereafter.

D. Required borings shall be located on the plan of the structure by station and offset from the base line. Five copies of the print shall be enclosed with the memorandum of transmittal. Request for borings shall be made as early as possible in the preliminary design stage.

34.2.2 Subsurface Exploration Program

A. When submitting a subsurface exploration request, the Designer should provide background information on the scope of the project, available information on soil contamination, and the following information.

   1. A tabulation of proposed borings with station, offset, purpose, proposed roadway cut/fill depth, and estimated quantity of soil/rock.
   2. Roadway profiles showing proposed and existing borings.
   3. Typical sections and cross sections, when applicable (such as for rock cut areas).
   4. Structure plot plans with proposed borings and bottom elevation of proposed footings, on ISO A4 sheets.

B. The exploration request plans should consist of two sets of the following:

   1. A Key Sheet.
   2. 1:1000 or 1:2000 scale plans on standard ISO A1 sheets with borings plotted and labeled. If 1:1000 or 1:2000 scale plans are not available, alternate scaled may be substituted.

34.2.3 Subsurface Exploration Program Review Process

A. The Geotechnical Engineering Unit will review the Designer's program, and, if necessary, conduct meetings with the Designer to finalize the exploration program.

B. The review process will also address soil contamination and the need for Health and Safety oversight during drilling, as recommended by the Bureau of Environmental Services.

C. After finalization of the boring program and determination of Health and Safety needs, the Designer will be advised to obtain the services of a drilling subcontractor.

34.2.4 Subsurface Exploration By Contractor

Upon notification of approval of the boring program, the Designer shall:

A. Provide contract documents for review and comment.

B. Provide additional copies of the finalized plans and contract documents, if requested.

C. Submit resumes to the Geotechnical Engineering Unit for inspectors to be used during the performance of the boring contract.

D. Received bids, and provide two copies of each bid proposal, tabulation of bids, and award recommendations.

E. Provide a copy of the executed contract, performance bond, and insurance certificates.

F. Within five days of completion of each week during actual drilling activity, submit "Weekly Contract Drilling Reports" (forms provided by the Geotechnical Engineering Unit), and one copy of the inspectors' field logs for all borings completed that week. The logs will contain sample identifications, after Burmister, and detailed rock descriptions including rock type, color, condition, percent recovery, and Rock Quality Designation after D. Deere.

G. Prepare and submit final typed logs on ISO A4 sheets, including the name of the Contractor and drilling personnel, within 20 days of completion of all borings. The format of a typical boring log is illustrated on Page 1.34-8.

H. Prepare and submit final as-drilled boring location plans to the Geotechnical Unit for approval within 20 days of completion of all borings.

I. Certify that the contractor has complied with all directions regarding clean-up an restoration of work areas and that all selected samples and cores have bee inspected for delivery. Also, provide one week notice for delivery of samples an cores for storage by the Department.

34.2.5 Field and Laboratory Test

During the performance of borings or immediately following the completion of all borings, the Designer shall submit, to the Geotechnical Engineering Unit, a laboratory testing program for soil and rock samples. Upon review of the program, the Geotechnical Engineering Unit will advise the Designer of the availability of NJDOT forces to perform testing. In the case of non-availability, the Designer will b authorized to perform the testing by using his own forces or a recognized Geotechnical Laboratory based upon a fee proposal.

34.2.6 Suggested Methods and Procedures for Test Boring

A. Boring Method

Borings shall be performed as per the most current edition of the *AASHTO Manual on Subsurface Investigations*.

B. Standard Penetration Test

1. The standard penetration test (SPT) shall be performed as per the most current edition of ASTM D 1586.

2. The SPT for each boring is to be taken at the surface and at intervals not exceeding 5 ft. Two or more consecutive tests are to be made starting at the approximate bottom elevation of structure footing. The SPT should also be made where changes in material or consistency are indicated.

3. Representative samples of the materials recovered shall be retained in sample jars, and the jars immediately labeled to indicate the project, boring number, sample number, and depth. If possible, jars shall be filled to the top with the material as representative of the undisturbed state as possible. All wash samples should be so identified.

C. Undisturbed Sampling

Undisturbed samples shall be obtained as per the most current edition of ASTM D 1587.

D. Field Identification of Sample

1. Soil samples shall be identified by methods proposed by Burmister ("*Suggested Methods of Test for Identification of Soils*" by D.M. Burmister, 1958).
2. Rock cores shall be identified by lithologic name and by descriptive terms relating to color, structure, mineralization and weathering. Recovery shall be ratio of the length of the recovered core to the length of coring run, expressed as a percentage. Also to be recorded is the Rock Quality Designation (RQD), after Deere. (Deere, Don U., *Geologic Considerations*, Rock Mechanics Seminar, April and May, 1968).

E. Rock Coring

Rock coring shall be accomplished with diamond core bits and double tube M-series core barrels. Coring shall be performed in 5 foot runs except in boulder areas, where shorter runs may be necessary until top of rock is confirmed. Drilling pressure, speed and water flow should be adjusted and only straight drill rods should be used in order to maximize recovery.

F. Additional Field Testing

Additional field tests (such as vane shear, hand penetrometer, & pressuremeter) should be conducted where appropriate, as per manufacturers' recommendations and applicable testing standards.

G. Groundwater Observation

1. The water level, initial and 24 hours after completion of the boring, shall be recorded or the "caved-in" depth shall be recorded as wet or dry.
2. Groundwater monitoring wells shall be installed and subsequently abandoned and sealed as per the most current NJDEP regulations.
3. Where applicable, groundwater monitoring wells at structure locations should be installed at the opposite ends of the structure, in the deepest test borings to be performed at that footing.

H. Presentation of Data

Borehole data shall be presented on a NJDOT approved log form (see Boring Log Form in Section 34.3). Field and final typed logs shall be completed by the Engineer and shall indicate level of proposed cut or fill and/or footing bottom at the boring location, as applicable.

Note: These suggested methods are not intended to be either all inclusive or exacting, but to serve only as a guide to methods of exploration.

34.2.7 Guidelines for Spacing and Depths of Test Boring

A. Spacing

1. Embankment
   a. Minimum one boring every 100 to 500 feet along the alignment.
   b. In compressible, cohesive soils, UD borings every 200 to 500 feet, based on initial information.
   c. Proposed spacing should also account for the height of the proposed embankment and the anticipated subsurface condition.
2. Cut

a. Minimum one boring every 100 to 500 feet along the alignment.

b. In rock areas, one to two NX size borings every 100 to 200 feet. Borings should be located so that problematic areas such as the ends of hills, saddles, and photo lineaments or suspected faults are investigated as well as the dominant structures.

3. Structure

a. For structures, minimum one boring every 50 feet along the proposed footing and at least two borings per footing, except for relatively small footings, where one boring may be sufficient.

b. For walls and culverts, minimum one boring every 50 to 100 feet.

c. For noise barriers, minimum one boring every 100 to 200 feet.

d. For temporary or left-in-place structures, sufficient borings should be taken for design and constructability evaluations.

e. For subsurface structures (pipes, electrical conduit, manholes, inlets and other similar structures), in areas with boulders, shallow bedrock or high ground water, borings should be taken at 100- to 500-foot intervals along the proposed subsurface structure.

B. Depth Criteria

1. Embankment

a. For an embankment height smaller or equal to 30 feet, the initial 10-20% of borings shall penetrate to depths equal to 2 times the height of the embankment (but not to exceed 50 feet) except to penetrate below compressible soils, in which case: penetrate approximately 15 feet (4 samples at 5-foot intervals) in coarse or fine grained soils with SPT value (N) greater than 30.

b. For an embankment height greater than 30 feet, initial 10-20% of borings to penetrate to a depth of 1-1/2 times height of embankment except to penetrate below compressible soils, in which case: either penetrate approximately 15 feet (4 samples at 5-foot intervals) into coarse or fine grained soils with SPT value (N) greater than 30, or else 10 feet into rock or glacial till.

c. Remaining embankment borings should be adjusted to reflect initial findings.

2. Cut

Borings in cut areas to extend a minimum of 8 feet below proposed profile grade. When compressible materials are encountered, depths of borings shall be extended as necessary.

3. Structure

a. For structures on shallow foundations, at least one boring per footing to penetrate not less than 25 feet (6 samples at 5-foot intervals) into granular or non-compressible soils (such as till) with N values exceeding 30 per sample or at least 10 feet into rock. The depths of remaining borings to be determined based on initial results.

b. For structures on deep foundations, a minimum of 20 feet below the anticipated pile or shaft tip elevation. Where pile or shaft groups will be used, at least two times the maximum pile group dimension below the anticipated tip elevation, unless the foundation will be end bearing on rock in which case a minimum of 10 feet of rock core shall be obtained at each exploration location to assure the boring has not been terminated on a boulder. For shafts supported on or extending into rock, a minimum of 10 feet of rock core, or a length of rock core equal to at least three times the shaft diameter for isolated shafts or two times the maximum shaft group dimension for a shaft group, whichever is greater, shall be obtained to assure the exploration has not terminated in a boulder and to determine the physical characteristics of rock within the zone of foundation influence for design.

c. For retaining walls, extend the boring to a minimum depth of 2 times the wall height or a minimum of 10 feet into bedrock.

d. For temporary sheeting, extend the boring to a minimum depth of 2 times the wall height.

Note: These criteria are meant to serve as guidelines, and programs should be adjusted as needed based upon the project type, local geological conditions and other applicable factors.

34.3 Boring Log Form

Form SO-2M

New Jersey Department of Transportation

Route: Local Name: NJDOT Boring No.:

SECTION: FIELD BORING NO.:

STATION: OFFSET: REFERENCE LINE: GROUND ELEVATION:

BORINGS BY: DATE STARTED:

INSPECTOR: DATE COMPLETED:

Ground Water Elevation

0 Hr. Date:

24 Hr. Date:

_____ P.P. Installed

DEPTH			Blows On Spoon					SOIL DESCRIPTION & STRATIGRAPHY
(Ft)	NO.	DEPTH	0	150	300	450	REC.	
5								
10								
15								
20								
25								
30								
34								
40								

Nominal I.D. of Drive Pipe	2½″	4″
Nominal I.D. of Split Barrel Sampler	1½″	
Weight of hammer on Drive Pipe	300 lb	
Weight of hammer on Split Barrel Sampler	140 lb	
Drop of hammer on Drive Pipe	24″	
Drop of hammer on Split Barrel Sampler	30″	

The subsurface information shown hereon was obtained for State design and estimate purposes. It is made available to authorized users only that they may have access to the same information available to the State. It is presented in good faith, but is not intended as a substitute for investigations, interpretation or judgement of such authorized users.

NEW JERSEY DEPARTMENT OF TRANSPORTATION

Geotechnical Engineering Unit

Core Size: _____

Soil descriptions represent a field identification after D.M. Burmister unless otherwise noted.

Approximate Change in Strata: _____

Driller: _____

Inferred Change in Strata: _

34.4 Geotechnical Engineering Studies and Reports

34.4.1 General

A. Upon completion of all subsurface exploration and laboratory testing, the Designer shall submit to the Geotechnical Engineering Unit two (2) copies of the following:

   1. Geotechnical Roadway and Rock Engineering Reports
   2. Geotechnical Foundation Engineering Reports for each structure.

B. Upon submission of the construction documents (PS&E), the Designer shall submit one set of compact disc (CD) consisting of PDF format of the following finalized reports and one set of hard copy of finalized reports to the Geotechnical Engineering Unit and NJDOT Project Manager.

   1. A finalized Geotechnical Roadway and Rock Engineering Reports. This final report should include modifications and changes made during the phase reviews and should reflect the final roadway design shown on the final construction plans.
   2. Finalized Geotechnical Foundation Engineering Reports for each structure. This final report should include modifications and changes made to the foundation design during the phase reviews and should reflect the final foundation designs shown on the final construction plans.

   Note: When computer programs are used in the preparation of these reports, the name, source and theoretical basis of each program should be provided in the appropriate report. Disks containing input/output files should also be provided.

34.4.2 Geotechnical Roadway Engineering Report

A. This report shall include all studies performed with regard to Roadway Foundation design and shall consist of:

   1. General project description including the geological condition, boring location sheets, soil and rock profiles with borings and groundwater elevations superimposed, and all other pertinent subsurface information.
   2. Description of all laboratory testing, evaluation of the test results, and the selection of soil and rock parameters used for the roadway foundation design.

B. The geotechnical roadway analysis should include, but not be limited to, the following, if required:

   1. Settlement Analysis: (i.e., amount and rate of settlement)
   2. Slope Stability Analysis: (i.e., stability of slope of roadway fills and cuts)
   3. Slope Stabilization Analysis: (i.e., stabilization of slope with geosynthetic reinforcements)
   4. Ground Modification Analysis: (i.e., wick drains, dynamic deep compaction, stone columns, etc.)
   5. Economic Analysis of Stabilization Techniques

   Note: Computations for which analyses have been performed, references and cost estimates should be provided in this report.

C. Explanation of instrumentation program in conjunction with the analyses above (i.e., piezometers, settlement platforms, slope indicators, etc.)

D. Conclusions and recommendations

34.4.3 Rock Engineering Report

This report shall include studies and evaluations related to rock slopes or other applications and shall consist of:

A. A compilation of all data which are significant to the stability of rock slopes from detailed line mapping of rock exposures, from core drilling observations and identifications, from field and laboratory tests, and from existing data; such as, publications, maps, aerial photos and other previous work.

B. A geologic structural analysis determining structural domains and design sectors, developing a rock mass model using stereographic projection, investigating the possible failure modes, and synthesizing of strength parameters for stability analysis.

C. Blasting and excavating considerations, remedial and stabilization measures, and cost estimates.

D. Width of top of rock recommendations.

E. Catchment area design recommendations.

F. Geophysical surveys when appropriate.

G. A summary table of information and recommendations.

Note: The Designer's attention is particularly directed to publications on rock engineering prepared by D. U. Deere, A. J. Hendron, and by D. R. Piteau and Associates, Ltd.

34.4.4 Geotechnical Foundation Engineering Report

This report shall contain specific foundation design criteria for each substructure unit and shall include:

A. Summary of all subsurface exploration data, including boring location sheets, subsurface soil profile, exploration logs, laboratory or in-situ test results, and groundwater information. The soil profile should include the elevation of the proposed and/or existing footings, existing water table and the standard penetration blow counts.

B. Interpretation and analysis of subsurface data. Laboratory testing shall be performed as necessary to determine the engineering properties, including unit weight, shear strength, compressive strength and compressibility.

C. Settlement and stability analyses, where applicable, including the pertinent soil parameters, computations and cross sections.

D. Selection of type of foundation.

1. Structures supported on spread footings:

   Method of foundation soil stabilization when required, limits of excavation, method of compaction, allowable soil bearing pressures, estimated differential and total residual settlement.

2. Structures supported on pile foundations:

a. Type of pile, nominal resistance and proposed type pile resistance factor, estimated negative friction (if any), group action, estimated tip elevation and/or minimum pile tip elevation of each pile, recommendations regarding the number and location of test piles, wave equation analysis, dynamic monitoring (Pile Driving Analyzer), pile load test(s) (when required), and recommendations for special construction procedures (when necessary).

b. Refer to Subsection 16.3 of this Manual for additional information that is to be provided.

c. Cost comparisons of foundation alternatives, including different types of piles, when applicable.

d. Proposed method of dewatering, where necessary.

e. Estimated depth of scour, where applicable. Scour protection should be provided where required.

f. Seismic design and analysis for the foundations in accordance with Section 38 of this Manual. The result of the investigation and analysis, as a result of earthquake motions, should include the determination of potential hazards and seismic design requirements related to (1) slope stability, (2) liquefaction (3) fill settlement, and (4) increase in lateral earth pressure.

g. Constructability and/or pile drivability for the proposed foundation. Other temporary and/or permanent sheeting or cofferdams should be discussed relative to their constructability.

h. All pertinent information regarding the existing structure, when the proposed foundation involves alterations to an existing structure or is close to an existing structure. Special methods of construction and their effect on the existing structure should also be included.

i. Illustrations

- Roadway Plans for each structure to appropriate scale folded to the format of the report.
- General soils profile for each structure.
- Cross sections at specific locations where analyses have been performed.
- Tables and graphical illustrations.

3. Structures supported on drilled shaft foundations:

   Refer to Section 16.3.4 Drilled Shaft Foundation.

34.5 Jetting and Preboring Of Piles

To provide a general idea for the proper use of the following methods, the following guidelines for jetting and pre-boring are given. A review and recommendations by the Bureau of Structural Engineering's Geotechnical Engineering Unit may be warranted on a project to project basis.

34.5.1 Jetting

A. Not to be used where a disturbance to existing foundations or utilities would result.

B. Not to be used where disposal of jet water and soil would be a problem.

C. In general, jetting would be used in very dense granular or silty soils where displacement piles are being driven in water.

34.5.2 Pre-Boring

A. To be used when displacement piles are to be driven through a compacted fill over 10 feet high.

B. To be used where driving piles full depth would disturb adjacent structures or utilities. Additionally, a survey, with photographs, should be performed before and after pre-boring and pile driving operations to verify occurrence of any damage to structures or utilities.

C. Pre-drilling should not be used below bearing soils for friction piles.

D. In loose granular soils or soft cohesive soils drilling mud may be necessary to keep the hole open.