The purpose of a geotechnical investigation is to provide subsurface information use to develop the plan documents, and to develop recommendations for the construction of the structure at reasonable cost versus short and long term performance. This often requires the geotechnical engineer to work closely with the structural design engineer.

Some of the main types of information that the subsurface investigation needs to provide are:

- Depth, extent and thickness of each soil or rock stratum.
- Soil texture, color, mottling and moisture content.
- Rock type, color, conditions, and characteristics.
- In-situ field tests to determine soil and rock parameters. (SPT, pocket penetration, vane shear, cone penetration, etc.)
- Laboratory samples for determining soil or rock design parameters. (moisture, density, unconfined compression, grain size analysis, consolidation, triaxial compression, corrosion, etc.)
- Water levels, water loss during drilling, artesians, presence of cobbles/boulders, utilities and any other relevant information

There are many subsurface investigation guidelines that apply globally to various types of structures, as outlined below. Guidelines pertinent to individual structure types will be presented in later sections that are focused on those individual types of structures. Each project/structure should have a unique subsurface investigation plan, as site/project variances will not allow a 'standardized' plan for all situations. The subsurface conditions at a proposed site must be ascertained to develop a proper and efficient foundation design.

7-4.1 Review of Proposed Plans

Prior to developing a subsurface investigation plan, a thorough understanding of the proposed project needs to be obtained. This includes project information related to geographic area, staging, time-of-year of construction operations, temporary needs during construction, proposed earthwork, site access issues, overhead and/or underground obstructions or utilities, etc. It is also important to fully understand information on the structure being proposed such as dimensions of structure, anticipated type of foundation(s), layout of foundation elements, base foundation elevation(s), type/values of applied foundation loads, relation to other structures (i.e. examples: MSE walls wrapping around bridge abutments, or twin bridge structures), proximity to adjacent facilities/structures, etc.

The geotechnical engineer should also determine if there are multiple project structures and/or roadway subsurface investigation work that can be combined to minimize drilling trips and mobilization costs.

7-4.2 Review of Existing Subsurface Information

Prior to developing any geotechnical subsurface investigation, available existing information should be collected and analyzed. Various sources can be consulted including published air photos, geological and groundwater information, NRCS information. The engineer should also incorporate their past knowledge/experience with this area and similar subsurface conditions into this review.

However, in planning the boring program, it is important to first review all available site data. Much useful information on anticipated soil textures, water table depth, bedrock type, and depth to bedrock can be obtained from a review of published geological sources. WisDOT generally has subsurface information for bridges since approximately 1960. A review of any existing information may give clear insight into anticipated subsurface conditions and suitable foundation choice. It may also significantly reduce or even eliminate the need for additional borings at the site. The geotechnical engineer must use good judgment in weighing the available data and developing a suitable subsurface investigation plan.

7-4.3 Field Investigation

The field subsurface investigation program typically requires machine borings and testing performed in accordance with AASHTO Method T-206, Standard Penetration Test (SPT), to retrieve soil samples and determine relative densities. The SPT 'N' number is the number of hammer blows required to drive a split spoon sampler a distance of 12-inches.

At a new structure site, or at a site with limited/no prior information, it is WisDOT practice to generally conduct at least one boring at each of the substructure units. The level of investigation is detailed in Chapter 10 of the

WisDOT Bridge Design Manual and Chapter 10.4 of the AASHTO specifications. If bedrock is encountered at depths of 10 feet or less or wherever a spread footing is anticipated, at least two borings spaced across the unit are typically necessary for bridge substructure units.

Generally, samples are collected at 5 foot intervals in accordance with AASHTO T-206. If a number of borings made at a site show thick layers of consistent material such as presented by outwash sand, it may be practical to open the sampling interval to 10 feet. For most sites, the sampling interval should remain at 5 feet.

The geotechnical engineer also needs to be in contact with the driller during field investigations to determine if modifications to the planned investigation need to be made, and to address findings of completed site borings. Borings should not simply be completed to the anticipated depths, without review by the geotechnical engineer during field drilling.

7-4.3.1 Exploration Depths

Structure borings are generally continued until one of the following conditions occurs:

1. Bedrock is reached at any depth. Once bedrock is reached, generally one bedrock core becomes necessary at a structure site. The need/depth of core will be dependent upon the type of foundation anticipated.
2. For borings greater than 60 feet in depth; after 15 feet of dense (N value> 30) or 10 feet of very dense (N value> 50) material is logged in granular materials, or 15 feet of very stiff (N value> 30) or 10 feet of hard (N value>50) material is logged in cohesive materials.
3. For borings less than 40 feet in depth; after 15 feet of dense (N value> 30) or very dense (N value> 50) granular material is logged, or 15 feet of very stiff (N value> 30) or hard (N value> 50) cohesive material is logged.
4. For borings between 40 and 60 feet; the geotechnical engineer should consider the relative density of the overlying material to determine when to stop the boring. Low blow count material over the dense or stiff (N value> 30) material would point to extending the boring.

7-4,3.2 Soil Descriptions

WisDOT generally uses the AASHTO soil classification system to characterize soils. A detailed soil description should be provided for each differing soil strata in a profile.

The relative density of granular soils can be determined from Table 1:

Table 1 – Relative Density of Granular Soils

Relative Density	Number of Blows/Ft AASHTO T-206
Very Loose	0 - 4
Loose	5 - 10
Firm (Medium-dense)	11 - 30
Dense	31 - 50
Very Dense	Greater than 50

The consistency of cohesive soils can be determined from Table 2:

Table 2 – Consistency of Cohesive Soils

Consistency	Number of Blows/Ft AASHTO T-206	Estimated Unconfined Compressive Strength (tsf)
Very Soft	0 - 2	Less than 0.25
Soft	2 - 4	0.25 – 0.50
Medium	5 - 8	0.50 – 1.00
Stiff	9 - 15	1.00 – 2.00
Very Stiff	16 - 30	2.00 – 4.00
Hard	Greater than 30	Greater than 4.00

The location of watertable (if encountered within the exploration depths) also needs to be recorded.

7-4.3.3 Bedrock Investigation

Loads from structures can be transferred to the underlying bedrock by piles, spread footings, or drilled shafts. In all circumstances, it is necessary to obtain cores of the bedrock to determine competency of the rock and load bearing capacity. Recording bedrock recovery (REC) and Rock Quality Designation (RQD) data of all bedrock cores is required. The following criteria will help determine the lengths, and numbers, of required cores:

1. For spread footings, generally one 5 foot core should be obtained at each structure. More cores may be necessary, dependent on the proposed design, uniformity of bedrock, and elevation of bedrock. If weathered zones, voids, or shear zones are encountered, the core depth may need to be increased to 10 feet. Generally there is an auger boring completed at the opposite end of a coring/boring for each bridge substructure foundation that is founded on spread footings, to establish bedrock surface elevation variations across the foundation/site.
2. For end bearing piles, the competence of the bedrock will control coring. In thick zones of weathered rock such as may be found in the north central part of the state, it may be difficult to retrieve a bedrock core. Attempting to drive a pile through weathered rock with N values greater than 100 will generally result in damage to the pile and should not be considered without the use of pile points.
3. For typical piles, a 5 foot core in competent bedrock is sufficient. If voids, weathered zones, or shear zones are encountered in the core, it may need to be increased to 10 feet.
4. If drilled shafts are considered for foundation support, cores should be continued to a depth equal to the shaft diameter plus 10 feet below the anticipated tip elevation. For design purposes, at least one core should be made at each substructure unit. Each core should be thoroughly examined and classified by an experienced geologist. Additional coring is normally required at each bridge drilled shaft location during construction.

The driller and geotechnical engineer need to obtain accurate bedrock elevations. Terminating borings on “probable bedrock” (or similar language) is generally not acceptable. The boring should be extended deeper by drilling or coring to confirm/refute the presence of bedrock and its condition. Geophysical investigation techniques may also assist in bedrock investigations.

7-4.4 Bore Logs

All boring logs should be complete and present the following information:

1. The location and elevation of each boring as referenced to established project control and datum. Locational information should also include the xyz-coordinates and the associated datum for these values.
2. Basic project/investigation data including: identification of the persons completing the work, type of drill rig, type of hammer, date of work, hammer efficiency, etc.
3. The vertical limits and textural description of each encountered stratum.
4. The SPT blow counts (‘N value’) and relative density as determined by AASHTO T-206 of each sampling interval along with the moisture condition.
5. Pocket penetration values of any cohesive soils.
6. The depth to static ground water and the time period for this determination.
7. The presence of boulders, cobbles, organic material, obstructions, artesians, or other unusual conditions.
8. The depth and elevation of bedrock, including any weathered zone, if encountered. All bedrock cores should be collected according to ASTM D2113 Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration. If bedrock cores are obtained, a description of the type of rock encountered and noting of any voids or irregularities encountered during coring. Bedrock recovery (REC) and rock quality designation (RQD) data should also be recorded.
9. For water-crossing bridges, also include sediment samples at the streambed and the associated laboratory gradations, so the hydraulic engineer can compute estimated scour depths.

These bore logs are then generally drawn on Subsurface Exploration plan sheets and become part of the contract documents. The geotechnical engineer should ensure that all data is completely and correctly transferred to the plan sheets.

Recently the Department began collecting soil boring structure logs and placing them into a database. WisDOT places their information into this database, and consultants are requested to submit their gINT structure logs (using the WisDOT template) to the following mailbox: DOTDTSDGeotechnicalgINT@dot.wi.gov.

7-4.5 Laboratory Testing

The geotechnical engineer should review the project needs, bore logs and soil samples and develop a laboratory testing program, if necessary. Testing programs should be individually developed to provide useful information and lab tests should only be completed if the results will be used in the design analyses. . The particular laboratory tests and frequency will depend on project needs and subsurface conditions/variability.

Testing should be related to specific soil types/strata data, and not be based on some pre-determined frequency. For instance, there is generally no reason to obtain multiple soil moisture values for multiple borings with similar soils at similar profile elevations.

Laboratory test results should be presented in the geotechnical report. This report will describe how these results were used in the analyses and recommendations for the project.

Recently, the Department began creating a database of soils laboratory test results and laboratory data sheets for structures. WisDOT places their information into this database, and consultants are requested to submit their pdf soil laboratory results to the following mailbox: mailto:DOTDTSDGeotechnicalgINT@dot.wi.gov.