Geotechnical Manual

Lexington-Fayette Urban County Government
Lexington, Kentucky

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OVERVIEW AND SUMMARY OF THE LEXINGTON-FAYETTE URBAN COUNTY GOVERNMENT GEOTECHNICAL MANUAL

Overview and Summary of the Lexington-Fayette Urban County Government Geotechnical Manual

This Manual is presented in a sequence to provide the reader with general information regarding the purpose and contents of the Manual, and then to lead the reader through the major component of performing geotechnical explorations for routine infrastructure projects.

The manual is separated into the following major sections:

1.0. General Information

2.0 Project Review and Site Reconnaissance

3.0. Drilling, Sampling, and Recording Procedures

4.0. Preparation of Boring Plans

5.0. Laboratory Testing

6.0 Engineering Analyses and Evaluations

7.0 Report Development

Summaries of the information included under each major heading are presented in the following paragraphs. Primary requirements identified in each section are also summarized. Additional guidelines and requirements are discussed throughout the text of the Manual. This overview has been developed to provide the reader with a brief survey of each section and the geotechnical requirements discussed therein.

Summary and Primary Requirements of Section 1.0

Summary

Section 1.0 identifies the purpose and contents of the LFUCG Geotechnical Manual. It includes a list of technical references that should be used in conjunction with the Manual. Project types for which use of the Manual is applicable are discussed and categorized as:

- Roadways and Streets
- Structures
  - small replacement or new single-span bridges
  - retaining walls
  - reinforced concrete box culverts and associated wingwalls
- Sanitary and storm sewers, pump stations and associated facilities

- Retention/Detention facilities

Section 1 also outlines the purposes of performing geotechnical explorations, and the necessary qualifications of those who will actually provide geotechnical services. Lists of definitions and references are included near the end of the chapter.

Primary Requirements

- Geotechnical Explorations shall be performed for all infrastructure construction.

- Beginning January 1, 2002, Geotechnical explorations shall be performed by consulting firms that are pre-qualified in applicable services areas by the Kentucky Transportation Cabinet (KTC).

Summary and Primary Requirements of Section 2.0

Summary

Section 2.0 discusses the initial planning efforts necessary to perform a geotechnical exploration. This section identifies the types of plans and information the Geotechnical Consultant shall have available to review prior to implementing an exploration. Requirements for performing a site reconnaissance and utility checks, and for obtaining access agreements and entry permits are also included.

- The Geotechnical Consultant shall be provided with all available project plans, mapping, etc., to review prior to developing a geotechnical exploration.

- The Geotechnical Consultant shall visit the project site and perform a site reconnaissance. As a result, the consultant shall photograph and document the approximate locations of any unusual geotechnical conditions that may need to be addressed during design and construction of the project.

- The Geotechnical Consultant shall check on the presence of underground and overhead utilities at the site. The exploration shall be planned to prevent damaging such utilities.

- The Geotechnical Consultant shall be responsible for obtaining access agreements from property owners, as necessary. Any special entry permits required to access a property shall be identified by the Engineer, Developer, or the LFUCG and shall be obtained by the Geotechnical Consultant prior to entering the property.

- If suspected hazardous materials and/or UST's are encountered at any time during implementation of geotechnical services, the Geotechnical Consultant shall contact the Engineer, Developer, or the LFUCG for direction prior to continuing the exploration. The consultant shall implement applicable safety precautions to protect personnel and the environment in the event hazardous materials are encountered during field work.

- The Geotechnical Consultant shall note any surface depressions and/or sinkholes that may be observed at a site. Such features shall be explored to determine if they should be classified as "Sinkhole-Related Non-Buildable Areas" in accordance with *Section 6-7(1) - Sinkholes* of the current *Land Subdivision Regulations for Lexington-Fayette County, Kentucky.*

Summary and Primary Requirements of Section 3.0

Summary

Section 3.0 discusses procedures for drilling, sampling, installing observation wells, performing test pit excavations, logging existing rock exposures; labeling, identifying, handling and disposing soil and rock core samples; describing soil and bedrock types encountered during geotechnical explorations; and developing written boring logs.

This chapter provides the basic definitions of borings and sample types that will be performed and collected during typical subsurface explorations. Section 3.0 is presented ahead of discussions regarding development of project boring plans (Section 4.0) and laboratory testing (Section 5.0) to provide the reader with required terminology with which to better understand these following sections of the manual.

Primary Requirements

- All drilling, sampling, and testing shall be in general accordance with applicable ASTM standards unless otherwise specifically noted.

- All firms/organizations performing test borings shall have on file within their offices a Groundwater Protection Plan meeting the requirements set forth in 401 KAR 5:037.

Summary and Primary Requirements of Section 4.0

Summary

Section 4.0 outlines the specific project types for which use of the manual is intended, and identifies how subsurface data/geotechnical explorations may be used in design and construction of these projects. The intent of this chapter is to provide the requirements for developing boring plans for specific project types. The numbers, locations, and borings types to be performed are identified. The typical depths to which borings shall be drilled are also noted. Figures 4.2 through 4.10 provide graphical examples of boring plans for the different project types discussed in the manual.

Primary Requirements

Roadways/Streets

- Soil profile borings shall be performed at maximum 300-foot center to center spacings along the roadway alignment through both cut and fill intervals. Moisture content samples shall be collected at these boring locations as described in Section 3.2.1(2).

- Bag samples shall be collected from the soil profile borings for each soil type encountered within each 1000-foot interval of roadway length. For roadways/streets less than 1000 feet in length, a minimum of two bag samples shall be collected, even if only one soil type is visually identified in the borings.

- At least one critical cut slope section shall be evaluated for each 500-foot length of roadway cut interval, or fraction thereof, which will exhibit cuts deeper than 15 feet. One or more rock core borings shall be performed at this section such that the entire geologic column within the cut, from the highest point to five feet below ditch grade, is recovered.

- Sample borings shall be performed for proposed embankment sections that will be greater than 20 feet in height from toe to crest. At least one critical embankment section shall be evaluated for each 1000-foot length of fill interval, or fraction thereof. Two borings shall be performed for each critical section, one at the highest point of the fill (the shoulder) and one near the toe of the proposed slope.

- A groundwater observation well shall be installed in each sample boring when the soil thickness within the boring exceeds 5 feet.

Single-Span Bridges

- At least one sample boring shall be performed at each abutment/end bent location. Rock coring shall also be conducted in the sample boring at locations where less than 60 feet of foundation soils are presented. Rock coring efforts shall extend a minimum of 10 feet into rock, and shall be deepened as subsurface conditions warrant.

- At least one rock sounding shall be performed at the opposite end of each abutment footprint from the position of the sample/core boring. If the structure is greater then 50 feet wide, an additional sounding shall be drilled on the abutment centerline between the sample/core boring and the first sounding.

- If the approach or spill-through embankments to the bridge exceed 20 feet in height, an additional sample boring shall be drilled at the toe of the spill-through slope considered to be most critical.

Culverts

- For single-barrel culverts six feet or less in width, a single line of borings shall be drilled along the centerline of the culvert at approximate intervals of 50 feet. This line of borings shall include at least three sample borings with rock coring; one drilled at each end of the culvert, and one near the midpoint of the structure. The two borings at the ends of the culvert shall be sampled continuously from the proposed flowline elevation to a depth of six feet below the flowline, or until bedrock is reached, whichever is less. Sampling in the boring performed near the midpoint may be done on five-foot centers. The remaining borings shall alternate between rock soundings and rock core borings on the noted fifty-foot, center-to-center spacing.

- For multi-barreled culverts, or single-barreled culverts greater than six feet in width, borings shall be drilled along each bearing line of the structure from the inlet to the outlet on a 50-foot center to center spacing. One sample boring with rock coring shall be performed at each end of the culvert and shall oppose one another on a diagonal. The remaining borings shall alternate between soil and rock core borings along the length of each bearing line and across the width of the culvert on the noted 50-foot spacing. Again, sample borings shall be drilled near the midpoint of the culvert, as for single barrel structures.

- Coring efforts shall be performed at the planned rock core boring locations <u>only if</u> bedrock is encountered at an elevation higher than five feet below the proposed flowline. If bedrock is encountered at a depth five feet or greater below the proposed flowline, rock coring shall not be required. Rock core borings shall extend to a minimum depth of five feet below the flowline, or be drilled a minimum of five feet into rock, when necessary.

Retaining Walls

- Soil profile borings shall be drilled at each end of a proposed retaining wall and on 50-foot centers along the length of the wall. These borings shall be drilled to depths of five feet below planned bearing elevation or to auger refusal, whichever is less. Moisture content and bag samples shall be collected as outlined in Section 4.2.2.

- Sample borings shall be drilled at the location of maximum wall height. One boring shall be positioned on the centerline of the wall. This sample boring may be used to replace a soil profile boring located near the centerline of the wall. Another sample boring shall be positioned behind the wall where material is to be retained. Sample borings shall be drilled to refusal or to maximum depths equal to twice the wall height, whichever is less.

- Rock coring shall be performed in selected borings if rock is encountered above or within a zone five feet below planned bearing elevations. Rock cores may be obtained from soil profile borings on 100-foot centers, as applicable. The core borings shall extend to a minimum of five feet below planned bearing, or a minimum of five feet into rock.

- Groundwater observation wells shall be installed in sample borings in which rock coring has not been performed. The wells shall be installed as outlined in Section 3.2.3.

Sanitary and Storm Sewers, and Associated Facilities

- Soil profile, sample, and rock core borings may be performed in place of rock soundings if there is a need to identify the subsurface materials in more detail. Borings drilled for sewer installations shall extend to bedrock or to a minimum of three feet below planned bottoms of pipes and manholes, whichever is less.

Detention/Retention Basins

- A geotechnical exploration shall be implemented for detention/retention basins to evaluate stability of the proposed berm and to establish compaction requirements for soils that will be used to construct the berm. The Engineer shall evaluate each detention/retention facility to determine if it could be defined as a structure regulated under 401KAR 4:030. If a detention/retention basin meets the criteria listed in that regulation, then it shall be designed in accordance with 401KAR 4:030 and Engineering Memorandum No. 5. The guidelines presented in the LFUCG Geotechnical Manual are not applicable to such structures.

- Borings performed for the exploration of proposed detention/retention basins shall consist of a minimum of two sample borings. These borings shall be drilled at the tallest or most critical cross section for each 200-foot length, or fraction thereof, of embankment/cut to be constructed. One boring shall be drilled at the location of the downstream shoulder, and one boring at the position of the downstream toe. A bag sample of each soil type encountered shall also be collected for subsequent laboratory testing. Observation wells shall be installed in the borings to monitor groundwater conditions. Borings are required for embankment/cuts greater than 15 feet tall measured from toe to crest; and for any berm exhibiting slopes steeper than 2.5H:1V and which will be greater than 10 feet in height. Borings shall be drilled to a depth equal to twice the embankment height/cut depth or to the top of bedrock, whichever is less.

Areas Used to Obtain Material for Infrastructure Construction

- Borings for areas that are to undergo mass grading operations shall be spaced on a grid pattern of approximately 400 feet. The borings shall consist primarily of soil profile borings to identify the soil types present at the drilling locations. These profile borings shall be drilled to depths equal to five feet below proposed grades or to auger refusal, whichever is less. A minimum of one bag sample of soil type identified shall be collected for subsequent laboratory testing.

- If bedrock excavation is anticipated on the site, rock core borings shall be included in those areas where rock excavation is expected to be most extensive. Rock core borings shall extend to a minimum depth of five feet below proposed grades.

- Proposed cut/fill soil slopes that are to remain after grading shall be evaluated for slope stability if the height of the slope will exceed 20 feet, or the proposed slope is to be steeper than 2.5H to 1V. Two sample borings shall be drilled at the cross section of the soil slope estimated to be most critical. One boring shall be located at the top of the proposed slope, and one located at the proposed toe. Both borings shall be drilled to depths equal to twice the depth/height of the cut/fill or to auger refusal, whichever is less. Observation wells shall be installed in both borings to monitor ground water levels.

Sinkholes

- Sinkholes present at a proposed site shall be explored to determine if they may be used for drainage and/or development areas, or if they will need to be classified as Sinkhole Related Non-Buildable Areas in accordance with *Section 6-7(1) - Sinkholes* of the current *Land Subdivision Regulations for Lexington-Fayette County, Kentucky*. Field exploration efforts performed to evaluate sinkholes often consist of either performing soil profile borings or test pit excavations, or a combination of the two. Bag and moisture content samples of each soil type encountered shall be collected during the exploration.

- The sinkhole size, shape, and potential effects on a planned facility will influence the type of exploration to be performed. Typically, two sinkhole situations are encountered. Refer to Figure 4.9 for a sketch of these two situations. The first situation consists of a basin that does not exhibit an open *throat* from bedrock to the ground surface. This type of basin shall be explored by drilling several soil profile borings within the basin on a pre-determined grid pattern. Center-to-center spacings of borings shall be based on the size of the depression being explored and the level of accuracy desired from the borings. All borings shall be drilled to auger refusal.

- The second situation consists of a basin showing a visible throat. The throat shall be carefully excavated or "chased" so that the extent, orientation, and impact of the sinkhole to the project can be evaluated and a treatment plan developed. Typically, backhoe equipment is used to excavate the throat area and expose the rock surface for evaluation. In this case, photographic documentation of the findings shall also be performed. This type of exploration may be supplemented with test borings as conditions warrant.

Fill/Debris Areas

- Some sites may have areas where old fill materials are present. These materials may consist of soils that have been dumped in place and not compacted; construction debris, trash, trees, etc., placed to fill in low-lying areas; and/or other materials not suitable to use for planned improvements.

  If old fill/construction debris/trash, etc., are encountered on a site, additional physical exploration efforts shall be required to help identify the limits of such materials. Soil profile borings, sample borings, and/or test pit excavations shall be performed to help better define the vertical and horizontal extents of the fill/debris. Borings and/or pits may be positioned on a grid pattern with spacings ranging from 10 to 100 feet, depending upon the level of accuracy desired to define the limits of suspect materials.

- In areas where the old fill consists primarily of uncompacted soils, sample borings shall be used most frequently. Continuous Shelby tube samples of the fill soils shall be collected from these borings to provide soil specimens for subsequent laboratory testing and evaluations.

In areas where the fill consists primarily of construction debris, trash, etc., soil sampling is not typically necessary. The main emphasis for these areas shall be to define the limits of such materials so they can be removed and replaced with suitable materials prior to or during project construction activities.

Summary and Primary Requirements of Section 5.0

Summary

Section 5.0 discusses laboratory testing procedures for soil and rock samples collected during geotechnical explorations. This chapter also identifies specific testing requirements for different project types.

Primary Requirements

- Soil and rock testing are to be performed in accordance with ASTM, AASHTO, or Kentucky Transportation Cabinet Test Methods as specified.

- For classification of soils, the ASTM procedure is designated D2487 *Classification of Soils for Engineering Purposes*. The system used in this procedure is commonly referred to as the Unified Soils Classification System (USCS). ASTM D 2487 shall be used as the primary classification procedure.

Roadways/Streets

- Laboratory evaluations for recovered bedrock samples from cut stability sections shall consist of slake durability index and jar slake testing. These tests shall be performed using portions of the core specimens that consist primarily of shale. One SDI/jar slake sample shall be tested for each five-foot length, or fraction thereof, of shale recovered during the coring process.

- Standard penetration test and Shelby tube samples shall be subjected to standard engineering classification testing consisting of particle size analysis, specific gravity and Atterberg limits. Moisture content testing shall be performed on each SPT sample.

- One unconfined compression test shall be conducted on each tube sample obtained from embankment stability borings. Consolidated-undrained triaxial compression tests shall be performed using representative tube samples of each type of soil identified by the borings. Effective-stress shear strength parameters shall be developed from these test results. These parameters will subsequently be utilized in performing embankment and soil cut stability analyses.

- Bag samples consisting of soils which will be used to construct roadway/street fills, and of soils near subgrade elevations, shall be subjected to particle size analyses, specific gravity, Atterberg limits, standard Proctor and CBR testing. These parameters shall be used during engineering evaluations to provide fill compaction and embankment construction criteria. CBR values shall be used by the Engineer in designing required pavement thicknesses.

- Bag samples consisting of soils which will be three-feet or more below grade and will not be used as fill shall only be subjected to engineering classification testing, i.e., particle size analysis, specific gravity and Atterberg limits.

- Water content testing shall be performed on all moisture content samples consisting of auger cuttings obtained from soil profile borings.

- If the heights of any embankments, in conjunction with observed subsurface conditions, are such that significant settlements of foundation soils are anticipated, one-dimensional consolidation testing of the soils shall be performed. One consolidation test shall be completed for each type of soil encountered in borings performed within planned fill areas. If the thickness of any one soil type exceeds five feet, then consolidation testing shall be performed for each sample collected within this soil on five-foot centers.

Single-Span Bridges

- Unconfined compression testing shall be performed at depth intervals of five feet on recovered samples of rock core. SDI testing shall be performed as outlined in Section 5.5.2, if necessary.

- SPT and Shelby tube samples shall be subjected to the same tests as outlined for Roadways/Streets.

Culverts

- Classify SPT and Shelby tube samples. SPT samples of the same soil type may be combined to perform this testing. One classification test shall be performed on a representative Shelby tube sample of each different soil type encountered. It is not required that each Shelby tube and SPT sample be subjected to classification testing.

- If the wingwalls and culvert barrel will be founded on soil, then unconfined compression testing shall be conducted on each tube sample.

- If it is expected that planned fill will cause settlement of the foundation soils beneath the culvert, then one-dimensional consolidation testing of each soil type encountered during drilling efforts shall be performed.

- Water content testing shall be conducted on each recovered sample. If the moisture content of a sample will be determined as part of other testing, it is not necessary to run additional water content tests on that particular sample.

Retaining Walls

- Laboratory testing of soil/rock samples recovered at retaining wall locations shall be performed as outlined for culverts. In addition, consolidated-undrained triaxial testing of foundation soils and of materials to be retained by the wall shall be completed, as applicable.

Sanitary and Storm Sewers

Typically, only rock soundings, and/or rock core borings are performed for exploration of sanitary and storm sewer lines. Soil sampling is usually not required. Therefore, laboratory testing on recovered samples is not commonly applicable.

Detention/Retention Basins

- The primary focuses of performing geotechnical explorations for detention/retention basins are to establish soil compaction and permeability criteria for fill placement; and to evaluate embankment/cut stabilities. Therefore, testing of recovered samples from these areas shall be tailored to provide shear strength parameters used in stability analyses and moisture-density relationships with which to establish fill compaction requirements.

- Standard penetration tests and Shelby tube samples shall be subjected to the same testing as outlined for roadways/streets. Bag samples collected from soils that may be used as fill in construction of the detention/retention berm shall be classified according to the USCS. Standard Proctor (moisture-density) and permeability testing shall also be performed on bag samples of each soil type observed in order to establish compaction requirements.

Areas Used to Obtain Material for Infrastructure Construction

- Bag samples collected from soils that will be used as fill shall be subjected to engineering classification and standard Proctor testing. CBR testing shall be performed using these soil samples if the material is to be used as subgrade support beneath pavements. One set of classification tests, one Proctor and one CBR test shall be conducted for each soil type obtained from cut areas, as applicable.

- SPT and Shelby tube samples collected from significant cut and/or fill areas shall be tested as outlined for Roadways/Streets. Moisture content testing of each "grab" sample obtained from soil profile borings shall also be performed.

Sinkholes

- Classification tests shall be performed on a representative bag sample obtained from each different soil type encountered in the field. If soils excavated during performance of test pits are to be re-used to fill the pits, then standard Proctor testing shall also be performed on such materials to establish moisture-density relationships and compaction control criteria. Water content testing shall be conducted on "grab" samples collected at the site.

Fill/Debris Areas

- SPT and Shelby tube samples from such borings shall be classified according the USCS. Shelby tube samples shall also be extruded, trimmed to six-inch long specimens, and measured for unit weight. Moisture content tests shall be conducted on each SPT and "grab" sample obtained from the borings. Bag samples collected of the predominant soils shall be tested to establish their standard Proctor maximum dry densities and optimum moisture contents.

- Laboratory testing of soils containing significant amounts of construction debris, trash, organics, etc., is usually not necessary. Removal of these materials from the site is quite often the most practical option for remediation.

Summary and Primary Requirements of Section 6.0

Summary

Section 6.0 provides requirements for performing geotechnical engineering analyses and evaluations on routine infrastructure projects.

This chapter provides discussions related to the following items:

1. Rock cut slope design
2. Evaluation of soils and rock for use as fill material
3. Slope stability analyses
4. Settlement of embankments
5. Subgrade evaluation and modification as related to pavement design
6. Selection of foundation types for bridges and culverts
7. Scour of soils and bedrock for wet bridge crossing
8. Internal and external stability of retaining walls
9. Sliding, overturning and bearing capacity for retaining walls
10. Permeability of soils used to construct detention/retention basins
11. Sinkholes
12. Old fill/debris areas

Primary Requirements

Roadways/Streets

- One critical rock cut section shall be evaluated for each 500-foot interval of roadway cut to be constructed that will exhibit cut slopes greater than 15 feet. All data obtained from rock soundings, rock core borings and sample borings drilled within a subject interval shall be used to design the cut configuration.

- Stability analyses shall be performed for selected embankment configurations that exhibit heights greater than twenty feet. Analyses shall also be performed for all bridge approach embankments over twenty feet in height.

- If the results of stability analyses indicate unacceptable safety factors, the Geotechnical Consultant and Engineer shall evaluate possible alternatives such as flattening slopes; controlling/slowing the rate of embankment construction when short-term analyses indicate a problem; use of geogrid reinforcement; removal and replacement of foundation soils; or other applicable options.

- Stability analyses shall be performed for cuts in soil when the depth of the cut exceeds 20 feet. One critical section shall be evaluated for each 500-foot length of soil cut interval to be constructed. Cut slope geometries shall be evaluated for short-intermediate-and long-term conditions.

- Settlement analyses for roadway and bridge approach embankments shall be performed when the height of an embankment exceeds 20 feet and the thickness of compressible foundation soils is equal to or greater than 10 feet. Analyses may also be necessary when smaller embankments are planned and/or shallower foundation soils are encountered if a bridge bent will be particularly sensitive to settlement, or if the soils exhibit significant consolidation potential.

- Settlement estimates shall also be performed when short-term embankment stability analyses return unacceptable safety factors. In these cases, the results of settlement estimates and rates of consolidation shall be used to establish embankment construction rates that will help maintain acceptable stability.

- The Geotechnical Consultant shall review the results of all drilling, laboratory testing, and material quantity estimates provided by the Engineer to determine the type of subgrade that will be constructed. If sufficient rock quantities will be available from roadway excavation, a two-foot rock roadbed (subgrade) may be recommended. Rock roadbed shall be constructed in accordance with Section 204 of the KTC's current *Standard Specifications for Road and bridge Construction.*

- If sufficient rock quantities are not available, then a soil subgrade shall be constructed to support pavements. The Geotechnical Consultant shall review the result of soils testing and recommend an appropriate CBR value to be used in the design of pavements.

Single-Span Bridges

- The Geotechnical Consultant shall evaluate the subsurface conditions identified during the field and laboratory testing phases of the exploration, in conjunction with structural details, to select the most practical foundation alternates.

- Rock cores shall be reviewed to select pile tip, bottom of footing and bottom of drilled shaft elevations as applicable. An estimated allowable rock bearing capacity shall also be determined for use in design of spread footings and drilled shafts.

- If friction piles are considered as a foundation alternate, static pile capacity, driving resistances and settlement potential shall be estimated using the methods represented in the FHWA's *Soils and Foundation Workshop Manual.*

- Settlements of approach embankments at the bridge end bent positions shall be evaluated by the Geotechnical Consultant.

- Lateral squeeze of foundation soils at bridge abutment location shall be evaluated by the Geotechnical Consultant.

- If scour is a concern, the Geotechnical Consultant shall report, D_{50} values of the soils at the site, as applicable. Scour of bedrock materials may also be of concern if the rock is comprised of non-durable materials. The Geotechnical Consultant shall review the rock cores recovered during field work and identify the scourability of rock, as applicable. Guidelines presented in *Section GT-606-2 of the current KTC Geotechnical Manual* shall be used to help assess the scour potential of bedrock.

Culverts

- Engineering evaluations for reinforced concrete box culverts shall be performed to determine:

  - If the culvert needs to be designed to utilize a yielding (soil bearing) or a non-yielding (rock bearing) foundation system;

  - The settlement profile across the length of the culvert if a yielding foundation will be used;

  - An estimated bearing capacity for wingwalls which may be positioned at the ends of the culvert;

  - And to provide recommendations related to materials used to backfill behind wingwalls.

Retaining Walls

- Small walls that meet the requirements presented in KTC Standard Drawing RGX-002-06 Retaining Wall, Gravity-Type, Non-Reinforced do not require site-specific designs and geotechnical explorations. All other walls shall require individual designs and associated explorations. Tied-back, pile and lagging and drilled shaft retaining walls are not addressed by this Manual.

- The internal stability of cantilever walls and all other gravity retaining walls, except those constructed of MSE, shall be determined by the Engineer. The external stability of a wall shall be determined by the Geotechnical Consultant through evaluations of overall slope stability, overturning, sliding, bearing capacity, and differential settlements along the length of the wall.

- If the toe pressure for the wall configuration exceeds the allowable bearing capacity of the foundation materials, the Geotechnical Consultant shall provide recommendations either to reduce the pressures exerted by the wall or to improve foundation conditions. Improvements of foundation conditions shall be such that an increase in the allowable bearing capacity equal to or greater than the toe pressure will be achieved.

Sanitary and Storm Sewers

- The primary focus of a geotechnical exploration performed for sanitary and storm sewer alignments is to provide information regarding soil thicknesses and depths to the top of bedrock. The Engineer may then use this data to estimate quantities of soils and rock that will need to be excavated to install the planned utilities. Generally, only a summary of the borings performed and soil thicknesses encountered will need to be issued by the Geotechnical Consultant as a product of this exploration.

Detention/Retention Basins

- Development of a detention/retention basin commonly requires excavation of soil materials from the interior of the planned detention area and construction of an exterior compacted earth berm. Engineering analyses performed for such facilities shall include:

  - Evaluation of soils for use as fill, including moisture-density requirements for compaction efforts;

  - Assessment of the permeabilities of soils which may be used to construct the berm; and

  - Cut/Embankment slope stability studies.

- The Geotechnical Consultant shall review the results of the drilling and laboratory test programs and evaluate the soils suitability for use in developing a detention/retention facility. As a minimum, any soil used for this purpose should exhibit a hydraulic conductivity equal to or less than $1x10^{-5}$cm/sec. The Consultant shall also recommend the moisture content and percent compaction at which the soil shall be placed to achieve the desired hydraulic conductivity.

- If the height of the berm exceeds 15 feet, then slope stability analyses shall be performed. These analyses shall include evaluations of short- and long-term conditions.

Areas Used to Obtain Materials for Infrastruction Construction

- Geotechnical engineering evaluations for mass grading operations shall include:
  - Reviews of the site for problem areas such as wet, soft zones; sinkholes and other karst features; and debris/waste areas, etc.;
  - Assessments of soil and rock materials for use as fill;
  - Stability analyses for cut and fill slopes over 20 feet, or which will exhibit grades steeper than 2.5H:1V.

Sinkholes

- Sinkhole evaluations are very dependent upon reviews of physical site conditions. The Geotechnical Consultant shall assess the results of borings and test pit excavations performed at sinkhole locations, in conjunction with planned site development. The intended use of the sinkhole area will influence the remedial treatment recommended. Remedial efforts for sinkholes in landscape areas may be substantially different from those positioned within the footprint of a proposed structure. Sinkhole explorations shall result in identification of such features as *Sinkhole Related Non-Buildable Areas* in accordance with *Section 6-7(1) - Sinkholes of the current Land Subdivision Regulations for Lexington, Fayette County, Kentucky*; or necessary remedial efforts shall be recommended so that such features may be used for drainage and/or development areas.

Fill/Debris Areas

- Any areas discovered on a site where old fill, construction debris, topsoil, trash, etc. have been dumped or wasted shall be identified as accurately as is practical during a subsurface exploration. The Geotechnical Consultant shall review the results of applicable test borings and test pit excavations in conjunction with previous and existing topographic data to help estimate the limits of these areas. Remedial treatment options shall also be provided by the Geotechnical Consultant.

Summary and Primary Requirements of Section 7.0

Summary

The intent of this Section 7.0 is to outline the minimum information to be included in geotechnical engineering reports; not to develop a rigid set of standard formats for presentation of data and recommendations. Unless specifically noted otherwise, all geotechnical reports shall be concise and provide appropriate discussions regarding:

- Project location and site description
- Regional and local geologic conditions
- The scope of work performed
- The results of drilling, laboratory testing and engineering analyses
- Recommendations relative to the geotechnical aspects of the project

Primary Requirements

Roadway/Streets, Bridges, Culverts and Retaining Walls

- Report format and data presentation for roadways/streets, bridges, culverts and retaining walls shall be in accordance with the KTC's *Geotechnical Manual, Section GT-800, Report Development.*

Sanitary and Storm Sewers

- Generally, a letter report shall be sufficient for geotechnical explorations related to sanitary and storm sewer projects. The letter report shall provide a brief description of the site and project location and a summary of borings performed. The summary shall identify borings by sewer line stationing if possible. Ground surface elevations, depths and elevations to the top of rock and to auger refusal shall also be reported for each boring. The scope of such a report may be expanded if additional geotechnical aspects of the project need to be addressed.

Detention/Retention Facilities

- Reports generated for detention/retention facilities shall identify:
    - The suitability of site materials to be used for construction of the facility
    - Soil compaction and hydraulic conductivity requirements
    - Results of applicable stability analyses performed
    - Recommendations for grades of outslopes to be used
- Drafted sheets shall be developed to show the plan locations of the detention/retention basin and borings performed. Sections of the proposed berm shall also be generated to show the results of stability analyses, as applicable.

Areas Used to Obtain Materials for Infrastruction Construction

- The information presented in a geotechnical report for mass grading operations shall include:

  - Evaluations of site materials planned to be used as fill

  - Recommended placement and compaction criteria

  - Results of cut and embankment stability analyses, as applicable

  - Recommended construction monitoring efforts

- Drawings depicting the positions of borings performed, graphical boring logs, results of stability analyses, and locations of problem areas identified shall also be included.

Sinkholes

- Geotechnical engineering reports generated for evaluation of sinkholes shall provide:

  - Discussions regarding the subsurface conditions observed at the sinkhole (depression location, soil types identified, groundwater or seeps noted, conditions of the bedrock surface, open throats observed, etc.).

  - Photographic documentation of test pit excavations performed at the sinkhole locations.

  - Recommended remedial efforts necessary to use the sinkhole area for the intended development or commentary that identifies the sinkhole as a "non-buildable area."

- Drawings submitted with the reports shall show the plan locations of the sinkholes, test borings, and test pit excavations. Additional drawings and/or sketches shall be provided, as necessary, to clarify recommended sinkhole treatments.

Fill/Debris Areas

- Reports for areas where old fill and/or debris have been encountered shall include:

  - Descriptions of the materials observed

  - Drawings of plan sheets showing the approximate limits of the subject area

  - Recommendations for removal and replacement of the materials, or for in-place stabilization

CHAPTER 1
GENERAL INFORMATION

1.1 Purposes and Contents of Manual

This Manual has been developed for the Lexington-Fayette Urban County Government (LFUCG), Consulting Engineers, and Developers involved in the planning, implementation and use of geotechnical explorations on infrastructure projects. The Manual establishes uniform policies and procedures, and outlines minimum requirements for such geotechnical explorations. Discussions concerning purposes of subsurface explorations; qualifications of geotechnical consultants; exploration planning, drilling and sampling; laboratory testing; engineering analyses; and report development are included.

References to the following items are made throughout the Manual:

- Annual Books of American Society for Testing and Materials (ASTM) Standards, *Soil and Rock (I): D420-D4914; and Soil and Rock (II): D 4943-latest.*

- American Association of State Highway Transportation Officials (AASHTO) *Standard Specifications for Transportation Materials and Methods of Sampling and Testing. Part I-Specifications; Part II-Tests.*

- The Kentucky Transportation Cabinet's *Geotechnical Manual*, current edition.

- The Kentucky Transportation Cabinet's *Bridge Design Guidance Manual*, current edition.

- The Kentucky Transportation Cabinet's *Professional Services Procurement Manual*, current edition.

- The Federal Highway Administration's *Soils and Foundations Workshop Manual - Second Edition. Publication No. FHWA-HI-88-009, 1993*.

- Naval Facilities Engineering Command Design Manuals, *NAVFACDM-7.1, Soil Mechanics and DM-7.2 Foundations and Earth Structures.*

- NCHRP Report 343 - *Manuals for the Design of Bridge Foundations*.

- The Federal Highways Administration's *Drilled Shafts: Construction Procedures and Design Methods - Publication No. FHWA-HI-88-042.*

- Lexington-Fayette Urban County Government Underground Storage Tank - Petroleum Products Regulations and the Hazardous Materials Ordinance §16A-8.

As a result, it is necessary for the readers of this Manual to use it in conjunction with the noted reference materials to achieve the desired benefits.

It must be emphasized that this Manual is not intended to be a set of rigid specifications, and that it does not address all possible situations and projects. Sufficient flexibility must be maintained to permit application of engineering judgment and common sense in the design of infrastructure elements, and in solving construction problems.

1.2 Project Types for Which Use of Manual is Applicable

Each year many routine infrastructure projects are designed and constructed in Fayette County through a cooperative effort of Engineers, Developers, Contractors and the LFUCG, and may generally be categorized as follows:

- Roadways and Streets
- Structures
  - Small replacement or new single-span bridges
  - Retaining walls
  - Reinforced Concrete Box Culverts
- Sanitary and Storm Sewers, Pump Stations and Associated Facilities
- Retention/Detention Facilities

These facilities may be constructed by the LFUCG with appropriated funding (capital construction projects), or they may be built by private developers and subsequently transferred to the LFUCG for ownership and maintenance. Larger and/or unique projects such as new buildings, multi-span bridges, arterial roadways, removal of underground storage tanks, hazardous materials sites, State or Federally regulated dams, landfills, etc., are not addressed by this Manual. If the reader has questions concerning application of the guidelines presented herein, he/she should contact the LFUCG for necessary clarifications prior to beginning work.

1.3 Purposes of Geotechnical Explorations

Geotechnical Engineering is the application of geology and civil engineering technology to solve civil engineering problems related to materials of the earth's crust. It includes the disciplines of soil mechanics, rock mechanics, engineering geology, geophysics, and other related sciences.

Geotechnical explorations are performed to collect soil, bedrock, and ground water data, evaluate such information, and provide recommendations for design and construction of civil engineering projects. Typical items that may be addressed during such an exploration include:

- Soil types and thicknesses
- Soil moisture contents and observed ground water conditions
- Bedrock types and qualities
- Allowable bearing capacities for soil and bedrock
- Erodability and scour potential of soils and/or bedrock
- Settlement potential
- Embankment and cut stabilities
- Subgrade support characteristics, i.e. CBR values, for roads/streets/parking lots
- Identification of potential problem areas such as soft, wet soils; karstic bedrock features - i.e., solution channels, sinkholes, caves; springs; non-engineered fill, etc

The goals of a well planned and implemented geotechnical exploration are to identify existing subsurface conditions; provide necessary geotechnical design parameters; and reduce the possibility of construction problems and change orders associated with unforeseen conditions.

1.4 Qualifications of Geotechnical Consultants

Beginning January 1, 2002, the LFUCG will require that geotechnical explorations and analyses be performed by consulting firms that are prequalified in applicable service areas by the Kentucky Transportation Cabinet (KTC). The KTC offers prequalifications in the following three areas of Geotechnical Engineering Services:

1. Laboratory Testing
2. Drilling
3. Engineering

Firms requesting prequalifications in these service areas must demonstrate the availability of experienced personnel, equipment, and facilities applicable to performing such work. As part of the KTC process, firms requesting prequalification for Laboratory Testing Services must provide verification from the AASHTO Materials Reference Laboratory (AMRL) that they have applied and paid annual fees for (1) on-site inspection of equipment and procedures used in the testing of soils, and (2) the Soil Proficiency Test Sample Program. Consulting firms that desire to be prequalified by the KTC should refer to the current edition of the KTC Professional Services Procurement Manual. **The LFUCG will require confirmation of appropriate prequalifications prior to commencement of work. A copy of the KTC's Consultant Prequalification List indicating a firm is prequalified in an applicable service area will be considered sufficient verification.**

CHAPTER 2
PROJECT REVIEW AND SITE RECONNAISSANCE

2.1 General

The initial step in performing a geotechnical exploration is to plan key elements of the study. This planning will typically include discussions with the Engineer to determine project needs; reviews of available plans, mapping and other documentation to identify the general project location, layout and regional geologic conditions; and a site reconnaissance to observe ground surface conditions, the presence of utilities and access requirements. A well planned geotechnical exploration will help determine appropriate design parameters, and should help expedite actual efforts and time required to implement field work and to generate a final report. The following sections present more detailed discussions regarding initial exploration planning and site reconnaissance. Development of boring plans and sampling frequencies are discussed in Chapter 4.

2.2 Reviews of Available Plans and Documents

The Geotechnical Consultant shall be provided with all available project plans and mapping to review prior to developing field exploration, laboratory testing and engineering analysis programs. These plans are generally available through the Engineer. The following sections identify the types of plans useful to review for specific projects.

2.2.1 Design Plans

Roadways/Streets –

- Plan views showing the proposed alignment, existing site features, underground and overhead utilities, and property owners, as applicable.

- Centerline profile showing existing groundline and planned roadway elevations along centerline of the proposed alignment.

- Cross sections exhibiting roadway/street template, existing groundline, and elevation datum.

Single-Span Bridges –

- Plan view showing the structure location, positions of substructure elements, existing site features, utilities, and property owners.

- Centerline profile indicating planned roadway grades at the abutment positions, proposed embankment and/or cut configurations at the abutments.

Reinforced Concrete Box Culverts and Associated Wingwalls –

- Plan view indicating the type, size, and location of the culvert, applicable wingwall configurations, existing site features, utilities, and property owners.

- Centerline profile showing the inlet and outlet elevations of the culvert, the amount of planned fill over the culvert, and proposed grades of the embankment slopes.

Retaining Walls –

- Plan view showing the proposed wall location, type of wall to be designed and constructed, existing site features, utilities, and property owners.

- Profile of the wall indicating maximum wall height, variations in height, and elevation datum.

- Cross sections showing proposed slopes to be retained by the wall, existing groundline and site features.

Sanitary and Storm Sewers –

- Plan view indicating the alignments of proposed sewer lines and locations of manholes, existing topography and site features, and property owner information.

- Profiles of the sewers showing planned grades and invert elevations at manhole positions.

Detention/Retention Facilities –

- Plan view indicating the location of the facility, proposed grading, existing site features, property owners, and utilities.

- Cross-sections showing the existing groundline and height of berm/embankment and/or cut to be constructed.

Mass Grading Projects

- Plan view with existing topographic mapping, proposed final grades, existing site features, utilities and property owners.

These documents can provide beneficial information for the Geotechnical Consultant to use in planning a subsurface exploration. However, quite often only very preliminary data is available. In such cases, verbal communication between the Engineer and the Geotechnical Consultant is critical to identify the project's geotechnical exploration needs.

2.2.2 Topographic and Geologic Quadrangle Maps and Natural Resources Conservation Service Data

The United States Geological Survey (USGS) publishes topographic and geologic quadrangle maps. Both types of maps are available for all of the Lexington-Fayette Urban County Government service area. These maps provide useful topographic and geologic information about a proposed project site. The Lexington area is underlain by sedimentary bedrock belonging to the Ordovician Geologic Period. Limestone, one of the rock's primary constituents, is susceptible to dissolutioning when exposed to water. This results in development of karst features such as voids, caves, clay-filled solution channels, rock crevices, etc. A review of available geologic and topographic mapping can help identify the possible presence of sinkholes at a site. If the presence of a sinkhole(s) is noted by the mapping, a geotechnical exploration can be developed to explore the feature(s) and assess its possible effects on design and construction of the planned facility.

The United States Department of Agriculture Natural Resources Conservation Service (formerly the USDA Soil Conservation Service) began publishing Soil Surveys of Kentucky's Counties in the late 1950's. These survey's were developed "to help farmers in planning the kind of management that (would) help protect their soils and provide good crop yields; assist engineers in selecting sites for roads, buildings, ponds and other structures; aid foresters in managing woodlands; and add to our knowledge of soil science". These surveys are available for the Lexington-Fayette County area and can be used to determine general types and characteristics of soils which may be present at a given project site.

Topographic and geologic quadrangle maps are available through the Kentucky Geologic Survey at the University of Kentucky. Soil surveys may be purchased through the U.S. Department of Agriculture Natural Resources Conservation Services. Other existing documentation, such as USGS Hydrologic Atlases, may also be useful to review prior to performing a physical site exploration. It must be noted that review of available mapping is only one of several steps in planning and performing a geotechnical exploration. It must also be emphasized that such mapping does not identify all karst features or problem areas that may be present at a site, and should only be used for a general review of local and regional topographic and geologic conditions.

2.3 Site Reconnaissance

An important item in planning and implementing a geotechnical exploration is the performance of a site reconnaissance. A site reconnaissance may be most useful if conducted prior to finalizing a test boring and physical exploration program. **During the reconnaissance, the Geotechnical Consultant shall visit the site and observe its general location; the position of planned project features on the site; the possible presence of underground and overhead utilities; site accessibility; indications of previous constructions activities; the occurrence of suspicious site features that may indicate the possible presence of hazardous materials or underground storage tanks; depressions or wet areas which may be associated with karst conditions and/or springs; and other significant site features.** The following sections discuss further details of performing a site reconnaissance and its associated benefits.

2.3.1 Site and Planned Facility Locations

Identification of a site's location, in conjunction with reviewing available mapping, will provide the Geotechnical Consultant with an indication of its regional geologic setting and general subsurface conditions. Observations of existing topography and activities on adjacent properties may offer insight regarding the possibility of previous grading (cut/fill) operations having occurred on the subject site. Review of existing surface drainage conditions may reveal areas of ponding water; erosion; soft, wet soils or other conditions which may need to be addressed during design and construction. **If such areas are discovered, the Geotechnical Consultant shall photograph and document their locations and conditions.** This data should also be used to help position test borings and/or other physical exploration techniques to further assess observed site conditions. **The Geotechnical Consultant shall correlate unusual or suspicious site features with planned locations of improvements to assist the Engineer in assessing how these conditions may affect design and construction. The Engineer shall be notified of any areas of concern as soon as practical.** This may provide an early opportunity to relocate planned improvements and avoid problem areas.

2.3.2 Underground and Overhead Utilities

During the site reconnaissance, the Geotechnical Consultant shall review the area for the presence of underground and overhead utilities. Available design plans may also provide information about existing utilities. The purpose of this effort is for the Geotechnical Consultant to be aware of such utilities so that they may be avoided during physical exploration of the site. It is not intended for the Geotechnical Consultant to be responsible for identifying, locating, and documenting all existing utilities. By being aware of such utilities, the Consultant can plan the subsurface exploration to help maintain an added level of safety for drilling personnel, and reduce the possibilities of disrupting utility services to the community. Table 2.1 presents a list of telephone numbers and associated organizations that should be contacted, as applicable, to help locate existing utilities prior to beginning field work.

TABLE 2. 1 - UTILITY CONTACTS

UTILITY ORGANIZATION	CONTACTS TELEPHONE NUMBER
Kentucky Underground Protection, Inc.	1-800-752-6007
Kentucky Utilities Company	(606) 278-9355 (Construction Switchboard)
Kentucky-American Water Company	(606) 268-6363 or (606)268-6354
TCI of Lexington (Telecable-direct)	(606) 268-1123, Extension 263
University of Kentucky	(606) 257-4786

Please note that Kentucky Underground Protection, Inc. (KUPI) will schedule utility locates with ACSI, AT&T, Ashland Oil, Columbia Gas, Columbia Gas Transmissions, GTE, Sprint and TCI. They will typically ask for a specific site location, and accept a request from the caller for a date and time to meet representatives on site. KUPI will provide the caller with a locate request confirmation number such as 92430435, for reference. Most of the organizations listed require two working days (48 hours) notice to schedule a utility locate. Additional utilities to those noted, and privately owned utilities, may also be present at a given site. The possible presence of these types of utilities must also be considered prior to performing any physical explorations of the subject area.

2.3.3 Site Access Requirements/Entry Permits

The Geotechnical Consultant shall determine access requirements prior to mobilizing personnel and equipment. The Consultant should identify if an area is readily accessible to equipment required to perform the exploration; or if special assistance, such as use of a bulldozer, will be necessary to access boring locations.

Some sites may require access to privately owned properties. **The Geotechnical Consultant will be responsible for obtaining permissions from applicable owners to enter and perform work on their properties. The Consultant will also be responsible for any access agreements made with such owners. If the Geotechnical Consultant is denied entry to a site, he shall contact the Engineer immediately for further direction and assistance.**

Any special entry permits required to access a property shall be identified by the Engineer, and shall be obtained by the Geotechnical Consultant prior to entering the property.

2.3.4 Hazardous Materials and Underground Storage Tanks

In January of 1987, the Lexington-Fayette Urban County Council adopted the Underground Storage Tank-Petroleum Products Regulation. That regulation defines Hazardous Materials and Underground Storage Tanks (USTs) as follows:

Hazardous Materials *- Any chemical, biological or radiological compound, gas, oil, gasoline, lubricant, or other petroleum products, substance, solution or mixture which because of its quality, quantity, concentration, physical or infectious characteristics, or any combination thereof, when released into the environment, presents or may present harmful or potentially harmful effects to human health or welfare or the environment. Hazardous materials shall include any substance, mixture, element, compound or solution in concentration greater than one (1) percent by volume designated pursuant to the Federal Water Pollution Control Act (otherwise known as the Clean Water Act) and the Comprehensive Environmental Response Compensation and Liability Act and any petroleum product as defined in this section.*

Except that radiological compounds or nuclear material shall be regulated by this chapter subject to the limits contained in the Atomic Energy Act, as amended, 42 U.S.C. 2011 et seq. and other applicable federal laws.

Underground Storage Tanks *- Any one (1) or combination of tanks (including underground pipes connected thereto) which is used to contain an accumulation of petroleum products, and the volume of which (including the volume of the underground pipes connected thereto) is ten (10) percent or more beneath the surface of the ground. Such term does not include any:*

- *(a) Farm or residential tank of eleven hundred (1100) gallons or less capacity used for storing petroleum for noncommercial purposes*
- *(b) Septic tank*
- *(c) Pipeline facility (including gathering lines) regulated under federal law*
- *(d) Surface impoundment, pit, pond, lagoon*
- *(e) Storm water or waste water collection system*
- *(f) Flow-through process tank*
- *(g) Tanks with 110 gallon capacity or less*
- *(h) Emergency spill and overfill tanks*
- *(i) Liquid trap or associated gathering lines directly related to oil or gas production and gathering operations*
- *(j) Storage tank situated in an underground area (such as a basement, cellar, mineworking, drift, shaft, or tunnel) if the storage tank is situated upon or above the surface of the floor*

The term "underground storage tank" shall not include any pipes connected to any tank that is described in (a) through (j).

Typically, the possible presence of hazardous materials and underground storage tanks is explored during performances of Level I and/or Level II Environmental Site Assessments. **Geotechnical explorations, as defined and discussed herein, do not include such environmental studies. If suspected hazardous materials and/or USTs are encountered during a pre-exploration site reconnaissance or during actual field work, the Geotechnical Consultant shall contact the Engineer for direction prior to continuing work. If such items are discovered during drilling and sampling efforts, the Geotechnical Consultant shall immediately discontinue drilling and other applicable**

exploration activities. The Geotechnical Consultant shall implement associated measures to protect personnel and the environment from exposure to the suspect materials as a result of their work, and then notify the Engineer and DEEM. The Engineer will then provide further direction concerning additional site exploration.

The reader should refer to the complete LFUCG Underground Storage Tank-Petroleum Products Regulation and the Hazard Materials Ordinance §16A-8 for additional information on these subjects.

2.3.5 Sinkholes, Springs, Etc.

During review of available mapping and performance of the site reconnaissance, the Geotechnical Consultant shall note any surface depressions and sinkholes shown on the mapping and/or observed to be present at the site. Such features will need to be explored to determine if they may be used for drainage and/or development areas, or if they will need to be classified as "Sinkhole Related Non-Buildable Areas" in accordance with Section 6-7(1)-Sinkholes of the current Land Subdivision Regulations for Lexington-Fayette County, Kentucky.

The Geotechnical Consultant shall also review the site for the presence of springs and seeps; soft, wet soils; existing fill materials; and other problem areas that may need to be addressed during design efforts and construction activities.

CHAPTER 3
DRILLING, SAMPLING AND RECORDING PROCEDURES

3.1 General

Following reviews of available design drawings and mappings, and subsequent to performance of a site reconnaissance, the Geotechnical Consultant shall develop a field exploration program. This portion of the geotechnical exploration will typically consist of drilling test borings; collecting disturbed and/or undisturbed soil samples; recovering rock core specimens; installing groundwater observation wells; logging existing rock exposures; and/or performing test pit excavations to help identify existing subsurface conditions. Project requirements and existing site conditions will obviously influence the numbers, locations, and types of borings and test pit excavations performed.

Chapter 3 defines boring types; outlines drilling, sampling, and recording procedures; and provides guidance for describing soil and bedrock materials during field work. Discussions regarding development of boring plans are presented in Chapter 4.

3.2 Methods for Drilling, Obtaining Samples, Installing Observation Wells, and Performing Test Pit Excavations

3.2.1 Types of Borings

Equipment to be used in the performance of a geotechnical exploration shall be of sufficient size and mechanical capability to perform the type of drilling and sampling required. All work shall be conducted in general accordance with applicable ASTM standards unless otherwise specifically noted herein. All borings and test pit excavations shall be properly backfilled upon completion to prevent damage to property and injury to people and animals. All firms/organizations performing test borings shall have on file within their offices a Ground Water Protection Plan which meets the requirement set forth in 401 KAR 5:037.

Discussions regarding identifications and labeling of samples, and describing the materials encountered are provided in Sections 3.3 and 3.4. Figures 3.1 through 3.5 show example formats to be used in developing boring logs.

For the purposes of developing this Manual, the following four types of borings are defined:

1. **Rock Sounding** - A mechanical auger boring drilled through soils either to a predetermined cut-off depth, to the top of bedrock, or to auger refusal. Rock soundings are generally drilled to determine soil thicknesses and the position of the top of rock relative to planned site improvements. In-depth description of subsurface materials is not performed for this type of boring. **Power augers shall be used to drill rock soundings unless other methods are approved by the LFUCG prior to performing the work.**

2. **Soil Profile Boring -** A mechanical auger boring drilled through soils either to a pre-determined cut-off depth, to the top of rock, or to auger refusal. Unlike a rock sounding, subsurface materials are identified and logged during the soil profile boring process. **These borings shall be performed in accordance with methods outlined in ASTM D 1452 and AASHTO T 203 -** ***Soil Investigation and Sampling by Auger Borings*****, unless an alternate method is approved by the LFUCG prior to the beginning of work.**

   During the augering process, the rate of rotation and the rate of down-feed of the augers shall be controlled such that individual soil types are readily discernible and the contacts between different soil horizons/deposits can be more accurately noted. All excess soil material from previous borings shall be removed from the augers prior to the beginning of a new boring to prevent mixing of soils and the possible masking of horizons. **Moisture content samples shall be obtained at a rate of one sample per five feet interval of soil drilled in all soil profile borings. Bag samples of the predominant soil types encountered during the augering process shall also be obtained from specified borings.** Additional discussions regarding moisture content and bag samples are provided in Section 3.2.2.

3. **Sample Boring** - A mechanical auger boring drilled through soils either to a predetermined cut-off depth, to the top of rock, or to auger refusal. As with the soil profile boring, subsurface materials are identified and recorded during this process. In addition, Standard Penetration Testing (SPT) and/or thin-walled (Shelby) tube sampling are performed at selected depth intervals; typically every five feet beginning approximately 2.5 feet below the ground surface. This sampling interval may be varied depending upon subsurface conditions encountered and project requirements.

   Standard penetration tests shall be conducted in accordance with ASTM D 1586 and AASHTO T 206 - *Standard Method for Penetration Test and Split-Barrel Sampling of Soils*. Standard penetration testing may be performed in granular or fine-grained soils, depending upon laboratory testing needs and data requirements.

   Thin-walled tube sampling is performed in cohesive soils such as clays, and plastic silts, and shall be conducted in accordance with ASTM D 1587 and AASHTO T 207 *Standard Method for Thin-Walled Tube Sampling of Soils*. If sample recovery is less than fifty percent, or if the recovered material is granular, a standard penetration test shall be performed immediately below the bottom depth of the sampled interval.

4. **Rock Core Boring** - A boring drilled to a selected depth into bedrock using diamond core drilling equipment. **Rock core drilling shall be performed in accordance with ASTM D 2113 and AASHTO T 225 - *Standard Method of Diamond Core Drilling for Site Investigation*.** Rock core borings may be drilled in conjunction with rock soundings, soil profile borings, and sample borings as subsurface conditions and project data requirements warrant.

3.2.2 Moisture Content and Bag Samples

Moisture content samples shall be collected from selected soil profile borings at depth intervals of five feet, and for every change in soil type. These samples consist of soil cuttings generated from the augering process. Moisture content samples shall not be collected from soil cuttings obtained below the water table. When the water table is encountered, other techniques such as thin-walled tube sampling or standard penetration testing shall be used to collect samples for moisture content testing.

Bag samples of the predominant soil types encountered shall be collected from selected soil profile borings to provide specimens for engineering classification, moisture-density (standard or modified Proctor), and California bearing ratio (CBR) testing. These samples also consist of soil cuttings generated by the augering process. Care should be exercised not to combine different soil types for the same bag sample. **Samples that will be used for a combination of classification, moisture-density, and CBR testing shall be a minimum of 50 pounds.**

3.2.3 Groundwater Observation Wells

Observations wells shall be installed in selected borings, as necessary, to provide a means of monitoring groundwater levels over extended periods of time. Guidance on where such wells are to be installed is provided in subsequent chapters. An observation well shall consist of PVC pipe with a minimum diameter of one inch. The pipe shall be perforated or horizontally slotted from the bottom of the well to within three feet of the ground surface. The maximum opening size of perforations/holes should not exceed one eighth of an inch in diameter. The maximum opening size of slots shall not exceed one sixteenth of an inch, and the length of any slot should not exceed forty percent of the circumference of the pipe. A minimum of sixteen perforations or six slots per foot of pipe should be developed. A permanent cap shall be installed on the bottom of the pipe to prevent soil intrusion during installation, and a removable cap shall be installed on the top of the pipe to prevent the introduction of foreign matter into the well between readings. Groundwater observation wells shall be installed to the depth indicated on the boring plan. The hole in which an observation well is to be installed shall exhibit a minimum diameter of four inches and shall be reasonably clean to the depth of installation. Following installation of the well, the hole may be backfilled with soil cuttings from the boring process. The top of the hole shall be mounded and graded to maintain positive drainage away from the pipe. If available backfill for the boring is of a granular nature, the top two feet of the hole shall be sealed by application of a bentonite plug. The water level shall be recorded upon completion of the well installation, and at specific intervals thereafter, as indicated by the boring plan. Figure 3.6 provides a graphical illustration of a completed observation well installation.

3.2.4 Logging Existing Rock Exposures

In some cases, it may be possible to supplement boring information with open-face logging of existing rock exposures. These exposures may consist of highway cuts, natural rock outcrops, and/or sidewalls of creek/river channels. **The visible rock shall be described in a similar manner as outlined in Section 3.4.2.** The information may be recorded using the boring log format in Figure 3.5. **Measurements of specific features such as contacts between rock types, clay seams, joints, etc., shall be referenced to an elevation datum if possible.**

3.2.5 Test Pit Excavations

Test pit excavations can provide useful information in sinkhole areas and locations on sites where old fill materials/construction debris are suspected to be present. Such excavations can help identify the vertical and horizontal limits of fill/debris; assess the extent of karst features; and evaluate possible remedial alternates. **Test pits shall be performed using appropriately sized backhoe equipment or other suitable excavation equipment and techniques. The materials encountered during this process shall be logged in a similar manner as outlined in Section 3.4.** Photographs of test pits can also be very helpful to document findings and should be used as necessary.

3.3 Sample Identification, Handling and Disposition

3.3.1 General

All samples obtained during a geotechnical exploration shall be recorded on the respective boring logs, properly labeled and placed in suitable sample containers, and stored for shipment to the testing laboratory. Care shall be exercised in the handling and transportation to minimize any disturbances of the samples. Refer to Figure 3.7 for examples of sample identification labels.

3.3.2 Disturbed Bag Samples

Soil cuttings shall be placed in a dust-proof bag of sufficient size to accommodate the quantity of sample required and of sufficient strength to resist rupture during handling and transporting. Samples that are to be subjected to classification, moisture-density, and CBR testing shall be a minimum of 50 pounds. Each sample shall be identified with a tag showing: 1) project name; 2) project number; 3) sample type and number; 4) the location or boring from which the sample was obtained; and 5) the depth interval of the sample.

3.3.3 Moisture Content "Grab" Samples

Moisture content samples shall be a minimum of eight ounces, and shall be stored in airtight containers made of either glass or plastic. Each sample shall be identified with a tag stating: 1) project name; 2) project number; 3) sample type and number; 4) the location or boring from which the sample was obtained; and 5) the depth of the sample.

3.3.4 Standard Penetration Test Samples

A standard penetration test sample shall be immediately placed in an airtight container made of plastic or glass. The container shall then be labeled with a tag identifying: 1) project name; 2) project number, 3) sample type and number; 4) the location or boring from which the sample was obtained; 5) the depth of the sample; 6) the length of recovered sample; and 7) the standard penetration test blow counts. If more than one soil type is recovered in the sampler, a separate sample container shall be used for each soil type, and the identification tags shall be labeled accordingly.

3.3.5 Thin-Walled Tube Samples

Upon retrieval of the thin-walled tube sample from the boring, the disturbed material in the upper end of the tube shall be removed and the amount of recovered sample shall be measured and recorded. The top and bottom of the tube shall then be sealed. A sample identification tag shall be affixed to the tube showing: 1) project name; 2) project number, 3) sample type and number, 4) the location or boring at which the sample was obtained, 5) the depth of the sample, and 6) the length of the recovered sample. A thin-walled tube sample shall be stored and transported in an upright posture similar to its in-situ orientation. **The**

tube sample shall not be allowed to experience large fluctuations in temperature, and shall be kept from freezing.

3.3.6 Rock Core Samples

Rock core samples shall be stored in a wooden box specifically sized and partitioned for the size of the recovered rock core. Refer to Figure 3.8 for an example of a typical core box and associated labeling. Orient the empty core box such that hinges are on the top and opposite side of the box from the person placing the rock core in the box. Open the lid, and beginning at the upper left hand corner of the box, begin filling the uppermost empty compartment with the coring run. As the uppermost compartment becomes full, continue placing core in the next lower compartment until the run is complete. Separate successive coring runs with a small block of wood (run block) of the same cross-sectional dimensions as the compartment, and label the block with the bottom depth of the coring run. **Additional run blocks or PVC pipe shall be placed in the box to note the locations and thicknesses of voids and other unrecovered materials such as clay seams and weathered rock.** Continue placing the recovered core sequentially in boxes until the termination depth of the boring is reached. The top and bottom depths of the core placed within an individual box shall be recorded on the box lid, as well as the sequential box number for that particular rock core hole. Care shall be exercised in the storage and handling of core to avoid breakage of any intact rock samples.

3.4 Soil and Bedrock Descriptions

3.4.1 Soil Descriptions

Soil materials shall be described in accordance with ASTM D 2488 and D 4083, as applicable. In general, each soil description shall include but is not limited to:

- Textural Classification (such as Clayey Sand, Lean Clay, Silt, etc.)
- Color
- Natural moisture content
- Relative-density for coarse-grained, soils
- Consistency for fine-grained soils
- Other descriptive terms relative to identification of the soil and its composition

In addition to the guidelines presented in the referenced ASTM Standards, the information included in Tables 3.1 and 3.2 shall be used to estimate relative densities and consistencies of soils.

TABLE 3. 1 - COARSE-GRAINED SOILS

SPT N-Value	Relative Density
0 - 4	very loose
5 - 10	loose
11 - 30	medium
31 - 50	dense
50+	very dense

TABLE 3. 2 - FINE-GRAINED SOILS

SPT N-Value	Unconfined Compressive Strength (TSF)	Consistency
0 - 2	0.00 - 0.25	very soft
2 - 4	0.25 - 0.50	soft
4 - 8	0.50 - 1.00	medium
8 - 15	1.00 - 2.00	stiff
>15	>2.00	very stiff

3.4.2 Bedrock Descriptions

In general, bedrock shall be described using the following parameters: rock type; color; textural characteristics such as grain size and crystalline matrix; bedding thickness; bedding attitude (i.e. degree or angle of dip, strike direction, etc.); hardness; and any supplementary descriptions such as broken, fractured, jointed, weathered, water-stained, etc.

The locations of clay seams, voids, solution features, and caves shall be accurately noted on the rock core log. The depths of any losses and regains of drilling fluid return (recorded in percentages) shall be noted. The depth of weathering near the top of bedrock shall be also recorded on the log. This weathered zone is commonly identified by the presence of decomposed rock, solutioning of intact rock, water staining, the presence of clay seams, etc. The weathered zone may be referred to as the Rock Disintegration Zone, or RDZ, in some bedrock classification systems.

An indication of the in-situ quality of the bedrock shall be obtained and recorded by estimating the Rock Quality Designation (RQD). The RQD is determined by measuring the recovered pieces of core in a single run that are over four inches in intact length, and dividing this cumulative length by the length of the corresponding coring run. The resulting number is multiplied by 100 to express the RQD value as a percentage. Breaks in the core that have been caused by drilling methods or equipment should be ignored when determining the lengths of intact pieces. If, during an individual run, more than one bedrock type is recovered, the RQD shall be estimated for each type of rock using the applicable fractional length of the coring run. **In addition to an RQD value, the run interval, recovery length, and recovery percentage shall be recorded for each coring run.**

3.5 Boring Logs

A written subsurface log shall be completed for every boring drilled, including rock soundings, and shall be prepared in general accordance with ASTM D 5434 Standard Guide for Field Logging of Subsurface Explorations in Soil and Rock. The drilling supervisor or the drill crew chief should be responsible for keeping an accurate record of the details concerning the drilling of the boring and the materials encountered. Refer to Figures 3.1 through 3.5 for example formats of completed boring logs. Information to be shown on all logs shall include but is not limited to:

- Project name, number and type
- Type of boring drilled
- Supervisor and Driller
- Person logging the boring
- Company/Organization performing the drilling
- Location of the boring (station, offset, boring number, etc.)
- Surface elevation of the boring
- Date the boring was begun and date completed
- Depth to any water table encountered and date/time of measurement. If water is not encountered, note "no water" in the appropriate space on the log
- Total depth of boring

CHAPTER 4
BORING PLANS

4.1 General

Prior to initiating field work, a boring plan and tabulation of borings shall be developed. The boring plan shall be presented on topographic or site mapping of sufficient scale to accurately depict site conditions. The plan shall show the locations and symbols for all borings proposed for the project. Symbols for different types of borings are provided in Figure 4.1. The tabulation of borings shall identify each hole; indicate the type of soil sampling to be performed and the length of rock core to be obtained; show the estimated depths of the borings; and identify any instrumentation, such as groundwater observation wells, to be installed in the borings.

The following sections of the Manual provide minimum requirements for the types and frequencies of borings and test pit excavations to be performed for specific projects. It shall be noted that additional subsurface exploration, or modifications of the guidelines presented, may be warranted depending upon site conditions observed and project requirements. Example boring plans for the different types of projects discussed are provided in Figures 4.2 through 4.10.

4.2 Roadways/Streets

4.2.1 General

A geotechnical exploration performed for a roadway/street shall provide subsurface data that may be used to evaluate:

1. Cut stability sections in soil and rock
2. Embankment construction/fill placement
3. Embankment stability
4. Settlements of embankments
5. Subgrade materials to be used for pavement support

Borings shall be performed along the roadway centerline to determine soil types and thicknesses. Soil samples collected from these borings may be subjected to standard engineering classification, water content, moisture-density, and California bearing ratio (CBR) testing. These test results shall then be used to design pavements. If significant cuts and fills are planned, then additional borings may be necessary at selected roadway sections to provide data with which evaluations of cut and embankment stabilities may be made.

4.2.2 Soil Profile Borings

Soil profile borings shall be performed at maximum 300-foot spacings along the project alignment through both cut and fill intervals. Typically, these borings shall be drilled along the centerline of the roadway. In an area of embankment construction that will require fill placement greater than 15 feet in height, the profile boring at that section shall be offset from centerline to the point of maximum fill height (the shoulder). Soil profile borings in fill intervals shall be advanced to a depth equal to the proposed fill height or to auger refusal, whichever is less. In areas requiring more than ten feet of excavation to obtain ditch grade, the boring shall be offset to the point of maximum excavation (the ditchline). Soil profile borings in a given cut interval shall be drilled to a depth equal to five feet below the ditch grade of the section on which they are to be drilled, or to auger refusal, whichever is less. Side-hill situations requiring both excavation and embankment construction at a single station may have two borings performed; one in the ditchline of the cut, and one at the fill shoulder.

Bag samples shall be collected for each soil type encountered within each 1,000-foot interval of roadway length. If the soil type collected will be used for fill during construction, then 30-pound samples shall be obtained so that enough soil will be available for appropriate laboratory testing. For roadways/streets less than 1,000-feet in length, a minimum of two bag samples shall be collected, even if only one soil type is visually identified in the borings. **Moisture content samples shall be recovered from each soil profile boring, as described in Sections 3.2.1 and 3.2.2.**

4.2.3 Cut Stability Borings

Cut intervals may require rock core borings, rock soundings, sample borings, and/or open face logging to provide sufficient data for cut slope design. **In general, at least one critical cut slope section shall be evaluated for each 500-foot length of roadway cut interval, or fraction thereof, which will exhibit cuts deeper than 15 feet.** Identification of a "critical section" requires engineering judgment and experience. A critical cut section is typically one that exhibits the deepest proposed excavation, and/or will expose complicated geologic conditions. **Rock core borings shall be located such that core samples from the entire geologic column, from the highest point in the cut interval to five feet below the lowest point of the ditch in the cut interval, are retrieved.** Cuts in steep side-hill situations may require more than one rock core boring per critical section to provide sufficient data for design of the cut slope. The first core boring shall be drilled in the ditchline, and the second boring drilled near the top of the proposed cut slope. Where more than one rock core boring is required to represent the entire geologic column in a cut interval, the rock recovered from the borings shall overlap a minimum of 10 feet, by elevation, in both cross section and profile views. If bedrock is not encountered within 10 feet of the ground surface in the rock core boring of a critical cut section, a sample boring shall be performed a minimum of 20 feet upslope and perpendicular to centerline from the rock core boring. An observation well shall be installed in this additional boring to monitor groundwater levels if the soil depth at this location exceeds 5 feet. To further identify soil depths within a cut interval, rock soundings shall be performed in the ditchline at approximate intervals of 100 feet. Such soundings shall be drilled to auger refusal or to a depth of five feet below the ditchline, whichever is less.

4.2.4 Embankment Stability Borings

Embankment stability borings shall be performed for proposed critical embankment sections that are greater than 20 feet in height from toe to crest. In general, at least one critical embankment section shall be evaluated for each 1,000-foot length of fill interval, or fraction thereof. A critical embankment section may be identified as the cross section exhibiting the tallest or least stable embankment configuration within the fill interval. Assessment of the plans and cross-sections to select critical sections requires engineering judgment and experience. **Embankment stability borings shall consist of sample borings and/or soil profile borings drilled to a depth equal to twice the height of the proposed embankment or to bedrock, whichever is less.** Two borings shall be performed for each critical section; one at the point of highest fill placement (the shoulder), and one boring near the toe of the proposed slope. When soil thicknesses exceed 5 feet in a sample boring drilled for evaluation of embankment stability, a groundwater observation well shall be installed prior to backfilling. Observation well readings shall be performed periodically to provide groundwater data to use in subsequent embankment stability analyses.

4.3 Single-Span Bridges

4.3.1 General

Subsurface explorations for bridges shall be conducted to provide geotechnical data to be used in:

1. Design of foundation elements

2. Evaluation of approach embankment settlement and stability

3. Estimation of soil/rock scour depths for wet crossings.

Combinations of rock soundings, sample borings, and rock core borings are commonly used to explore subsurface conditions for structure locations.

4.3.2 Sample and Rock Core Borings

A minimum of one sample boring shall be drilled at each abutment location. Where the proposed approach or spill-through embankments to the bridge exceed 20 feet in height (measured from toe to shoulder), a second sample boring shall be drilled at the toe of the spillthrough slope considered to be most critical. These borings shall be drilled to auger refusal. Rock coring shall also be performed at abutment locations displaying soil depths less than 60 feet. Rock coring may be conducted in the same hole drilled for a sample boring, and shall be extended to a sufficient depth to recover a minimum of 10 feet of competent bedrock from beneath the proposed bearing elevation of the abutment. If drilled shaft foundations are to be explored as options, the core boring shall be drilled into rock to a depth equal to three shaft diameters below an estimated shaft bottom elevation. Drilled shaft bottom elevations are commonly positioned five to ten feet below the top of rock for smaller bridges.

4.3.3 Rock Soundings

To supplement rockline data obtained from the sample/core boring, a rock sounding shall be drilled at the opposite end of the abutment footprint from the position of the sample/core boring. If a structure is less than 30 feet wide, or if the underlying bedrock is relatively flat, the soundings may be omitted. **If a structure is greater than 50 feet wide, an additional sounding shall be drilled within the footprint of the substructure element between the sample/core boring and the first sounding.**

4.3.4 Sloping Rocklines

If the rockline at a substructure element location is anticipated to slope significantly, one boring shall be drilled at each corner of the foundation footprint. These four borings shall consist of three soundings and one sample/rock core boring. The sample/rock core boring shall be located at the corner of the element that exhibits the highest top of rock elevation in this situation.

4.4 Reinforced Concrete Box Culverts

4.4.1 General

Geotechnical studies shall be performed for culverts to:

1. Develop foundation recommendations

2. To estimate potential settlements along the culvert profile for a soil bearing, or "yielding" foundation.

This section pertains primarily to reinforced concrete box culverts. Subsurface explorations are not typically performed for pipe culverts. However, if either the size of the pipe, the height of the embankment to be placed over the pipe, or the consistencies of the foundation soils warrant a detailed subsurface exploration for a pipe culvert, then the guidelines presented herein for single barrel culverts shall be followed.

4.4.2 Single-Barrel Culverts of Widths Six Feet or Less

Typically, for single-barrel culverts six feet or less in width, a single line of borings shall be drilled along the centerline of the culvert at approximate intervals of 50 feet. This line of borings shall include at least three sample borings with rock coring; one drilled at each end of the culvert, and one near the midpoint of the structure. The two borings at the ends of the culvert shall be sampled continuously from the proposed flowline elevation to a depth of six feet below the flowline, or until bedrock is reached, whichever is less. Sampling in the boring performed near the midpoint may be done on five-foot centers. The remaining borings shall alternate between rock soundings and rock core borings on the noted fifty-foot, center-to-center spacing.

4.4.3 Multi-Barrel Culverts and Single Barrel Culverts greater than Six Feet in Width

For multi-barreled culverts, or single-barreled culverts greater than six feet in width, borings shall be drilled along each bearing line of the culvert from the inlet to the outlet. One sample boring with rock coring shall be performed at each end of the culvert and shall oppose one another on a diagonal. The remaining borings shall alternate between soil and rock core borings along the length of each bearing line and across the width of the culvert on the noted fifty-foot, center-to-center spacing. Again, sample borings shall be drilled near the midpoint of the culvert, as for single barrel structures.

4.4.4 Notes on Rock Coring Requirements

Coring efforts shall be performed at the planned rock core boring locations only if bedrock is encountered at an elevation higher than five feet below the proposed flowline. If bedrock is encountered at a depth five feet or greater below the proposed flowline, rock coring shall not be required. Rock core borings shall extend to a minimum depth of five feet below the flowline, or be drilled a minimum of five feet into rock. Additional borings may be added if erratic top of rock elevations or severe karst conditions are discovered.

4.5 Retaining Walls

4.5.1 General

Geotechnical explorations for retaining walls are necessary to:

1. Evaluate foundation conditions
2. Estimate settlements for soil bearing structures
3. Review the overall stability of the wall and retained slope configuration
4. Provide other associated information used in design of a wall

A subsurface exploration is required for walls retaining more than six feet of soil if the backfill is to be level; for walls more than four feet in height that will retain sloping backfill; and for any wall used to retain water.

4.5.2 Soil Profile Borings

Soil profile borings shall be drilled at each end of a wall and on 50-foot centers along the length of the wall. These borings shall be drilled to depths of five feet below planned bearing elevation or to auger refusal, whichever is less. Moisture content and bag samples shall be collected as outlined in Section 4.2.2.

4.5.3 Sample Borings

Sample borings shall be drilled at the location of maximum wall height. One boring shall be positioned on the centerline of the wall. This sample boring may be used to replace a soil profile boring located near the centerline of the wall. Another sample boring shall be positioned behind the wall where material is to be retained. This sample boring shall be located at the shoulder of sloping backfill, or approximately 10 to 20 feet behind the wall for level backfill configurations. Sample borings shall be drilled to refusal or to maximum depths equal to twice the wall height, whichever is less. Thin-walled, Shelby tube sampling and/or standard penetration testing shall be performed on five-foot centers, as applicable. Additional sample borings may be performed as wall configurations and/or subsurface conditions warrant.

4.5.4 Rock Coring

Rock coring shall be performed in selected borings if rock is encountered above or within a zone five feet below planned bearing elevations. Rock cores may be obtained from soil profile borings on 100-foot centers, as applicable. The core borings shall extend to a minimum of five feet below planned bearing, or a minimum of five feet into rock.

4.5.5 Groundwater Observation Wells

Groundwater observation wells shall be installed in sample borings in which rock coring has not been performed. The wells shall be installed as outlined in Section 3.2.3.

4.6 Sanitary and Storm Sewers

Borings are commonly drilled at specified intervals along the planned alignments of sanitary and storm sewers to provide information regarding existing soil depths and the position of the top of rock. This data may then be used by the Engineer to estimate the amount of soil and rock that will need to be excavated to install the sewer lines, manholes and pump stations. Soil profile, sample, and rock core borings may be performed in place of rock soundings if there is a need to identify the subsurface materials in more detail. **Borings drilled for sewer installations shall extend to bedrock or to a minimum of three feet below planned bottoms of pipes and manholes, whichever is less.**

4.7 Detention/Retention Basins

4.7.1 General

Detention/retention facilities are often developed by excavating materials from the interior of the planned detention area and using the excavated soils to construct an exterior berm. Detention basins are sometimes formed by using fill materials exclusively. **A geotechnical exploration shall be implemented for such facilities to evaluate stability of the proposed berm and to establish compaction requirements for soils that will be used to construct the berm. The Engineer shall evaluate each detention/retention facility to determine if it could be defined as a structure regulated under 401KAR 4:030. If a detention/retention basin meets the criteria listed in that regulation, then it shall be designed in accordance with 401KAR 4:030 and Engineering Memorandum No. 5, or as otherwise directed by the LFUCG.** The guidelines presented in the LFUCG Geotechnical Manual are not applicable to such structures.

4.7.2 Borings for Detention/Retention Basins

Borings performed for the exploration of proposed detention/retention basins shall consist of a minimum of two sample borings. These borings shall be drilled at the tallest or most critical cross section for each 200-foot length, or fraction thereof, of embankment/cut to be constructed. One boring shall be drilled at the location of the downstream shoulder, and one boring at the position of the downstream toe. A bag sample of each soil type encountered shall also be collected for subsequent laboratory testing. **Observation wells shall be installed in the borings to monitor groundwater conditions.** Borings are required for embankment/cuts greater than 15 feet tall measured from toe to crest; and for any berm exhibiting slopes steeper than 2.5H:1V and which will be greater than 10 feet in height. **Borings shall be drilled to a depth equal to twice the embankment height/cut depth or to the top of bedrock, whichever is less.** The need for exploring smaller embankments/cuts and less steep slopes must be evaluated by the Geotechnical Consultant on a project by project basis.

4.8 Areas Used to Obtain Material for Infrastructure Construction

Several items shall be considered when developing a field exploration program as part of a geotechnical study for mass grading operations. The Engineer and Geotechnical Consultant shall determine areas from which borrow materials will be obtained, and areas which will receive fill. The Consultant must also consider if significant soil cut and/or fill slopes will be constructed and expected to maintain long term stability.

Borings for areas that are to undergo mass grading operations shall be spaced on a grid pattern of approximately 400 feet. The borings shall consist primarily of soil profile borings to identify the soil types present at the drilling locations. These profile borings shall be drilled to depths equal to five feet below proposed grades or to auger refusal, whichever is less. A minimum of one bag sample of soil type identified shall be collected for subsequent laboratory testing. If bedrock excavation is anticipated on the site, rock core borings shall be included in those areas where rock excavation is expected to be most extensive. Rock core borings shall extend to a minimum depth of five feet below proposed grades. If rock slopes are to remain exposed after excavation is complete, the slopes shall be designed for long-term stability based on data obtained from the rock core borings.

Proposed cut/fill soil slopes that are to remain after grading shall be evaluated for slope stability if the height of the slope, will exceed 20 feet, or the proposed slope is to be steeper than 2.5H to 1V. Two sample borings shall be drilled at the cross section of the soil slope estimated to be most critical. One boring shall be located at the top of the proposed slope, and one located at the proposed toe. Both borings shall be drilled to depths equal to twice the depth/height of the cut/fill or to auger refusal, whichever is less. Observation wells shall be installed in both borings to monitor ground water levels.

4.9 Sinkholes

Sinkholes present at a proposed site shall be explored to determine if they may be used for drainage and/or development areas, or if they will need to be classified as Sinkhole Related Non-Buildable Areas in accordance with Section 6-7(1) - *Sinkholes of the current Land Subdivision Regulations for Lexington-Fayette County, Kentucky*. Field exploration efforts performed to evaluate sinkholes often consist of either soil profile borings or test pit excavations, or a combination of the two. Evaluation of such features includes the identification of soil types, soil moisture contents, and the locations and conditions of the top of rock. Bag and moisture content samples of each soil type encountered shall be collected during the exploration.

The sinkhole size, shape, and potential effects on a planned facility will influence the type of exploration to be performed. Typically, two sinkhole situations are encountered. Refer to Figure 4.9 for a sketch of these two situations. The first situation consists of a basin that does not exhibit an open *throat* from bedrock to the ground surface. This type of basin shall be explored by drilling several soil profile borings within the basin on a grid pattern determined by the Geotechnical Consultant. Center-to-center spacings of borings shall be based on the size of the depression being explored and the level of accuracy desired from the borings. All borings shall be drilled to auger refusal. The data obtained in these borings shall help identify anomalies and variations in subsurface conditions and thereby establish if there is a need for further exploration and/or treatment.

The second situation consists of a basin showing a visible throat. The throat shall be carefully excavated or "chased" so that the extent, orientation, and impact of the sinkhole to the project can be evaluated and a treatment plan developed. Typically, backhoe equipment is used to excavate the throat area and expose the rock surface for evaluation. In this case, photographic documentation of the findings shall also be performed. The Geotechnical Consultant may choose to supplement this type of exploration with test borings.

4.10 Fill/Debris Areas

Some sites may have areas where old fill materials are present. These materials may consist of soils that have been dumped in place and not compacted; construction debris, trash, trees, etc., placed to fill in low lying areas; and/or other materials not suitable to use for planned improvements.

If old fill/construction debris/trash, etc., are encountered on a site, additional physical exploration efforts may be required to help identify the limits of such materials. Soil profile borings, sample borings, and/or test pit excavations shall be performed to help better define the vertical and horizontal extents of the fill/debris. Borings and/or pits may be positioned on a grid pattern with spacings ranging from 10 to 100 feet, depending upon the level of accuracy desired to define the limits of suspect materials.

In areas where the old fill consists primarily of uncompacted soils, sample borings shall be used most frequently. Continuous Shelby tube samples of the fill soils shall be collected from these borings to provide soil specimens for subsequent laboratory testing and evaluations.

In areas where the fill consists primarily of construction debris, trash, etc., soil sampling is not typically necessary. The main emphasis for these areas is to define the limits of such materials so they can be removed and replaced with suitable materials prior to or during project construction activities.

CHAPTER 5
LABORATORY TESTING

5.1 General

This chapter discusses laboratory testing procedures for soil and rock samples collected during geotechnical explorations. Laboratory testing is necessary to help establish specific characteristics and engineering properties of the subsurface materials encountered. Such parameters are subsequently used in engineering analyses to develop pavement designs; evaluate cut and embankment slope stabilities; estimate settlements of fills and foundation elements; determine allowable bearing capacities for the soil and/or bedrock encountered at a site; and provide construction monitoring criteria such as soil moisture-density relationships and fill compaction requirements.

The following sections identify specific test procedures and provide general guidelines for testing to be performed on different project types. Laboratory analysis is an important element of a geotechnical exploration. Testing can, however, be expensive and time consuming. **The Geotechnical Consultant shall evaluate specific project needs and develop a testing program which will provide necessary data in the most cost effective and efficient manner possible.**

5.2 Test Procedures

The following soil and rock test procedures shall be performed in accordance with ASTM, AASHTO, or Kentucky Transportation Cabinet test methods as specified. These tests are commonly used in the development of geotechnical recommendations. **The specific test methods used shall be identified on corresponding laboratory data sheets, and in the geotechnical report.**

1. ***Laboratory Determination of Moisture Contents of Soils*** The moisture contents of soil samples shall be determined in accordance with either ASTM D 2216 or AASHTO T 265. These are test procedures commonly used on both disturbed (auger cuttings, SPT samples) and undisturbed (Shelby tube) samples to determine the percent of moisture in a soil relative to the soil's dry unit weight. The results of this testing may be compared to moisture-density relationships to determine if in-situ water contents are above or below a soil's optimum moisture content. This comparison may help identify if a soil will require the addition of water, or if it will need to be dried, during construction when it is used as fill material. Review of moisture contents may also provide an indication of the presence of groundwater, seepage, very wet or dry soils, etc.

2. ***Particle Size Analysis of Soils*** - ASTM D 422 or AASHTO T 88. This procedure includes a sieve analysis, wash gradation and hydrometer analysis of a soil sample, and is used in determining the engineering classification of a soil. This battery of tests also provides specific data regarding grain sizes of a soil. Estimation of specific grain sizes may be necessary for subsequent engineering analyses. As an example, the D50 grain size of a soil is commonly used in scour evaluations for bridge foundation elements.

3. ***Specific Gravity of Soils*** - ASTM D 854 or AASHTO T 100. Specific gravity is a relationship between the unit weight of water and the unit weight of the soil. It can be used to estimate void ratio when a soil's unit weight and water content are known.

4. ***Atterberg Limits*** **–** (Liquid Limit, Plastic Limit, Plastic Index) - ASTM D 4318 or AASHTO T 90. Atterberg limits are water contents at which the engineering behavior of a soil changes. These test results help provide a qualitative indication of a soil's tendency to shrink or swell with changes in moisture contents. Atterberg limits are commonly used to establish engineering classifications of soils.

5. ***Moisture-Density Test (Standard Proctor Method)*** **–** ASTM D 698 or AASHTO T 99. This procedure determines relationships between water contents and dry unit weights of a soil sample for which 70 percent or more, by weight, of the sample passes a ¾-inch sieve. It establishes a soil's maximum dry density and optimum moisture content. The results of this test are used to develop soil

compaction criteria, and help determine percent compaction of fill during construction activities.

6. ***Moisture-Density Test (Modified Proctor Method)*** - ASTM D 1557 or AASHTO T 180. This procedure also determines relationships between moisture contents and dry unit weights of a soil sample for which over 30 percent, by weight, of the sample is retained on a ¾-sieve.

7. ***California Bearing Ratio Test*** - ASTM D 1883. The resulting CBR value is used in conjunction with traffic data to develop pavement designs. Other test methods such as AASHTO T 193 and KM 64-501 are also used to estimate CBR methods. However, ASTM D 1883 shall be followed to determine soil CBR values for all projects performed under the guidance of this Manual.

8. ***Unconfined Compression Test (Soil)*** - ASTM D 2166 or AASHTO T 208. This test is performed on specimens obtained from thin-walled tube samples and yields a sample's unconfined compressive strength, qu. A soil's unconfined compressive strength may be used to provide an estimate of allowable bearing capacities for shallow and deep foundation elements. It may also be used to estimate undrained shear strength. The undrained shear strength, c, is commonly estimated as ½ qu. This value is utilized in short term (total stress) embankment stability analyses.

9. ***Unconfined Compression Test (Rock Core Specimens)*** - ASTM D 2983 or AASHTO T 226. This test yields the unconfined compressive strength of an intact piece of rock core sample. The results may be used to estimate allowable bearing capacity values for bedrock.

10. ***Unconsolidated-Undrained Total Stress Triaxial Test*** - AASHTO or T 296. Kentucky Test Method KM 64-502. This test is performed on cohesive, thin-walled tube samples that have high silt/sand contents; or which, for other reasons, may not be suitable for standard unconfined compression testing. The results of this test may also be used to determine a soil's undrained shear strength.

11. ***Consolidated-Undrained Triaxial Test with Pore Pressure Measurements*** - ASTM D 4767 or AASHTO T 297. This test is typically performed on thin-walled tube samples to determine effective stress shear strength parameters of the soil. These test results are commonly utilized to evaluate long-term embankment stability, and cut stability.

12. ***Wash Gradation*** - ASTM D 1140 or AASHTO T 11. This procedure determines the amount of the sample that will pass a No. 200 sieve. Soils retained on the No. 200 sieve are classified as granular (sand, gravel, boulders), while soils passing through the No. 200 sieve are termed fine-grained and consist of silts and/or clays.

13. ***One-Dimensional Consolidation Test*** - ASTM D 2435 or AASHTO T 216. The consolidation test provides the void ratio reduction of a given sample versus

applied load. The results of this test are used to estimate settlements of soils when subjected to foundation and/or embankment loadings.

14. ***Subgrade Modification Test Using Chemicals*** - Kentucky Test Method KM 64-520. This test determines the percentage of a chemical (such as lime) required to improve subgrade characteristics of a tested soil.

15. ***Slake Durability Index (SDI) Test*** - Kentucky Test Method KM 64-513. This test is performed on rock core samples composed primarily of shale to provide an indication of the durability of the bedrock specimens. This data can be used to help develop rock cut slopes recommendations and establish guidelines for placement of shot rock materials as fill. The results provide an indication of how open rock cuts and shot rock materials may behave when exposed to weathering agents such as snow or rain.

16. ***Measurement of Hydraulic Conductivity*** - ASTM D 5084-90. This test is performed on undisturbed or compacted/remolded specimens which will exhibit a hydraulic conductivity less than or equal to 1x10-3 cm/s. A material's hydraulic conductivity may be used to access its suitability for use as a detention/retention berm, or liner for ponds and/or landfill applications.

17. ***Jar Slake Test*** - Kentucky Test Method KM 64-514. This test is performed on rock core samples composed primarily of shale to provide a visual observation of the weathering potential of the sample. This test is commonly used in conjunction with the results of Slake Durability Index tests to help design rock cut slopes.

5.3 Classification of Soils

Soils shall be classified and reported according to either ASTM or AASHTO procedures. Both procedures index the results of classification testing based on grain size analysis, liquid limit, and plasticity index. The ASTM procedure is designated D 2487 Classification of Soils for Engineering Purposes, and is commonly referred to as the Unified Soils Classification System (USCS). This procedure is performed on that portion of the soil sample that passes a three-inch sieve. The AASHTO procedure is designated M-145, The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes. The results of AASHTO classification testing may also be used as an evaluation of the suitability of a soil for use in embankments, subgrades, subbases, and bases for road/street projects.

5.4 Classification of Bedrock

Bedrock shall be identified and described as outlined in Section 3.4.2. Rock mass classification may be useful for some projects and may be performed in accordance with ASTM D 5878.

Fayette County, Kentucky, is underlain by sedimentary bedrock of the Ordovician Geologic Period. This bedrock is comprised predominantly of limestone and shale strata. Limestone is a carbonate rock which is bedded in thicknesses ranging from less than one inch to as much as several feet, and has crystalline structure which varies from very fine to coarse grained. The color of the limestone bedrock typically varies from light to medium gray. Darker streaks or seams of interbedded shale may be present within a given unit. Occasionally, limestone in the area contains a high percentage shale in the crystalline matrix and is termed argillaceous.

Shale is a medium to dark gray rock that is composed of clay-sized particles arranged in a matrix that texturally varies from blocky to fissile. Thicknesses of shale seams typically vary from as small as fractions of an inch to as large as several feet.

Shales may be further categorized in terms of durability. The Kentucky Transportation Cabinet uses the results of Slake Durability Index (SDI) and Jar Slake testing to identify durable and non-durable shales. Shales exhibiting SDI values grater than or equal to 95 and Jar Slake values of 6 are termed "Durable," while those shales returning lesser values are classified as "Non-durable." The non-durable shales are further subdivided into three classes by the KTC as shown in Table 5.1.

TABLE 5. 1 - NON-DURABLE SHALE CLASSES

Class	SDI Range	Jar Slake Range
I	80 - 94	4 or 5
II	50 - 79	3 or 4
III	<50	<3

5.5 Testing Requirements for Specific Project Types

5.5.1 General

Laboratory testing guidelines for different project types are discussed in the following sections of this chapter. Geotechnical parameters obtained from testing and their intended uses in subsequent engineering analyses/evaluations are also identified.

5.5.2 Roadways/Streets

Laboratory evaluations for recovered bedrock samples from cut stability sections shall consist of slake durability index and jar slake testing. These tests shall be performed using portions of the core specimens that consist primarily of shale. One SDI/jar slake sample shall be tested for each five-foot length, or fraction thereof, of shale recovered during the coring process. SDI/jar slake testing of samples comprised predominantly of limestone should not be necessary. The results of these tests are used by the Geotechnical Consultant to assess the durability of rock that will be excavated from cut areas and possibly used in fills; and to help evaluate the weathering potential of exposed rock cuts.

SPT and Shelby Tube Samples

SPT and Shelby tube samples are typically collected from borings performed in areas where soil cut and embankment stability analyses are required. Therefore, laboratory testing must provide data necessary to conduct such analyses. Engineering classification, moisture content and shear strength tests are required to derive applicable soil parameters for stability analyses. **Standard penetration test and Shelby tube samples shall be subjected to standard engineering classification testing consisting of particle size analysis, specific gravity and Atterberg limits. Moisture content testing shall be performed on each SPT sample.**

One unconfined compression test shall be conducted on each tube sample obtained from embankment stability borings. The results of these tests may be used to estimate undrained soil shear strengths for modeling short-term embankment stability evaluations. **Consolidated-undrained triaxial compression tests shall be performed using representative tube samples of each type of soil identified by the borings.** Effective stress shear strength parameters should be developed from these test results. These parameters will subsequently be utilized in performing embankment stability analyses for long-term loading conditions, and for soil cut stability analyses.

Bag Samples

Bag samples consisting of soils which will be used to construct roadway/street fills, and of soils near subgrade elevations, shall be subjected to particle size analyses, specific gravity, Atterberg limits, standard Proctor and CBR testing. These parameters will be used during engineering evaluations to provide fill compaction and embankment construction criteria. CBR values shall be used by the Engineer in designing required pavement thicknesses.

Bag samples consisting of soils which will be three-feet or more below grade and will not be used as fill shall only be subjected to engineering classification testing, i.e., particle size analysis, specific gravity and Atterberg limits.

Moisture Content Samples

Water content testing shall be performed on all moisture content samples consisting of auger cuttings obtained from soil profile borings.

Consolidation Testing

If the heights of any embankments, in conjunction with observed subsurface conditions, are such that significant settlements of foundation soils are anticipated, one-dimensional consolidation testing of the soils shall be performed. One consolidation test shall be completed for each type of soil encountered in borings performed within planned fill areas. If the thickness of any one soil type exceeds five feet, then consolidation testing shall be performed for each sample collected within this soil on five-foot centers. The results of consolidation testing shall be used to estimate potential embankment settlements. These test results may also be utilized to help determine the required rate of embankment construction to maintain acceptable factors of safety for slope stability, as applicable.

5.5.3 Single-Span Bridges

As discussed in Section 4.3, a geotechnical exploration for a single-span bridge is performed to provide:

1. Foundation recommendations for the end bents/abutments
2. Evaluate stability of approach embankment slopes
3. Provide soil data for use in evaluating scour at foundation element locations for wet crossings

An appropriate laboratory testing program shall be implemented to determine the soil and rock parameters necessary to perform the required analyses and develop applicable recommendations.

Unconfined compression testing shall be performed at depth intervals of five feet on recovered samples of rock core. These test results will be used to help estimate allowable rock bearing capacities for foundation elements. SDI/jar slake testing may also be useful if it is anticipated that foundation excavations in rock may be exposed to water. **SDI testing shall be performed as outlined in Section 5.5.2, if necessary.**

SPT and Shelby tube samples shall be subjected to the same tests as outlined in Section 5.5.2. The results will be used to determine allowable soil bearing capacities, as applicable;

evaluate approach embankment stability; and estimate embankment settlements. In addition, soil particle size test results (D50 grain sizes) may be used by the Engineer in evaluating scour potential of the soils at substructure element positions.

5.5.4 Reinforced Concrete Box Culverts

A laboratory testing program for a culvert shall develop parameters which may be used to determine if the structure's foundations may be designed as "yielding" or "non-yielding"; establish soil and /or rock bearing capacities for use in design of wingwall foundations; and estimate the amount of settlement the soils upon which the culvert will be founded may experience as a result of fill placed over the culvert or from structural loads imposed by the culvert itself.

To develop these parameters the following tests shall be performed:

1. **Soil classification of SPT and Shelby tube samples. SPT samples of the same soil type may be combined to perform this testing. One classification test shall be performed on a representative Shelby tube sample of each different soil type encountered. It is not required that each Shelby tube and SPT sample be subjected to classification testing.**

2. **If the wingwalls and culvert barrel will be founded on soil, then unconfined compression testing shall be conducted on each tube sample.**

3. **If it is expected that planned fill will cause settlement of the foundation soils beneath the culvert, then one-dimensional consolidation testing of each soil type encountered during drilling efforts shall be performed.**

4. **Water content testing shall be conducted on each recovered sample. If the moisture content of a sample will be determined as part of other testing, it is not necessary to run additional water content tests on that particular sample.**

5.5.5 Retaining Walls

Laboratory testing of soil/rock samples recovered at retaining wall locations shall be performed as outlined for culverts in Section 5.5.4. In addition, consolidated undrained triaxial testing of foundation soils and of materials to be retained by the wall shall be completed, as applicable. Results of this type of testing are necessary to develop shear strength parameters used in evaluating overall stability of the proposed wall/slope configuration. This testing shall be performed on each type of foundation soil encountered, and on each type of material to be retained.

5.5.6 Sanitary and Storm Sewers

Typically, only rock soundings, and/or rock core borings are performed for exploration of sanitary and storm sewer lines. Soil sampling is usually not required. Therefore, laboratory testing on recovered samples is not commonly applicable. Occasionally, however, there may be a need to evaluate subsurface materials more in depth. **In such cases, the Geotechnical Consultant shall develop drilling, sampling and testing programs to provide the necessary information.**

5.5.7 Detention/Retention Basins

The primary focuses of performing geotechnical explorations for detention/retention basins are to establish soil compaction and permeability criteria for fill placement; and to evaluate embankment/cut stabilities. **Therefore, testing of recovered samples from these areas shall be tailored to provide shear strength parameters used in stability analyses and moisture-density relationships with which to establish fill compaction requirements.**

Standard penetration tests and Shelby tube samples shall be subjected to the same testing as outlined in 5.5.2. Bag samples collected form soils that may be used as fill in construction of the detention/retention berm shall be classified according to the USCS. Standard Proctor (moisture-density) and permeability testing shall also be performed on bag samples of each soil type observed in order to establish compaction requirements.

5.5.8 Areas Used to Obtain Material for Infrastructure Construction

Bag samples collected from soils that will be used as fill shall be subjected to engineering classification and standard Proctor testing. CBR testing shall be performed using these soil samples if the material is to be used as subgrade support beneath pavements. One set of classification tests, one Proctor and one CBR test shall be conducted for each soil type obtained from cut areas, as applicable.

SPT and Shelby tube samples collected from significant cut and/or fill areas shall be tested as outlined in Section 5.5.2. Moisture content testing of each "grab" sample obtained from soil profile borings shall also be performed.

5.5.9 Sinkholes

Classification tests shall be performed on a representative bag sample obtained from each different soil type encountered in the field. If soils excavated during performance of the test pits are to be re-used to fill the pits, then standard Proctor testing shall also be performed on such materials to establish moisture-density relationships and compaction control criteria. Water content testing shall be conducted on "grab" samples collected at the site. The results of the moisture content tests may show that wet soils are present, which may provide an indication of the presence of water associated with karst activity.

5.5.10 Fill/Debris Areas

As described in Section 4.10, soil profile and sample borings may be conducted in areas where old fill soils, relatively free of other deleterious materials, have been placed without being compacted. **SPT and Shelby tube samples from such borings shall be classified**

according the USCS. Shelby tube samples shall also be extruded, trimmed to six -inch long specimens, and measured for unit weight. **Moisture content tests shall be conducted on each SPT and "grab" sample obtained from the borings. Bag samples collected of the predominant soils shall be tested to establish their standard Proctor maximum dry densities and optimum moisture contents.** These values can then be compared to the unit weights of the Shelby tube samples to provide an indication of the percent compaction the soils may exhibit in their existing conditions. The results of such testing may provide an indication of the acceptability of existing soil densities, or if the soils will need to be removed and replaced using appropriate moisture-density control.

Laboratory testing of soils containing significant amounts of construction debris, trash, organics, etc., is usually not necessary. Removal of these materials from the site is quite often the most practical option for remediation.

CHAPTER 6
ENGINEERING ANALYSES AND EVALUATIONS

6.1 General

Chapter 6 provides information for performing geotechnical engineering analyses and evaluations on routine infrastructure projects. It must be noted that the analytical procedures outlined herein may not be the only acceptable methods of performing some analyses. **The Geotechnical Consultant shall select appropriate methods to perform engineering evaluations and shall document the methods used.**

Additional studies may be necessary for other project situations and unique conditions not specifically addressed by this Manual. The Geotechnical Consultant and the Engineer shall review development plans and site characteristics to identify areas and project features that may warrant additional evaluations.

This chapter provides discussions related to the following items:

1. Rock cut slope design
2. Evaluation of soils and rock for use as fill material
3. Slope stability analyses
4. Settlement of embankments
5. Subgrade evaluation and modification as related to pavement design
6. Selection of foundation types for bridges and culverts
7. Scour of soils and bedrock for wet bridge crossing
8. Internal and external stability of retaining walls
9. Sliding, overturning and bearing capacity for retaining walls
10. Permeability of soils used to construct detention/retention basins
11. Sinkholes
12. Old fill/debris areas

Although this chapter is organized to identify specific project types, many analyses are common to several categories of projects. Such analyses will be identified by reference to previous sections, as applicable.

6.2 Roadways/Streets

6.2.1 General

As noted in Chapter 5, a geotechnical exploration for a roadway/street project shall provide subsurface data that may be used to:

- **Design rock cut slope configurations**
- **Perform soil cut and embankment stability analyses**
- **Estimate settlements of larger embankments**
- **Evaluate subgrade conditions and develop recommendations for pavement designs**
- **Identify problem areas which may require special design and construction considerations**

The drilling, sampling and laboratory testing programs discussed in Chapters 3 through 5 shall be established to provide the necessary data to perform these evaluations and develop applicable recommendations for roadway design and construction.

6.2.2 Rock Cut Slope Design

One critical rock cut section shall be evaluated for each 500-foot interval of roadway cut to be constructed that will exhibit cut slopes greater than 15 feet. All data obtained from rock soundings, rock core borings and sample borings drilled within a subject interval shall be used to design the cut configuration. The results of laboratory evaluations such as SDI and Jar Slake tests must also be used, as applicable, to assist in designing rock cut slopes.

Cut slope geometries should be based primarily on the inclination and continuity of joints identified within the bedrock. Such features significantly influence the grades or angles of cut slopes used. The lithology of the bedrock to be exposed also influences cut slope grades, but plays a more substantial role in selecting the locations of intermediate benches to be constructed. Intermediate benches should typically be positioned at the top of the lithologic unit that will be least resistant to weathering and degradation when exposed in an open cut.

Limestone

Bedrock within the Lexington, Kentucky area is commonly comprised of limestone with varying percentages of shale. If the bedrock unit is composed primarily of massive limestone, cut slope configurations ranging from 1/2H:1V to 1H:20V may be used. The grade of the slope selected will depend upon the presence of joints, fractures, solution features, bedding conditions, etc. Lift heights up to a maximum of 60 feet may be used in such rock. Intermediate bench widths in the rock cut slope may vary from 18 to 20 feet.

Shaley Limestone

If the bedrock unit consists of shaley limestone, or has zones of shale throughout its lithology, then cut slopes may vary from 2H:1V to 1/2H:1V. Maximum lift heights in this type of rock may range up to 45 feet. Intermediate benches will typically exhibit widths of 18 to 20 feet.

Intermediate Bench

The elevations/positions of intermediate benches are determined by changes in lithology and/or lift heights. As previously noted, intermediate benches should be located at the tops of materials that are expected to weather, degrade and possibly undercut more resistant rock units.

It should be noted that 18-foot wide intermediate benches are frequently used below lift heights of 30 feet or less. Cuts exceeding 30 feet in height should be positioned above minimum 20-foot wide intermediate benches. The widths of benches may be increased depending upon specific geologic conditions and project requirements.

Intermediate benches that will intercept ditch grade should be transitioned to zero width at the ditch. This transition should be constructed over a horizontal distance ranging from approximately 150 to 200 feet.

Overburden Benches

If soil thicknesses at the top of the cut exceed five feet, or if the Rock Disintegration Zone (RDZ) is deeper than five feet, overburden benches may be constructed at the base of the RDZ. Overburden bench widths are commonly about 15 feet. Such benches may exhibit grade changes through a given cut interval. If the terrain is steep or if the depth from the top of the cut to the base of the RDZ is less than five feet, overburden benches may be omitted.

Additional discussions regarding rock cut slope design are provided in the current edition of the KTC *Geotechnical Manual* and Publication No. FHWA-TS-89-045, *Rock Slopes: Design, Excavation, and Stabilization.*

6.2.3 Slope Stability

6.2.3.1. General

Slope stability is defined as the ratio of available shear strength of an embankment/cut configuration along a predicted failure surface to the strength required to maintain equilibrium of the slope being evaluated, and is represented by a safety factor. Safety factors greater than 1.0 do not necessarily constitute reserves of unused shear strength. Rather, the safety factor is a working element of design. Target factors of safety are identified to accommodate uncertainties in modeling; site geometries; characteristics of soils and other construction materials; the estimated position and influence of the groundwater table; and construction techniques. Confidence and reliability in these parameters influence the selection of target safety factors to be used when evaluating slope stability. The values presented in Table 6.1 may be used as a guide in selecting target safety factors.

TABLE 6. 1 - TARGET FACTORS OF SAFETY
SLOPE STABILITY ANALYSES

Condition Evaluated	Short Term	Intermediate	Long Term	Rapid Drawdown
Roadway and mass grading embankments	1.1 - 1.3	*	1.4 - 1.6	1.0 - 1.2
Bridge approach slopes, retaining walls (external or overall wall stability) embankments over culverts	1.2 - 1.4	*	1.6 - 1.8	1.0 - 1.2
Cut slopes in soil	1.2 - 1.4	1.2 - 1.4	1.4 - 1.6	*
***Not applicable**				

More specific discussions regarding short-term, intermediate, long-term, and rapid-drawdown analyses are provided in subsequent sub-sections of this Chapter.

6.2.3.2. Selection of Shear Strength Parameters

The results of the drilling and laboratory testing programs of a geotechnical exploration must be used to develop models of subsurface conditions at critical stability sections. These models will be used in conjunction with proposed slope configurations to evaluate stability. Shear strength parameters for each subsurface soil type encountered and for each embankment/fill material to be placed must be established for subsequent use in the analyses.

Cohesive Soils

Shear strength parameters of cohesive soils (i.e. clays and plastic silts) shall be based upon SPT and/or laboratory test results. Short-term, or total stress parameters, for embankment construction should be established from a review of unconfined compression, standard penetration, and/or unconsolidated-undrained triaxial testing.

Quality Shelby tube samples of cohesive soils may not always be available for testing for various reasons such as low sample recoveries, higher percentages of rock fragments within the samples, sample disturbance, etc. Shear strength parameters in these cases may need to be estimated by correlating SPT N-values and/or soil classifications with published data. NAVFAC DM-7.2 and the FHWA's *Soils and Foundations Workshop Manual* contain such correlations for reference.

Granular Soils

Shear strength parameters for granular soils shall be developed using SPT N-values corrected for existing overburden pressures, and published correlations such as those presented in NAVFAC DM-7.2 and the FHWA's *Soils and Foundation Workshop Manual*.

Compacted Embankments

Shear strength properties of proposed embankment materials must also be determined for use in embankment stability evaluations. Shear strength testing such as unconfined compressive strength, unconsolidated undrain triaxials (U-U tests) and consolidated undrained triaxials (CU tests) may be performed using remolded samples of proposed fill materials. Such testing may be conducted during the geotechnical exploration if fill/embankment materials can be specifically identified. Many times precise identification of fill soils/borrow materials is not possible during the design phase. In such cases, an estimation of the shear strengths of compacted soils may be developed using references of material properties presented in NAVFAC DM-7.2.

The values presented in Table 6.2 may also be used for embankments constructed primarily of rock.

TABLE 6. 2 - SHEAR STRENGTH PARAMETERS FOR ROCK EMBANKMENTS

Rock Type	Total Stress (Short term)	Effective Stress (Long Term)
Limestone, Durable Shale, Select Granular Embankment*	ϕ = 34°-40°, c = 0	ϕ' = 34°-40°, c' = 0
Non-Durable Shale		
Class I	ϕ = 0°, c = 1000-1500 psf	ϕ' = 28°-32°, c' = 100 psf
Class II	ϕ = 0°, c = 1000-1500 psf	ϕ' = 23°-27°, c' = 150 psf
Class III	ϕ = 0°, c = 1000-1500 psf	ϕ' = 18°-22°, c' = 200 psf

*Select Granular Embankment is as defined in the current edition of the KTC's *Special Provision No. 69.*

6.2.3.3. Embankment Stability

Stability analyses shall be performed for selected embankment configurations that exhibit heights greater than twenty feet. Analyses shall also be performed for all bridge approach embankments over twenty feet in height. The spill-thru slope beneath a bridge often displays more critical stability conditions than adjacent roadway slopes. The height of an embankment is defined as the difference in elevation measured from the toe of the fill slope up to shoulder grade. As discussed in Section 4.2.4, the critical cross-section selected will generally represent the tallest embankment configuration within a given interval. Embankments less than twenty feet in height may also need to be checked for stability if unusual subsurface conditions are identified, or fill slopes steeper than 2H:1V are proposed.

The stability of several different loading conditions shall be evaluated depending upon the planned embankment configurations and identified subsurface conditions. Short-term, long-term and rapid draw-down (as applicable) loading conditions are commonly evaluated for critical embankment sections.

Short-Term Conditions

Short-term analyses are performed using total stress shear strength parameters for both foundation soils and embankment materials. This evaluation models conditions that may exist during or shortly after construction. When cohesive foundation soils are loaded by embankment placement, increases in pore water pressures develop which can significantly reduce a soil's shear strength. Because clayey soils have low permeability and drain slowly, dissipation of pore water pressures induced by embankment loads also occurs slowly. Short term loading is commonly the critical embankment stability condition for cohesive foundation and fill soils. Pore water pressures which develop from embankment loading in granular soils, and in granular components of layered foundation systems, dissipate relatively quickly because of the soil's higher permeability and more free-draining characteristics. Effective stress shear strengths of granular soils shall be used even when evaluating short-term stability.

Long-Term Conditions

Long-term embankment stability analyses model conditions that may exist following embankment construction and after excess pore water pressures have dissipated. Long-term analyses shall be performed using effective stress parameters for both cohesive and granular soil types.

Rapid Draw-Down Analyses

Some roadway embankments may be subjected to high water ponded against the outslopes during flood events. This situation may cause embankment and foundation soils to become saturated. Soils may not drain as quickly as the water recedes and may remain saturated for some period after the water returns to its normal lower elevation. This situation can create a critical embankment stability condition commonly referred to as a "rapid draw-down" condition. Stability analyses performed to evaluate this situation shall model the embankment as being saturated up to the high water elevation, and shall be performed using effective stress parameters for foundation soils and embankment materials.

The target factors of safety presented in Table 6.1 shall be used to evaluate whether or not acceptable slope stability will be exhibited by proposed embankment configurations.

If the results of stability analyses indicate unacceptable safety factors, the Geotechnical Consultant and Engineer shall evaluate possible alternatives such as flattening slopes; controlling/slowing the rate of embankment construction when short-term analyses indicate a problem; use of geogrid reinforcement; removal and replacement of foundation soils; or other applicable options.

6.2.3.4. Soil Cut Stability

Stability analyses shall be performed for cuts in soil when the depth of the cut exceeds 20 feet. One critical section shall be evaluated for each 500-foot length of soil cut interval to be constructed. This section should commonly represent the deepest cut within a given interval. Cuts less than 20 feet deep shall be evaluated if unusual subsurface conditions are identified; if slopes steeper than 2H:1V are planned; and if structures or other features will be positioned near the daylight point of the top of the cut. Soil cut stability sections may also need to be analyzed if problems in cut-to-fill transitions are anticipated.

Cut slope geometries shall be evaluated for short-intermediate- and long-term conditions. Although the intermediate- or long-term conditions may be critical for most soil cuts, short-term analyses using total stress parameters in cohesive soils may be warranted. Cuts constructed in soft cohesive soils may have a tendency to develop high positive excess pore water pressures during shear, which could result in a critical total stress condition. The Geotechnical Consultant shall evaluate the need to analyze short-term conditions for soil cuts on a case by case basis. For granular soils, or granular components of layered systems, the short-term condition is identical to the intermediate-term condition, and both shall be performed using effective shear strength stress parameters.

The presence of a water table within a planned cut section may have a significant effect on the stability of the slope. During evaluation of this condition, the water table shall be positioned at its maximum anticipated elevation, even though the water table may actually be lowered as a result of the cut. The intermediate-term condition shall also be modeled using effective stress parameters obtained from laboratory testing and applicable correlations of published data for each soil type observed.

Long-term analyses model conditions after excess pore water pressures have dissipated and the groundwater table has been lowered because of the cut. As the water table lowers, an increase in the safety factor may occur. However, cohesive soils will tend to swell as a result of stress relief and exposure to rain and snow. This swelling effect may cause a decrease in soil shear strengths and, consequently, a decrease in slope stability. The Geotechnical Consultant shall model this condition by reducing the cohesion for long-term analyses to 20 percent of the value used during intermediate-term analyses. Highly plastic clays may experience severe swelling and softening, and commonly exhibit significant potential for sloughing-types of slope failures. Long-term conditions in these types of soils may be more accurately modeled by neglecting cohesion all together in the analyses. The long-term condition is frequently the most critical concern for cuts in soils.

6.2.4 Settlements of Roadway and Bridge Approach Embankments

6.2.4.1. General

Settlement analyses for roadway and bridge approach embankments shall be performed when the height of an embankment exceeds 20 feet and the thickness of compressible foundation soils is equal to or greater than 10 feet. Analyses may also be necessary when smaller embankments are planned and/or shallower foundation soils are encountered if a bridge bent will be particularly sensitive to settlement, or if the soils exhibit significant consolidation potential.

Evaluation of settlement may be particularly important at structure locations such as bridge bents/abutments, reinforced concrete box culverts and pipe culverts. Settlement considerations at bridges may influence what types of foundation systems to use and when the foundations may be installed. Magnitudes of total settlements may also influence culvert design and construction. As an example, a culvert flow line may need to be cambered near the middle of the structure to help accommodate future settlements and remain functional. Additional discussions regarding settlements of embankments at bridge and culvert locations are provided in Sections 6.3. and 6.4.

Settlement estimates shall also be performed when short-term embankment stability analyses return unacceptable safety factors. In these cases, the results of settlement estimates and rates of consolidation may be used to establish embankment construction rates that will help maintain acceptable stability.

6.2.4.2. Methods to Estimate Settlement

Numerous methods are available to use in performing settlement analyses and estimating consolidation rates. For the purposes of this Manual, it is recommended that procedures presented in the FHWA's *Soils and Foundation Workshop Manual* be used to perform such calculations. The current addition of the KTC's *Geotechnical Manual* also outlines procedures for evaluating controlled embankment construction (See KTC *Geotechnical Manual - GT-601-7; Slope Stability - Controlled Loading*).

6.2.5 Subgrade Evaluation and Pavement Design Considerations

6.2.5.1. General

Some of the largest costs associated with roadways/streets are construction and maintenance of pavements. A pavement section typically consists of: a soil or rock subgrade; an aggregate base, commonly DGA or crushed stone; and subsequent layers of asphalt or concrete. The subgrade is a very important component of the pavement system, particularly when asphalt is used to complete the section. Most pavement design methodologies are based upon using traffic volumes and some index of subgrade strength, such as CBR or Resilient Modulus values, to estimate required aggregate base and asphalt thicknesses. The lower the subgrade strength, i.e. the lower the CBR or resilient modulus value, the thicker the pavement section becomes for a given traffic volume. Combinations of low subgrade strength and high traffic volumes can result in very thick pavement sections. This Manual provides guidance related to evaluation of subgrade materials used in design and construction of pavements. Specific pavement design criteria and methodologies are presented in the LFUCG *Roadway Manual*.

6.2.5.2. Selection of CBR Values

The Geotechnical Consultant shall review the results of all drilling, laboratory testing, and material quantity estimates provided by the Engineer to determine the type of subgrade that will be constructed. If sufficient rock quantities will be available from roadway excavation, a two-foot rock roadbed (subgrade) should be utilized. Rock roadbed should be constructed in accordance with Section 204 of the KTC's current *Standard Specifications for Road and Bridge Construction.*

Rock Roadbed

Typical CBR values to be used for rock roadbed in design of pavement sections are presented in Table 6.3.

TABLE 6. 3 - CBR VALUES FOR ROCK ROADBEDS

Material Type	Estimated CBR Values
Limestone, Durable Sandstone	9 to 11
Non-durable Sandstone, Durable Shale	7 to 11
Non-Durable Shale*	2 to 5
*May require additional chemical modification to provide adequate subgrade strength.	

Soil Subgrade

If sufficient rock quantities are not available, then a soil subgrade will be constructed to support pavements. **The Geotechnical Consultant shall review the result of soils testing and recommend an appropriate CBR value to be used in the design of pavements.**

Soils within the Lexington Area commonly consist of moderately to highly plastic clays that swell and lose shear strength when exposed to water. These soils generally exhibit low CBR values and classify as relatively poor subgrade materials for use in support of pavements. Typical CBR values for soils in this area of Kentucky range from one to five, and rarely exceed six.

In addition to a resulting increase in pavement thickness, clayey soils with low CBR values can present constructability difficulties. When such soils become wet they are difficult to place and compact. Even when proper compaction is achieved, soil subgrades exposed to weather and construction traffic prior to completion of the pavement section will deteriorate and often require re-working or stabilization efforts. Modification of the subgrade soils prior to construction of the aggregate base and asphalt courses can result in reduced pavement thicknesses, increased constructability, and extended service life.

Chemical Modification of Subgrades

The Geotechnical Consultant shall evaluate the results of CBR testing performed on soil types that will be used for pavement subgrade construction. If the soils exhibit CBR's equal to or less than four, then chemical or mechanical modification of the subgrade shall be utilized. Clayey soils requiring stabilization and exhibiting plasticity indices greater than 20 should normally be treated with lime. Silty or sandy soils with plasticity indices less than 20 are commonly cement modified.

The appropriate chemical treatment shall be determined in accordance with the FHWA's *Soil Stabilization Manual, FHWA-ID-80-2*. Guidelines for construction using lime and cement shall be in accordance with the KTC's Special Provision No. 84, current edition, and Section 304 of the current KTC *Standard Specifications for Road and Bridge Construction*.

Acceptable alternatives to chemical modification of subgrade soils on relatively small projects may be replacement of a portion of the soil subgrade with aggregate such as No. 2 Stone, or use of a combination crushed stone and a geotextile fabric.

If the subgrade is chemically or mechanically modified, the resulting increase in shear strength of the modified zone may be included in design of the pavement section. The AASHTO method of pavement design shall be used to design required pavement sections. This method is based upon the assignment of structural numbers, or coefficients, to pavement components. The following structural numbers shall be used for modified subgrade thicknesses:

TABLE 6. 4 - AASHTO STRUCTURAL NUMBERS FOR MODIFIED SUBGRADES

Modified Subgrade Type	**AASHTO Structural Number**
Chemically modified by use of lime or cement	0.08 to 0.10
Mechanically modified by under cutting and replacing with No. 2 Stone.	0.06 to 0.08

6.3 Single-Span Bridges

6.3.1 General

Geotechnical engineering analyses related to single-span bridges should focus primarily on:

- Selection of foundation types for the end bents/abutments
- The interactions between the approach embankments and foundation elements

6.3.2 Selection of Foundation Types

Most single-span bridges designed and constructed in the Lexington Area utilize rock bearing foundation elements. These foundation systems commonly consist of spread footings, steel H-piles or drilled shafts (caissons). However, other foundation systems such as spread footings on soil and/or friction piles may be possible options. **The Geotechnical Consultant shall evaluate the subsurface conditions identified during the field and laboratory testing phases of the exploration, in conjunction with structural details, to select the most practical foundation alternates.**

Rock cores shall be reviewed to select pile tip, bottom of footing and bottom of drilled shaft elevations as applicable. An estimated allowable rock bearing capacity shall also be determined for use in design of spread footings and drilled shafts. Estimates shall be based on the results of unconfined compression tests in conjunction with reviews of discontinuities within recovered core samples; or on published data, such as that presented in NAVFAC DM 7.2, when site-specific test results are not available.

Drilled shaft options may be most useful when significant karst features such as caves, solution crevices, etc., have been identified within the bedrock. Drilled shafts can be extended below such features to bear on more competent bedrock. Drilled shafts may also be designed to develop significant capacities through a combination of side-load transfer to and bearing on bedrock. More detailed discussions and analytical methods to evaluate axial capacities of drilled shafts are presented in the *NCHRP Report 343 - Manuals for the Design of Bridge Foundations, and FHWA-HI-88-042 - Drilled Shafts: Construction Procedures and Design Methods.*

If friction piles are considered as a foundation alternate, static pile capacity, driving resistances and settlement potential shall be estimated using the methods presented in the FHWA's *Soils and Foundation Workshop Manual*. Bearing capacity and settlement calculations shall be also performed for soil bearing spread footings. Total and differential foundation settlements must not exceed tolerable magnitudes for a given structure.

6.3.3 Settlements of Approach Embankments

Settlements of approach embankments at the bridge end bent positions shall be considered in design and construction of these elements. As foundation soils and subsequently approach embankments settle, soils surrounding deep foundation systems may cause negative skin friction, or a down-drag effect, on individual piles or shafts. Studies performed by the FHWA indicate that this effect can occur with as little as one-half inch of settlement. If enough downdrag occurs, the axial capacities of piles or shafts may be exceeded. Therefore, it is important to evaluate potential approach embankment settlements at the bent positions and determine if downdrag will occur. Once it is determined that downdrag is possible, an estimate of the negative skin resistance shall be performed. Procedures outlined in Section GT-605-7 of the KTC's *Geotechnical Manual* and in the FHWA's *Soils and Foundation Workshop Manual* shall be followed to estimate negative skin friction.

Downdrag may be reduced by using one of the alternates described in the KTC's *Special Note for Pile Protection*, or by using a waiting period between the completion of the embankment and the installation of foundation elements. Alternates A and C in KTC's Special Note provide means to isolate a portion of the foundation element from the surrounding embankment. Downdrag may still occur for that length of element installed within foundation soils. Alternate B of the Special Note describes the use of a bitumen slip layer, or coating, applied to an H-pile. This method is currently considered to reduce the downdrag by 90 percent over the coated interval. However, care must be exercised during construction to avoid damaging the bitumen coating and thereby reducing its effectiveness.

Use of a waiting period between completion of the embankment and installation of foundations permits settlement to occur prior to driving piles or installing shafts. Downdrag loads may be considered negligible if the settlement following completion of the waiting period is expected to be less than one-half inch. If this method of eliminating dragdown is implemented, settlement platforms will need to be installed within the embankment and monitored during construction. These platforms are necessary to help determine when adequate settlement has occurred to allow installation of foundation elements. Such platforms should be installed and monitored in accordance with Section 730 of KTC's *Standard Specifications for Road and Bridge Construction.*

6.3.4 Lateral Squeeze Potential

Lateral squeeze is defined as the deformation and displacement of soft, cohesive foundation soils when subjected to embankment loadings. Lateral squeeze potential is of particular concern at bridge bents where piles have been installed through soft, compressible clayey soils. If squeeze occurs, it may load the foundation elements horizontally and cause subsequent rotation and horizontal displacement of the abutments. **The potential for lateral squeeze exists when the weight of the embankment exceeds three times the undrained shear strength of a foundation soil. The Geotechnical Consultant shall check the bent locations for the possibility of lateral squeeze by performing such a comparison.** Design solutions for preventing damage associated with and reducing the potential for lateral squeeze are presented in the FHWA's *Soils and Foundations Workshop Manual*. These solutions may include oversizing the foundation elements to accommodate increased horizontal loads; or implementing a waiting period between completion of the embankment and installation of foundation elements to allow time for squeeze to occur.

6.3.5 Scour Considerations

Scour may be of concern for bridges crossing streams or rivers. During high water events, soils and/or non-durable bedrock may be eroded from embankment and/or foundation areas. Most current methods available to evaluate the scour potential of soils utilize the D_{50} grain size of the soil particles. D50 is determined using a soils grain-size distribution curve obtained from grain size analyses (i.e. sieve and hydrometer tests).

The "D" refers to the grain size, or apparent diameter, of the soil particles and the subscript 50 denotes the percent of all particles smaller than the apparent diameter. For example, D_{50} = 0.420 mm means that 50 percent of these soil grains are smaller than 0.420 mm. **When scour potential needs to be addressed on a given project, the Geotechnical Consultant shall report applicable D50 values of the soils at the site.**

Scour of bedrock materials may also be of concern if the rock is comprised of non-durable materials. **The Geotechnical Consultant shall review the rock cores recovered during field work and identify the scourability of rock, as applicable. Guidelines presented in *Section GT-606-2 of the current KTC Geotechnical Manual* shall be used to help assess the scour potential of bedrock.**

6.4 Reinforced Concrete Box Culverts

6.4.1 General

Engineering evaluations for reinforced concrete box culverts shall be performed to determine:

- If the culvert needs to be designed to utilize a yielding (soil bearing) or a non-yielding (rock bearing) foundation system
- The settlement profile across the length of the culvert if a yielding foundation will be used
- An estimated bearing capacity for wingwalls which may be positioned at the ends of the culvert
- And to provide recommendations related to materials used to backfill behind wingwalls

6.4.2 Selection of Foundation Type

The Geotechnical Consultant shall review available subsurface data in conjunction with plans of the proposed culvert to determine if a yielding or non-yielding foundation should be recommended. Generally, if rock is positioned deeper than three feet below the culvert flow line a yielding foundation would be applicable. When rock is located within three feet of the flow line a rock bearing, or non-yielding, foundation design may be appropriate. Of course, there are exceptions to these generalities and the Geotechnical Consultant must review all available data before recommending a foundation type.

6.4.3 Settlement Profile

Significant amounts of fill are usually placed over culverts as part of roadway embankment construction. Because of this, classical bearing capacity failures of culverts are not typically of concern. Bearing capacity estimates for use in the design of the barrel's foundations are not commonly provided.

It is important, however, to evaluate settlement potential at the ends and middle of the culvert profile for a yielding foundation design. Normally, the majority of settlement induced in the foundation soils for a culvert situation is a result of embankment loadings. **Therefore, a settlement profile along the length of the culvert shall be estimated using the methods described in Section 6.2.4.** The largest settlement along the culvert length is usually observed near the middle of the structure where the fill height over the culvert is at a maximum. As the height of the fill decreases towards the ends of the structure, the amount of settlement also decreases.

The results of these analyses may be used to determine if excessive amounts of settlement will occur; if the culvert flow should be cambered; or if removal and replacement of portions of the foundation soils may be necessary to reduce estimated settlements.

6.4.4 Wingwall Evaluations

Wingwalls are commonly designed at the ends of culverts to retain fill slopes, thereby preventing them from encroaching upon the drainage path. Because the fill height is small near the ends of the structure, bearing capacity of the foundation materials at the wingwall positions should be evaluated. **If the wingwall footings will be placed directly on rock, then a bearing capacity shall be estimated as outlined in Section 6.3.2.** Bearing capacities of shallow foundations on soil should be estimated using methods presented in FHWA's *Soils and Foundations Workshop Manual*, or other applicable procedures. The ultimate capacity of cohesive soils is typically based upon the results of laboratory testing (i.e., unconfined compressive strength) of samples recovered at or near proposed bearing elevations. The ultimate bearing capacity of granular soils is commonly based upon estimates of the soil's internal friction angle that may be derived from correlations of SPT N-values, soil classification and published data. **Ultimate capacities shall be divided by an appropriate safety factor to determine an allowable capacity to be used for design. A safety factor of three is recommended.** If soil strength parameters and structural loading data are very well defined, the Geotechnical Consultant may consider using a safety factor of two to estimate allowable capacities.

In addition to providing bearing capacity estimates, **the Geotechnical Consultant shall estimate the internal friction angle of materials to be used as backfill behind wingwalls**. The friction angle may then be utilized to estimate equivalent fluid pressures for design of the wingwalls and culvert barrel. Friction angles and equivalent fluid pressures may be approximated using published correlations presented in NAVFAC DM-7.2. Alternately, Exhibit 66-04-13 in the KTC's *Bridge Design Guidance Manual* may be utilized in selection of design loads for small retaining walls.

6.5 Retaining Walls

6.5.1 General

This section provides guidance in performing geotechnical engineering analyses related to gravity, mechanically stabilized earth (MSE), and cantilever retaining walls. **Tied-back, pile and lagging, and drilled shaft retaining walls are not addressed by this Manual.**

Small walls that meet the requirements presented in KTC Standard Drawing RGX-002-05 Retaining Wall, Gravity-Type, Non-Reinforced do not require site-specific designs and geotechnical explorations. All other walls will require individual designs and associated explorations.

6.5.2 Internal and External Wall Stability

The internal stability of cantilever walls and all other gravity retaining walls, except those constructed of MSE, shall be determined by the Engineer. The internal stability of an MSE wall is dependent upon the height and width (lengths of straps, grids, etc.) of the wall and shall be evaluated by the Engineer or by the proprietary wall representative, as applicable. **The external stability of a wall shall be determined by the Geotechnical Consultant through evaluations of overall slope stability, overturning, sliding, bearing capacity, and differential settlements along the length of the wall.**

6.5.3 Overall Slope Stability

Methodologies for performing stability analyses and associated factors of safety are presented in Section 6.2.3. The internal stability of a wall is assumed to be adequate when evaluating overall slope stability. Therefore, the wall area may be modeled using relatively high shear strength parameters so that predicted failure surfaces will pass behind the wall and not through the structure. The wall area should include the zone of reinforcement for an MSE wall, and the soil above the heel for a cantilever wall.

6.5.4 Sliding, Overturning, and Bearing Capacity

Many publications provide detailed procedures and methodologies to evaluate sliding, overturning, and heel and toe bearing pressures for retaining walls. Procedures such as those presented in the current editions of the *AASHTO Standard Specifications for Highway Bridges*, *NAVFAC DM-7.2* or other available resources may be used to perform such evaluations. It is recommended that safety factors of 1.5 (neglecting passive resistance) and 2.0 be targeted when analyzing sliding and overturning, respectively.

If the toe pressure for the wall configuration exceeds the allowable bearing capacity of the foundation materials, the Geotechnical Consultant shall provide recommendations either to reduce the pressures exerted by the wall or to improve foundation conditions. Improvements of foundation conditions should be such that an increase in the allowable bearing capacity equal to or greater than the toe pressure will be achieved.

6.6 Sanitary and Storm Sewers

The primary focus of a geotechnical exploration performed for sanitary and storm sewer alignments is to provide information regarding soil thicknesses and depths to the top of bedrock. The Engineer may then use this data to estimate quantities of soils and rock that will need to be excavated to install the planned utilities. **Generally, only a summary of the borings performed and soil thicknesses encountered will need to be issued by the Geotechnical Consultant as a product of this exploration.** However, some projects may require additional geotechnical considerations related to sanitary and storm sewer installations. As an example, a situation may occur where substantial fill will be placed over a previously installed sewer line. In this case, settlement analyses may need to be performed to determine if the installed line can tolerate the estimated settlement resulting from the embankment loadings. The Geotechnical Consultant and Engineer should discuss project needs as the exploration is planned so that appropriate geotechnical engineering evaluations can be made.

6.7 Detention/Retention Basins

6.7.1 General

Development of a detention/retention basin commonly requires excavation of soil materials from the interior of the planned detention area and construction of an exterior compacted earth berm. **Engineering analyses performed for such facilities shall include:**

- **Evaluation of soils for use as fill, including moisture density requirements for compaction efforts**
- **Assessment of the permeabilities of soils which may be used to construct the berm**
- **Cut/Embankment slope stability studies.**

6.7.2 Evaluation of Fill Materials

The Geotechnical Consultant shall review the results of the drilling and laboratory test programs and evaluate the soils suitability for use in developing a detention/retention facility. As a minimum, any soil used for this purpose should exhibit a hydraulic conductivity equal to or less than $1x10^{-5}$cm/sec. **The Consultant shall also recommend the moisture content and percent compaction at which the soil should be placed to achieve the desired hydraulic conductivity.**

6.7.3 Slope Stability

If the height of the berm exceeds 15 feet, then slope stability analyses shall be performed. These analyses shall include evaluations of short- and long- term conditions. Additional slope stability studies for detention/retention facilities may also be necessary. These studies may consist of evaluations of rapid-drawdown conditions for the interior slope; and/or saturated embankment conditions. The Engineer and Geotechnical Consultant shall review the intent of each facility and determine if water would possibly be retained within the basin for a long enough period of time to create such conditions.

6.8 Areas Used to Obtain Materials for Infrastruction Construction

6.8.1 General

Geotechnical engineering evaluations for mass grading operations shall include:

- **Reviews of the site for problem areas such as wet, soft zones; sinkholes and other karst features; and debris/waste areas, etc.**
- **Assessments of soil and rock materials for use as fill**
- **Stability analyses for cut and fill slopes over 20 feet, or which will exhibit grades steeper than 2H:1V.**

6.8.2 Site Review / Problem Areas

A thorough site review may identify areas that will require special attention during construction. Such areas could include sinkholes, waste piles, wet and soft soils, etc. **The Geotechnical Consultant shall identify these types of features observed during the exploration, and provide recommendations related to the treatment of such areas.** Sinkholes and fill/debris areas are discussed in more detail in Sections 6.9 and 6.10.

6.8.3 Fill Soils

Mass grading operations may include excavation and placement of both soil and bedrock materials. The Geotechnical Consultant shall review the results of drilling and laboratory testing efforts and evaluate the suitability of site materials for use as fill. Particular attention should be given to clays exhibiting high plasticity (liquid limits greater than 50) and non-durable shales. These materials are difficult to work with and are subject to loss of shear strength when they become wet. **Specific recommendations for placement and compaction of site materials shall be provided by the Geotechnical Consultant.**

6.8.4 Slope Stability

As a minimum, analyses shall be performed for cut or fill slopes exceeding 20 feet in height, or for planned slopes that will exhibit grades steeper than 2H:1V. These analyses shall be performed as outlined in Section 6.2.3. Stability studies may also be necessary for other situations and unique conditions not specifically addressed in this Manual. The Geotechnical Consultant and Engineer shall review project plans and site characteristics to determine specific areas that may warrant additional evaluations.

6.9 Sinkholes

Sinkhole evaluations are very dependent upon reviews of physical site conditions. The Geotechnical Consultant shall assess the results of borings and test pit excavations performed at sinkhole locations, in conjunction with planned site development. The intended use of the sinkhole area will influence the remedial treatment recommended. Remedial efforts for sinkholes in landscape areas may be substantially different from those positioned within the footprint of a proposed structure. **Sinkhole explorations shall result in identification of such features as *Sinkhole Related Non-Buildable* Areas in accordance with *Section 6-7(1) - Sinkholes of the current Land Subdivision Regulations for Lexington, Fayette County, Kentucky*; or necessary remedial efforts shall be recommended so that such features may be used for drainage and/or development areas.**

6.10 Fill/Debris Areas

Any areas discovered on a site where old fill, construction debris, topsoil, trash, etc. have been dumped or wasted should be identified as accurately as practical during a subsurface exploration. **The Geotechnical Consultant shall review the results of applicable test borings and test pit excavations in conjunction with previous and existing topographic data to help estimate the limits of these areas. Remedial treatment options shall also be provide by the Consultant.**

CHAPTER 7
REPORT DEVELOPMENT

7.1 General

The intent of this chapter is to outline the minimum information to be included in geotechnical engineering reports; not to develop a rigid set of standard formats for presentation of data and recommendations. **Unless specifically noted otherwise herein, all geotechnical reports shall be concise and provide appropriate discussions regarding:**

- Project location and site description
- Regional and local geologic conditions
- The scope of work performed
- The results of drilling, laboratory testing and engineering analyses
- Recommendations relative to the geotechnical aspects of the project

Presentations of drafted sheets showing the positions of borings and/or test pit excavations performed; graphical boring logs; tables of test results; sketches and photographs should also be used to illustrate, support, and clarify the narrative portions of the report. The Engineer and Geotechnical Consultant should select the drafted sheet size most applicable to project needs. The results of a geotechnical exploration shall provide the project team information from which appropriate foundation and earthwork designs, plans and specifications may be developed.

The remaining sections of this chapter outline specific items to be included in geotechnical reports for different project types. Combinations of data from the various types of reports discussed may be necessary for larger projects.

7.2 Roadways/Streets, Single-Span Bridges, Reinforced Concrete Box Culverts and Retaining Walls

Report format and data presentation for roadways/streets, bridges, culverts and retaining walls shall be in accordance with the KTC's *Geotechnical Manual, Section GT-800, Report Development.* Many items noted to be included in a roadway/street report may not be required depending upon the size and character of the project. If the scope of the project is such that evaluations of cut and embankment stability, settlement, etc., are not required, then these sections may be omitted from the report.

7.2.1 Roadways / Streets

A report for a roadway or street shall generally be structured using the following outline:

I. Project Location and Description

II. Topography and Drainage

III. Geology

IV. Scope and Results of Drilling and Sampling

V. Results of Laboratory Testing

VI. Engineering Analyses

  a. Materials evaluation

  b. Cut stability

  c. Embankment stability

  d. Subgrade considerations

  e. Special conditions

VII. Recommendations

The report appendices should include:

A. A project location map (1" = 2000')

B. Triaxial test failure envelopes

C. Consolidation and settlement vs. time curves, settlement calculations

D. Drafted sheets

1. Boring symbol/legend sheet

2. Geotechnical note sheet

3. Soil profile sheets

4. Critical cut stability sections

5. Critical embankment stability sections

7.2.2 Bridges

Geotechnical reports generated for bridges shall also include as a minimum the following information:

- The recommended foundation type

- Estimated bearing elevations for spread footings, piles, drilled shafts, etc., as applicable

- Allowable bearing capacities for soil and/or bedrock, as required

- Evaluations of approach embankment stability, settlement, lateral squeeze and down-drag potential at the end bent/abutment positions

- Drafted sheets showing plan and profile views of the bridge, boring locations, graphical boring logs, results of stability and settlement analyses, etc.

- Any special requirements such as use of settlement platforms and/or piezometers to control embankment construction rates, use of pile coatings to reduce downdrag loads, etc.

7.2.3 Culverts

In addition to general site and project descriptions, culvert reports shall identify:

- Whether the culvert foundation will be designed as yielding (soil bearing) or non-yielding (rock bearing)

- Allowable soil or rock bearing pressures for wingwall design

- Applicable equivalent fluid pressures for wingwall and barrel wall designs

- Settlement profile along the length of the culvert for a yielding foundation design

- If a camber is needed to accommodate some of the predicted settlement

- Necessary foundation improvements to provide more uniform bearing conditions

7.2.4 Retaining Walls

A retaining wall report shall indicate the type of wall proposed, the maximum wall height anticipated, the length of the structure, and the backfill configuration (i.e., sloping, level). In addition to the general items noted in Section 7.1, geotechnical reports for retaining walls shall discuss:

- The recommended foundation type

- Allowable soil or rock bearing capacities

- Overall stability

- Sliding and overturning

- Settlement potential

- Necessary improvements to existing foundation conditions to accommodate toe pressures

- Design parameters for backfill materials

- Drainage requirements behind the wall

Drafted sheets shall be included showing a plan view of the wall and boring positions, and graphical logs of borings. Sections of the wall and proposed backfill configurations shall also be developed and should show the results of overall stability analyses and settlement calculations. Any undercutting and replacement of foundation soils with granular material required to improve bearing conditions shall be identified on both plan and profile sheets.

7.3 Sanitary and Storm Sewers

Generally, a letter report will be sufficient for geotechnical explorations related to sanitary and storm sewer projects. The letter report shall provide a brief description of the site and project location and a summary of borings performed. The summary shall identify borings by sewer line stationing if possible. Ground surface elevations, depths and elevations to the top of rock and to auger refusal shall also be reported for each boring. The scope of such a report may be expanded if additional geotechnical aspects of the project need to be addressed.

7.4 Detention/Retention Facilities

Reports generated for detention/retention facilities shall include the general information outlined in Section 7.1. and shall also identify:

- The suitability of site materials to be used for construction of the facility
- Soil compaction and hydraulic conductivity requirements
- Results of applicable stability analyses performed
- Recommendations for grades of outslopes to be used

Drafted sheets shall be developed to show the plan locations of the detention/retention basin and borings performed. Sections of the proposed berm shall also be generated to show the results of stability analyses, as applicable.

7.5 Areas Used to Obtain Materials for Infrastruction Construction

The information presented in a geotechnical report for mass grading operations shall include:

- Evaluations of site materials planned to be used as fill
- Recommended placement and compaction criteria
- Results of cut and embankment stability analyses, as applicable
- Identification of and recommended treatments for observed problem areas such as soft, wet soils; old fill materials; sinkholes; etc.
- Recommended construction monitoring efforts

Drawings depicting the positions of borings performed, graphical boring logs, results of stability analyses, and locations of problem areas identified shall also be included.

7.6 Sinkholes

Geotechnical engineering reports generated for evaluation of sinkholes shall provide:

- Discussions regarding the subsurface conditions observed at the sinkhole (depression location, soil types identified, groundwater or seeps noted, conditions of the bedrock surface, open throats observed, etc.)

- Photographic documentation of test pit excavations performed at the sinkhole locations

- Recommended remedial efforts necessary to use the sinkhole area for the intended development; or commentary that identifies the sinkhole as a "non-buildable area"

Drawings submitted with the reports shall show the plan locations of the sinkholes, test borings, and test pit excavations. Additional drawings and/or sketches shall be provided, as necessary, to clarify recommended sinkhole treatments.

7.6 Fill/Debris Areas

Reports for areas where old fill and/or debris have been encountered shall include:

- Descriptions of the materials observed
- Drawings of plan sheets showing the approximate limits of the subject area
- Recommendations for removal and replacement of the materials, or for in-place stabilization

APPENDIX A

FIGURES

GEOTECHNICAL GUIDANCE MANUAL

FIGURE 3.1

SOUNDING LOG EXAMPLE

SUBSURFACE LOG

Page 1 of 1

Project Number 1997-4
Project Name Bridge over Lexington Creek
County Fayette
Project Type Roadway Structure
Supervisor I.B. Engineer Driller I.B. Driller
Type of Boring Sounding

Location Station 4+55, 10' Rt.
Boring No. 3 Total Depth 16.7'
Surface Elevation 745.0
Date Started 07/03/97 Completed 07/03/97
Depth to Water 15.2' Date/Time 07/03/97 - 11:15 a.m.
Depth to Water 14.7' Date/Time 07/10/97 - 4:00 p.m.

Lithology Elevation	Lithology Depth	Description	Overburden / Rock Core	Sample # / RQD	Depth / Run	Rec. Ft. / Rec. Ft.	Mois.Cont.% / Rec. %	Type / SDI	Remarks
745.0	0.0	Top of Hole							Ground Water Observation Well Installed on 07/03/97
		Overburden							
728.5	16.5	Top of Rock							
728.3	16.7	Auger Refusal							
		Bottom of Hole							Top of rock indicates rock-like resistance to the advancement of the augers. An accurate determination of the top of bedrock can only be made utilizing rock coring methods.

GEOTECHNICAL GUIDANCE MANUAL

FIGURE 3.2

SOIL PROFILE BORING LOG EXAMPLE

SUBSURFACE LOG

Page 1 of 1

Project Number	1997-4	Location	Station 4+55, 10' Rt.
Project Name	Lexington Highway	Boring No.	3 Total Depth 16.7'
County	Fayette	Surface Elevation	745.0
Project Type	Roadway Structure	Date Started	07/03/97 Completed 07/03/97
Supervisor	I.B. Engineer Driller I.B. Driller	Depth to Water	15.2' Date/Time 07/03/97 - 11:15 a.m.
Type of Boring	Soil Profile	Depth to Water	– Date/Time –

Lithology		Description	Overburden	Sample #	Depth	Rec. Ft.	Mois.Cont.%	Type	Remarks
Elevation	Depth		Rock Core	RQD	Run	Rec. Ft.	Rec. %	SDI	
745.0	0.0	Top of Hole							
744.4	0.6	Topsoil							
		Lean clay with sand, red-brown to dark brown, moist, medium to stiff, with manganese concretions throughout		1	3.0		26	M.C.	
				2	8.0		29	M.C.	
733.0	12.0								
		Fat clay, yellow-brown, moist to wet, stiff, with many manganese nodules and occasional limestone slabs.		3	13.0		30	M.C.	
728.5	16.5	Top of Rock							
728.3	16.7	Auger Refusal							
		Bottom of Hole							

GEOTECHNICAL GUIDANCE MANUAL

FIGURE 3.3

SOIL BORING LOG EXAMPLE

SUBSURFACE LOG

Page 1 of 1

Project Number	1997-4	Location	Station 1+55, 10' Rt.
Project Name	Bridge over Lexington Creek	Boring No.	3 Total Depth 16.7'
County	Fayette	Surface Elevation	745.0
Project Type	Roadway Structure	Date Started	07/03/97 Completed 07/03/97
Supervisor	I.B. Engineer Driller I.B. Driller	Depth to Water	15.2' Date/Time 07/03/97 - 11:15 a.m.
Boring Type	Sample	Depth to Water	14.7' Date/Time 07/10/97 - 4:00 p.m.

Lithology Elevation	Lithology Depth	Description	Overburden / Rock Core	Sample # / RQD	Depth / Run	Rec. Ft. / Rec. Ft.	Blow Count / Rec. %	Type / SOI	Remarks
745.0	0.0	Top of Hole							Ground Water Observation Well installed on 07/03/97
744.4	0.6	Topsoil							
		Lean clay, brown, moist, stiff, with manganese nodules throughout		1	3.0 - 5.0	2.0	–	ST	
735.0	10.0			2	8.0 - 10.0	2.0	—	ST	
		Fat clay, yellow to brown, moist, stiff to very stiff, gravel present below 15.0'		3	13.0 - 15.0	1.7	–	ST	
728.5	16.5	Top of Rock		4	15.0 - 16.5	1.2	12/17/36	SPT	
728.3	16.7	Auger Refusal							
		Bottom of Hole							

GEOTECHNICAL GUIDANCE MANUAL

FIGURE 3.4

SOUNDING AND ROCK CORE LOG EXAMPLE

SUBSURFACE LOG

Page 1 of 1

Project Number	1997-4	Location	Station 1+55, 10' Rt.
Project Name	Bridge over Lexington Creek	Boring No.	3 Total Depth 37.0'
County	Fayette	Surface Elevation	745.0
Project Type	Roadway Structure	Date Started	07/03/97 Completed 07/03/97
Supervisor	I.B. Engineer Driller I.B. Driller	Depth to Water	15.2' Date/Time 07/03/97 - 11:15 a.m.
Boring Type	Sounding and Rock Core	Depth to Water	— Date/Time —

Lithology Elevation	Lithology Depth	Description	Overburden Sample # / Rock Core RQD	Depth / Run	Rec. Ft. / Rec. Ft.	Mois.Cont.% / Rec. %	Type / SDI	Remarks
745.0	0.0	Top of Hole						
		Overburden						
728.5	16.5	Top of Rock						
728.3	16.7	Auger Refusal - Begin core						
		Limestone, light to medium gray fine to coarsely crystalline grained, locally interbedded with thin gray shale seams, hard.						Base of weathered bedrock @ 27.0'
	21.7	Clay seams @: 17.0 - 17.2, 17.6 - 17.9, 18.7 - 18.8	31%	16.7 - 21.7	4.4	88%		Lost 20% water return @ 21.3'
	31.7	Voids @: 21.2 - 21.3, 25.6 - 25.9	45%	21.7 - 31.7	9.7	97%		Lost 100% water returned @ 25.9'
		Water stained to 27.0'						(Loss in last run due to slipped core at bottom)
708.0	37.0	Bottom of Hole	47%	31.7 - 37.0	5.1	96%		
		2 boxes of core						

FIGURE 3.5

OPEN FACE LOG EXAMPLE

OPEN FACE LOG

Page 1 of 1

Project Number 1997-4
Project Name Lexington Highway
County Fayette
Project Type Roadway
Logged by John Geologist

Location West Bound - Sta. 102+80 (Median side)
Highwall No. -- Total Height 49.5'
Surface Elevation 792.5
Date Started 12/30/96
Completed 12/30/96

Lithology		Description	Sample #	Type	Remarks
Elevation	Depth		RQD	SDI	
792.5	0.0	Top of Highwall			
789.5	3.0	Soil Overburden	--		
780.5	12.0	Limestone, gray, fine to coarsely crystalline grained, thin to thick bedded.	85		
759.0	33.5	Limestone (70%) interbedded with shale (30%) Limestone is gray, micrograined to medium grained thin bedded with convoluted beds, occasional fossiliferous zones, shale is gray, fissile, calcareous	30		Weathered shale layer 12.0' - 13.5' shales slightly undercutting limestones at some locations
753.0	39.5	Limestone, gray, micrograined to fine grained, thin to thick bedded	75		
743.0	49.5	Limestone, gray, micrograined to finely crystalline grained, very thin to thin bedded, areas with convolute bedding, with thin shale layers and partings	20		Occasional near vertical joints noted
		Base of highwall No signficant talus observed in ditch			

GEOTECHNICAL
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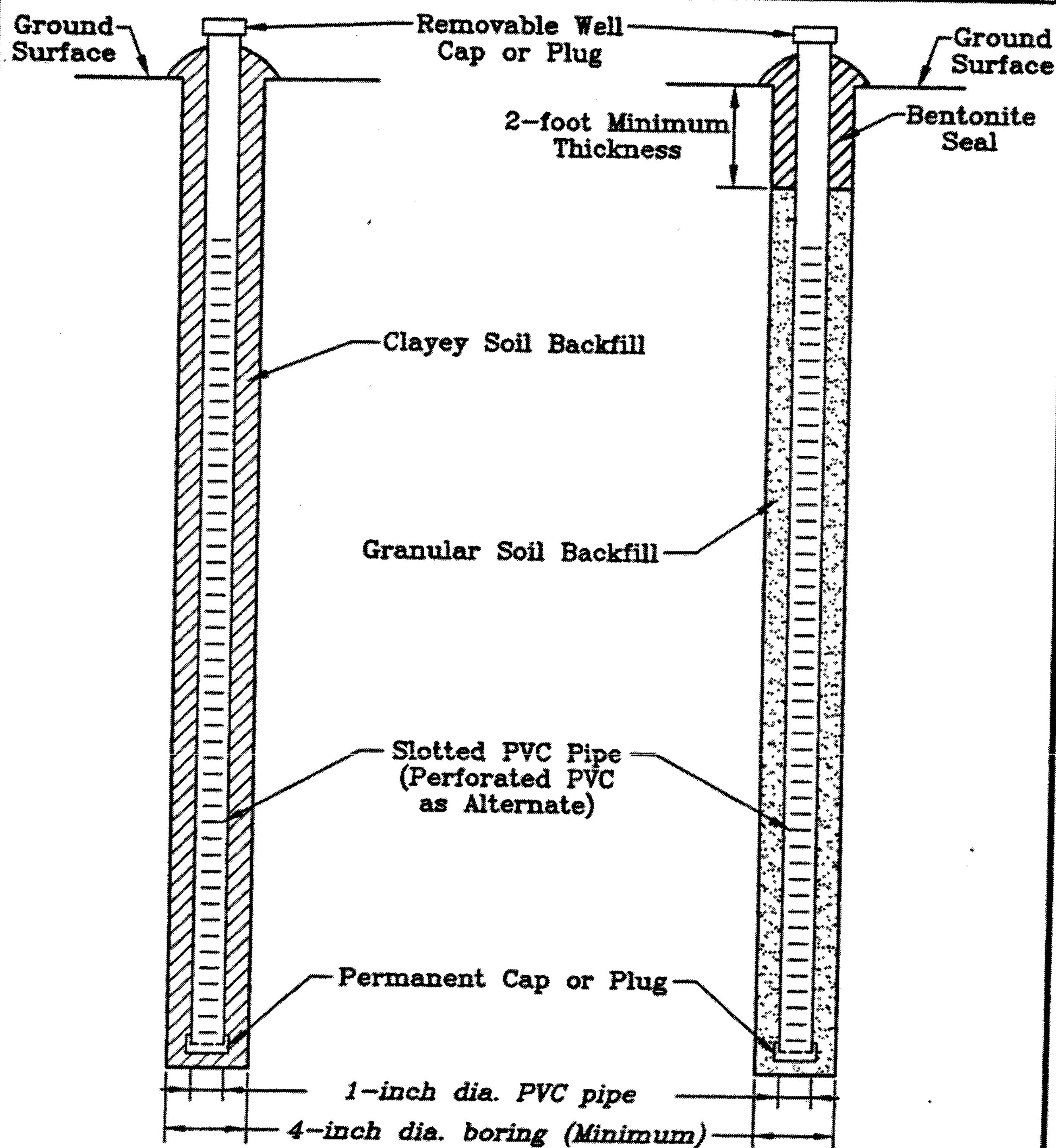
FIGURE 3.6
Groundwater Obsevation Well Installation



A. CLAYEY SOILS
Not to Scale

B. GRANULAR SOILS
Not to Scale

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FIGURE 3.7 Sample Identification Labels

Job No. 1997-1
Project LFUCG Roadway
Sample No. Bag ①
Offset Sta. 1+00, 50' Rt.
Depth 3.0'-7.0'

DISTURBED BAG

Job No. 1997-2
Project LFUGC Structure
Sample No. ST ①
Offset Sta. 5+09, 10' Lt. Hole 3
Depth 9.5'-11.5' 1.7' Rec.

THIN-WALLED TUBE

Job No. 1997-2
Project LFUCG Structure
Sample No. SPT ①
Offset Sta. 5+09, 10' Lt. Hole 3
Depth 4.5'-6.0' 1.2' Rec.
B.C. 10/10/14

STANDARD PENETRATION TEST

Job No. 1997-3
Project LFUCG Roadway
Sample No. MC #2
Offset Sta. 1+50, C L
Depth 3.5'

MOISTURE CONTENT 'GRAB'

97065\VDLABELS

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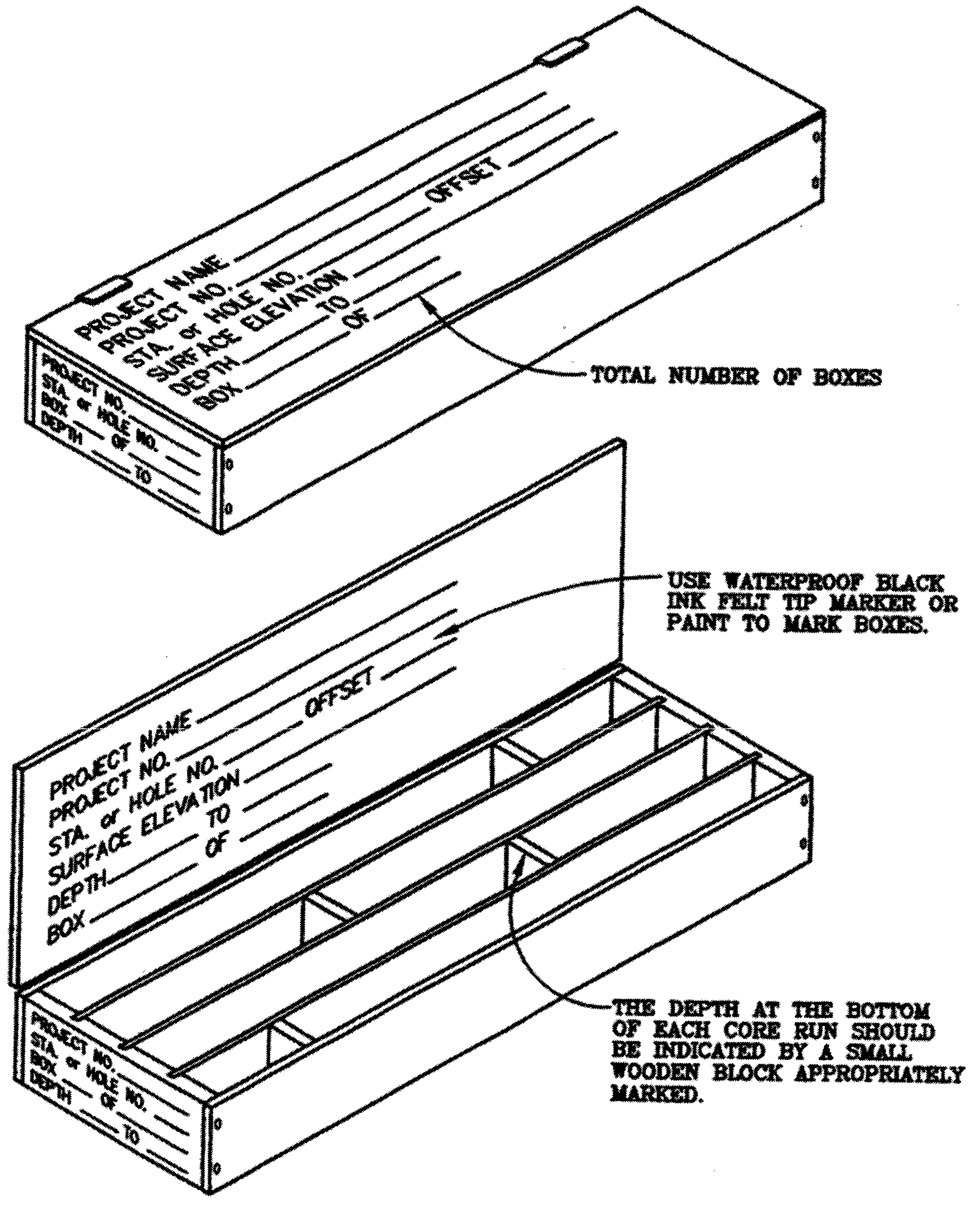
FIGURE 3.8 Rock Core Box And Box Labeling



97065\COREBOX

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FIGURE 4.1
Geotechnical Legend Sheet

AASHTO Classification of Soils and Soil–Aggregate Mixtures

General Classification	Granular Materials (35% or less passing 0.075 mm)							Silt–Clay Materials (More than 35% passing 0.075 mm)			
Group Classification	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5, A-7-6
Sieve Analysis, percent Passing: 2.00 mm (No. 10)	50 max	—	—	—	—	—	—	—	—	—	—
0.425 mm (No. 40)	30 max	50 max	51 min	—	—	—	—	—	—	—	—
0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
Characteristics of Fraction Passing 0.425 mm (No. 40): Liquid Limit	—		—	40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
Plasticity Index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min

Unified Soil Classifications

MAJOR DIVISIONS		SYMBOL	NAME
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	Well-graded gravels or gravel-sand mixtures, little or no fines.
		GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.
		GM	Silty gravels, gravel-sand-silt mixtures.
		GC	Clayey gravels, gravel-sand-clay mixtures.
	SAND AND SANDY SOILS	SW	Well-graded sands or gravelly sands, little or no fines.
		SP	Poorly graded sands or gravelly sands, little or no fines.
		SM	Silty sands, sand-silt mixtures.
		SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	SILTS AND CLAYS LL IS LESS THAN 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
	SILTS AND CLAYS LL IS GREATER THAN 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
		CH	Inorganic clays of high plasticity, fat clays.
UNCLASSIFIED MATERIAL		NONE	Non-classified material (i.e. overburden, pavement, slag, etc.) include visual description.

AI	Activity Index
LI	Liquidity Index
S+C(%)	Silt + Clay (% finer than No.200 Sieve)
	Rockline Soundings
	Disturbed Sample Boring
	Undisturbed Sample Boring
	Undisturbed Sample Boring & Rock Core
	Rock Core
	Slope Inclinometer Installation typical applications:
OW	Observation Well
	Approximate Footing Elevation
(Date)	Water Elevation
VS (psf)	Field Vane Shear Strength
	Thin-walled Tube Sample
	Standard Penetration Test Sample
N	Penetration Resistance
Qu (psf)	Unconfined Compressive Strength
UU (psf)	Unconsolidated Undrained Triaxial Strength
w(%)	Moisture Content
RQD	Rock Quality Designation
SDI (JS)	Slake Durability Index (Jar Slake Test)
REC	Core Recovery
ϕ	Angle of Internal Friction (Total Stress)
$\bar{\phi}$	Angle of Internal Friction (Effective Stress)
c (psf)	Cohesion (Total Stress)
$\bar{c}$ (psf)	Cohesion (Effective Stress)
γ (psf)	Total Unit Weight
RDZ	Rock Disintegration Zone
OB	Overburden Bench
IB	Intermediate Bench
R	Refusal
NR	Refusal Not Encountered

Relation of RQD and in situ Rock Quality

RQD	Rock Quality
90–100	Excellent
75–90	Good
50–75	Fair
25–50	Poor
0–25	Very Poor

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LIMESTONE

SANDSTONE

DURABLE SHALE (SDI $\geq$ 95)

NONDURABLE SHALE (SDI $\leq$ 95)

COAL

TALUS, FILL MATERIAL, BOULDERS, & ETC.

ROADWAY FILL–GRANULAR EMBANKMENT

STRUCTURE GRANULAR BACKFILL

SLOPE PROTECTION

97064\LEGEND

FIGURE 4.2
Typical Boring Layout For Roadway Alignment

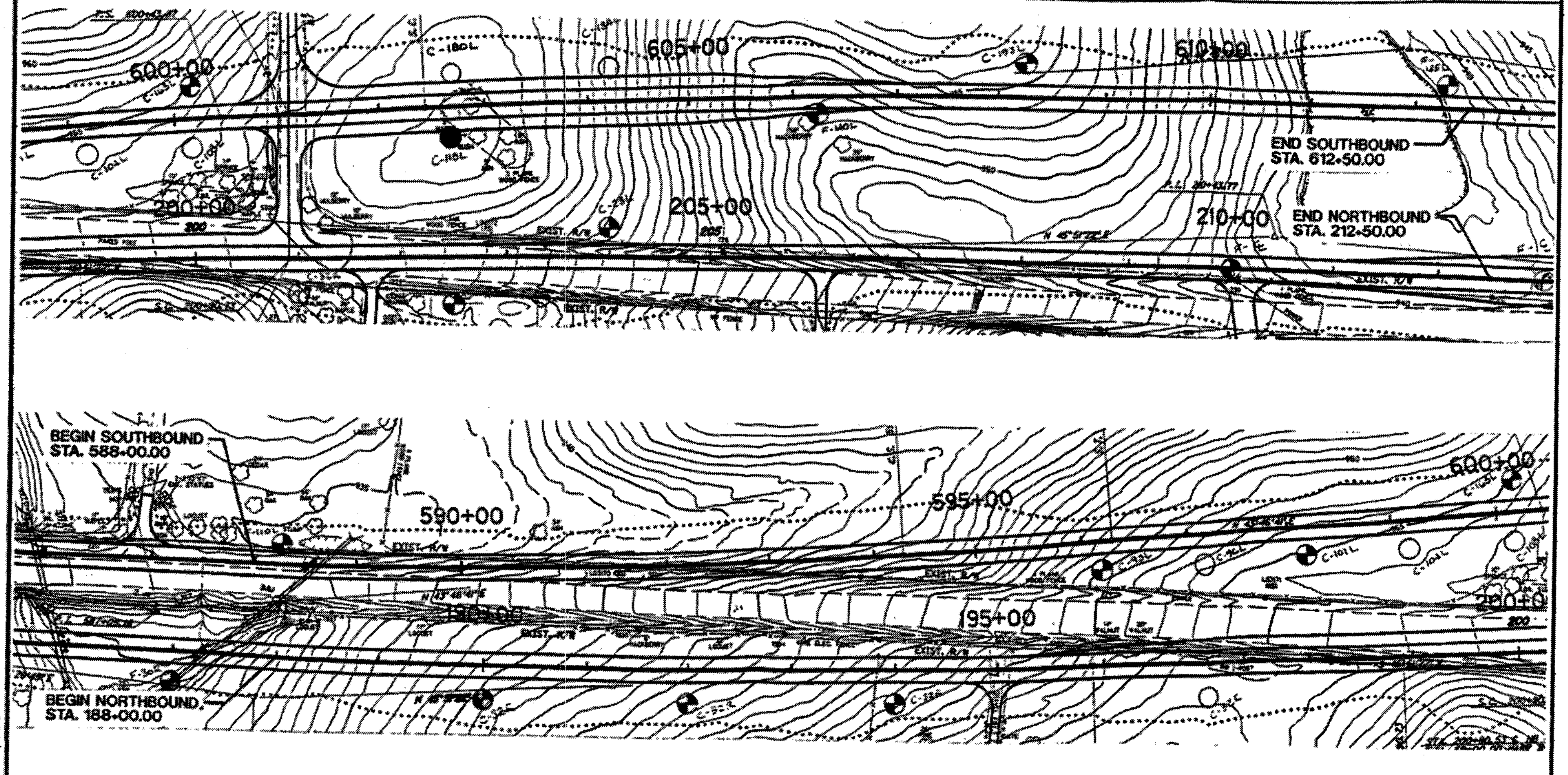

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FIGURE 4.3
Typical Boring Layouts For Single Span Bridges

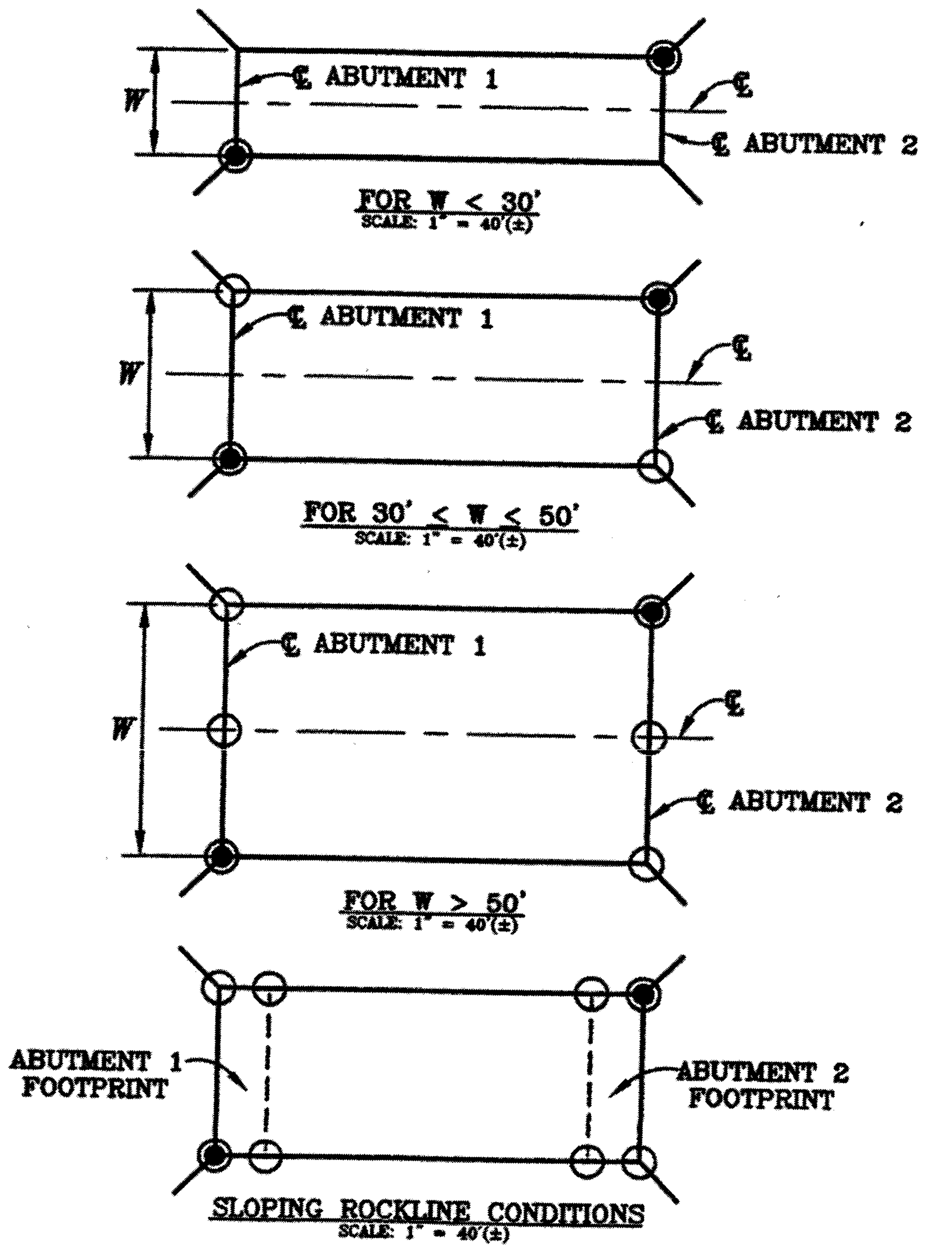

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FIGURE 4.4
Typical Boring Layouts For Culverts

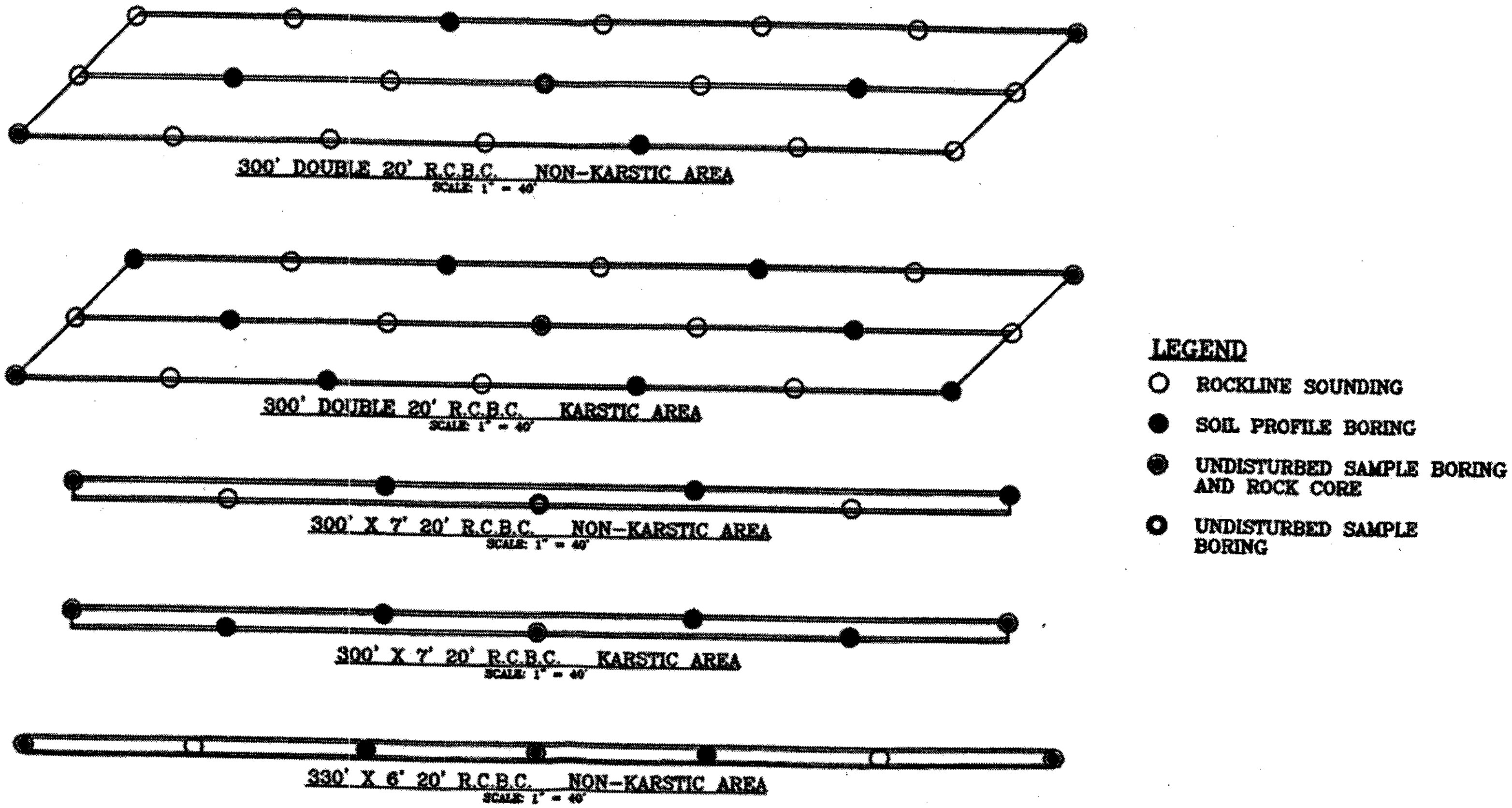

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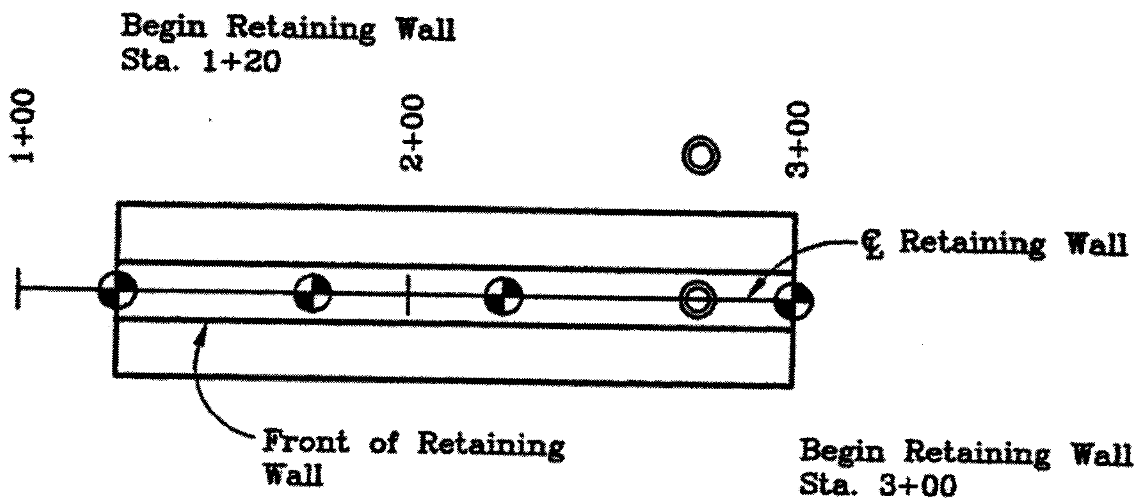
FIGURE 4.5
Typical Boring Layout For Retaining Wall



97085\RWALLPLN

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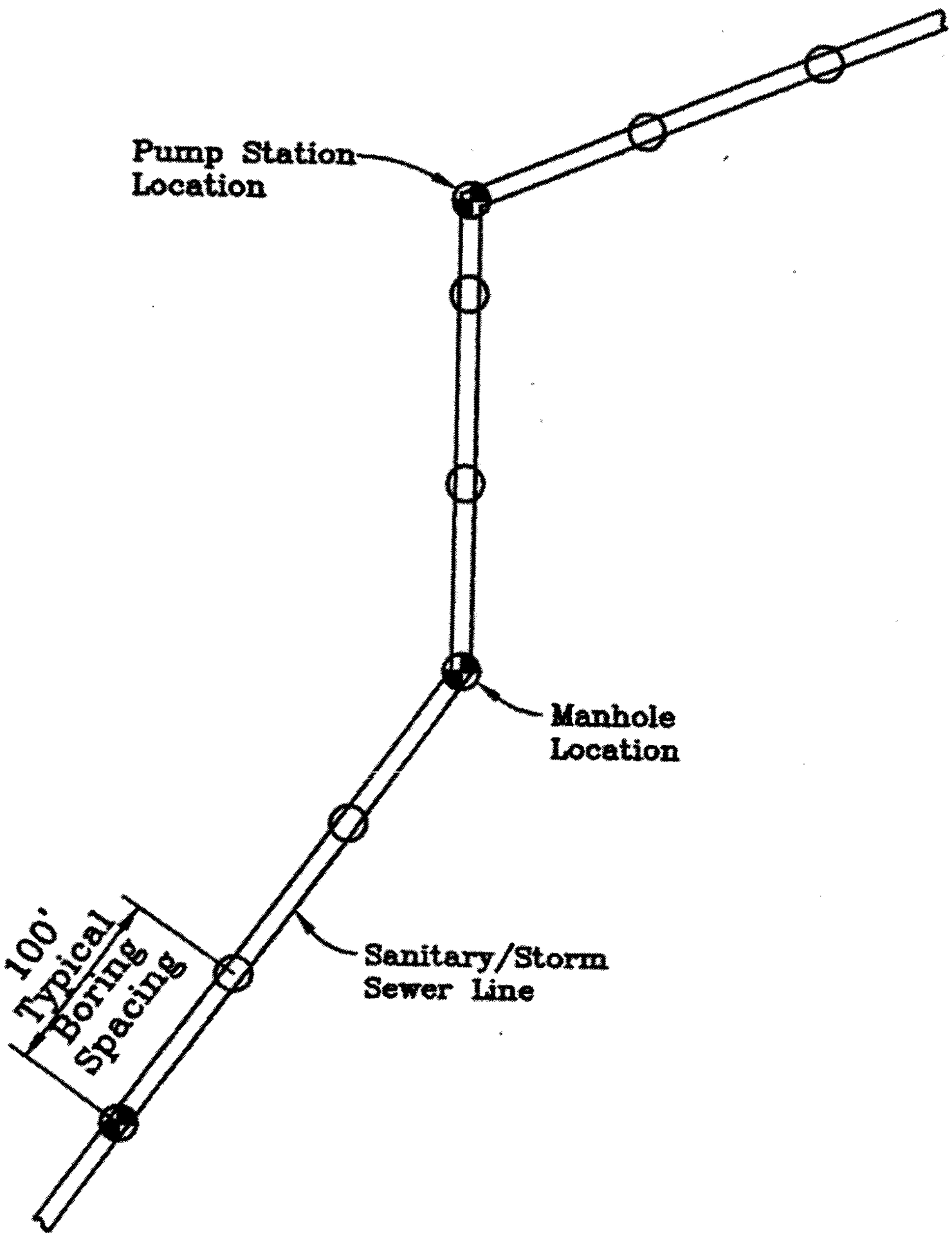
FIGURE 4.6
Typical Boring Layout For Sanitary And Storm Sewers



97068\5-SPLH

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FIGURE 4.7
Typical Boring Layout For Detention/Retention Areas

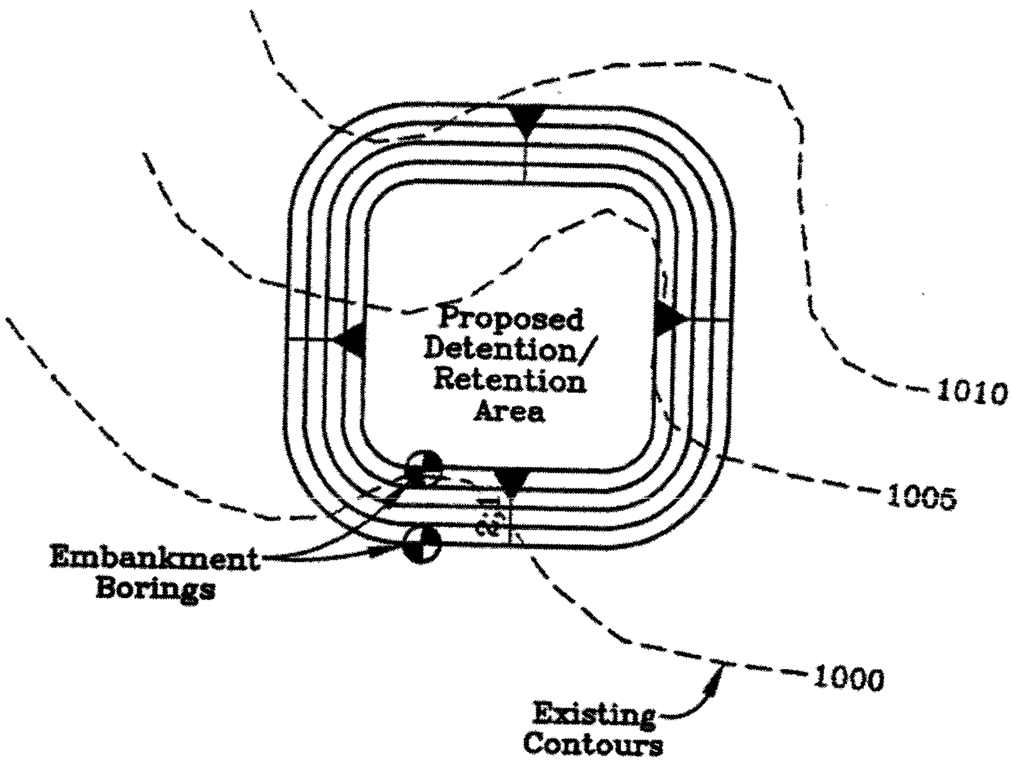

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FIGURE 4.8
Typical Boring Layout For Mass Grading

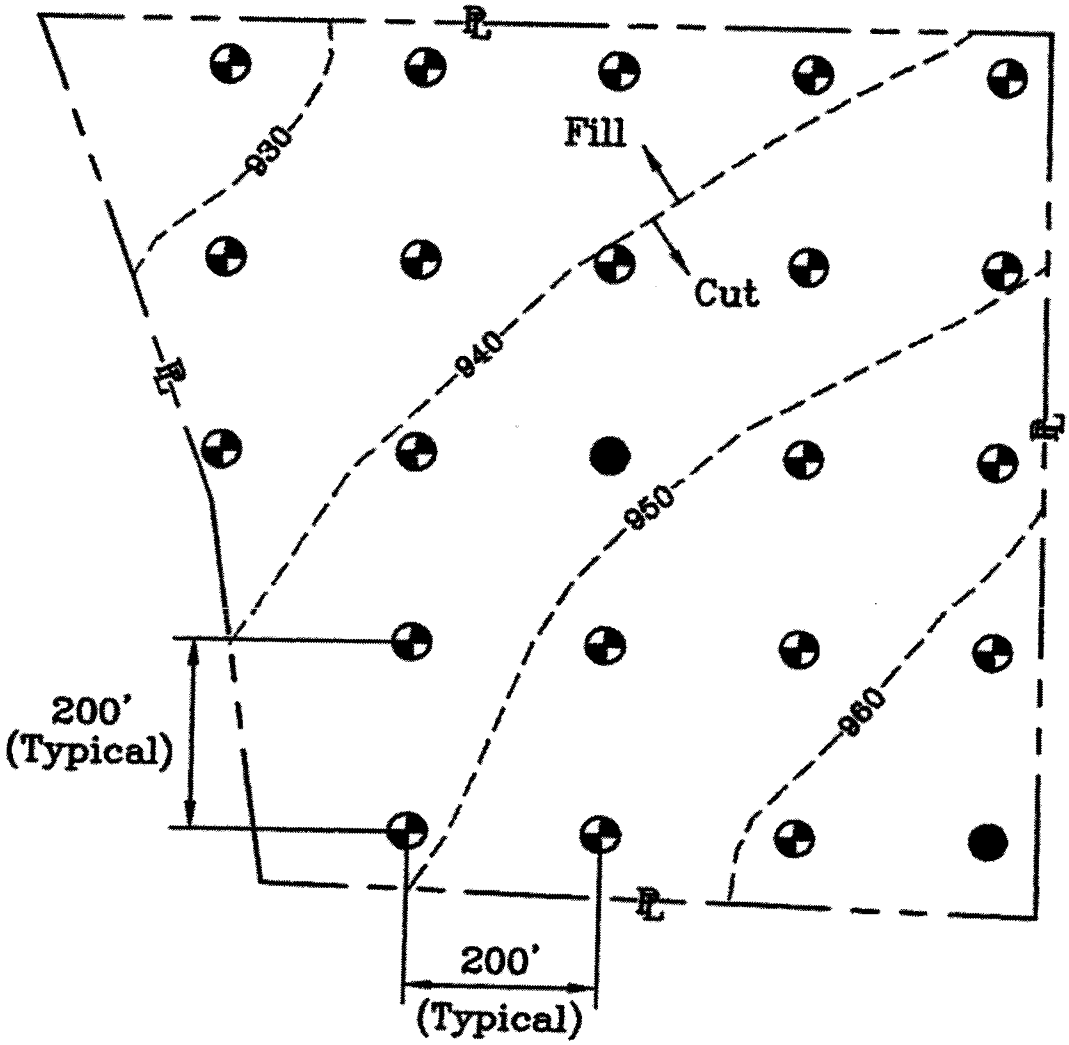

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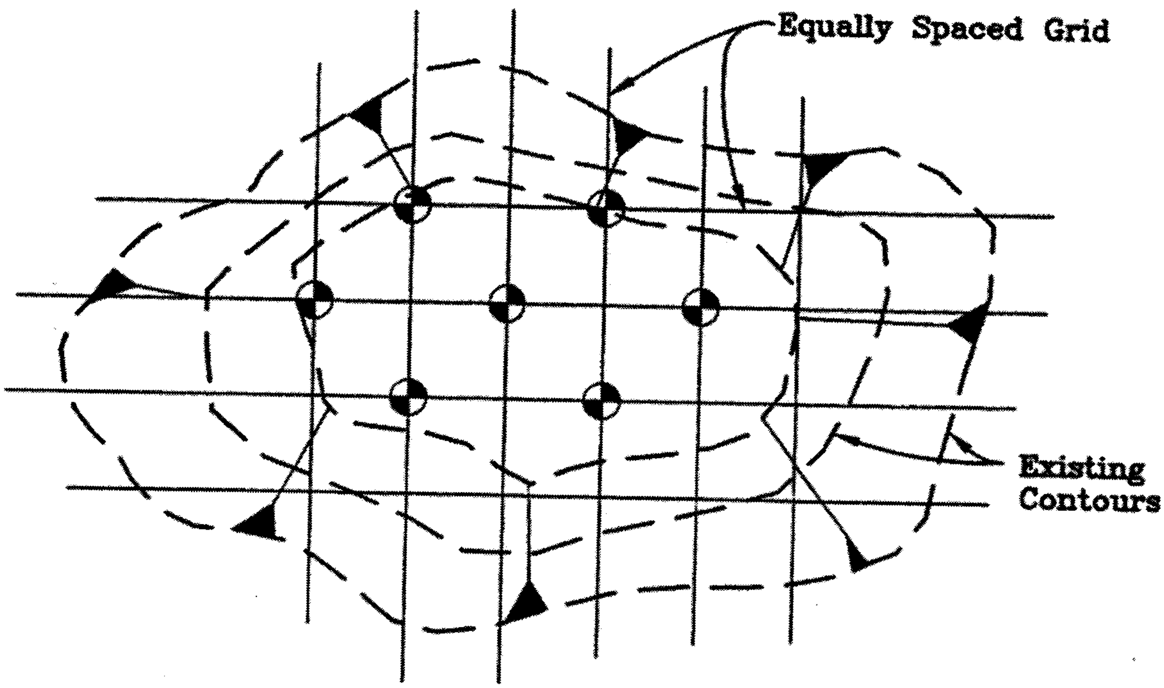
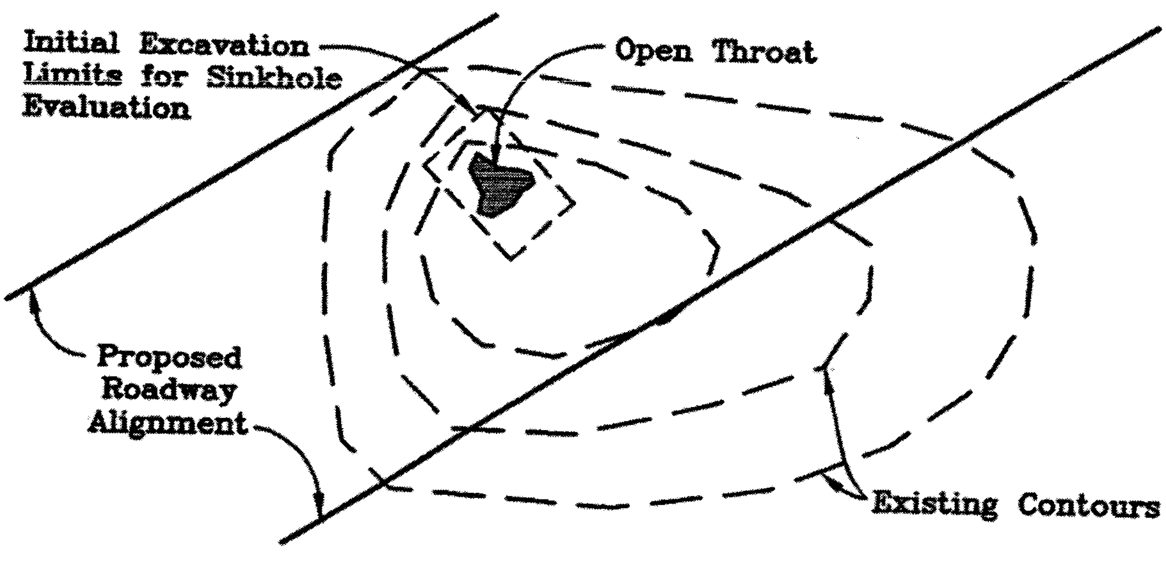
FIGURE 4.9
Typical Sinkhole Situations



SINKHOLE WITH NO VISIBLE THROAT



SINKHOLE WITH VISIBLE THROAT

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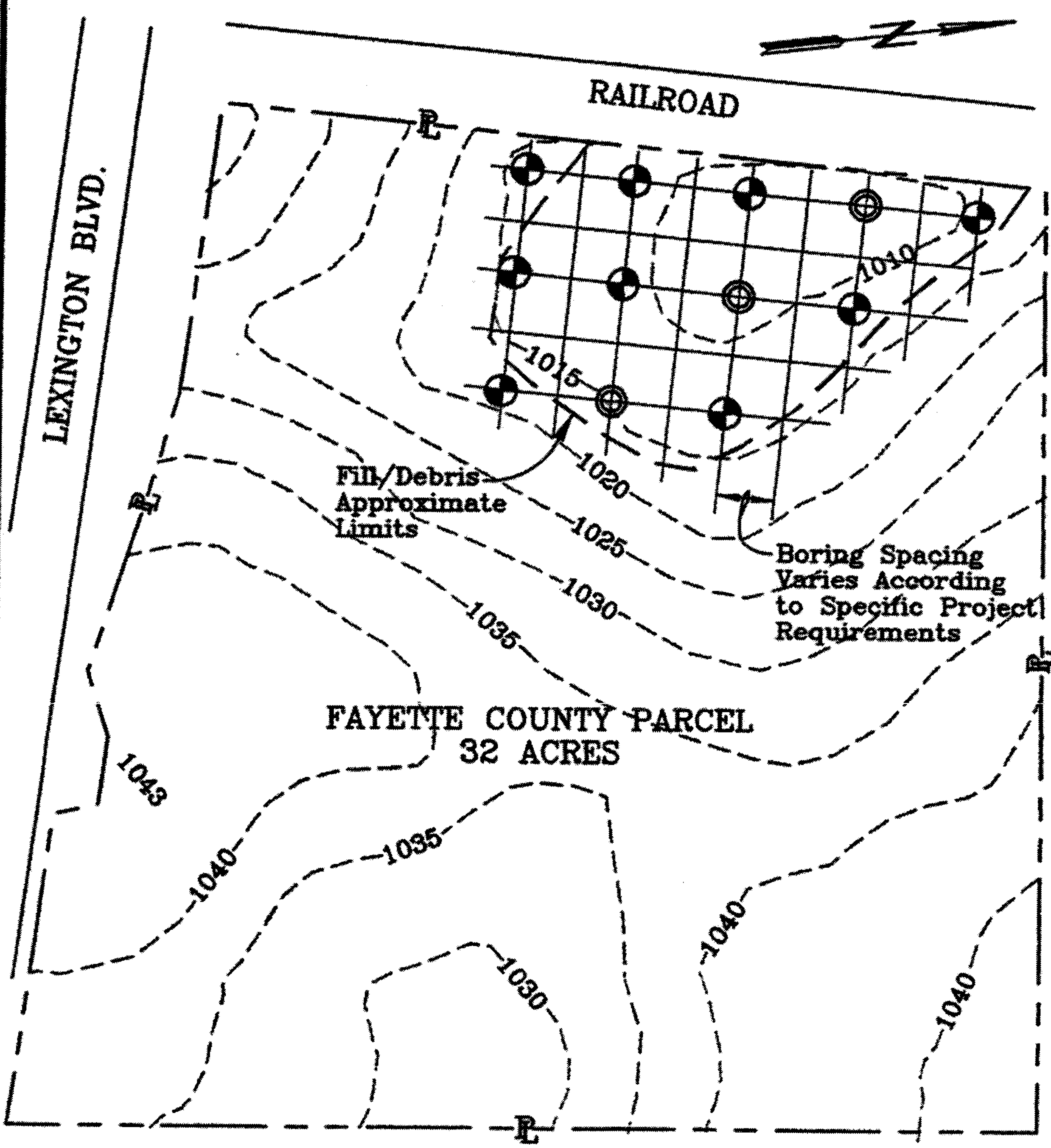
FIGURE 4.10
Typical Boring Layout For Fill/Debris Areas



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