GEOTECHNICAL MANUAL OF INSTRUCTION

Utah Department of Transportation

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CHAPTER 1: INTRODUCTION

1.1 GENERAL

The purposes of this Manual include the following:

- Outline the roles and interaction of the UDOT Geotechnical Division and of Consultant Geotechnical Engineers within the Project team for work on UDOT projects.
- Identify Standard procedures, practices, manuals, specifications, computer software, etc. for use in UDOT geotechnical work, including investigations, testing, design, and construction.
- Establish standards for presentation of geotechnical information, including reports, test hole logs, and laboratory test results.
- Define UDOT requirements and expectations for geotechnical work; particularly where UDOT's expectations may differ from or are not clearly addressed by the requirements of the referenced Standards.

Imperative statements in this Manual indicate requirements for geotechnical work on UDOT projects, and the subject of imperative statements is the Project Geotechnical Engineer, unless otherwise noted.

It is not the intent of this Manual to be all-inclusive. Where this manual uses the terms "include" or "including," the implied meaning is "including but not limited to." Address all geotechnical issues that are pertinent to the Project, regardless of whether or not a given issue is specifically addressed by this Manual. Consult with the UDOT Geotechnical Division in developing an approach to geotechnical topics not specifically addressed by this Manual or its Standards.

Wherever a publication is referenced in this Manual, the reference refers to the current edition and all current interims, unless explicitly stated otherwise in the reference. Consult with the UDOT Geotechnical Division for clarification as needed.

This Manual requires that various items be submitted to the UDOT Geotechnical Consultant Manager. The UDOT Geotechnical Division will provide comments on submittals at its discretion. Allow adequate time (generally 5 to 10 business days) for the UDOT Geotechnical Division to provide comments on submittals.

The UDOT Geotechnical Division recognizes the importance of engineering judgment, schedule, and economy in geotechnical work for UDOT projects, and may accept project-specific exceptions to the requirements of this Manual at its discretion. Where the Project Geotechnical Engineer concludes that a specific exception is justified and particularly advantageous to the Project, submit written justification of the proposed exception to the UDOT Geotechnical Consultant Manager. Obtain written acceptance of

the proposed exception from the UDOT Geotechnical Consultant Manager prior to proceeding with the related work.

The UDOT Geotechnical Division maintains and updates this Manual to accommodate advances in geotechnical engineering and AASHTO practice, and welcomes comments and suggestions to be considered for implementation in future editions.

1.2 DEFINITIONS OF SELECTED TERMS USED IN THIS MANUAL

Manual: The phrase "this Manual" refers to this document, the current UDOT *Geotechnical Manual of Instruction*.

Project Geotechnical Engineer: The Geotechnical Engineer of Record. A Professional Engineer registered in the State of Utah and responsible for the geotechnical work performed on the Project. The Project Geotechnical Engineer may be a UDOT Geotechnical Engineer or a Geotechnical Consultant (including a consultant working for another entity on the Project).

Subsurface Exploration: Any subsurface exploration as a part of a geotechnical investigation to determine the engineering properties of the subsurface materials. A subsurface exploration may include soil borings, test pits, trenches, rock coring/boring, and in-situ testing such as SPTs, CPTs, field permeability tests, etc.

UDOT Geotechnical Consultant Manager: Representative of the UDOT Geotechnical Division assigned to a project in cases where the Project Geotechnical Engineer is a Geotechnical Consultant.

1.3 SELECTED ACRONYMNS USED IN THIS MANUAL

AASHTO: American Association of State Highway and Transportation Officials

ADSC: Association of Drilled Shaft Contractors

ASTM: ASTM International (American Society for Testing and Materials)

CPT: Cone Penetration Test

DFI: Deep Foundations Institute

FHWA: Federal Highway Administration

LRFD: Load-and-Resistance Factor Design

MSE: Mechanically-Stabilized Earth

NACSN: North American Commission on Stratigraphic Nomenclature

NCHRP: National Cooperative Highway Research Program

NHI: National Highway Institute

OSHA: Occupational Safety and Health Administration

PDA: High-Strain Dynamic Pile Testing (e.g., Pile Driving Analyzer)

PGA: Peak Ground Acceleration

QC/QA: Quality Control / Quality Assurance

QSM: Quality Systems Manual

RFP: Request for Proposals

RQD: Rock Quality Designation

SPT: Standard Penetration Test

TRB: Transportation Research Board

UDOT: Utah Department of Transportation

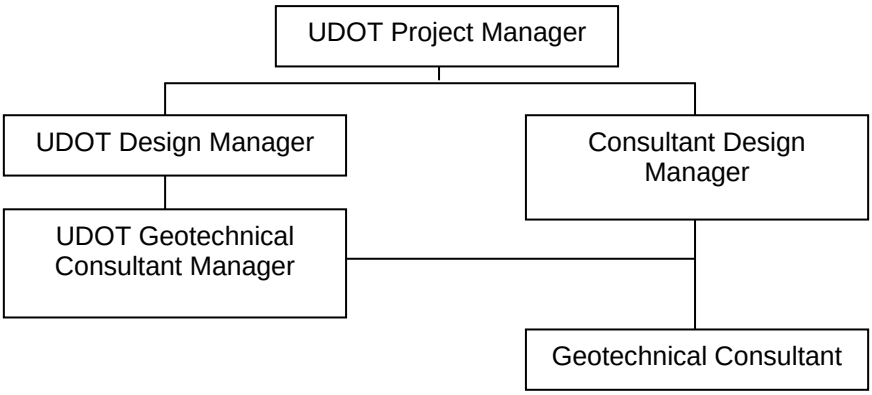
USCS: Unified Soil Classification System

USGS: United States Geological Survey

WEAP: Wave Equation Analysis of Pile Driving

1.4 GEOTECHNICAL PROJECT ORGANIZATION STRUCTURE

For projects employing a Geotechnical Consultant as the Project Geotechnical Engineer, conduct geotechnical work in accordance with the Project team structure illustrated by the diagram below.



Submit all geotechnical reports to the UDOT Geotechnical Consultant Manager, and allow time for comment prior to finalizing reports. The Project Geotechnical Engineer bears the ultimate responsibility for all geotechnical work.

1.5 UDOT DESIGN PROCESS

Conduct work in accordance with the UDOT *2009 Design Network*, including the following activities:

- 11G Preliminary Geotechnical Investigation
- 31G Conduct Geotechnical Investigation
- 33G Conduct Geotechnical Testing
- 35G Develop Geotechnical Design
- 37G Draft Geotechnical Report
- 51G Finalize Geotechnical Report
- 71G Develop Geotechnical Project Documents

Participate in other activities and meetings as needed for the Project.

The UDOT Geotechnical Division does not conduct pavement design. Where geotechnical input is needed for pavement design, refer to the UDOT *Pavement Management and Pavement Design Manual*.

1.6 LOCAL GOVERNMENT PROJECTS

For details on the design process for local government projects, refer to the UDOT *Local Government Design Process Manual*. While oversight authority lies with the local government agency on these projects, the lines of responsibility for geotechnical services and oversight are the same as for State transportation projects. Conduct geotechnical work for local government projects in accordance with this Manual.

1.7 DESIGN-BUILD PROJECTS

Conduct geotechnical work for UDOT Design-Build projects in accordance with this Manual and the other Standards listed by priority in the Project RFP. The UDOT Geotechnical Division will assign a Geotechnical Oversight Engineer to assist the Project management team. Good communication between the UDOT Geotechnical Oversight Engineer and the Design-Builder's Geotechnical Engineer is essential to the successful completion of Design-Build projects.

1.8 MAINTENANCE SUPPORT

The UDOT Geotechnical Division will provide support to UDOT's maintenance group regarding issues such as landslides, rockfalls, and other geotechnical concerns.

UDOT may occasionally retain consultants to assist the Geotechnical Division in specialized situations. Consultants retained to assist with maintenance issues will provide services in accordance with applicable procedures and standards.

CHAPTER 2: GEOTECHNICAL STANDARDS, REFERENCES, AND SOFTWARE

2.1 GEOTECHNICAL STANDARDS

Conduct all geotechnical work for UDOT projects in accordance with the Standards listed in Table 2-1. In the case of conflicting requirements, the requirements of the highest priority Standard take precedence.

Table 2-1

Standards for UDOT Geotechnical Work		
Priority	**Author or Agency**	**Title**
1	UDOT	Contract Documents for the Project
2	UDOT	*Supplemental Specifications to the Standard Specifications for Road and Bridge Construction*
3	UDOT	*Standard Specifications for Road and Bridge Construction*
4	UDOT	*Supplemental Drawings to the Standard Drawings for Road and Bridge Construction*
5	UDOT	*Standard Drawings for Road and Bridge Construction*
6	UDOT	*Geotechnical Manual of Instruction*
7	AASHTO	*Guide Specifications for LRFD Seismic Bridge Design*
8	AASHTO	*LRFD Bridge Design Specifications* (Customary U.S. Units)
9	AASHTO	*Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*
9	FHWA	*Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines* NHI-10-024 (Berg et al, Nov 2009)
9	FHWA	*Soil Nail Walls, Geotechnical Engineering Circular No. 7* FHWA-IF-03-017 (Lazarte et al., 2003)

2.2 GEOTECHNICAL REFERENCES

The References section at the end of this Manual (Appendix I) contains complete references for the publications listed in Table 2-1. In addition to the Standards listed in Table 2-1, the UDOT Geotechnical Division commonly uses the other resources referenced in this Manual, and may refer to these references in reviewing geotechnical work, including investigations, testing, reports, design submittals, and proposed methodologies.

2.3 GEOTECHNICAL SOFTWARE

Appendix A lists accepted software for use in UDOT geotechnical work. Obtain written acceptance from the UDOT Geotechnical Consultant Manager prior to relying on software not listed in Appendix A for geotechnical work.

CHAPTER 3: GEOTECHNICAL INVESTIGATIONS

Consult with the UDOT Geotechnical Consultant Manager in planning and conducting geotechnical investigations.

3.1 LITERATURE REVIEW

Prior to commencing subsurface explorations, conduct a review of available literature and records applicable to the Project. Common sources of geotechnical and geological literature and data useful for UDOT projects include those listed in Table 3-1.

Table 3-1

Common Sources of Geotechnical and Geological Literature and Data	
Source	**Type of Information**
UDOT	previous geotechnical investigation reports; as-constructed drawings from Structures Division records for existing highway facilities (including soil data sheets); construction monitoring and test records; maintenance records; UDOT research reports
USGS	geologic maps, charts, books; probabilistic seismic hazard deaggregations
Utah Geological Survey	geologic maps, charts, books
State, County, and Local Governments	well installation records; geological and geotechnical studies
Utah Department of Natural Resources	well installation records (Division of Water Rights)
Local Colleges and Universities	theses and dissertations on geotechnical and geologic topics of local interest; out-of-print geologic publications
Various Government Agencies	aerial photographs (review with stereoscope may show features/details not obvious to the naked eye); soil surveys (agricultural, engineering, etc.)

3.2 FIELD RECONAISSANCE

Subsequent to the literature review, provide for site inspection by a geologist and/or a geotechnical engineer. Obtain as much surface and subsurface information as possible prior to performing subsurface explorations, including the following:

- site accessibility and potential traffic problems
- topography
- surface water and groundwater
- erosion patterns
- geologic structure and soil/rock profiles
- surface features that may affect design, construction, and performance of proposed facility

Refer to Appendix B of this Manual for an example field reconnaissance report form.

Where applicable, obtain information regarding the soil (nature and thickness of strata) and bedrock (lithology and structure) by observing natural and man-made exposures, including river banks, escarpments, quarries, and highway and railway cuts.

3.3 SUBSURFACE EXPLORATION PLANNING

3.3.1 General

Conduct and finalize site exploration planning in advance of any actual subsurface exploratory work. Ensure that all permits and clearances are obtained and that all necessary precautions (such as evaluations of potential hazards at or near the site) are taken ahead of time.

3.3.2 UDOT Encroachment Permits

Obtain encroachment permits prior to performing any subsurface exploration or testing on UDOT property. Contact the local UDOT region office to apply for permits.

3.3.3 Permission to Access Private Property

Obtain and document permission to access private property directly from the property owner. A sample permit to enter and conduct exploratory drilling is included in Appendix B of this Manual.

3.3.4 Railroad Right of Way

Coordinate all access to Railroad right of way with the UDOT Engineering Coordinator of Utilities and Railroads.

3.3.5 Environmental Clearances and Permits

Obtain all required environmental clearances and permits prior to initiating investigations. Cease exploration operations and contact UDOT's Risk Management Group if potentially hazardous conditions are identified. Record and immediately report evidence of contamination in any explorations to the Region Environmental Engineer.

3.3.6 Traffic Control Plans

For all exploration sites that require drilling equipment, support vehicles and/or personnel to be located within 30 feet of a traveled way, submit a traffic control plan and obtain acceptance from the Region Traffic and Safety Engineer.

3.3.7 Utility Clearances

Obtain utility clearances through Blue Stakes of Utah (tel. 1-800-662-4111) and any other entities (e.g., railroads, irrigation companies, etc.) that may own or operate utilities in the area. Provide locations of the proposed subsurface explorations to utility locating organizations. Obtain clearances as necessary for both overhead and buried utilities. A sample job site form is included in Appendix B of this Manual.

Blue Stakes requires that the address, location, and nature of the work be submitted at least two full working days prior to commencement of subsurface explorations. Blue Stakes can schedule an on-site meeting with utility locators in cases where the proposed subsurface exploration locations are difficult to describe. Where the exploration is near an existing utility, the utility company may require that their representative be present at the beginning of the investigation, and may require hand digging or potholing to a depth below the utility.

3.3.8 Impacts to UDOT Property

If UDOT property is damaged or modified in any way due to drilling operations, contact the UDOT region maintenance office and mitigate the impacts as directed.

3.3.9 Health and Safety

Comply with UDOT safety standards and all federal (including OSHA), state, and local laws and ordinances. Conduct drilling using trained and certified personnel equipped with appropriate safety equipment.

3.3.10 Interactions with the Public

Conduct all interactions with the public with respect and courtesy. Cooperate with property owners, public safety officers, and UDOT personnel to minimize and mitigate potential impacts and hazards of field investigations.

Protect the public from falling and tripping hazards posed by test holes. Provide advance notice of lane closures and other potential impacts in heavily-travelled areas. Refer specific questions from the public regarding UDOT projects to the UDOT Project Manager and/or Project public involvement personnel.

3.4 SUBSURFACE EXPLORATION

Submit all subsurface exploration plans to the UDOT Geotechnical Consultant Manager prior to beginning field work.

3.4.1 Soil Borings

Soil borings are an essential element of the preliminary engineering investigations for highway bridge foundation design, cut and natural slope stability evaluations, embankment stability and settlement evaluations, and highway location selection. The purposes of soil borings include the following:

- Determine the extent and characteristics of the various natural soil formations.
- Obtain high-quality samples representative of the different soil formations for laboratory testing and subsequent engineering analyses.

- Investigate possible trouble conditions such as springs, swamps, bogs, seepage zones, slide areas, expansive soils or rock, collapsible soils, soft soils, weak soils or rock, compressible soils, liquefiable soils, or other unusual soil or rock, or moisture conditions which could affect construction of highway structures or roadbed stability.

Conduct soil boring, sampling, and in-situ testing in accordance with the specifications and procedures of this Manual and the relevant AASHTO and ASTM standards.

Drilling procedures will vary due to the variety of geologic conditions encountered within Utah. Use drill crews trained and equipped to perform investigations in the anticipated geologic conditions. Ensure that drilling crews conduct work in accordance with the procedures outlined in the AASHTO *Manual on Subsurface Investigations* (1988).

3.4.2 Test Hole Frequency and Depth

Exercise engineering judgment in planning and performing subsurface explorations. Consider the following:

- type and criticality of Project elements
- soil and rock formations and characteristics
- subsurface variability at the site
- lengths and widths of Project elements
- loads to be imposed on the foundation materials
- availability and applicability of previous investigations at the site
- groundwater characteristics and conditions

Conduct subsurface explorations meeting the frequency and depth requirements listed in Table 3-2. CPT probes may be used for some of the required test holes where appropriate.

Table 3-2

Frequency and Depth of Geotechnical Subsurface Explorations		
Project Element	**Test Hole Frequency**	**Minimum Test Hole Depth (See discussion following table)**
Roadway Embankments	Every 200 to 600 feet, depending on variation in subsurface conditions	Twice the embankment height.
Cut Slopes	Every 200 to 600 feet, depending on conditions. Minimum of one for every cut exceeding 15 feet in depth.	15 feet below anticipated base of cut, and into competent soils or rock.
Buried Structures	One or more at each buried structure location.	15 feet below anticipated foundation elevation
Noise Walls	Every 250 to 500 feet, depending on variation in subsurface conditions.	10 feet below anticipated foundation elevation
Structural Foundations	See Section 10 of *AASHTO LRFD Bridge Design Specifications*, except provide at least 2 test holes for substructures more than 70 feet wide.	
Retaining Walls	See Section 10 of *AASHTO LRFD Bridge Design Specifications*	
Roadway Pavement	Refer to UDOT *Pavement Management and Pavement Design Manual*	

In developing the subsurface exploration plan, consider the widths of Project elements such as pavements, embankments, and buried structures. Where the element width exceeds about 70 feet, perform test holes along each side of the Project element at the frequencies listed in Table 3-2.

Project conditions may require more and/or deeper test holes than specified by Table 3-2, at the discretion of the Project Geotechnical Engineer in consultation with the UDOT Geotechnical Division. For example, wide embankments on compressible soils may require test holes to depths much greater than twice the fill height. In all cases, perform sufficient subsurface explorations to provide the information needed for the design and construction of each Project element. Base the extent and number of explorations and possible additional explorations on the variability of subsurface conditions in consultation with the UDOT Geotechnical Division.

It is not the intent of this Manual to require test holes in excessive quantities or depths. In particular, test holes for walls and embankments need not extend excessive depths into competent, incompressible strata. The UDOT Geotechnical Division may accept reduced test hole frequencies and/or depths at the recommendation of the Project Geotechnical Engineer.

3.4.3 Logging of Soil Borings

Log soil borings in the field and record, as a minimum, the information outlined in Appendix C of this Manual. Prepare final logs in English units and as outlined in Appendix C.

3.4.4 Rock Coring/Boring

Obtain and recover rock cores in accordance with the applicable sections of the AASHTO *Manual on Subsurface Investigations* (1988). Log rock cores as outlined in Appendix E.6 of the same manual, and as outlined in the *North American Code of Stratigraphic Nomenclature* (NACSN, 2005). Include on the logs RQD data relevant to Project requirements (see Appendix D of this Manual). Obtain downhole digital images or oriented cores where appropriate.

3.4.5 Test Pits/Trenches

The Project Geotechnical Engineer may use test pits for shallow soil investigations such as pavement subgrade investigations, and may use exploratory trenches for fault investigations, collapsible soils identification, etc. Log excavations (test pits and trenches) in the field and record the findings as outlined in Appendix E of this Manual.

3.4.6 Groundwater

Record groundwater levels in test holes during drilling/excavation and upon completion. Include the date and time of each groundwater level measurement on the field log. Note

pertinent details such as height and/or rate of flow where artesian conditions are encountered.

In many cases, the water level in a test hole will not stabilize to the natural groundwater level until hours or days after drilling is complete. Where necessary, install temporary pipe in test holes to allow subsequent measurements of groundwater levels. If the primary drilling method does not permit reliable measurements of groundwater levels, conduct supplementary test holes to determine the depth to groundwater.

3.5 IN-SITU TESTING

In-situ tests used most frequently for UDOT projects include the Standard Penetration Test (SPT) and the Cone Penetration Test (CPT). These and other in-situ tests that may be advantageous for a given project include those listed in Table 3-3.

Table 3-3

In-Situ Tests for Subsurface Explorations	
Test	**Application**
Becker Penetration Test	Evaluates penetration resistance in deposits of hard and/or oversize material (gravels and cobbles) where SPT is less meaningful. May obtain sample using open-ended casing.
Borehole Shear Test	Simulates direct shear test in measuring pullout resistance of borehole sidewalls.
Cone Penetration Test	Records continuous profile of soil behavior versus depth in soft/loose to moderately stiff/dense soils. May also be used to measure shear wave velocities, pore pressures, etc.
Field Permeability Test	Estimates in-situ permeability of soil for detention basins and similar applications.
Field Vane Shear Test	Provides indication of in-situ undrained strength of soft to stiff fine-grained soils. Particularly useful where sampling disturbance may reduce soil strength.
Flat Plate Dilatometer Test	Estimates stratigraphy, lateral stresses, elastic modulus, and shear strength in sands, silts, and clays.
Plate Load Test	Models resistance of soil to shallow foundation loads.
Pressuremeter Test	Provides indication of deformation modulus of soil and rock.
Screw Plate Load Test	Measures soil response to vertical loading of plate installed at bottom of boring.
Standard Penetration Test	Obtains a disturbed sample for classification and testing. Blow count provides good indication of density in cohesionless soils.

Use in-situ testing as appropriate to characterize the subgrade materials. Attempt a given type of in-situ testing only with a prior understanding of the applicability and limitations of the method to be employed. Conduct in-situ testing in accordance with the applicable AASHTO and ASTM standards. For tests not addressed by published standards, use widely-accepted methodologies and carefully document the procedures used.

Do not rely exclusively upon any type of testing that does not acquire a soil sample. Obtain samples of material from all soil strata for visual-manual classification and

laboratory testing. Use in-situ testing of strength characteristics only as a supplement to laboratory testing. Consult with the UDOT Geotechnical Division regarding correlations proposed for use in design.

3.5.1 Logging of In-Situ Tests

Present the results of in-situ tests using English units. On CPT logs, include as a minimum the tip resistance, sleeve resistance, friction ratio, ground surface elevation, and soil type interpretation versus depth. Include additional information such as pore pressures and seismic sounding information where available.

3.6 GEOPHYSICAL METHODS

Use geophysical testing as appropriate for the Project. Consider performing Seismic CPT testing at bridge sites where CPT soundings are conducted. Refer to ASTM D 6429 for guidance in selective geophysical methods. Conduct all geophysical testing in accordance with applicable ASTM standards, or in accordance with widely-accepted guidelines in cases where standards do not exist.

3.7 ABANDONMENT OF SUBSURFACE EXPLORATIONS

Where subsurface explorations require excavation through existing pavements, sidewalks, bridge decks, etc., properly patch the pavement upon completion of the exploration.

3.7.1 Borings

Backfill or grout borings as directed by the UDOT Geotechnical Consultant Manager and in accordance with NCHRP Report 378 (Lutenegger et al., 1995). Certify that each of the borings has been abandoned in accordance with all applicable rules and guidelines.

3.7.2 Test Pits/Trenches

Upon completion of the exploration, backfill excavations with the excavated material or other suitable soil material. In cases where any structure, wall, embankment, pavement, or other flatwork could be located over the excavation, backfill the excavation with suitable material, compacted in lifts with appropriate equipment as specified in Section 02056 of the UDOT Standard Specifications. When excavations are outside the footprint of any proposed Project element, tamp the backfill material in lifts no thicker than 12 inches to at least 90 percent of the maximum laboratory density as determined by AASHTO T 99 (Standard Proctor).

Where excavations are located in agricultural areas or other areas used to support plant growth, cover the backfilled excavation with topsoil so that the impacted area will support vegetation as well as or better than the original condition.

3.8 SOIL SAMPLING AND CLASSIFICATION

3.8.1 Sampling

Perform soil sampling to obtain samples that are as representative of subsurface materials as feasibly possible. Conduct sampling in general accordance with the *FHWA-NHI Subsurface Investigations Manual* (Mayne et al., 2001) and the AASHTO *Manual on Subsurface Investigations* (1988). In soft to very soft cohesive soils, use a piston sampler to obtain relatively undisturbed samples for consolidation testing. Do not attempt to use a driven California sampler to obtain undisturbed samples without prior acceptance by the Geotechnical Division.

Seal soil samples in air-tight containers as soon as they have been exposed and logged. Take particular care to seal samples promptly in extreme weather conditions. Seal thin-walled tube samples with rubber stoppers, o-ring caps, or paraffin wax. Make every effort to obtain, transport, and store samples in a manner that ensures and maintains sample integrity and quality. Avoid exposing samples to bumps, jolts, vibrations, or freezing temperatures.

Conduct SPT sampling using sampling hammers that have been calibrated in accordance with ASTM D 4633 within one year of the sampling date.

For sites in areas of moderate or high seismicity (sites having mapped *PGA* greater than about 0.20g for the seismic event having a three-percent probability of exceedance in 75 years), perform soil sampling and laboratory testing for liquefaction analysis. Conduct SPT testing and sampling at depth intervals of two to three feet in the upper 30 feet where soils may be susceptible to liquefaction. Where liquefaction is a concern for a particular site, perform CPT probes to more specifically assess liquefaction potential and to evaluate its effects.

3.8.2 Field Classification

Classify soils in accordance with the approach and format detailed in ASTM D 2488. Record the basic soil profile elements in the field, including changes in strata, relative properties of soil types in layered/bedded deposits, and presence of cobbles or boulders. Make corrections and additions to the field classification, where necessary, by laboratory testing of the soil samples. Appendix C lists requirements for field logs and final logs.

Provide on the test hole logs soil descriptions that are precise and comprehensive, without being verbose. Include details without distorting the overall impression of the soil by excessive emphasis on less significant details.

Record descriptions in the Soil Description column of the boring log for every soil sample collected. The preferred order for soil descriptions is as follows:

- Soil name (ASTM D 2488 Group Name) with appropriate modifiers
- Group symbol
- Relative density or consistency
- Moisture condition
- Grain size, soil structure, mineralogy, or other descriptors
- Color

Include the gradation of coarse-grained soil (more than 50 percent retained on No. 200 sieve) in the specific soil name in accordance with ASTM D 2488. Record the maximum size and angularity or roundness of gravel and sand-sized particles. For fine grained soil (50 percent or more passing the No. 200 sieve), modify the name with the appropriate plasticity term in accordance with ASTM D 2488.

Describe interlayered soil zones beginning with an introductory name, followed by the soil types in order of predominance (e.g., “Interlayered Sand and Silt). Indicate the relative proportion of each type of soil observed in interlayered samples.

Where helpful, justify evaluations of soil plasticity with brief descriptions of visual-manual procedures, such as reaction to shaking, toughness of a soil thread, smear test, or dry strength, as outlined in ASTM D 2488.

3.8.3 Group Symbol

List the appropriate group symbol from ASTM D 2488 after each soil name. Dual symbols (e.g., GP-GM, SW-SC, CL-ML) may be used in accordance with ASTM D 2488. Borderline symbols (e.g., GM/SM, SM/SC) may be used occasionally on field logs to indicate that a soil sample has properties that do not distinctly place the soil in a specific group. In general, use the group name assigned to a soil as the group name for the first symbol. Avoid indiscriminate use of borderline symbols. Classify the soil in a single group wherever possible.

3.8.4 Relative Density and Consistency

Indicate the relative density of coarse-grained soils based on SPT N-values (ASTM D 1586). Show on the logs the raw blow counts for each 6-inch increment (or refusal) and the corrected $(N_1)_{60}$ values. Include applicable corrections for hammer energy ratio, overburden pressure, rod length, and sampler size.

Where sample disturbance or large gravel prevents a reliable estimate of in-situ relative density or consistency, omit this item from the description, and note the reason for the omission on the boring log.

Use the results of vane shear, miniature vane shear (torvane), or pocket penetrometer testing as the primary field methods for evaluating consistency of fine-grained (cohesive) soil.

Correlations between field test results and relative density for coarse-grained soils are listed in Table 3-4, and correlations for consistency of cohesive soils are listed in Table 3-5.

Table 3-4

Relative Density of Coarse-Grained Soils			
$(N_1)_{60}$ (blows/ft)		**Relative Density**	**Field Test with ½-inch steel rod**
≤35% Gravel	**>35% Gravel**		
<5	<18	very loose	Very easily penetrated when pushed by hand
5-10	18-26	loose	Easily penetrated when pushed by hand
11-30	27-49	medium	Easily penetrated when driven with 5-lb hammer
31-50	50-75	dense	Penetrated 1 foot with difficulty when driven with 5-lb hammer
>50	>75	very dense	Penetrated less than 3 inches when driven with 5-lb hammer

Table 3-5

Consistency of Fine-Grained Soils				
N_{60} (blows/ft)	**Consistency**	**Torvane (kg/cm^2)***	**Pocket Penetrometer (kg/cm^2)***	**Field Test**
<2	very soft	<0.12	<0.25	Easily penetrated several inches by fist
2-4	soft	0.12-0.25	0.25-0.50	Easily penetrated several inches by thumb
5-8	firm	0.25-0.50	0.50-0.10	Penetrated several inches by thumb with moderate effort
9-15	stiff	0.5-1.0	1.0-2.0	Readily indented by thumb but penetrated only with great effort
16-30	very stiff	1.0-2.0	2.0-4.0	Readily indented with thumbnail
>30	hard	>2.0	>4.0	Indented with difficulty by thumbnail

* Standard units for instrument, proximate to tsf.

3.8.5 Moisture Content

Define the degree of moisture present in the soil sample in accordance with Table 3-6.

Table 3-6

Criteria for Describing Moisture Condition	
Description	**Criteria**
Dry	Absence of moisture, dusty, dry to the touch
Slightly Moist	Apparent moisture but well below optimum moisture content
Moist	Damp, but no visible water; at or near optimum moisture content
Very Moist	Above optimum moisture content
Wet	Visible free water; substantially above optimum moisture content; at or above liquid limit

3.8.6 Soil Structure, Mineralogy, and Other Descriptors

Describe discontinuities, inclusions and other features, including joints or fissures, slickensides, bedding or laminations, veins, root holes, and wood or other debris.

Note significant mineralogical information, such as cementation, abundant mica, or unusual mineralogy such as pinhole structure, and other information such as oxidation, ferrous minerals, calcium, organic debris, odor, etc.

Include other descriptors if important for the Project or for describing the sample, including particle size, range and percentages, particle angularity, particle shape, maximum particle size, hardness of large particles, plasticity of fines, dry strength, dilatancy, toughness, reaction to HCL, etc.

If possible, describe the relict rock structure and identify the parent rock for residual soils having characteristics of both rock and soil.

3.8.7 Color

Record the basic color of a soil. Assign colors in accordance with Munsell color charts. Use modifiers such as “light” and “dark” if necessary. Especially note staining or mottling, as this information may indicate water table fluctuations or contamination.

3.8.8 USCS Laboratory Classification

Modify field descriptions of soils using USCS laboratory classifications as appropriate.

3.8.9 AASHTO Laboratory Classification

Classify soils according to the AASHTO classification system based on available laboratory data in accordance with AASHTO M-145. Show the AASHTO classification symbol in parentheses next to the USCS symbol on the boring logs.

3.9 ROCK CLASSIFICATION

Classify rock samples with the aid of the *North American Code of Stratigraphic Nomenclature* (NACSN 2005) and the appropriate section of the AASHTO *Manual on Subsurface Investigations* (1988), and as outlined in Appendix D of this Manual.

CHAPTER 4: GEOTECHNICAL TESTING

4.1 INTRODUCTION

Conduct the geotechnical testing program at the discretion of the Project Geotechnical Engineer and meeting the requirements the Project and of this Manual. Exercise engineering judgment in developing the testing program. Use a testing laboratory accredited by AASHTO and ASTM. Maintain current certifications through the duration of the Project for all testing personnel.

Prior to commencing any laboratory testing, review the laboratory's policies and procedures with the UDOT Geotechnical Consultant Manager. Adjust policies and procedures as necessary to meet project requirements.

The UDOT Geotechnical Laboratory is located in the Materials Testing Facility directly east of the Calvin Rampton building, and its primary function is to provide testing services for UDOT's in-house geotechnical design engineers, and for Geotechnical Consultants doing UDOT work on a project-by-project basis.

4.2 LABORATORY TESTING REQUIREMENTS

Conduct laboratory soil testing in accordance with the following requirements:

- Visually classify in the laboratory all soil samples extracted from the borings.
- Conduct moisture content and density tests on all undisturbed cohesive samples, and perform Atterberg limits tests on selected samples to provide data for correlation and identification.
- Perform gradation/hydrometer testing to characterize grain size for any loose to medium-dense continuous sand deposits, or any loose to medium-dense non-continuous sand deposits greater than three feet thick.
- Where consolidation settlement is a concern, perform an adequate number of consolidation tests to determine variation of preconsolidation pressure with depth and variations of compressibility in different strata. Test consolidation samples at loads sufficiently large to accurately determine consolidation parameters. Record consolidation measurements versus time over a time period sufficient to determine rates of both primary and secondary consolidation under loads representative of the in-situ soil stresses anticipated during the Project.
- Conduct proper testing for determination of secondary settlement characteristics, amount of surcharge to use, and the percent consolidation to achieve long-term settlement requirements of the project.
- Conduct shear strength tests such as triaxial shear, direct shear, vane shear, and unconfined compression on samples from each definable soil deposit, depending on the soil type and the nature, purpose, and importance of the Project element.

- Perform pH, resistivity, sulfate, chloride, and soluble salt tests to evaluate potential for corrosion and deterioration of concrete and metal.
- Where sensitive soils are encountered, conduct shear strength tests to evaluate soil sensitivity.
- Test to evaluate potential for collapse, expansion, and other problematic behavior.
- In selecting tests for specific Project features, comply with the requirements and guidelines of applicable AASHTO and UDOT design specifications and manuals, including the *AASHTO LRFD Bridge Design Specifications* and the UDOT *Pavement Management and Pavement Design Manual*.

Perform geomechanical (rock core) testing in accordance with the guidelines set forth in the FHWA-NHI Subsurface Investigations Manual (Mayne et al., 2001).

4.3 LABORATORY TESTING PROCEDURES

Follow the applicable testing procedures outlined in the current AASHTO and ASTM Standards listed below:

- AASHTO *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*
- *ASTM Volume 04.08: Construction: Soil and Rock (I)*

4.4 SOIL STRENGTH TESTING

Do not rely entirely on field methods such as miniature vane shear or pocket penetrometer tests to estimate shear strength properties of the subsurface materials. Conduct laboratory shear strength tests (e.g., triaxial shear, direct shear, unconfined compression) to supplement the results of field tests.

4.5 FORMAT OF LABORATORY DATA AND RESULTS

The exact format of laboratory data and results is not critical. Present the required information for each test in a neat and concise manner.

4.6 QUALITY ASSURANCE AND QUALITY CONTROL

Conduct laboratory testing in accordance with the Laboratory's QC/QA plan and QSM. Where samples are disturbed, contaminated, or otherwise compromised, make special note of the condition and its potential impacts on the test results. Make every effort to test only high-quality samples.

4.7 SAMPLE RETENTION

Retain and preserve samples in their original state until final acceptance of the Project following construction. Retain laboratory worksheets and records for verification purposes for at least five years following construction of the Project.

4.8 LABORATORY SUBCONTRACTING

The Project Geotechnical Engineer is ultimately responsible to UDOT for the laboratory testing for the Project, but may subcontract portions of the work to an accredited laboratory with the concurrence of the UDOT Geotechnical Consultant Manager. The same contract requirements apply to the subcontracted laboratory.

CHAPTER 5: GEOTECHNICAL DESIGN

5.1 GENERAL

This Chapter provides an overview of accepted UDOT analysis and design practices. It is not the intent of this Chapter to provide step-by-step procedures for analysis and design. Use expertise and engineering judgment in carrying out the analysis and design necessary to comply with all requirements. Do not hesitate to contact the UDOT Geotechnical Consultant Manager to review assumptions and approaches to analysis and design procedures.

To properly accommodate the guidelines presented herein and to incorporate any other project-specific requirements for design and construction, it may be necessary to modify some UDOT standard specifications or drawing details, or to develop special provisions for the Project. Ensure that such items are properly incorporated in the Project specifications and drawings.

5.2 SEISMIC POLICY AND PROCEDURES

5.2.1 General

Bridges built under the Department's oversight are designed in accordance with the policies and procedures specified by the UDOT Structures Division. Design bridge foundations, retaining walls, embankments, and other related elements in accordance with the policies and procedures presented in this Manual. For the purposes of seismic design, use the definitions and seismic design criteria shown in Table 5-1 for retaining walls and slopes.

Table 5-1

Seismic Design – Retaining Walls and Slopes		
Category	**Definition**	**Seismic Design Criteria**
Retaining walls and slopes adjacent to bridges	Located within 50 feet of bridge foundations, or within a greater distance where failure or excessive deformation would impact the seismic performance of the bridge	Meet the same criteria as the adjacent bridge(s). Estimate seismic deformations and confirm that the estimated displacements are compatible with the bridge design criteria and displacements.
Retaining walls and slopes adjacent to other critical facilities	Located where failure or excessive deformation will impact adjacent critical facilities.	Design to protect the adjacent facility in a large earthquake (i.e., 3 percent probability of exceedance in 75 years). Estimate seismic deformations and confirm that the estimated displacements do not present a hazard to the adjacent facilities.
Other retaining walls	All other retaining walls.	Design for the seismic event having a 7 percent probability of exceedance in 75 years, in accordance with the *AASHTO LRFD Bridge Design Specifications.*

5.2.2 Site-Specific Seismic Analyses

The UDOT Geotechnical Division encourages the use of site-specific procedures to determine design response spectra. In many cases, a detailed site-specific analysis will reduce design seismic ground motions for UDOT projects. Meet the requirements and comply with the guidelines of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design* and the *AASHTO LRFD Bridge Design Specifications* in selecting sites for and performing site-specific seismic analyses.

Review the proposed site-specific seismic analysis methodologies with the UDOT Geotechnical Division and obtain the Division's acceptance prior to undertaking the analyses. Before designing bridges or other Project elements using the results of site-specific seismic analyses, submit the analysis to the UDOT Geotechnical Consultant Manager.

5.2.3 Mapped Probabilistic Ground Motions

For the 1,033-year seismic event (7 percent probability of exceedance in 75 years, approximate 1,000-year event) evaluated using the General Procedure (as detailed in the *AASHTO LRFD Bridge Design Specifications* and the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*), determine the mapped ground motion parameters *PGA*, S_a, and S_1 for the site latitude and longitude using the USGS CD-ROM accompanying the *AASHTO LRFD Bridge Design Specifications* or the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*.

Where using the General Procedure for other seismic events (e.g., the approximate 2,500-year event), determine the mapped ground motion parameters for the site latitude and longitude using the USGS interactive deaggregation tools found online at http://eqint.cr.usgs.gov/deaggint. The 2008 deaggregation tool is presently only available in a preliminary version, and the USGS CD-ROM that accompanies the AASHTO bridge design specifications (see previous paragraph) is based on the 2002 mapping system. For UDOT projects, use the 2002 USGS deaggregations for all projects that commence before the newer deaggregation tool becomes available in its final form.

Because mapped ground motion parameters vary significantly over relatively small distances in many parts of Utah, do not use paper maps or zip code lookup tools to determine ground motion parameters for UDOT projects.

5.2.4 Design Event Magnitudes

Where seismic analyses require an estimate of the earthquake magnitude, use the USGS deaggregation tool referenced in the previous section of this Manual to estimate

the event magnitude. Guidelines for selecting design event magnitudes are provided in Article C6.8 of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*.

5.2.5 Liquefaction

Evaluate the potential for liquefaction and design for its impacts in accordance with Articles 6.8 and C6.8 of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design*. Liquefaction-related impacts pertinent to UDOT projects include the following:

- Flow failures on steep slopes (greater than 6%)
- Lateral spread down gentle slopes (less than about 6%)
- Ground oscillation on flat ground underlain by liquefiable layers
- Ground settlement
- Reduced soil strength impacting stability of walls and slopes
- Settlement and reduced bearing resistance for shallow foundations
- Settlement, downdrag, and reduced resistance for deep foundations

5.2.6 Lateral Spread

For the purposes of UDOT geotechnical work, “lateral spread” refers to lateral displacements of the ground surface caused by liquefaction of a laterally-continuous subsurface soil layer, and is not to be confused with localized limit-equilibrium slope instability, including flow failure or rotational slump. Lateral spread displacement occurs either in a down-slope direction on gently-sloping topography, or in the direction of a free face topographic feature where gentle or negligible slopes are interrupted by a relatively abrupt downward slope. Slopes and free-face ratios conducive to lateral spreading are outlined by Bartlett and Youd (1992) and Youd et al. (2002).

Where the potential for liquefaction exists, address in the geotechnical report(s) the potential for lateral spreading, including the following considerations:

- Depth and continuity of soil layer(s) susceptible to liquefaction
- Topography of the site and vicinity
- Site geology and evidence of past liquefaction and lateral spreading

As a minimum, use the revised empirical equations of Youd et al. (2002) to estimate lateral spread displacements for UDOT projects where conditions are conducive to lateral spreading. With prior acceptance of the UDOT Geotechnical Division, the Project Geotechnical Engineer may also use other methods to further evaluate potential lateral spread displacements.

Where ground modification is warranted to mitigate the effects of lateral spread, design a ground modification program to prevent liquefaction of the soils contributing to the potential for lateral spreading. Article C6.8 of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design* briefly discusses potential ground improvement techniques for liquefaction mitigation.

The UDOT Geotechnical Division prefers the use of over-excavation and replacement or vibro-replacement (stone columns) for liquefaction mitigation. Obtain the prior acceptance of the UDOT Geotechnical Division for any other proposed mitigation methods. Develop special provisions requiring in-situ post-mitigation testing to verify that the soils left in place within the mitigated zone will not liquefy in the design event.

Drainage improvements alone are not acceptable for lateral spread mitigation on UDOT projects, but may be used in combination with replacement, densification, or alterations of the soil composition. Shear stress redistribution techniques using high-modulus elements are not acceptable for mitigating lateral spread on UDOT projects.

5.2.7 Seismic Soil Strength Reductions

For soils that are prone to liquefaction or severe strength loss as a result of ground shaking (e.g., sensitive soils), determine dynamic and post-earthquake strength parameters using cyclic triaxial tests where the loading is based on the design earthquake. Correlations with residual shear strength may be used in the absence of cyclic triaxial testing.

For cohesive soils that are not susceptible to appreciable dynamic/cyclic softening, account for a 10 to 20 percent increase in pore pressures or decrease in soil strength in post-earthquake analyses.

Refer to Section C6.8 of the *AASHTO Guide Specifications for LRFD Seismic Bridge Design* for guidance in addressing the timing of seismic soil strength loss relative to peak ground shaking.

5.2.8 Global Seismic Stability of Walls and Slopes

Evaluate global seismic stability of retaining walls and slopes for the following conditions:

- Dynamic condition during earthquake ground motions
- Post-earthquake condition after ground motions cease and dynamic strength losses are fully developed.

For the dynamic condition, conduct global seismic stability analyses using a horizontal pseudo-static coefficient equal to $0.5A_S$, with A_S determined in accordance with the *AASHTO LRFD Bridge Design Specifications*. If the factor of safety determined from the pseudo-static analysis is at least 1.0, and the value A_S for the site is less than 0.3, the permanent deformation associated with the dynamic condition can be assumed to be insignificant. For all other cases, supplement the results of the pseudo-static analyses by estimating the likely permanent deformations resulting from the dynamic condition.

Acceptable methods for estimating dynamic deformations of walls and slopes include the following:

- Newmark Sliding Block Analysis: Determine yield acceleration from pseudo-static analysis, then double-integrate acceleration time histories to estimate permanent deformations where the ground acceleration exceeds the yield acceleration. Use a minimum of three time histories that are appropriate for the site.
- Newmark-Based Displacement Charts and Equations: If a site-specific Newmark Analysis is not performed, compute and compare deformations estimated using at least two of the following methods.
    - Makdisi and Seed (1978)
    - Bray and Travasarou (2007)
    - Idriss and Boulanger (2008)
    - Rathje and Saygili (2008)
    - Saygili and Rathje (2008)

Obtain the acceptance of the UDOT Geotechnical Division prior to using more complex methods of dynamic deformation analysis, such as dynamic stress-deformation models. Submit to the UDOT Geotechnical Consultant Manager the qualifications of the engineer(s) responsible for the modeling work, and documentation validating the proposed modeling method.

5.3 BRIDGE FOUNDATIONS

5.3.1 General

Comply with the *AASHTO LRFD Bridge Design Specifications* for all aspects of bridge design, with any exceptions as directed by the UDOT Structures Division or the UDOT Chief Geotechnical Engineer.

Bridge foundations for UDOT projects typically consist of deep foundations (piles or drilled shafts) or spread footings. Spread footings are generally not considered acceptable to the Structures or Hydraulics Divisions at stream crossings. Conduct an economic analysis to determine the optimal foundation system of those technically feasible. Do not use auger-cast piles, timber piles, or rammed aggregate piers as a substitute for deep foundations to support UDOT bridges.

The foundation types applicable to a given project depend on anticipated loads and scour depths (where applicable), along with proper consideration of settlements, downdrag, bearing resistance, lateral load resistance, seismic hazards, constructability, and other applicable factors. Communicate with the Project Bridge and Hydraulics Engineers early in the Project and follow up regularly to develop a cost-effective foundation design.

5.3.2 Driven Piles

Driven piles should consist of steel H-pile or steel pipe pile (typically concrete-filled), or pre-stressed concrete pile. Yield strength values used in design are not to exceed the values prescribed in the following specifications (regardless of any higher "heat" values):

- Pipe pile: ASTM A-252 Grade 2 (35 ksi) or Grade 3 (45 ksi) steel
- H-pile: ASTM A-36 or A-50 steel

Where driven piles are used, include as a minimum the following items for each abutment and bent on the pile details drawing:

- Required Driving Resistance
- Estimated Pile Toe Elevation
- Elevation of Minimum Acceptable Pile Penetration
- Pile Axial Compression Resistance at the Strength Limit State
- Pile Axial Compression Resistance at the Extreme Limit State
- Pile Uplift Resistance at the Strength Limit State
- Pile Uplift Resistance at the Extreme Limit State

UDOT Standard Specification 02455 lists installation requirements for driven piles, including required dynamic pile testing (PDA testing) with accompanying signal matching analyses for at least one pile at each abutment and bent. Determine the required number of dynamic tests with signal matching required for each bridge site in accordance with the *AASHTO LRFD Bridge Design Specifications*, including as to what constitutes a bridge "site" for the Project (as accepted by the Department) with at least one tested pile at each abutment and bent, and state this requirement on the pile details drawing. Where pile relaxation is a concern, require PDA testing during initial drive as well as restrike PDA testing at a minimum specified time following initial drive. Require PDA testing during initial driving at sites where difficult driving and excessive driving stresses are possible.

Evaluate pile drivability using WEAP for a range of driving systems that are likely to be proposed for use on the Project, and present the result of the analyses in the geotechnical report. Locally-available pile driving hammers typically used for UDOT projects include the following:

- Delmag D 30-32
- Delmag/APE D 36-32
- ICE I-30
- ICE I-36
- IHC S-70
- IHC S-90

Unless the UDOT Geotechnical Division accepts a different approach in writing, design piles to meet all of the following drivability criteria:

- Ensure that the anticipated pile driving blow counts are not excessive (greater than about 120 blows per foot) for driving to the estimated pile toe elevation during initial drive conditions.
- Verify that the hammer(s) will deliver energy sufficient to demonstrate the required driving resistance at the estimated toe elevation during restrike conditions. State the minimum rated hammer energy on the pile detail drawings.
- State the minimum pile section and yield strength on the pile details drawing to minimize the potential for excessive driving stresses. If these requirements vary depending upon hammer type (e.g., diesel hammers versus hydraulic hammers), state the minimum requirements for each hammer type.

Where precast concrete piling is to be used, modify Special Provision 02455S as appropriate for the type and size of piling to be used.

5.3.3 Drilled Shafts

UDOT Standard Specification 02466 is intended for use with shafts of relatively small diameter and depth. Where necessary, develop a special provision for drilled shaft construction that addresses construction issues relevant to the Project, including the following:

- Use of casing (temporary and/or permanent) to advance shaft excavations
- Use of drilling fluid (water, mineral slurry, polymer slurry)
- Concrete placement beneath groundwater and/or drilling fluid
- Maximum permissible time between beginning of drilling and beginning of concrete placement (to minimize degradation or expansion of exposed shaft sidewalls)
- Inspection of cleanliness at bottom of shaft
- Time constraints for drilling near recently-completed shafts
- Non-destructive testing (e.g., cross-hole sonic logging, gamma-gamma logging, low-strain dynamic testing) to verify integrity of completed shafts
- Requirements for post-grouting of drilled shaft tips

The UDOT Geotechnical Division encourages the use of post-grouting of drilled shaft tips for large diameter shafts relying on toe resistance.

For drilled shafts in gravelly soils, follow the design procedures for shaft friction outlined by Rollins, et al, 2005.

5.3.4 Load Testing of Deep Foundations

The Project Geotechnical Engineer may use static load tests to justify larger resistance factors for deep foundations in accordance with the *AASHTO LRFD Bridge Design Specifications*. Account for the following factors in determining whether to use static load testing:

- Cost of testing
- Potential savings resulting from increased resistance factors
- Number of foundations to which load tests will apply
- Group effects that may control available foundation resistance
- Schedule implications and timing of testing (design or construction phase)
- Adaptability of foundation design to account for test results

Evaluate site variability and determine the required number of load tests for each site in accordance with the *AASHTO LRFD Bridge Design Specifications*. In determining the minimum number of load tests for UDOT projects, limit the radius of each "site" to no more than 300 feet.

UDOT owns a pile load test frame that may be available for use on a given project. The UDOT Geotechnical Division can provide information regarding the availability of the load test frame and the conditions governing its use.

Do not use the Osterberg cell to assess load-supporting capacity of deep foundations for the purpose of applying an increased LRFD resistance factor. Do not use the results of load tests to estimate long-term foundation settlement.

5.3.5 Downdrag

Account for downdrag effects of settling soils on deep foundations, including that caused by liquefaction and by secondary consolidation settlement, in accordance with the *AASHTO LRFD Bridge Design Specifications*. The UDOT Geotechnical Division prefers the use of the neutral plane approach recommended by Fellenius (2004) or Briaud and Tucker (1997) for analysis of pile settlement and drag load.

As an option, use oversized pile sleeves or bituminous coating to reduce the effects of downdrag. Do not use friction-reducing rings in an attempt to reduce downdrag.

5.4 FOUNDATIONS FOR SIGNS, LIGHTING, AND SIGNALS

Conduct appropriate subsurface explorations and testing for foundations of signs, lighting, and signals. Use the design procedure of *Standard Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals*, and the computer programs listed in Appendix A of this Manual (as applicable) to design foundations for these structures.

Where justified by the magnitude of loading and the soil and groundwater conditions, use drilled shafts or driven piles to support signs, lighting, and signals. Do not use helical screw anchors to support signs, lighting, and signals.

5.5 EMBANKMENTS AND RETAINING WALLS

Evaluate all new embankment fills, retaining walls and modifications of existing fills for settlement, stability, and other applicable geotechnical considerations. For global stability of embankment slopes and retaining walls, meet the requirements of Section 5.5.2 in this Manual. Design all retaining walls in accordance with Section 11 of the *AASHTO LRFD Bridge Design Specifications* and the applicable UDOT Special Provisions (see Section 5.5.3 in this Manual).

5.5.1 Settlement

Estimate both magnitudes and time rates of anticipated settlements associated with the Project. Address the potential for immediate settlements and both primary and secondary consolidation.

Where the anticipated settlement magnitudes will adversely affect facilities within or outside the Project, or where the estimated settlement times cannot be accommodated within the Project schedule, evaluate potential methods for reducing settlement magnitudes and durations.

Settlement mitigation approaches applicable to UDOT projects include the following:

- Lightweight fills used to reduce settlement magnitudes
- Vertical drains used to accelerate primary consolidation
- Surcharge/preloading used to reduce post-construction settlements
- Ground modification used to reduce settlement magnitudes and/or accelerate primary consolidation.

Submit the proposed mitigation methods to the UDOT Geotechnical Consultant Manager. At bridge approaches (within 150 feet of bridge abutment centerlines) where post-construction settlements of new embankments are to be mitigated using surcharge, design the mitigation program to complete at least 98 percent of the settlement under the surcharge before surcharges are released for removal. At all other locations, complete at least 95 percent of the settlement under the surcharge before releasing surcharges.

5.5.2 Global Stability

Evaluate global stability of embankments using widely-accepted methodologies and applicable computer software listed in Appendix A of this Manual. For medium-stiff to very soft fine-grained foundation soils, evaluate the potential for lateral squeeze.

Table 5-2 lists the minimum acceptable factors of safety for global stability of embankments and retaining walls on UDOT projects.

Table 5-2

Minimum Acceptable Factors of Safety – Global Stability			
Category	**Feature**	**Condition**	**Minimum Factor of Safety**
Slopes and walls located where failure or excessive deformation will impact adjacent bridges or critical facilities	Retaining Walls	Construction	1.3
		Static Long-Term	1.5
		Pseudo-static Seismic	1.0*
		Post-Earthquake	1.1
	Embankments and Cut Slopes	Construction	1.3
		Static Long-Term	1.3
		Pseudo-static Seismic	1.0*
		Post-Earthquake	1.1
All other slopes and walls	Retaining Walls	Construction	1.1
		Static Long-Term	1.3
		Pseudo-static Seismic	1.0*
		Post-Earthquake	1.1
	Embankments and Cut Slopes	Construction	1.1
		Static Long-Term	1.2
		Pseudo-static Seismic	Not required
		Post-Earthquake	Not required

*Estimate deformations where required by subsection 5.2.8 in this Manual.

As an alternative, the Project Geotechnical Engineer may evaluate global embankment stability for the static long-term condition using the LRFD approach outlined in Article 11.6.2.3 of the *AASHTO LRFD Bridge Design Specifications*.

Evaluate and recommend appropriate means of meeting the Factors of Safety listed above. Acceptable means of improving factors of safety include modifying embankment slopes, dimensions, and materials, reinforcing embankment and foundation soils, and ground improvement. For short-term construction-phase stability deficiencies, evaluate the potential benefits of staged fill placement, using instrumentation to closely monitor stability conditions.

5.5.3 Retaining Walls

Select and design retaining walls in accordance with the *AASHTO LRFD Bridge Design Specifications*.

The UDOT Geotechnical Division maintains the following special provisions applicable to Retaining Walls, and will provide the current version of each to the Project Geotechnical Engineer upon request.

- 02831S: Retaining Walls – Alternate Systems (insert project-specific soil parameters and seismic criteria)
- 02832S: Select Backfill for MSE Walls
- 02833S: MSE Walls Using Concrete Facing Panels and Metal Reinforcing Elements
- 02834S: MSE Walls Using Concrete Facing Panels and Geogrid Reinforcing Elements
- 02835S: MSE Walls Using Modular Block Units and Metal Reinforcing Elements
- 02836S: MSE Walls Using Modular Block Units and Geogrid Reinforcing Elements
- 02837S: Two-stage MSE Walls Using Concrete Facing Panels and Metal Reinforcing Elements
- 02838S: Two-stage MSE Walls Using Concrete Facing Panels and Geogrid Reinforcing Elements
- 02839S: Prefabricated Modular Gravity Wall (PMGW) Systems Using Large Modular Block Units
- 02840S: MSE Walls Using Wire Face and Metal Reinforcing Elements

Use only retaining walls approved by UDOT. Special Provision 02831S lists the retaining wall systems approved for use on UDOT projects, and includes design and construction requirements for the approved wall systems. Submit any proposed modifications to the special provisions listed above to the UDOT Geotechnical Consultant Manager.

Conform to the current FHWA-NHI publication on MSE Walls and Reinforced Soil Slopes (NHI-00-043, Elias et al., 2001) in the design of two-stage walls, and submit analyses and designs for such walls to the UDOT Geotechnical Consultant Manager.

Provide a minimum four-foot wide horizontal bench in front of retaining walls founded on slopes. No bench is required where the slope in front of the wall consists of concrete slope paving.

Avoid the use of acute corner MSE walls whenever possible, particularly those having an interior angle less than 70 degrees. For any wall having an angle less than 70 degrees, design the system as an internally tied bin structure with full at-rest lateral earth pressures. In any event, do not use any acute corner MSE wall having an interior angle less than 45 degrees.

5.6 FILL AND OTHER GEOTECHNICAL MATERIALS

UDOT Standard Specification 02056 describes the use of excavated materials in embankments, without specified exclusions. However, placement of moderately to highly plastic clay, problematic shale, certain volcanics, and other deleterious excavated materials can adversely affect long-term performance of embankments. Exclude the use

of such materials in embankments by modified specification or special provision for the Project where necessary.

Other geotechnical materials acceptable for use on UDOT projects include geotextiles, prefabricated vertical drains (wick drains), composite drains, horizontal drains, sand drains, and certain lightweight fill materials. Acceptable lightweight fill materials include expanded polystyrene (e.g., Geofoam), expanded shale/ceramic aggregate, foamed concrete (e.g., Elastizell and Northeastern Soltite), pumice, certain inert steel slag products, and scoria. The UDOT Geotechnical Division maintains special provisions for Geofoam and wick drains and for scoria, pumice, and steel slag lightweight aggregates.

Do not use shredded tires, fly ash, bottom ash, or wood fibers in fills.

5.7 CUT SLOPES

Evaluate cut slopes for static and dynamic conditions using methods outlined in one or more of the following publications:

- TRB Special Report 247 – Landslides: Investigation and Mitigation
- Abramson, et al. (1995)
- Huang (1983)

For cut slopes, meet the minimum factors of safety listed in Table 5-2.

Evaluate rockfall hazards using the Oregon DOT Rockfall Catchment Area Design Guide, acceptable simulation programs (e.g., CRSP), and the Ritchie Ditch criteria (Figure 18-15 in TRB Special Report 247). Conduct stereonet evaluations where applicable. Where concrete barriers are provided, design the catchment area for at least 90 percent rock catchment at the base of the barrier (i.e, 10 percent or less are retained by barrier). The minimum catchment width with barriers is 12 feet for maintenance access.

5.8 GEOTECHNICAL REPORTS

Prepare geotechnical reports in accordance with Appendix F of this Manual. Submit final reports bearing the seal and signature of a Professional Engineer licensed in the State of Utah.

5.9 GEOLOGIC REPORTS

As directed by UDOT, provide geologic reports as outlined in Appendix G, and prepared by a Professional Geologist licensed in the State of Utah with a minimum of five years experience in similar type of work and report preparation.

5.10 SOIL DATA SHEETS

Prepare signed and sealed soil data sheets in accordance with UDOT requirements for inclusion in structure drawing sets.

CHAPTER 6: CONSTRUCTION-PHASE SERVICES

6.1 GENERAL

The Project may require construction-phase services of the Project Geotechnical Engineer, including the following:

- Ensure compliance with geotechnical designs and recommendations
- Develop and implement an instrumentation program, with appropriate related construction recommendations
- Perform static pile load testing
- Review existing conditions and revise recommendations where appropriate
- Evaluate pile resistance using PDA with signal matching
- Provide clarification related to recommendations and specifications

Provide construction-phase services (where requested) in accordance with applicable standards.

On Design-Build projects, the Design-Builder is responsible for construction as designed. The Design-Builder's Geotechnical Engineer provides construction-phase services to ensure compliance with geotechnical designs and recommendations.

6.2 RECORD KEEPING

Maintain a thorough log of all field visits and record all observations and recommendations. Document and substantiate all changes to the original design made in the field. Before changes are made, submit all proposed changes to the UDOT Resident Engineer and the UDOT Geotechnical Consultant Manager for concurrence.

6.3 INSPECTION OF DRIVEN PILE FOUNDATIONS

Where requested, provide pile driving inspection in accordance with the DFI *Inspector's Manual for Driven Pile Foundations* (1997). Use the pile driving forms found in Appendix H of this Manual. Note any observed or reported anomalies on the pile driving log.

6.3.1 Dynamic Pile Testing with Signal Matching Analysis

UDOT Standard Specification 02455 specifies procedures for driven pile installation and PDA testing with signal matching on UDOT projects.

The UDOT Resident Engineer will arrange for PDA testing with signal matching analyses to be conducted by either the UDOT Geotechnical Division or a qualified PDA testing firm. The PDA testing firm is responsible for QC/QA of its work. The UDOT Resident Engineer will coordinate with the Geotechnical Consultant Manager and the

Project Geotechnical Engineer to resolve deficiencies in driving resistance determined from PDA testing.

On Design-Build Projects, unless otherwise specified by the Project RFP, the Design Builder is responsible for PDA testing and signal matching analyses, under the direction of the Design-Builder's Geotechnical Engineer.

Establish pile driving criteria based on a pile for which the required driving resistance has been verified by PDA testing and signal matching analysis. In the pile driving criteria for remaining piles, specify the minimum blow count and either the hammer energy or the hammer stroke corresponding to the minimum blow count.

Acceptance of piles based on projected setup is not allowed on UDOT projects. Where additional setup is anticipated and is necessary to meet the required driving resistance, conduct PDA testing and signal matching analysis after the setup has occurred.

Submit all results of PDA testing and signal matching analyses to the UDOT Geotechnical Consultant Manager.

6.4 INSPECTION OF DRILLED SHAFT FOUNDATIONS

Provide for inspection of the drilled shafts by a representative of the Project Geotechnical Engineer. The following manuals provide guidance for drilled shaft inspection.

- *Drilled Shaft Inspector's Manual* (DFI/ADSC, 2004)
- *Drilled Shafts: Construction Procedures and Design Methods* FHWA-IF-99-025 (O'Neil and Reese, 1999)
- *Drilled Shafts for Bridge Foundations* FHWA-RD-92-004 (Baker et al., 1992)

6.5 STATIC LOAD TESTS OF DEEP FOUNDATIONS

Conduct or provide oversight of static load tests where required. Use the procedures specified in the *AASHTO LRFD Bridge Design Specifications*. Submit load test results, analyses, and conclusions to the UDOT Geotechnical Consultant Manager.

6.6 VIBRATION MONITORING

Monitor vibration at properties potentially impacted by roadway blasting, construction equipment, pile driving, compaction traffic, etc. The UDOT Geotechnical Division maintains Special Provision 02498S - Vibration Control during Construction Related Activities.

6.7 INSTRUMENTATION

Develop a detailed instrumentation plan to monitor parameters including settlements, slope/wall stability and movements, movements of nearby structures, buildings, utilities,

and other facilities, and pore pressures (as applicable) during construction. Submit the plan to the UDOT Geotechnical Consultant Manager. Where long-term settlement of embankments or facilities may occur, provide long-term settlement instrumentation arrays in secure locations.

Consult the paper entitled “Instrumentation and Construction Performance Monitoring for I-15 Reconstruction Project in Salt Lake City, Utah” (Bartlett et al., 2001) in developing construction monitoring programs and stability thresholds for embankments and retaining structures on soft sediments.

Include in the Project drawings and specifications requirements for sturdy, lockable instrumentation covers. Provide redundancy in instrumentation as appropriate to ensure compliance with designs and recommendations. Develop an action plan to be implemented in the event that a given instrument is damaged or fails to operate properly. Ensure that the Project special provisions make the Contractor responsible for replacing all instrumentation damaged during construction, including long-term instrumentation arrays.

APPENDIX A: GEOTECHNICAL SOFTWARE

Geotechnical Structure Foundation Analysis

- CAPWAP
- COM624
- Driven
- FLPIER
- LPILE, GROUP
- GRLWEAP
- PDA
- UniPile

Embankment Design and Landslide Analysis

- DigiPro, DMM for Windows
- EMBANK
- PCSTABL, STABL5M, STABL6, XSTABL
- SIGMA/W, SLOPE/W
- UniSettle
- UTEXAS

Geotechnical Seismic Analysis

- DEEPSOIL
- LiquefyPro
- QUAKE/W
- SHAKE

Geotechnical Modeling

- FLAC

Rockfall and Rock Slope Stability

- CRSP
- Rocfall, RockPack, RocPlane
- Stereonet Programs
- Swedge

Soil Nail Walls

- GoldNail
- SNAILZ (Caltrans)

APPENDIX B: SAMPLE FIELD WORK FORMS

See the following three pages.

EXAMPLE FIELD RECONNAISSANCE REPORT FORM

BRIDGE FOUNDATION OR OTHER DRILLING SITE
GEOTECHNICAL DIVISION
UTAH DEPARTMENT OF TRANSPORTATION

PROJECT NO.:_____ COUNTY: _____ STA. NO.: _____
REPORTED BY:_____ DATE _____

1. STAKING OF LINE
   ____Well Staked
   ____Poorly Staked, Can we still use? ____
   ____Request Division to Restake

2. BENCH MARKS
   In Place: Yes _____ No _____
   Distance from Bridge __ (ft/m)

3. PROPERTY OWNERS
   Granted Permission: Yes _____ No _____
   Remarks On Back _____

4. UTILITIES
   Will Drillers Encounter Underground or Overhead
   Utilities: Yes ____ No _____ Maybe ____
   At Which Holes? _____
   What Type? _____
   Who to See for Definite Location _____
   _____

5. GEOLOGIC FORMATION _____
   _____

6. SURFACE SOILS
   Sand ___ Clay ___ Sandy Clay/Clayey Sand
   Rock _____ Silt _____ Other _____

7. GENERAL SITE DESCRIPTION
   Topography
   Level _____ Rolling _____ Hillside _____
   Valley _____ Swamp _____ Guillied _____
   Groundcover:
   Cleared _____ Farmed _____ Buildings ____
   Heavy Woods _____ Light Woods _____

8. BRIDGE SITE
   Replacing _____
   Widening _____
   Relocation _____
   Check Appropriate Equipment
   (describe any potential problems with access)
   _____ Truck Mounted Drill Rig
   _____ Track Mounted Drill Rig
   _____ Failing 1500
   _____ Truck Mounted Skid Rig
   _____ Skid Rig
   _____ Rock Coring Rig

8. BRIDGE SITE - Cont'd
   ____ Wash Boring Equipment
   ____ Water Wagon
   ____ Pump
   ____ Hose (ft/m)
   Cut Section _____ (ft/m)
   Fill Section _____ (ft/m)
   If Stream Crossing:
   Will Pontoons Be Necessary? _____
   Can Pontoons Be Placed In Water Easily?
   _____
   Can Cable Be Stretched Across Stream?
   ____ How Long? _____ (ft/m)
   Is Outboard Motorboat Necessary? _____
   Current:
   Swift: ___ Moderate: ___ Slow: ____
   Describe Streambanks Scour:
   If Present Bridge Nearby:
   Type of Foundation_____
   _____
   Any Problems Evident in Old Bridge?
   (Incl scour):_____
   if nec, describe on back
   Is Water Nearby for Wet Drilling? Dis: __ (ft/m)

9. GROUNDWATER TABLE
   Close to Surface _____ (ft/m)
   Nearby Wells _____ (ft/m)
   Intermediate Depth _____(ft/m)

10. ROCK
   Boulders Over Area? Yes _____ No _____
   Definite Outcrop? Yes _____ No _____
   (show sketch on back)

11. SPECIAL EQUIPMENT NECESSARY
   _____
   _____

12. REMARKS ON ACCESS
   _____
   _____

13. DEBRIS AND SANITARY DUMPS
   Stations _____
   Remarks _____

Reference: 1978 AASHTO Foundation Investigation Manual

SAMPLE PERMIT TO ENTER AND CONDUCT EXPLORATORY DRILLING

Job. No.: _____ Address (attach map): _____

Incident to the "Project description", _____ hereinafter referred to as " _____", and the owner of the property at the above indicated address, hereinafter referred to as "OWNER", do agree as follows:

The OWNER hereby authorizes _____ or its agent or Contractor, to enter and conduct exploratory drilling on the property; install inclinometer casing and/or water observation wells; and to occasionally enter the property on an as-needed basis to conduct downhole monitoring.

The OWNER hereby certifies that he/she is the OWNER of the property at the address indicated above.

This permit shall expire at the completion of the Project or two years from the date of signing of this permit, or by revocation by OWNER in writing.

The foregoing covenants in each and every particular are and shall be construed as real covenants and shall run with the land, and the same hereby made binding upon the heirs, administrators, executors, devisees, assigns and successors in interest of the parties hereto.

Geotechnical Consultant: _____

By: _____ _____

Project Manager Date Owner Date

SAMPLE JOB SITE FORM

Project Name _____ Project No. _____
Drilling Site Location _____
County _____ Date Inspected _____ Geologist _____
Driller _____

ELECTRIC POWER COMPANY:
Name of Co. _____
Date Contacted _____ Person Contacted _____
Location Aerial Lines _____
Location Buried Lines _____
FUEL COMPANY:
Name of Co. _____
Date Contacted _____ Person Contacted _____
Location Buried Lines _____
PHONE COMPANY:
Name of Co. _____
Date Contacted _____ Person Contacted _____
Location Aerial Lines _____
Location Buried Lines _____
WATER & SEWER COMPANY:
Name of Co.
Date Contacted Person Contacted
Location Buried Lines
OTHER UTILITIES; RAILROADS:
Name of Co. _____
Date Contacted _____ Person Contacted _____
Location Buried Lines _____
Owners Name _____
Address _____ Phone _____
Special Provisions_____
Remarks _____
Owners Name _____
Address _____ Phone _____
Special Provisions_____
Remarks _____
Owners Name _____
Address _____ Phone _____
Special Provisions_____
Remarks _____

Sketch Map

ON SITE VISUAL INSPECTION

Geo.	Driller	
1. ___	___	Overhead power of telephone line- Minimum 10 ft. clearance
2. ___	___	Buried cable markers, power, telephone.
3. ___	___	Buried gas line markers.

APPENDIX C: EXPLORATION LOG REQUIREMENTS

Provide the following information on both field and final exploration logs (borings and test pits), unless otherwise specified:

1. Project name
2. Project location
3. UDOT Project number
4. Location of borehole or test pit. Where UDOT stationing is available, describe the position of the exploration with respect to the stationing, including the offset (left or right) from centerline. Where useful, provide a sketch of the exploration position on the field boring log. Where stationing is not available, determine and record locations accurately determined by tape or survey.
5. Start date of exploration.
6. Completion date of exploration.
7. Weather: Record the approximate ambient conditions, i.e. temperature, wind and amount/type of precipitation at the time of exploration.
8. Exploration number. Number test holes using a consistent, organized, and intuitive numbering system, and briefly explain the numbering system in the Geotechnical Report.
9. Borehole inclination
10. Sheet ___ of ___ numbers
11. Name of geotechnical firm
12. Name of field engineer/geologist
13. Name of drilling/excavation contractor(s).
14. Names of all equipment operators and crew members.
15. Method of drilling
16. Drilling fluid: mineral slurry, polymer, water, or none
17. Make of drilling equipment
18. Drill model number
19. Surface elevation. Measure the ground surface elevation of the exploration to an accuracy of 0.1 foot or better.
20. Borehole diameter.
21. Drill bit type and size
22. Inside diameter of casing
23. Casing wall thickness
24. Cased depth
25. Excavation method and equipment: Identify the mode and make (John Deere, Case, etc.) of backhoe or other excavator, together with the bucket width.
26. Depth scale
27. Methods of sampling (pushing, hammering, drilling, coring)
28. Sampler type and size.
29. Blow counts

30. Sample depth
31. Depth of changed ground/drilling conditions
32. Soil information (description, ASTM classification, USCS symbol, color, density or consistency/hardness, moisture, plasticity, minor constituents, etc.)
33. Depth of exploration termination
34. Length of sample recovered
35. Date and time of each groundwater level measurement on the field log.
36. Backfilling information
37. Abandonment procedures
38. Abandonment certification
39. Field testing (pocket penetrometer, field vane shear, torvane, falling head permeability)
40. Depth of wells/piezometers, with material and installation details
41. Piezometer screen interval
42. Groundwater levels: during exploration, subsequent to completion, and after installation of well (see notes that follow this list)
43. Descriptions of any contamination encountered
44. Comments: Include all pertinent observations (changes in drilling fluid color or loss, rod drops, drilling chatter, rod bounce as in driving on cobble, easy advancement of hollow stem augers, damaged samplers, equipment malfunctions, etc.) in the field log. Also note if rock coring was used at any point to advance the boring through cobbles, boulders, etc. Instruct the driller to report any significant changes during drilling (changes in material, changes in drilling rates, pressures, advancement, occurrence of boulders, and loss of drilling fluid).

Meet the following additional requirements for final test hole logs:

- Use a depth scale on the log that is suitable to the depth of the test hole and the level of detail shown on the log.
- Clearly indicate the top and bottom depth of the range of sampler penetration. Also indicate whether the sample is disturbed or relatively undisturbed. Enter the depth range of the sample interval and the amount of recovery.
- Show the length to the nearest inch of soil sample recovered from the sampler. Do not include slough in the sample.
- List the raw number of blows required for each 6 inches of sampler penetration and the corrected $(N_1)_{60}$ value. Clearly identify where driving is terminated due to practical refusal, defined as a blow count of 50 for an interval less than 6 inches. Record partial penetration, for example of 50 blows for 1 inch, as 50/1”. Also enter the size, type, and section length of the sampling rods. Indicate the hammer weight, type, drop interval, and sampler dimensions in cases where these parameters vary from AASHTO T 206.
- Soil Description: Follow the USCS format. Where appropriate laboratory tests have been performed, assign the equivalent AASHTO soil designations and present them in parentheses on the final logs. Include the soil moisture

content, unit weight, strength properties, and other properties where these properties have been tested in the laboratory.

- Groundwater: Enter the depth below ground surface to the static groundwater level in the exploration if encountered, and the date and time of the measurement. When groundwater is encountered, leave borings open for however long possible to monitor groundwater elevations. Generally, measure groundwater levels and record the date and time of the measurement at the end of each day of drilling, each morning before resuming drilling, and at the completion of each boring. Note on the log where free groundwater is not encountered during drilling, or cannot be detected because of the drilling method.

APPENDIX D: GEOMECHANICAL LOGGING

Use the Geomechanical Logging form included at the end of Appendix D to log rock cores. The following sections describe application of the entries of this form and accepted practice for rock core logging.

Drill Interval (From-To column)

The drill interval is the depth of where a drill run begins and ends, corresponding to the Driller's wooden blocks, which are typically placed at the beginning and end of each run. Record this interval record in the "From-To" column.

Recovery (recovered length)

Recovery is the actual length of core retrieved from a drill run. In some cases, recovery will be less than 100 percent of the drilled interval, due to washing of fines, compaction of soft units, or the inability of the core spring (catcher) to break the stub flush with the bottom of the run. Conversely, recovery sometimes exceeds 100 percent due to some caving of the hole (re-drills), expanding clays, or removal of the entire stub at the bottom of the hole during core barrel retrieval. Avoid inadequate and improper drilling methods which decrease the amount of core recovered. Triple-tube core barrels, which add another separate, non-rotating liner, may increase recovery in poor quality, semi-cemented soils, or in zones of highly variable hardness and consistency.

RQD Length (+2X core diameter)

Disregarding mechanical breaks, RQD (Rock Quality Designation) length is the sum of the lengths of the whole core pieces that are equal to or greater than twice the core diameter. Mechanical breaks are not true natural fractures, and for that reason, they are disregarded when considering RQD length, number of whole pieces, and longest-piece measurements. Mechanical breaks frequently form perpendicular to the core axis and are the result of breakage during handling or drilling.

Fracturing often occurs parallel or oblique to the axis of the core, resulting in wedge to rectangular shaped core halves. Determine RQD length for these conditions in the following manner: Project an imaginary line through the center of the core. The RQD length of an individual piece of core is defined as the distance between where this imaginary line intersects the midpoint of the structural plane bounding one end of the piece of core to a point where the line intersects the midpoint of the structural plane bounding the other end of the piece of core.

Whole Piece

Classify as a whole piece any core specimen meeting one of the following criteria:

- Some component of the core specimen has a full core diameter
- If core is fractured down the middle (parallel to the core axis) classify individual pieces with lengths equal to or greater than the core diameter as whole pieces.

Number of Whole Pieces

Disregarding mechanical breaks, the number of whole pieces are the number of pieces that fit the criteria discussed above. Do not count whole pieces in “broken” or “rubbly” zones, as defined in this Appendix.

Mark the location of mechanical breaks induced during extraction from the core barrel and/or transferring the material to core boxes, particularly where core lengths are broken with a hammer to fit into the box. Minimize the practice of breaking core to fit a core box

Length Longest Piece

Disregarding mechanical breaks, measure and record the longest whole piece of core for each drill run. If there are no whole pieces in the drill run, the recovered portion is considered to be broken material, and the length of the longest piece is zero.

Length of Whole Core

This is the sum of all whole core pieces present in the drill interval.

Length Broken Zone

A broken zone consists of a core interval composed of pieces with length of less than one core diameter in which more than 50% of the material is made up of fragments with a diameter of greater than ½ inch.

Length Rubbly Zone

A rubbly zone consists of a core interval composed of pieces with length of less than one core diameter in which more than 50% of the material is made up of fragments with a diameter of less than ½ inch.

Hardness (H)

Use Table D-1 in this Appendix for hardness field testing of each drill run.

Bedding Angle

Record the bedding angle (the surface parallel to the surface of deposition) if the bedding plane is apparent. Adjust the bedding angle for the inclination of the drill hole if the drill hole is not vertical.

Fractures and Fracture Angle

Measure and record the total number of fractures for each angle classification for each drill run. Measure the angle relative to the core axis, with 90° being parallel to the axis of the core and 0° perpendicular to the core axis.

Fracture Filling

Note any fracture filling material and include secondary mineralization and clay gouge along the fractures.

Compressive Strength Testing

Test representative samples of each rock type and variation in the laboratory in accordance with ASTM D 7012.

Notes

The combined lengths of “whole core”, “broken zone” and “rubbly zone” should equal the “recovered” core length.

Make every effort to maximize recovery during rock coring. Box, label, and store all recovered core in accordance with the current AASHTO *Manual on Subsurface Investigations*.

See the following two pages for Table D-1 and Geomechanical Logging form.

Table D-1
Relationship Between Hardness or Consistency and Unconfined Compressive Strength

Hardness	Consistency	Field Identification	Approximate Range of Unconfined Compressive Strength (psi)
		Soils and Fault Gouges	
S1	Very Soft Soil	Easily penetrated several inches by fist	< 3.5
S2	Soft Soil	Easily penetrated several inches by thumb	3.5 – 7
S3	Firm Soil	Can be penetrated several inches by thumb with moderate effort	7 - 14
S4	Stiff Soil	Readily indented by thumb but penetrated only with great effort	14 – 28
S5	Very Stiff Soil	Readily indented by thumbnail	28 – 56
S6	Hard Soil	Indented with difficulty by thumbnail	> 56
		Rock	
R0	Extremely Soft Rock	Indented by thumbnail	28 – 100
R1	Very Soft Rock	Crumbles under firm blows with point of geological pick, can be peeled by a pocket knife	100 – 1000
R2	Soft Rock	Can be peeled by a pocket knife with difficulty, specimen can be fractured with single firm blow of hammer end of geological pick	1000 – 4000
R3	Average Rock	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with single firm blow of hammer end of geological pick	4000 – 8000
R4	Hard Rock	Specimen requires many blows of hammer end of geological pick to fracture it	8000 – 16,000
R5	Very Hard Rock	Specimen requires many blows of hammer end of geological pick to fracture it	16,000 – 32,000
R6	Extremely Hard Rock	Specimen can only be chipped with geological pick	> 32,000

Table based on work by Deere (1968), Terzaghi and Peck (1967), Jennings and Robertson (1969), and Piteau (1970).

Project: _____ Core Size: _____ Dip: _____ Water Depth: _____ Date: _____

DDH No: _____ Total Depth: _____ Azimuth: _____ Logged By: _____ Page _____ of _____

Depth	Graphic	Geologic Description Rock Type, Alteration, Texture, etc.	Drill Run/Core Rec.			RQD		Pieces / Run	Long-Piece	Hard-ness	Bedd. Angle	Fract. Angle				Fracture Filling	Whole Core	Broken Zone	Rubbly Zone	Is (psi)
			From To	Len.	%	Len.	%					0-30	30-45	45-60	60-90					

APPENDIX E: TEST PIT/TRENCH SAMPLING AND LOGGING

Collect sufficient amounts of representative material from the test pit for the intended laboratory observation and testing.

If samples are required from a specific part of the test pits, do not accept a sample that has been raked up through the overburden and topsoil.

Seal samples to prevent moisture loss. Label samples clearly with the test pit/trench number, sample number and sample depth, and identify sample locations on the test pit log.

Obtain intact soil samples from test pits/trenches by cutting ring samples or block samples from the sides or bottom of the hole. The UDOT Geotechnical Division often obtains samples using U type rings having an outside diameter of 2.50 inches and an inside diameter of 2.42 inches, in heights of 1.0 inch and 3.0 inches, and has found the 3.0-inch ring height to be particularly useful for obtaining samples for collapse tests. Carefully handle and transport all samples to the laboratory to preserve their integrity. Ensure that samples are not contaminated by foreign or dissimilar materials.

Prepare logs of exploratory test pits/trenches including the following information:

Depth Below Surface: Use a depth scale on the test pit log that is suitable to the depth of the test pit and the details shown on the log.

Sample Type and Depth: Enter the sample type (i.e., U-type, bag, bulk, etc.), location, and depth. Clearly indicate the top and bottom depth of the range of the collected sample.

Soil Description: Follow the USCS format described in ASTM 2488. Where laboratory classification testing has been performed, show the AASHTO letter/number designation next to the USCS description.

Include also the following information on the logs:

- Lenses or layers of gravel, pea gravel, sand, silt or clay (either in the form of clay balls or clay lenses). This would also include isolated pockets of sand, silt, or clay.
- Record any measurable amount of soft sedimentary rock, clay, silt balls, elongated or flat particles, and list estimated percentages of these features on the logs.
- If groundwater is encountered, indicate the depth below ground level and whether water flows or seeps into the test hole.
- Measure and sketch on the log any observed variations.

Where large rock is encountered, record the following:

- Average size rock encountered by percentage
- Type of rock (granite, quartz, sandstone, limestone, etc.)
- Whether the material is well graded or poorly graded

While digging the area make a sketch of the trench/pit location, boundaries, and topographic features. Map man-made features including pipelines, telephone, etc.

APPENDIX F: GEOTECHNICAL REPORT REQUIREMENTS

TABLE OF CONTENTS

Show page numbers for main headings. Include lists of figures, appendices, and attachments

1 GENERAL

Explain the purposes of the study and scope of work.

1.1 PROJECT DESCRIPTION

State the background information which may be necessary to understand or interpret the materials and foundation report. Discussion of the suggested items may be very brief where they may have been adequately covered in a project report.

1.1.1 General

Describe existing site conditions with emphasis on site locations, existing structures and embankments, etc. The size of the Project and the length of corridor segments may require that the site description be broken down into stations or individual structure areas.

1.1.2 Proposed Improvements

Outline proposed improvements and contiguous road system. Describe new structures, embankments, and MSE walls, etc. in this section.

2 PREVIOUS REPORTS AND INVESTIGATIONS

Reference all pertinent reports and correspondence. Provide a brief description of the nature of the paper if the title is not self-explanatory. It is not necessary to append material which could be normally found in UDOT headquarters files such as foundation reports by UDOT and project reports. Do append such items as materials investigations by outside consultants, etc. (i.e., materials are not available in UDOT headquarters.)

Provide a brief description of previous investigations including number of borings, depths, dates of explorations, and drilling. Include relevant subsurface conditions.

3 EXISTING FACILITIES

If portions of the existing highway are to be included, describe the type, age, and condition (including deflection data when available) of the structural section. If pertinent, describe cracking of pavement on embankments and pumping/failing of PCC pavement and their probable causes. Where cross streets are to be replaced in kind, describe the structural section.

Append pictures of existing facilities and the new alignment to aid the presentation.

4 FINDINGS

4.1 SITE CONDITIONS

Provide a brief discussion of topography, terrains, land use, and other surface conditions affecting the highway and proposed widening. Identify sensitive surface and subsurface substructures, existing and abandoned utilities, presence of hazardous and toxic substances which could affect the overall construction of the Project.

Use the UDOT alignment stations for locations.

4.2 SURFACE DRAINAGE

Discuss briefly surface drainage of the site with particular emphasis on springs and signs of groundwater flow. Identify any potential surface drainage problems that may exist within the site, e.g., low areas subject to ponding and flooding, locations of nearby creeks, ponds, and rivers.

4.3 GEOLOGY

Outline the general geological formations at the Project site. Mention the presence of old slides, unstable areas, areas of cracking and subsidence, etc. Append any necessary topographic or geological maps, etc. and reference them in this section.

4.4 FAULTING AND SEISMICITY

Mention the presence of active faults and the seismicity of the area. Append any seismic maps, seismic surveys, etc. and reference them in this section. Discuss estimated mean peak ground accelerations within the study area due to previous or future MCE events. Describe types of faults and ages if applicable.

4.5 SOIL MATERIALS

Describe previous site explorations made in the Project site. Outline general types of soil materials encountered in or inferred from the previous site explorations.

4.6 GEOHYDROLOGIC CONDITIONS

Describe regional geohydrologic conditions based upon previous subsurface investigations and desk studies. Include unusual groundwater conditions, springs, artesian water flow, local ponding, etc.

4.7 CLIMATIC CONDITIONS

Discuss the climatic conditions relevant to the project, including freeze-thaw conditions and the use of deicing salt during winters.

5 FIELD AND LABORATORY TESTING

Provide a concise summary of laboratory and field testing, and the physical relationship to the plan and profile of the planned improvement. Discuss the numbering system used to identify test holes and the methods and equipment used in the investigation. List the types of laboratory tests performed. Direct the reader to the locations of test hole logs and laboratory test results in the appendices of the report.

6 STRUCTURES

6.1 DESCRIPTION

6.1.1 General

Describe the proposed structures to be constructed and adjoining bridges in detail. These include the dimensions, types of structures, number of bents, bent spacings, pier heights, types of bridge deck, etc. Include design foundation loads and pile cap elevations, if available for the new structures, types of foundation, footing or pile cap elevations of the adjoining bridges, etc. which could be referenced from as-built foundation plans.

6.1.2 Subsurface Conditions

Describe subsurface conditions underlying the structures on the basis of the new and old site investigation data. Emphasize problem soils that would cause undue total and differential settlements of the structures and instability of embankments.

Provide a general description of the stratigraphy (using USCS classifications). If there are significant differences between borings, describe the strata encountered in each boring. Briefly summarize the results of laboratory testing for the various types of soils and rock encountered. Geologic cross-sections or fence diagrams may be useful in describing subsurface relationship.

6.1.3 Groundwater

Report groundwater measured during current drilling and past subsurface investigations. Also report the range of water levels in creeks and river channels.

Estimate maximum rise of groundwater level. Make note of any evidence of perched groundwater.

6.1.4 Earthquake Considerations

6.1.4.1 Seismic Hazards

Provide discussions of seismic hazards such as ground shaking, fault rupture, seismic criteria, liquefaction potential and lateral spreading at the Project site.

6.1.4.2 Seismic Design Criteria

Identify the seismic site class and provide ground motion parameters for use in AASHTO LRFD design.

6.1.5 Potentially Hazardous Materials

Describe all soil and groundwater contamination encountered during the subsurface investigation. Identify any special procedures or equipment used during drilling and handling of samples. Select Environmental Protection Agency (EPA) standard test method(s) based on site assessment of area, historical use of land, and field observations. Report results of chemical testing in tabular form. Include constituent, units of concentration, reporting limits, and results. Compare concentrations of contaminants to listed values in state and federal regulations to determine severity of contamination.

6.2 RECOMMENDATIONS

6.2.1 Bridge Structures

Discuss appropriate foundation types, including advantages and disadvantages of each type considered.

6.2.1.1 Foundation Design

A. Pile Support (driven or drilled cast-in-place shafts)
    1. Method of support (skin friction and/or end bearing) in clays and dense sandy materials.
    2. Suitable pile type(s)- reasons for choice and/or exclusion of types.
    3. Pile toe elevations and length of piles.
    4. Pile axial compression resistance at the applicable AASHTO LRFD limit states.
    5. Reduction of pile resistance due to negative skin friction.
    6. Scour depth (elevation) if applicable and method of determination.
    7. Effects of induced loads on piles due to adjoining new or existing embankments.

B. Footing Support (if applicable)
    1. Elevation of bottom of footing
    2. LRFD bearing resistance
    3. Approximate settlements at loads corresponding to the applicable AASHTO LRFD limit states
    4. Brief description of material on which the footing is to be placed and soil improvement, if expected (i.e., subexcavation)
    5. Scour depth (elevation)

6.2.1.2 Settlements

Estimate group settlements and time for the settlements to occur. Discuss potential differential settlements of new and/or existing foundations due to varying subsurface conditions.

6.2.1.3 Uplift

Determine uplift resistance of deep foundations at the applicable AASHTO LRFD limit states. Discuss what governs the uplift capacity and whether the weight of pile should be included in calculating resistance to uplift.

6.2.1.4 Lateral Loading

Determine lateral capacity versus deformation of the pile. Discuss how pile layout, length, spacing, head-fixity and loading conditions would affect the lateral capacity of the piles. Present load-deformation analysis result summary.

6.2.1.5 Load Tests

Discuss the need for pile dynamic analyzer (PDA) tests and static load tests to verify design loads. Recommend pile load test programs for piles near abutments, bent locations if deemed appropriate.

6.2.1.6 Construction Considerations

A. Water table-seasonal or long term fluctuations, data for possible control in excavations (i.e. pumping, well points, tremie seals, amount of groundwater, etc.)
B. Adjacent structures-protection against damage from excavations, pile driving, dewatering, etc.
C. Pile driving - difficulties, clearance, overhead or underground utilities, other unusual conditions, etc. Effects on existing structures due to pile driving, and the corresponding mitigation measures. Include preliminary WEAP evaluations and discuss the implications in terms of required hammer energy, pile section, and pile material strengths.
D. Excavation for pile caps and footings - control of earth slopes including shoring, sheet piles, bracing, and safety considerations.

E. Need for dewatering excavations and evaluation of potential effects on surrounding area/structures.
F. Effects of induced load on piles due to adjoining new or existing embankments.
G. Corrosion effects of various soils and waters, and possibility of galvanic reaction from stray currents.

6.2.2 Embankments

Discuss where new embankments or approach fill embankments are located relative to existing structures. Describe the soil materials on which embankments will be founded.

6.2.2.1 Slope Stability

Conduct stability analyses of proposed embankments for construction conditions, long-term static conditions, and seismic conditions, and discuss the results. Recommend potential mitigation methods where needed. Embankments without walls and not adjacent to bridges or critical facilities do not require seismic analysis or mitigation.

6.2.2.2 Settlements

Estimate short term (initial) and long term (primary and secondary) settlements of the embankments and discuss the results.

6.2.2.3 Time rate of settlements

Estimate rate of primary and secondary settlements based upon laboratory and field data. Discuss the results.

6.2.2.4 Construction Considerations

As the construction of the embankments is controlled by the soft grounds, recommend such measures as (1) fill height limit on untreated foundation, (2) controlled rate of loading, (3) surcharging the area, (4) waiting periods, (5) use of wick drains to shorten the required time delay period, (6) slope protection, (7) use of light weight fills to reduce amount of settlement, and (8) any control devices required such as settlement platforms, piezometers, surface hubs, etc. These issues will be discussed in the following subsections on Staged Construction and Instrumentation.

6.2.2.5 Staged Construction

Discuss staged construction as a means to prevent foundation instability and the gain in undrained shear strength as a result of the staged construction. Discuss also the time required for each staged construction, referencing relevant stability analyses.

6.2.2.6 Instrumentation

Discuss where necessary the need for field instrumentation to monitor settlements including types of instrumentation, e.g., settlement platforms, settlement hubs, piezometers, etc.

6.2.2.7 Foundation Treatments

Make specific recommendations for foundation treatments. As may be necessary, recommend wick drains, stone columns, stabilization trenches, stripping, and special treatments of original ground. Provide any additional information as required.

6.2.3 Retaining Walls and Noise Walls

6.2.3.1 Foundation Designs

Carry out global and external stability of the retaining structures (note that a check of internal stability is also needed for MSE walls); specify allowable and ultimate footing pressures. Provide a brief description of material on which the wall footing is to be founded. Recommend scour depth if footing is subject to damage by flood scour.

6.2.3.2 Settlements

Estimate total and differential settlements of the walls based on the anticipated static and seismic loadings. Briefly discuss method of estimating settlements.

6.2.3.3 Earth Pressures and Geotechnical Parameters

Recommend static earth pressures for level and sloping grounds in terms of equivalent fluid pressures, sliding resistance, adhesion mobilized along the wall base, passive earth pressures and zone, unit weight of backfill, etc.

6.2.3.4 Seismic Loading

Develop seismic earth pressures (in terms of equivalent fluid pressures, where appropriate) for level and sloping grounds and recommend resultant seismic forces that develop behind the wall and inertial forces from backfill (if any).

6.2.3.5 Construction Considerations

Make a provision of a drainage system behind all the walls to intercept groundwater. Discuss specific cut or excavation conditions within given limits. Topics which may require discussion include types and conditions of materials, groundwater and springs, existing slopes, underground utilities, faults, temporary support, cut slope design, benching, maintenance, debris interception, temporary slope protection, etc. Make any suggestions considered necessary for excavation procedures. Discuss select material when pertinent. Provide any additional recommendations as needed.

6.2.3.6 Foundation Treatments (if applicable)

Recommend types of stabilization methods to mitigate unacceptable differential settlements of the walls and to enhance wall stability.

7 EARTHWORK

7.1 ROADWAY AND EMBANKMENTS

Evaluate and discuss the existing conditions. Items which may require discussion include relative compaction of existing fills, groundwater, springs, unsuitable soils, expansive soils, dumps, underground utilities, etc. Use concise engineering classification in discussion of soils.

7.2 SITE PREPARATION

Provide a brief discussion of site and subgrade preparation.

7.3 FILL PLACEMENT AND COMPACTION

Recommend methods of fill placement and compaction for embankments and retaining walls in accordance with UDOT standard specifications. These may include recommendations for moisture control, fill placement over frozen soils, erosion control, contouring, temporary drainage and expansive soil. Where applicable, include recommendations for special treatments to mitigate settlement or compression within the approach embankments to structures. This may include use of imported borrow, special compaction, or other methods as may be dictated by the available material.

7.4 EXCAVATION

Briefly discuss anticipated permanent and temporary excavations with particular reference to soil conditions. Discuss and evaluate potential adverse effects of excavations on adjacent structures and buildings.

7.5 EARTHWORK FACTORS

Provide earthwork factors and pertinent information for excavation and backfill.

7.6 RE-USE OF EXCAVATED SOIL MATERIALS

Briefly discuss re-use of excavated materials. It may be appropriate to discuss availability or scarcity of materials, quality, economic factors, or other factors which may affect material selection or embankment design. Where applicable, comment on material disposal, potential disposal sites, stockpiling for other parts of the Project, etc.

7.7 CUT & FILL SLOPES

Provide specific recommendations for cut and fill slopes. These may include proposed cut and fill slope design, surface erosion mitigation, control groundwater flow and springs by means of subdrains or dewatering systems.

7.8 TEMPORARY EXCAVATIONS

Provide specific recommendations for temporary cut and fill slopes and temporary surface erosion mitigation.

7.9 DEWATERING AND SUBDRAINS

Recommend methods of dewatering for excavations and types of sub-drainage systems for the Project.

8 CORROSION INVESTIGATIONS

Obtain soil samples from test holes and confirm the corrosion potential of soils to material types to be used for any subsurface structure. Report test results of laboratory analysis of soil. Typical laboratory testing includes pH, resistivity, sulfates, chlorides, and soluble salts. Use test results to determine corrosion potential of soil.

Where applicable, conduct a culvert study from the pH and electrical resistivity values to determine estimated life span for a standard gage steel culvert. Recommend a gage type to increase longevity to 50-year life span.

Provide a recommendation of the appropriate cement type to be used for concrete in contact with soils.

State that the estimated years to detrimental corrosion can vary significantly according to the factual variables of concrete manufacture that are used in construction. If there are existing structures, describe any visible evidence of distress caused by the environment. For example, the evidence of distress could be described by a simple statement such as “Concrete cracking and rust stains in substructure.”

9 RECOMMENDED MATERIAL SPECIFICATIONS

Include suggested specifications for all materials used in the structural section, plus imported borrow, structure backfill, embankment fill, ballast and sub-ballast (if applicable) and drainage materials. Where possible, use UDOT standards and special provisions as references. For MSE backfill, use UDOT special provisions.

10 CLOSURE

Provide a brief closure of the report. List areas or topics that may require further investigation.

11 LIMITATIONS

List statements of limitations and potentials for unknowns.

12 REFERENCES

Provide complete citations for all references in alphabetical order.

TABLES

Present tables referenced in the body of the report, except where such tables are presented within the body.

FIGURES

Present figures referenced in the body of the report. Examples are vicinity map, site plans, geologic maps, fault maps, test hole location plans, subsurface soil profiles, seismic design response spectrum, etc.

APPENDICES

Examples of material include boring logs, CPT logs, laboratory testing data, field test data (if applicable), instrumentation data (if applicable), copies of reports by outside consultants, seismic surveys, special correspondence or memos, maps, and cross-sections, as-built foundation drawings, etc. Organize and label appendices so that information can be easily accessed.

PHOTOGRAPHS

Append photos of existing facilities and the new alignment.

APPENDIX G: GEOLOGIC REPORT REQUIREMENTS

1 Introduction
- 1.1 Purpose of Project
- 1.2 Location and Limits of Project
- 1.3 Site Description
- 1.4 Main Project Features
- 1.5 Purpose of Report
- 1.6 Related Reports

2 Subsurface Exploration

3 Geologic Setting
- 3.1 Regional Geology
- 3.2 Seismicity
  - Surface Fault Rupture
  - Ground Shaking
- 3.3 Site Geology
  - Fills
  - Talus
  - Colluvium
  - Alluvium
  - Bedrock
- 3.4 Discontinuities in Rock Mass
  - Bedding
  - Folds
  - Faults & Shear Zones
  - Jointing
- 3.5 Geologic Conditions Along Alignment or Area (including possibility of failure along each geologic segment)
  - Failure Types-wedge, sliding, bedding plane, toppling
- 3.6 Geohydrologic Conditions
  - Surface
  - Subsurface
- 3.7 Geotechnical Engineering Properties
  - Description
  - Soil Overburden Design Parameters
  - Bedrock

4 Geologic Features of Engineering & construction Significance
- 4.1 Talus Slopes
- 4.2 Rock Fall Zones
- 4.3 Fault & Shear Zones

5 Man-made Features of Engineering & Construction Significance
- 5.1 Existing Landslides
- 5.2 Existing Roadway and Culverts

5.3 Adjacent Communities
5.4 Utilities
5.5 Railroads
6 Cuts and Retaining Walls
6.1 Rock Cuts
Local Experience
Design Considerations and Assumptions
Construction Sequence
Behavior During Excavation
Excavation Methods
Blasting Specification
Ground Support
6.2 Soil Overburden Cuts
Design Considerations and Assumptions
Construction Sequence
Behavior During Excavation
Excavation Methods
Ground Support
6.3 Retaining Walls
Design Considerations and Assumptions
Construction Sequence
Behavior During Excavation
7 Geotechnical Instrumentation and Monitoring
References
List of Tables
List of Figures
Appendices
Photographs

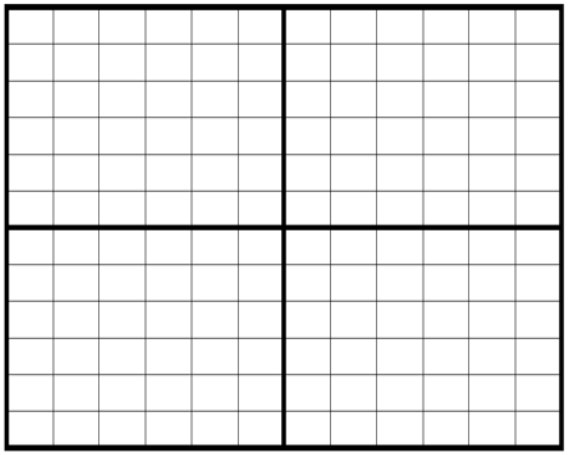
APPENDIX H: PILE DRIVING FORMS

See the following three pages.

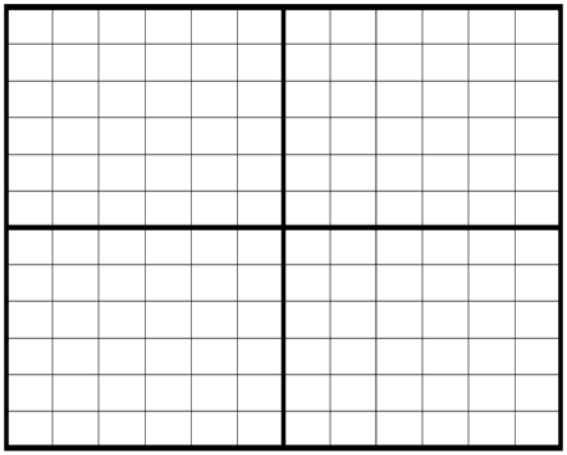
PILE DRIVING RECORD

Project:		Hammer Type:		Date:	
Location:		Hammer Model:		Inspector:	
Resident Engineer:		Pile Location & No.:		Weather:	
General Contractor:		Pile Type & Dia.:		Temp:	
Pile Contractor:		Pile Tip:		Final Length:	

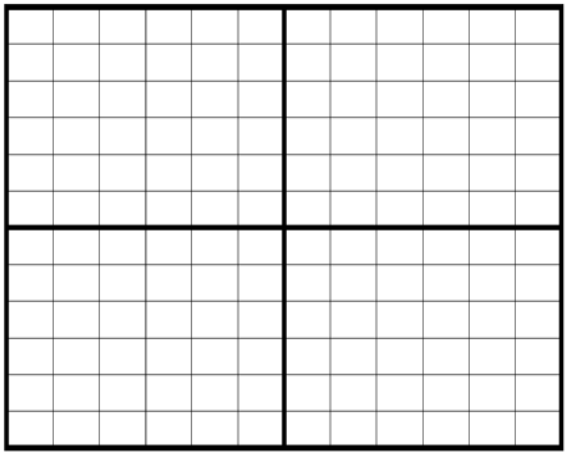
PLUMBNESS



PILE CENTER



PILE CAP LAYOUT



COMMENTS: _____

PILE DRIVING RECORD

for piles up to 90 feet deep

Depth (ft)	Blows	Remarks	Depth (ft)	Blows	Remarks	Depth (ft)	Blows	Remarks
1			31			61		
2			32			62		
3			33			63		
4			34			64		
5			35			65		
6			36			66		
7			37			67		
8			38			68		
9			39			69		
10			40			70		
11			41			71		
12			42			72		
13			43			73		
14			44			74		
15			45			75		
16			46			76		
17			47			77		
18			48			78		
19			49			79		
20			50			80		
21			51			81		
22			52			82		
23			53			83		
24			54			84		
25			55			85		
26			56			86		
27			57			87		
28			58			88		
29			59			89		
30			60			90		

PILE DRIVING RECORD

for piles 90 to 130 ft. deep with relatively easy driving in upper 50 ft.

Depth (ft)	Blows	Remarks	Depth (ft)	Blows	Remarks	Depth (ft)	Blows	Remarks
0-5			71			101		
5-10			72			102		
10-15			73			103		
15-20			74			104		
20-25			75			105		
25-30			76			106		
30-35			77			107		
35-40			78			108		
40-45			79			109		
45-50			80			110		
51			81			111		
52			82			112		
53			83			113		
54			84			114		
55			85			115		
56			86			116		
57			87			117		
58			88			118		
59			89			119		
60			90			120		
61			91			121		
62			92			122		
63			93			123		
64			94			124		
65			95			125		
66			96			126		
67			97			127		
68			98			128		
69			99			129		
70			100			130		

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