PDHonline Course C260 (3 PDH)

Planning Subsurface Investigations

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CHAPTER 2.0

PROJECT INITIATION

2.1 PROJECT TYPE

2.1.1 New Construction

In general there are two types of subsurface investigation that new construction may require; the first being a conceptual subsurface investigation, or route selection study, where the geotechnical engineer is asked by the designers to identify the best of several possible routes or locations for the proposed structures, or to evaluate foundation alternatives. This type of project generally does not require a detailed subsurface investigation. It is normally limited to geologic reconnaissance and some sampling, field identification of subsurface conditions to achieve generalized site characterization, and general observations such as the depth to rock or competent soils, presence of sinkholes and/or solution cavities, organic deposits in low lying swampy areas, and/or evidence of old fill, debris, or contamination. Conceptual study investigations require limited laboratory testing and largely depend on the description of subsurface conditions from boring logs prepared by an experienced field engineer and/or geologist. Properly performed exploratory investigations, in cases where the designers have flexibility in locating the project to take advantage of favorable subsurface conditions, have the potential for resulting in substantial savings by avoiding problematic foundation conditions and costly construction methods.

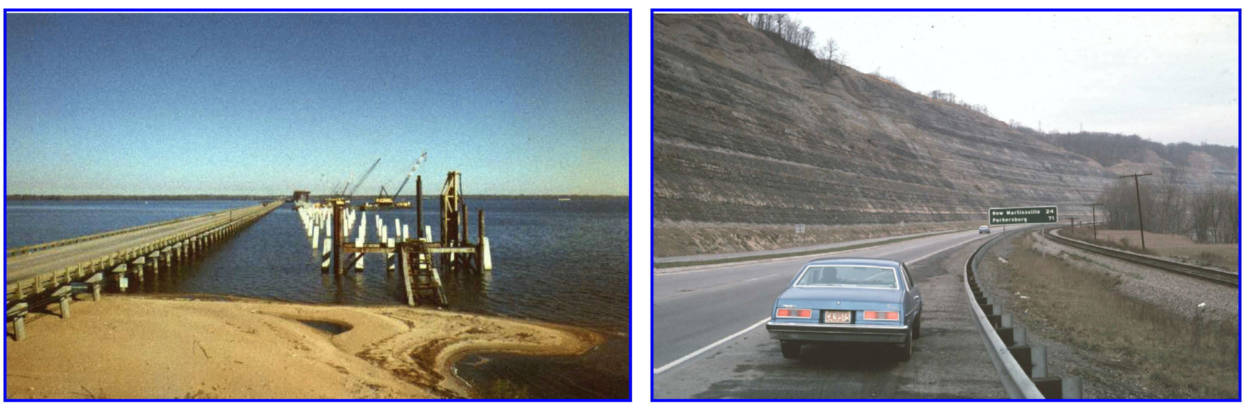

Figure 2-1. New Highway Construction: (a) Pile Bent Bridge in NC and (b) Cut Slope in VA.

The second and more common type of subsurface investigation is the detailed investigation to be performed for the purpose of detailed site characterization to be used for design (Figure 2-1). Frequently, the design phase investigation is performed in two or more stages. The initial, or preliminary design, stage investigation is typically performed early in the design process prior to defining the proposed structure elements or the specific locations of foundations, embankments or earth retaining structures. Accordingly, the preliminary design investigation typically includes a limited number of borings and testing sufficient for defining the general stratigraphy, soil and rock characteristics, groundwater conditions, and other existing features of importance to foundation design. Subsequently, after the location of structure foundations and other design elements have been determined, a second, or final design, phase investigation is frequently performed to obtain site specific subsurface information at the final substructure locations for design purposes and to reduce the risk of unanticipated ground conditions during construction. Further investigation stages can be considered if there are significant design changes or if local subsurface anomalies warrant further study. When properly planned, this type of multi-phase investigation provides sufficient and timely subsurface information for each stage of design while limiting the risk and cost of unnecessary explorations.

Prior to planning and initiating the investigation, the geotechnical engineer needs to obtain from the designers the type, load and performance criteria, location, geometry and elevations of the proposed facilities. The locations and dimensions of cuts and fills, embankments, retaining structures, and substructure elements should be identified as accurately as practicable. Bridge locations, approaches, and types of bridge construction should be provided in sufficient detail to allow a determination of the locations, depths, type, and number of borings to be performed. In cases where the investigation is being done for buildings, such as toll plazas, tourist information centers, and recreational or rest facilities, the designers should provide the layout and footprint of the building, plans, and any column and wall loads.

2.1.2 Rehabilitation Projects

Many geotechnical investigations involve rehabilitation and remediation of highway projects, including landslide failures, embankment stability, slope stabilization, subgrade & pavement settlement, and replacement of old foundation systems (see Figure 2-2).

Figure 2-2. Rehabilitation Projects Including: (a) Highway Slope Failure Involving Loss of Life; (b) Roadway Landslide; (c) Sinkhole in Orlando, Florida; and (d) Slope Stabilization.

The detail required for the subsurface investigation of rehabilitation projects depends on a number of variables, including:

- The condition of the facility to be rehabilitated.

- If the facility is distressed, the nature of distress (pavement failure, deep seated failures, structure settlement, landslides, drainage and water flow, imminent collapse)

- Whether the facility will be returned to its original and as-built condition or will be upgraded, say adding another lane to a pavement or a bridge.

- If facilities will be upgraded, the proposed geometry, location, loadings and structure changes (i.e. culvert to bridge).

- The required design life of the rehabilitated facility.

The above information should be obtained to aid in planning an appropriate investigation program.

2.1.3 Contaminated Sites

The geotechnical engineer occasionally must perform subsurface investigations at sites with contaminated soils or groundwater. Contamination may be of a non-hazardous or hazardous nature. Sampling and handling of contaminated samples is a complicated topic which is beyond the scope of this course. However, it is necessary for all involved in geotechnical investigations to be aware of the salient points of these procedures. The US Environmental Protection Agency (EPA) document number 625/12-91/002 titled "Description and Sampling of Contaminated Soils - A Field Pocket Guide" contains guidelines and background information, and a list of useful references on the topic.

When an investigation is to be performed, acquisition records for newly obtained right-of-way (ROW) will indicate the most recent land use for the area. Furthermore, the environmental section of the agency will most probably have developed environmental impact statements (EIS) and will have identified contaminated areas and the type of contamination. The ROW and environmental sections of the agency should be routinely contacted for this information at the investigation planning stage. On rehabilitation projects where the only planned activities will be on the existing ROW the information available may vary from very complete to none. Old gravel or compacted soil roads have occasionally been constructed using waste products as dust palliatives, and where these roads were later covered with, say bituminous hot mix concrete, the subsurface exploration may encounter layers of contaminated soils. Also, there may be a risk of contaminant migration through groundwater movement from off-site sources.

Some signs of possible contamination are:

- Prior land use (e.g. old fill, landfills, gas stations, etc.).

- Stained soil or rock.

- Apparent lack of vegetation or presence of dead vegetation and trees.

C Odors (It should be noted that highly organic soils often will have a rotten egg odor which should not be construed as evidence of contamination. However, this odor may also be indicative of highly toxic hydrogen sulfide. Drilling crews should be instructed as such).

C Presence of liquids other than groundwater or pore water.

C Signs of prior ground fires (at landfill sites). Established landfills will emit methane gas which is colorless and odorless, and in high concentrations in the presence of sparks or fire it will explode. At low concentrations under certain conditions (i.e. lightning) it will burn. Areas containing natural organic deposits also produce and emit methane gas.

C Presence of visible elemental metals (i.e., mercury).

C Low (<2.5) or High (>12.5) pH.

Easy to use field testing equipment such as air quality monitoring devices, pH measurement kits, photoionization detectors, etc. can be used to perform preliminary tests to identify the presence of some contaminants.

EPA documents provide guidelines and protocols for sampling, packaging, and transporting of contaminated soils as well as for field and laboratory testing. Additionally, many states have developed their own protocols, some of which are stricter than the ones developed by EPA. These documents need to be consulted prior to any attempt to sample or test suspect materials.

In most environmental applications, the US Department of Agriculture Soil Conservation Service (SCS) taxonomy rather than geotechnical engineering classifications are applied. A complete reference work to SCS soil taxonomy is "The Agricultural Handbook No. 18" published by the Soil Conservation Service, Washington, D.C. Copies of this handbook can be obtained through state or regional offices of SCS.

2.2 EXISTING DATA SOURCES

The first step in the investigation process is the review of existing data. There are a number of very helpful sources of data that can and should be used in planning subsurface investigations. Review of this information can often minimize surprises in the field, assist in determining boring locations and depths, and provide very valuable geologic and historical information which may have to be included in the geotechnical report.

Following is a partial list of useful sources of geological, historical, and topographic information. Specific information available from these and other reference sources is presented in the U.S. Navy Design Manual 7.1 (1982).

C Prior subsurface investigations (historical data) at or near the project site.

C Prior construction and records of structural performance problems at the site (i.e. pile length, driveability problems, rock slides, excessive seepage, unpredicted settlement, and other information). Some of this information may only be available in anecdotal forms. The more serious ones should be investigated, documented if possible, and evaluated by the engineer.

C U.S. Geological Survey (USGS) maps, reports, publications, and websites (www.usgs.gov).

C State Geological Survey maps, reports, and publications.

C State flood zone maps prepared by state or U.S. Geological Survey or the Federal Emergency Management Agency (FEMA: www.fema.gov) can be obtained from local or regional offices of these agencies.

C Department of Agriculture Soil Conservation Service (SCS) Soil Maps - A list of published soil surveys is issued annually. It should be noted that these are well researched maps but they only provide detailed information for shallow surficial deposits. They may show frost penetration depths, drainage characteristics, USDS soil types, and agrarian data.

C Geological Societies (Association of Engineering Geologists, Association of American State Geologists).

C Local university libraries and geology departments.

C Public Libraries and the Library of Congress.

C Earthquake data, seismic hazards maps, fault maps, and related information prepared by:
  - U.S. Geological Survey (USGS).
  - Earthquake Engineering Research Center (EERC), University of California, Berkeley.
  - Earthquake Engineering Research Institute (EERI), Stanford University
  - National Earthquake Engineering Research Program (NEERP), Washington, D.C.
  - Multidisciplinary Center of Earthquake Engineering Research (MCEER), Buffalo, N.Y.
  - Advanced Technology Council (ATC), Redwood City, California
  - Mid-America Earthquake Center (MAEC), Univ. of Illinois, Urbana.
  - Pacific Earthquake Engineering Center (PEER), Univ. of California-Berkeley.

C Worldwide National Earth-Science Agencies (USGS Circular 716, 1975).

C U.S. Bureau of Mines (USBM)

C State, City, and County Road Maps

C Aerial Photographs (USGS, SCS, Earth Resource Observation System).

C Remote Sensing Images (LANDSAT, Skylab, NASA).

C Site Plans showing locations of ditches, driveways, culverts, utilities, and pipelines.

C Maps of streams, rivers and other water bodies to be crossed by bridges, culverts, etc., including bathimetric data.

The majority of the above information can be obtained from commercial sources (i.e. duplicating services) or U.S. and state government local or regional offices. Specific sources (toll free phone numbers, addresses etc.) for flood and geologic maps, aerial photographs, USDA soil surveys, can very quickly identified through the Internet.

2.3 SITE VISIT/PLAN-IN-HAND

It is imperative that the geotechnical engineer, and if possible the project design engineer, conducts a reconnaissance visit to the project site to develop an appreciation of the geotechnical, topographic, and geological features of the site and become knowledgeable of access and working conditions. The plan-in-hand site visit is a good opportunity to learn about:

C Design and construction plans

C General site conditions

C Geologic reconnaissance

C The geomorphology

C Access restrictions for equipment

C Traffic control requirements during field investigations

C Location of underground and overhead utilities

C Type and condition of existing facilities (i.e. pavements, bridges, etc.)

C Adjacent land use (schools, churches, research facilities, etc.)

C Restrictions on working hours

C Right-of-way constraints

C Environmental issues

C Escarpments, outcrops, erosion features, and surface settlement

C Flood levels

C Water traffic and access to water boring sites

C Benchmarks and other reference points to aid in the location of boreholes

C Equipment storage areas/security

2.4 COMMUNICATION WITH DESIGNERS/PROJECT MANAGERS

The geotechnical engineer should have periodic discussions with the field inspector while the investigation program is ongoing. He or she should notify the project or the design engineer of any unusual conditions or difficulties encountered, and any changes made in the investigation program or schedule. The frequency of these communications depends on the critical nature of the project, and on the nature and seriousness of the problems encountered. A useful *Field Instructions Form* which can be used to clearly communicate the general requirements of the investigation program to all field personnel is shown below in Figure 2-3.

Geotechnical Project Information

Project No.:______________________________

Name:______________________________

Location:______________________________

Site Contact (Project Engineer):______________Phone:______________

Utility Contact:______________Reference No.:______________

Right of Entry Contact:______________________________

Other Contact (specify): ______________Home Phone: ______________

Estimated Time:______________________________

Soil Test Boring & Drilling Information

Boring No.	Depth	Drilling Sequence	Sampling	Remarks (piezometers, water levels, etc.)

Health and Safety Provisions: Special Plan:______________________________

Sample type, frequency:______________________________

Disposal of Cuttings/Drill Fluids:______________________________

Boring Closure: Cuttings: ______________Grout:______________

Remarks:______________________________

Figure 2-3. Example *Field Instructions Form* for Geotechnical Investigations.

2.5 SUBSURFACE EXPLORATION PLANNING

Following the collection and evaluation of available information from the above sources, the geotechnical engineer is ready to plan the field exploration program. The field exploration methods, sampling requirements, and types and frequency of field tests to be performed will be determined based on the existing subsurface information, project design requirements, the availability of equipment, and local practice. The geotechnical engineer should develop the overall investigation plan to enable him or her to obtain the data needed to define subsurface conditions and perform engineering analyses and design. A geologist can often provide valuable input regarding the type, age and depositional environment of the geologic formations present at the site for use in planning and interpreting the site conditions.

Frequently, the investigation program must be modified after initiating the field work because of site access constraints or to address variations in subsurface conditions identified as the work proceeds. To assure that the necessary and appropriate modifications are made to the investigation program, it is particularly important that the field inspector (preferably a geotechnical engineer or geologist) be thoroughly briefed in advance regarding the nature of the project, the purpose of the investigation, the sampling and testing requirements, and the anticipated subsurface conditions. The field inspector is responsible for verifying that the work is performed in accordance with the program plan, for communicating the progress of the work to the project geotechnical engineer, and for immediately informing the geotechnical engineer of any unusual subsurface conditions or required changes to the field investigation. Table 2-1 lists the general guidelines to be followed by the geotechnical field inspectors.

2.5.1 Types of Investigation

Generally, there are five types of field subsurface investigation methods, best conducted in this order:

1. Remote sensing
2. Geophysical investigations
3. Disturbed sampling
4. In-situ testing
5. Undisturbed sampling

Remote Sensing

Remote sensing data can effectively be used to identify terrain conditions, geologic formations, escarpments and surface reflection of faults, buried stream beds, site access conditions and general soil and rock formations. Remote sensing data from satellites (i.e LANDSAT images from NASA), aerial photographs from the USGS or state geologists, U.S. Corps of Engineers, commercial aerial mapping service organizations can be easily obtained, State DOTs use aerial photographs for right-of-way surveys and road and bridge alignments, and they can make them available for use by the geotechnical engineers.

The geotechnical engineer needs to be familiar with these sampling, investigation and testing techniques, as well as their limitations and capabilities before selecting their use on any project. The details of these investigation methods will be presented in subsequent chapters of this module.

TABLE 2-1.

GENERAL GUIDELINES FOR GEOTECHNICAL FIELD INSPECTORS

Fully comprehend purpose of field work to characterize the site for the intended engineering applications.:

- C Be thoroughly familiar with the scope of the project, technical specifications and pay items (keep a copy of the boring location plan and specifications in the field).
- C Be familiar with site and access conditions and any restrictions.
- C Review existing subsurface and geologic information before leaving the office.
- C Constantly review the field data obtained as it relates to the purpose of the investigation.
- C Maintain daily contact with the geotechnical project engineer; brief him/her regarding work progress, conditions encountered, problems, etc.
- C Fill out forms regularly (obtain sufficient supply of forms, envelopes, stamps if needed before going to the field). Typical forms may include:
  - Daily field memos
  - Logs of borings, test pits, well installation, etc.
  - Subcontract expense report - fill out daily, co-sign with driller
- C Closely observe the driller's work at all times, paying particular attention to:
  - Current depth (measure length of rods and samplers)
  - Drilling and sampling procedures
  - Any irregularities, loss of water, drop of rods, etc.
  - Count the SPT blows and blows on casing
  - Measure depth to groundwater and note degree of sample moisture
- C Do not hesitate to question the driller or direct him to follow the specifications
- C Classify soil and rock samples; put soil samples in jars and label them; make sure rock cores are properly boxed, photographed, stored and protected.
- C Verify that undisturbed samples are properly taken, handled, sealed, labeled and transported.
- C Do not divulge information to anyone unless cleared by the geotechnical project engineer or the project manager.
- C Bring necessary tools to job (see Table 2-4).
- C Take some extra jars of soil samples back to the office for future reference.
- C Do not hesitate to stop work and call the geotechnical project engineer if you are in doubt or if problems are encountered.
- C **ALWAYS REMEMBER THAT THE FIELD DATA ARE THE BASIS OF ALL SUBSEQUENT ENGINEERING DECISIONS AND AS SUCH ARE OF PARAMOUNT IMPORTANCE.**

Geophysical Investigation

Some of the more commonly-used geophysical tests are surface resistivity (SR), ground penetrating radar (GPR), and electromagnetic conductivity (EM) that are effective in establishing ground stratigraphy, detecting sudden changes in subsurface formations, locating underground cavities in karst formations, or identifying underground utilities and/or obstructions. Mechanical waves include the compression (P-wave) and shear (S-wave) wave types that are measured by the methods of seismic refraction, crosshole, and downhole seismic tests and these can provide information on the dynamic elastic properties of the soil and rock for a variety of purposes. In particular, the profile of shear wave velocity is required for seismic site amplification studies of ground shaking, as well as useful for soil liquefaction evaluations.

Disturbed Sampling

Disturbed samples are obtained to determine the soil type, gradation, classification, consistency, density, presence of contaminants, stratification, etc. Disturbed samples may be obtained by hand excavating methods by picks and shovels, or by truck-mounted augers and other rotary drilling techniques. These samples are considered “disturbed” since the sampling process modifies their natural structure.

In-Situ Investigation

In-situ testing and geophysical methods can be used to supplement soil borings. Certain tests, such as the electronic cone penetrometer test (CPT), provide information on subsurface soils without sampling disturbance effects with data collected continuously on a real time basis. Stratigraphy and strength characteristics are obtained as the CPT progresses in the field. Since all measurements are taken during the field operations and there are no laboratory samples to be tested, considerable time and cost savings may be appreciated. In-situ methods can be particularly effective when they are used in conjunction with conventional sampling to reduce the cost and the time for field work. These tests provide a host of subsurface information in addition to developing more refined correlations between conventional sampling, testing and in-situ soil parameters.

Undisturbed Sampling

Undisturbed samples are used to determine the in place strength, compressibility (settlement), natural moisture content, unit weight, permeability, discontinuities, fractures and fissures of subsurface formations. Even though such samples are designated as “undisturbed,” in reality they are disturbed to varying degrees. The degree of disturbance depends on the type of subsurface materials, type and condition of the sampling equipment used, the skill of the drillers, and the storage and transportation methods used. **As will be discussed later, serious and costly inaccuracies may be introduced into the design if proper protocol and care is not exercised during recovery, transporting or storing of the samples.**

2.5.2 Frequency and Depth of Borings

The location and frequency of sampling depends on the type and critical nature of the structure, the soil and rock formations, the known variability in stratification, and the foundation loads. While the rehabilitation of an existing pavement may require 4 m deep borings only at locations showing signs of distress, the design and construction of a major bridge may require borings often in excess of 30 m. Table 2-2 provides guidelines for selecting minimum boring depths, frequency and spacing for various geotechnical features. Frequently, it may be necessary or desirable to extend borings beyond the minimum depths to better define the geologic setting at a project site, to determine the depth and engineering characteristics of soft underlying

TABLE 2-2.

MINIMUM REQUIREMENTS FOR BORING DEPTHS

Areas of Investigation	Recommended Boring Depth
Bridge Foundations* Highway Bridges	
1. Spread Footings	For isolated footings of breadth L_f and width # $2B_f$, where L_f # $2B_f$, borings shall extend a minimum of two footing widths below the bearing level. For isolated footings where $L_f \$5B_f$, borings shall extend a minimum of four footing widths below the bearing level. For $2B_f$ # L_f # $5B_f$, minimum boring length shall be determined by linear interpolation between depths of $2B_f$ and $5B_f$ below the bearing level.
2. Deep Foundations	In soil, borings shall extend below the anticipated pile or shaft tip elevation a minimum of 6 m, or a minimum of two times the maximum pile group dimension, whichever is deeper. For piles bearing on rock, a minimum of 3 m of rock core shall be obtained at each boring location to verify that the boring has not terminated on a boulder. For shafts supported on or extending into rock, a minimum of 3 m 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, whichever is greater, shall be extended below the anticipated shaft tip elevation to determine the physical characteristics of rock within the zone of foundation influence.
Retaining Walls	Extend borings to depth below final ground line between 0.75 and 1.5 times the height of the wall. Where stratification indicates possible deep stability or settlement problem, borings should extend to hard stratum. For deep foundations use criteria presented above for bridge foundations.
Roadways	Extend borings a minimum of 2 m below the proposed subgrade level.
Cuts	Borings should extend a minimum of 5 m below the anticipated depth of the cut at the ditch line. Borings depths should be increased in locations where base stability is a concern due to the presence of soft soils, or in locations where the base of the cut is below groundwater level to determine the depth of the underlying pervious strata.
Embankments	Extend borings a minimum depth equal to twice the embankment height unless a hard stratum is encountered above this depth. Where soft strata are encountered which may present stability or settlement concerns the borings should extend to hard material.
Culverts	Use criteria presented above for embankments.

*Note: Taken from AASHTO Standard Specifications for Design of Highway Bridges soil strata, or to assure that sufficient information is obtained for cases when the structure requirements are not clearly defined at the time of drilling. Generally it should be assumed that the structure may have an influence on the supporting subgrade soils down to a depth of twice the foundation width for static loads and four times the foundation width for seismic loads. Where borings are drilled to rock and this rock will impact foundation performance, it is generally recommended that a minimum 1.5-m length of rock core be obtained to verify that the boring has indeed reached bedrock and not terminated on the surface of a boulder. Where structures are to be founded directly on rock, the length of rock core should be not less than 3 m, and extended further if the use of socketed piles or drilled shafts are anticipated. Selection of boring depths at river and stream crossings must consider the potential scour depth of the stream bed.

The frequency and spacing of borings will depend on the variability of subsurface conditions, type of facility to be designed, and the investigative phase being performed. For conceptual design or route selection studies, very wide boring spacing (up to 300 m, or more) may be acceptable particularly in areas of generally uniform or simple subsurface conditions. For preliminary design purposes a closer spacing is generally necessary, but the number of borings would be limited to that necessary for making basic design decisions. For final design, however, relatively close spacings of borings may be required, as suggested in Table 2-3.

Subsurface investigation programs, regardless to how well they may be planned, must be flexible to adjust to variations in subsurface conditions encountered during drilling. The project geotechnical engineer should at all times be available to confer with the field inspector. On critical projects, the geotechnical engineer should be present during the field investigation. He/she should also establish communication with the design engineer to discuss unusual field observations and changes to be made in the investigation plans.

2.5.3 Boring Locations and Elevations

It is generally recommended that a licensed surveyor be used to establish all planned drilling locations and elevations. For cases where a surveyor cannot be provided, the field inspector has the responsibility to locate the borings and to determine ground surface elevations at an accuracy appropriate to the project needs. Boring locations should be taped from known site features to an accuracy of about ±1.0 m for most projects. Portable global positioning systems (GPS) are also of value in documenting locations. When a topographic survey is provided, boring elevations can be established by interpolation between contours. This method of establishing boring elevations is commonly acceptable, but the field inspector must recognize that the elevation measurement is sensitive to the horizontal position of the boring. Where contour intervals change rapidly, the boring elevations should be determined by optical survey.

A reference benchmark (BM) should be indicated on the site plans and topographic survey. If a BM is not shown, a temporary benchmark (TBM) should be established on a permanent feature (e.g., manhole, intersection of two streets, fire hydrant, or existing building). A TBM should be a feature that will remain intact during future construction operations. Typically, the TBM is set up as an arbitrary elevation (unless the local ground elevation is uniform). Field inspectors should always indicate the BM and/or TBM that was used on the site plan.

An engineer's level may be used to determine elevations. The level survey should be closed to confirm the accuracy of the survey. Elevations should be reported on the logs to the nearest tenth of a meter unless other directions are received from the designers. In all instances, the elevation datum must be identified and recorded. Throughout the boring program the datum selected should remain unchanged.

2.5.4 Equipment

A list of equipment commonly needed for field explorations is presented in Table 2-4.

TABLE 2-3.

GUIDELINES FOR BORING LAYOUT*

Geotechnical Features	*Boring Layout*
Bridge Foundations	For piers or abutments over 30 m wide, provide a minimum of two borings. For piers or abutments less than 30 m wide, provide a minimum of one boring. Additional borings should be provided in areas of erratic subsurface conditions.
Retaining Walls	A minimum of one boring should be performed for each retaining wall. For retaining walls more than 30 m in length, the spacing between borings should be no greater than 60 m. Additional borings inboard and outboard of the wall line to define conditions at the toe of the wall and in the zone behind the wall to estimate lateral loads and anchorage capacities should be considered.
Roadways	The spacing of borings along the roadway alignment generally should not exceed 60 m. The spacing and location of the borings should be selected considering the geologic complexity and soil/rock strata continuity within the project area, with the objective of defining the vertical and horizontal boundaries of distinct soil and rock units within the project limits.
Cuts	A minimum of one boring should be performed for each cut slope. For cuts more than 60 m in length, the spacing between borings along the length of the cut should generally be between 60 and 120 m. At critical locations and high cuts, provide a minimum of three borings in the transverse direction to define the existing geological conditions for stability analyses. For an active slide, place at least one boring upslope of the sliding area.
Embankments	Use criteria presented above for Cuts.
Culverts	A minimum of one boring at each major culvert. Additional borings should be provided for long culverts or in areas of erratic subsurface conditions.

*Also see *FHWA Geotechnical Checklist and Guidelines*; FHWA-ED-88-053

TABLE 2-4.

LIST OF EQUIPMENT FOR FIELD EXPLORATIONS

Paperwork/Forms	Site Plan Technical specifications Field Instructions Sheet(s) Daily field memorandum forms Blank boring log forms Forms for special tests (vane shear, permeability tests, etc.) Blank sample labels or white tape Copies of required permits Field book (moisture proof) Health and Safety plan Field Manuals Subcontractor expense forms
Sampling Equipment	Samplers and blank tubes etc. Knife (to trim samples) Folding rule (measured in 1 cm increments) 25 m tape with a flat-bottomed float attached to its end so that it can also be used for water level measurements Hand level (in some instances, an engineer's level is needed) Rags Jars and core boxes Sample boxes for shipping (if needed) Buckets (empty) with lid if bulk samples required Half-round file Wire brush
Safety/Personal Equipment	Hard hat Safety boots Safety glasses (when working with hammer or chisel) Rubber boots (in some instances) Rain gear (in some instances) Work gloves
Miscellaneous Equipment	Clipboard Pencils, felt markers, grease pencils Scale and straight edge Watch Calculator Camera Compass Wash bottle or test tube Pocket Penetrometer and/or Torvane Communication Equipment (two-way radio, cellular phone)

2.5.5 Personnel and Personal Behavior

The field crew is a visible link to the public. The public's perception of the reputation and credibility of the agency represented by the field crew may be determined by the appearance and behavior of the personnel and field equipment. It is the drilling supervisor's duty to maintain a positive image of field exploration activities, including the appearance of equipment and personnel and the respectful behavior of all personnel. In addition, the drilling supervisor is responsible for maintaining the safety of drilling operations and related work, and for the personal safety of all field personnel and the public. The designated Health and Safety Officer is responsible for verifying compliance of all field personnel with established health and safety procedures related to contaminated soils or groundwater. Appendix A presents typical safety guidelines for drilling into soil and rock and health and safety procedures for entry into borings.

The field inspector may occasionally be asked about site activities. The field inspector should always identify the questioner. It is generally appropriate policy not to provide any detailed project-related information, since at that stage the project is normally not finalized, there may still be on going discussions, negotiations, right-of-way acquisitions and even litigation. An innocent statement or a statement based on one's perception of the project details may result in misunderstandings or potentially serious problems. In these situations it is best to refer questions to a designated officer of the agency familiar with all aspects of the project.

2.5.6 Plans and Specifications

Each subsurface investigation program must include a location plan and technical specifications to define and communicate the work to be performed.

The project location plan(s) should include as a minimum: a project location map; general surface features such as existing roadways, streams, structures, and vegetation; north arrow and selected coordinate grid points; ground surface contours at an appropriate elevation interval; and locations of proposed structures and alignment of proposed roadways, including ramps. On these plans, the proposed boring, piezometer, and in-situ test locations should be shown. A table which presents the proposed depths of each boring and sounding, as well as the required depths for piezometer screens should be given.

The technical specifications should clearly describe the work to be performed including the materials, equipment and procedures to be used for drilling and sampling, for performing in situ tests, and for installing piezometers. In addition, it is particularly important that the specifications clearly define the method of measurement and the payment provisions for all work items.

2.6 STANDARDS AND GUIDELINES

Field exploration by borings should be guided by local practice, by applicable FHWA and state DOTs procedures, and by the AASHTO and ASTM standards listed in Table 2-5.

Current copies of these standards and manuals should be maintained in the engineer's office for ready reference. The geotechnical engineer and field inspector should be thoroughly familiar with the contents of these documents, and should consult them whenever unusual subsurface situations arise during the field investigation. The standard procedures should always be followed; improvisation of investigative techniques may result in erroneous or misleading results which may have serious consequences on the interpretation of the field data.

TABLE 2-5.

FREQUENTLY-USED STANDARDS FOR FIELD INVESTIGATIONS

Standard		
AASHTO	***ASTM***	***Title***
M 146	C 294	Descriptive Nomenclature for Constituents of Natural Mineral Aggregates
T 86	D 420	Guide for Investigating and Sampling Soil and Rock
-	D 1194	Test Method for Bearing Capacity of Soil for Static Load on Spread Footings
-	D 1195	Test Method for Repetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Airport and Highway Pavements
-	D 1196	Test Method for Nonrepetitive Static Plate Load Tests of Soils and Flexible Pavement Components, for Use in Evaluation and Design of Airport and Highway Pavements
T 203	D 1452	Practice for Soil Investigation and Sampling by Auger Borings
T 206	D 1586	Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
T 207	D 1587	Practice for Thin-Walled Tube Sampling of Soils
T 225	D 2113	Practice for Diamond Core Drilling for Site Investigation
M 145	D 2487	Test Method for Classification of Soils for Engineering Purposes
-	D 2488	Practice for Description and Identification of Soils (Visual-Manual Procedure)
T 223	D 2573	Test Method for Field Vane Shear Test (VST) in Cohesive Soil
-	D 3550	Practice for Ring-Lined Barrel Sampling of Soils
-	D 4220	Practice for Preserving and Transporting Soil Samples
-	D 4428	Test Method for Crosshole Seismic Test (CHT)
-	D 4544	Practice for Estimating Peat Deposit Thickness
-	D 4700	General Methods of Augering, Drilling, & Site Investigation
-	D 4719	Test Method for Pressuremeter Testing (PMT) in Soils
-	D 4750	Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
-	D 5079	Practices for Preserving and Transporting Rock Core Samples
-	D 5092	Design and Installation of Ground Water Monitoring Wells in Aquifers
-	D 5777	Guide for Seismic Refraction Method for Subsurface Investigation
-	D 5778	Test Method for Electronic Cone Penetration Testing (CPT) of Soils
-	D 6635	Procedures for Flat Plate Dilatometer Testing (DMT) in Soils
-	G 57	Field Measurement of Soil Resistivity (Wenner Array)