Alaska
Department of
Transportation
and
Public
Facilities

Alaska Geological Field Investigations Guide

(March 2007)

INTRODUCTION

The Alaska Geotechnical Procedures Manual consists of a series of guidelines for geological/geotechnical investigations, procedures, and reports for the Department. The Alaska Geotechnical Procedures Manual guidelines are intended to aid Department staff and consultants whose task is to obtain geological/geotechnical data for use in the design process and for other Departmental purposes.

Throughout this guide, the term “geotechnical” is used broadly to denote a general terminology for geotechnical engineering and support functions such as geological investigation and data interpretation and analysis, geotechnical design engineering, materials lab testing, GIS mapping in support of geological investigations, pavement management and design, etc. This broad use is contrasted with the use of the term geotechnical engineering, a specialty branch of civil engineering. The “geotechnical” staff may be thought of as a subset of the “materials” staff.

This Geological Field Investigation Guide is about the collection of geological and geotechnical engineering data, but is not intended as an exhaustive directive as to all the possible procedures and methods used to obtain the data. The individuals or teams who are tasked with collecting the data will, of necessity, adjust their methods and procedures to meet the specific project needs and requirements.

This guide is based on and borrows from numerous references that are listed in Section 20. Below is a listing of authoritative references that are used in conjunction with the guide. Each of the Department’s materials sections and the consultants who perform geotechnical investigations under contract to the Department should have copies of these references to use along side this guide.

AASHTO, “*Manual on Foundation Investigations*,” Washington, D.C., 1978

AASHTO, “*Manual on Subsurface Investigations*,” Washington, D.C., 1988

FHWA, *“Evaluation of Soil and Rock Properties,”* Geotechnical Engineering Circular No. 5, FHWA-IF-02-034, DOT, FHWA, 2002.

FHWA, “*Soils and Foundations Workshop Manual, 2nd Edition*,” FHWA-HI-88-009, 1993.

FHWA, “*Subsurface Investigations*,” NHI Course Manual No. 13231 (Module 1), FHWA-HI-97-021, 1997

Topics Not Covered in this Guide

The three topics of interest listed below are not specifically addressed in this guide.

Material site investigations will be addressed in a separate guide that is in progress at the time of this writing in 2006.

Slope stability investigations are also not covered in this guide. A guideline for this topic is under consideration. The Transportation Research Board (TRB) has a publication (listed below) that has thorough and authoritative coverage of landslide investigations. There is also a 2005 publication (also listed below) on landslide investigation, analysis and mitigation by Derek Cornforth. Together, these two references will provide excellent guidance for landslide investigations. Department Geotechnical staff working on slope stability issues should have ready access to both Special Report 247 and to the Cornforth book.

TRB, "*Landslides: Investigation and Mitigation*," Transportation Research Board Special Report 247, ISBN 0-309-06151-2, 1996.

Cornforth, Derek H., "*Landslides in Practice*," John Wiley & Sons, Inc., ISBN 0-471-67816-3, 2005.

Foundation investigations for bridges, retaining walls, buildings, marine facilities, etc., are not given in-depth coverage in this guide. The drilling methods discussed are applicable to foundation investigations. The AASHTO "Manual on Foundation Investigations" listed above is nearly thirty years old and a Department guide is under consideration. The requirement for a foundation investigation is addressed in the AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications, 2004. Our drilling methods are subject to modification to meet requirements of LRFD as applied to bridges and foundations. There may also be modifications to drilling methodology to accommodate LRFD methods for earthwork in the future

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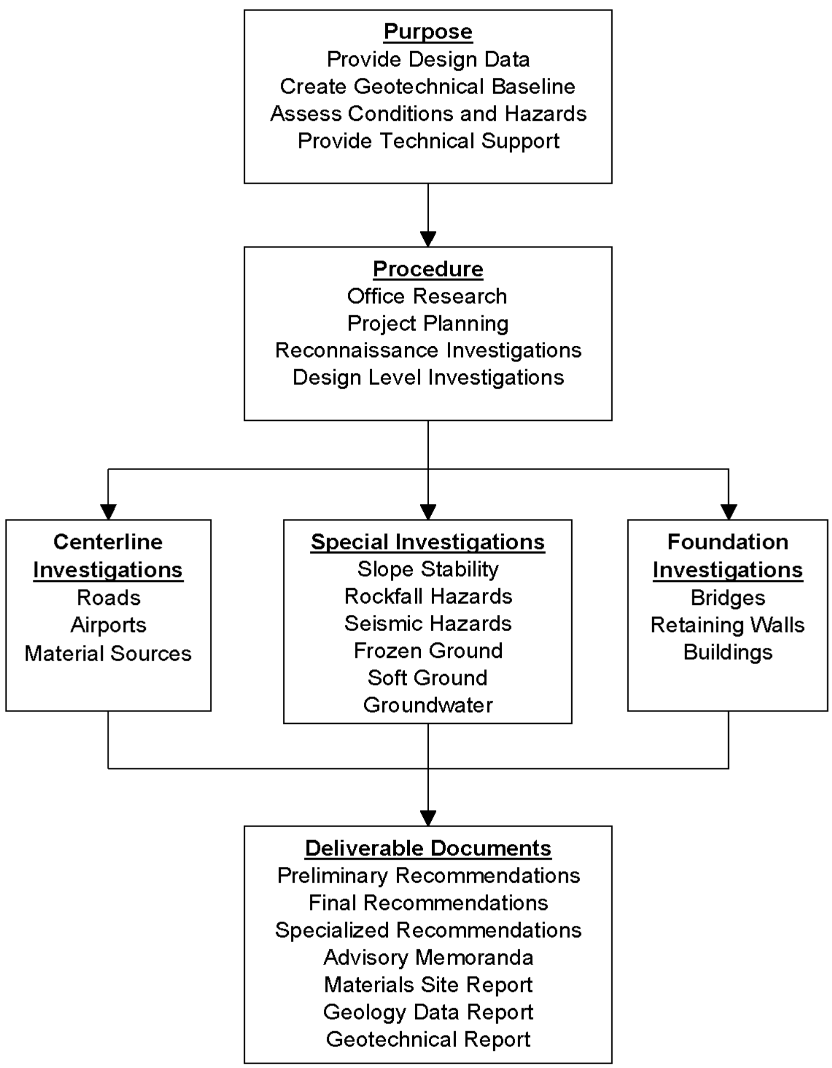
1.0 PURPOSE OF GEOLOGICAL/GEOTECHNICAL INVESTIGATIONS

1.1. Purpose

The Department is responsible for understanding the characteristics of soil and rock materials that support or are adjacent to transportation facilities to ensure that the facility, when designed and constructed, will adequately and safely perform its intended function. The purpose of geotechnical investigations is to support transportation engineers by providing design data and a geotechnical baseline, assessing hazards, assessing conditions of existing structures and other transportation facilities.

This geotechnical work provides technical support for projects from the development stage and project conception, design, and construction and throughout the maintenance and operations phase. See Figure 1-1 below.

Figure 1-1
Purposes, Procedures, and Deliverables for Geological Investigations



1.2. Requirement for Geotechnical Investigation

Geotechnical investigation and design is needed for all Department projects, and particularly for those that include significant soil or rock cuts or fills, involve unstable ground (landslides or rockfall, e.g.), soft ground (peat or soft sediments, e.g.), frozen ground, or other hazardous conditions, or include structures such as buildings, retaining walls or bridges.

> "Both an adequate site investigation and a comprehensive geotechnical report are necessary to construct a safe, cost-effective project." (*Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications, FHWA Publication No. ED-88-053, Federal Highway Administration, 2003.*

> "The initial step in any highway project must include consideration of the soil or rock on which the highway embankment and structures are to be supported. The extent of the site investigation will depend on many factors. . . ." (*Soils and Foundations Workshop Manual, 2nd Ed.*, FHWA Publication No. HI-88-009, National Highway Institute, 1993).

> "Subsurface explorations shall be performed for each substructure element to provide the necessary information for the design and construction of foundations." (*AASHTO LRFD Bridge Design Specifications*, 3rd Ed., American Association of State Highway and Transportation Officials, 2004.)

In some cases, there will be sufficient data and information already compiled and no additional investigation is necessary. In most cases, however, an investigation will be needed to provide adequate data to support a design. A geological investigation must be conducted by engineering geologists who possess adequate training and experience and in accordance with Department standards and policies and regionally or nationally accepted state of the practice standards and methods.

1.3. Requirement for Geotechnical Report

A geotechnical report should be prepared for each Department project. The interaction between Department road and airport embankments, bridges, buildings and other facilities and the soil and rock materials that support or are adjacent to the facilities requires careful consideration in the design process. The geotechnical investigation is the means by which the interaction between our facilities and the earth is analyzed. The geotechnical report is the tool used to communicate the site conditions and design and construction recommendations to the design and construction staff. The geotechnical report may be in a variety of formats depending on the stage of the project and requirements of the user. Draft reports and memoranda may be used to transmit data and recommendations, but a final report suitable for inclusion in project bid documents should be prepared for each project. Refer to Alaska Geotechnical Report Preparation Guidelines.

The geologists and other staff assigned to the project are responsible for the development of exploration plans for geotechnical investigations that meet project requirements and local conditions while adhering to minimum requirements for geotechnical investigations. No standard approach is possible for all geotechnical investigations because of the diverse variety of conditions from project to project, differences in project scope, budget and time constraints, availability of equipment, experience of assigned staff, etc. This guide is intended to aid geotechnical staff in conducting investigations, but does not provide a step-by-step process.

The collected field data, assessments and interpretations are the basis for all subsequent engineering decisions and, as such, are of paramount importance to the design and success of a project. The data collected and collated during the course of an investigation and published as the project's geotechnical report, together with previous (still valid) geotechnical data and reports, establish the geotechnical baseline from which potential differing site conditions are judged. By outlining and describing these requirements and steps, it will be possible to standardize procedures and considerably reduce time and expense that would be required to return to the project site and obtain important information not obtained during the initial investigation.

The complexity and detail of the geotechnical investigation and of the geotechnical report should reflect the complexity of the project. Simple overlay projects do not require the same detail and level of effort as a project involving hundreds of feet of rock cuts. The following are fundamental data requirements, most of which should be obtained for most projects during a geotechnical investigation and published in the geotechnical report:

- Condition and performance of existing transportation facilities including embankments, slopes, structures such as bridges and retaining walls.
- Identification, delineation and characterization of soil and rock strata.
- Qualitative and quantitative information (field and laboratory testing) on the character and engineering properties of the soil and rock designated on the specific project as borrow, unclassified or classified excavation materials, select material or processed aggregates.
- Groundwater levels and environmental issues, if any
- Geologic hazards or constraints such as unstable soil or rock slopes, seismic hazards, permafrost soil, drainage issues, etc.

The basic steps for a geological investigation are summarized in this and other guides contained in the Geotechnical Procedures Manual. Here we consider the commonly used methods for performing field explorations. This guide addresses procedures for investigations for various types of projects including roadway and airport centerline investigations, foundation investigations and special investigations for slope stability. Guides for description and classification of soil and rock, and preparation of geotechnical reports, and other topics are located elsewhere in the Manual.

2.0 ROLE OF MATERIALS SECTIONS

The four materials sections (three Regional materials sections and Statewide Materials) all have responsibilities for conducting the Department's geotechnical program. The role of the materials sections in the project development process is outlined in the *Alaska Preconstruction Manual*. Additional detail is provided in the *Alaska Geotechnical Procedures Manual*, of which this *Geological Field Investigation Guide* is a part. The materials sections conduct geological/geotechnical investigations or supervise consultants who conduct the work. The investigations result in the collection and publication of the geotechnical data needed to supply the design staff with information to support project designs. The information may include raw or processed data and interpretations of conditions, along with geological recommendations and geotechnical design recommendations.

In addition to the design process for project development, the material sections and geotechnical staff perform numerous services and functions throughout all phases of the Department's operations. The services and function include such diverse topics as:

- providing technical advice and recommendations for mitigation of geological hazards,
- conducting slope stability investigations,
- research into geotechnical issues such as use of hard aggregate in pavement, use of wire mesh to control rockfall, use of geophysical methods in geotechnical investigations, etc.,
- development of standards and procedures for geotechnical work.

A substantial part of the Department's design work is performed by contractors (about half the design work at the time of this writing). One of the materials sections' primary functions should be to monitor the geotechnical work undertaken by our contractors. The materials sections should have a role from the initial development of the scope of the investigation and exploration plan, through field work and including review of the final geotechnical report and the plans and specifications for the project.

3.0 PROJECT DEVELOPMENT

Geotechnical work is part of all phases of project development from initial conception and scoping, through the environmental, design and construction phases of the project, and continuing through the life of the project during maintenance activities. The Alaska Preconstruction Manual outlines the involvement of the geotechnical sections through the design process. During the initial phases of the project, staff may rely on existing geotechnical data to support scoping and pre-design or preliminary engineering work. Preliminary geotechnical site visits or reconnaissance investigations are conducted to assist staff in siting facilities and selecting alignments. During this reconnaissance phase for larger or more complex projects, the geotechnical section may conduct mapping, sampling and drilling test holes or excavating test pits.

Geological field investigations should not be conducted until certain project-specific information has been obtained. Table 3-1 identifies typical project requirements and suggests where the necessary information on specific subjects may be obtained. Table 3-1 may be used as a guide for determining the sources of documentation for this preliminary information.

While considering the project development phase, remember the importance of site visits and on-the-ground inspections of the project area. For every project, numerous questions will be answered and numerous others raised by a simple walking tour of the project area. Other sources of site specific information should be considered. Table 3-1 provides a listing of potential sources.

Table 3-1
Sources for Site Specific Information

Project Specifics	Information Sources
Type of proposed project. Proposed project termini. Scope of Project. Design Study Report. Funds available. Schedule requirements. Items requiring investigation. Local contacts. Location and type of utilities present.	Design Project Manager
Scope of investigation required. Timing of investigation. Availability of exploration equipment. Exploration Plan.	Regional Materials Engineer, Foundation Engineer, Geotechnical Engineer, Regional Geologist, Chief Geologist
Location of structures.	Bridge Section, Design Project Manager
Site maps Air Photos Field reference systems	GIS Unit, Location/Survey Unit, Statewide Planning, Right of Way, private vendors
Permits and specific site restrictions such as water quality, environmental considerations, or other agency considerations.	Regional preliminary design and/or environmental staff, through Design Project Manager

3.1. Use of Consultants

Ordinarily, the materials section having subject or area responsibility conducts the geotechnical work for a project. For example, regional materials sections are responsible for centerline investigations and Statewide

Materials is responsible for foundation investigations. However, a significant percentage of Department projects are designed under contracts with engineering design consultants. For most of these projects, geotechnical investigations are part of the contracted services. Whenever feasible, the design project managers responsible for these projects should solicit the appropriate materials section to review the scope of work. The materials section should review and comment on the exploration plan and the work products produced under the contract, particularly the final geotechnical report. The materials sections also should review and comment on the plans and specifications produced under the design contract.

3.2. Preliminary Engineering through Environmental Document (Preconstruction Manual §430)

In the earliest phases of projects, the development process includes route studies and selection of alternatives. During this phase, support groups such as the materials sections begin assessment of the preliminary alternatives in conjunction with the environmental process. Once alternative routes for highways or airports have been selected, the geotechnical staff provides information to refine locations, to assess potential hazards, to assess material sites, and to consider options for construction methods. This preliminary engineering to develop and support the environmental document should include geotechnical field reconnaissance. During this phase, the geotechnical staff may produce memoranda or preliminary reports to assist designers. In some cases the material section may produce a formal reconnaissance investigation report. Depending on the project, most of the geotechnical work to support the final design may be conducted during the preliminary phases of development.

3.3. Preliminary Engineering through Final PS&E (Preconstruction Manual §450)

Once the project enters the final design stage, the appropriate materials section conducts design-level geotechnical investigations to characterize the topography, drainage, soil and rock characteristics, geological hazards, and other geotechnical aspects of the project. This final geotechnical work culminates in the production of preliminary and final geotechnical recommendations and the final geotechnical report for the project. The geotechnical report is the tool used to communicate the site conditions and design and construction recommendations to the design and construction staff. The geotechnical report also establishes the baseline of geotechnical data for the project, against which potential differing site conditions are compared during construction.

Each project has its own specific attributes and requirements. When planning geotechnical investigations and considering the needs and requirements for geotechnical data, refer to the FHWA Geotechnical Engineering Circular No. 5 – Evaluation of Soil and Rock Properties, Table 1, pages 12 to14 for a comprehensive summarization of requirements for various highway applications.

3.4. Work Flow for Geotechnical Investigations

Multiple project tasks are undertaken as the project development progresses. In keeping with accepted organizational principles, the responsibility and decision-making for these tasks should be assigned as far down the chain of command as is feasible. Table 3-2, below shows common principal tasks associated with geotechnical investigations.

Table 3-2
Geotechnical Tasks

GEOTECHNICAL TASK OR INFORMATION	PERFORMED OR PROVIDED BY
Scope, Schedule & Budget Request Design Study Report Air Photos Location Drawings Preliminary Plan Set X-Sections	**Provided by** Design Project Manager
Scope, Schedule & Budget	**Drafted by** Field Geologist **Concurred by** Regional Materials Engineer, Geotechnical Engineer, Regional Geologist, Chief Geologist **Approved by** Design Project Manager
Exploration Plan	**Drafted by** Field Geologist **Concurred by** Regional Geologist, Regional Materials Engineer **Reviewed by** Chief Geologist **Approved by** Design Project Manager
Environmental Permits for Drilling or Access	**Applied for by** Field Geologist through Design Project Manager
Access Permits Rights of Entry	**Requested by** Field Geologist from Right - of – Way section through Design Project Manager
Traffic Control Plan	**Prepared by** Field Geologist **Approved by** Traffic Engineer
Traffic Control Contract	**Requested by** Field Geologist **Work Scope Drafted by** Regional Geologist or Chief Geologist **Issued by** Contracts Section
Conduct Investigation	**Conducted by** Field Geologist
Preliminary Memoranda and Recommendations	**Prepared by** Field Geologist **Approved by** Regional Geologist **Concurred by** Regional Materials Engineer **Reviewed by** Chief Geologist **Submitted to** Design Project Manager
Final Geology Data or Geotechnical Report	**Prepared by** Field Geologist **Concurred by** Regional Geologist **Approved by** Regional Materials Engineer **Reviewed by** Chief Geologist **Submitted to** Design Project Manager

4.0 PRELIMINARY GEOTECHNICAL ACTIVITIES

4.1. Review of Project Requirements

The first step in performing a geological investigation is a thorough review of the project requirements. It is important that geological investigations be carefully planned, and coordinated between those who will obtain the field data and the end users of the information. The geologist and geotechnical engineer should thoroughly understand the following project details and limitations before planning and performing the geological investigation:

- Project location and size
- Project type and features (airport, highway, realignment, rehabilitation, bridge, retaining wall, rock cut, embankment, etc.)
- Project criteria (alignment, approximate structure locations, approximate structure loads, approximate bridge span lengths and pier locations, soil and rock cut and fill area locations, required quantities of borrow materials, structural fills, etc.)
- Project constraints (ROW, environmental and cultural assessments, permitting, etc.)
- Project design and construction schedules and budgets
- Field exploration constraints such as environmental permitting, rights of entry, utility conflicts, climate or weather-related time constraints, etc.

Depending on the stage of project development, the materials staff should have access to typical section, plan and profile sheets, and cross sections with a template for the proposed roadway showing cuts and fills. This project specific data aids the staff in planning the investigation to meet the project requirements. One goal of properly planning a geotechnical investigation is to minimize exploration costs and the number of site visits needed to obtain vital design information.

Prior to performing any fieldwork, the geologist assigned to the project must have obtained Right of Entry permits to the site and any necessary environmental permits through the design project manager. Copies of the environmental permits should be taken to the field. Following the identification of proposed exploration sites, the field geologist will obtain utility locations and clearances before proceeding with the investigation.

4.2. Use of Geographical Information Systems

Geographical Information Systems (GIS) have become an integral part of the materials sections' methodology. Each region has to some degree incorporated GIS in its set of geotechnical tools. GIS can be used to develop an integrated model of geotechnical information about a project. GIS can be used to digitally store, retrieve, and integrate geotechnical data into a digital or paper format for analysis and display. Geo-referenced data can be located on displays with layers for survey boundaries, topographic maps, air photos. Layers can be added for geologic mapping, test hole data, soils and rock characteristics, drainage patterns, etc. A GIS project can be used by interested parties such as environmental staff, design staff, geotechnical staff, construction staff and maintenance and operations forces for a variety of purposes. The Department has invested considerable resources into development of this useful tool and the geotechnical staff is a primary user in planning, conductin8yand reporting on geotechnical investigations. Little mention of this useful tool will be made in this manual, but keep in mind the uses for GIS in all phases of geotechnical investigations.

4.3. Office Review of File Materials and Other Available Data

After gaining a thorough understanding of the project requirements, the geologist will collect and review all relevant available information on the project site. Data may be available from previous projects in the same area or on nearby projects from the Department, other state or federal agencies, local government, Native corporations, or other private sources. Available data may consist of reports, maps, aerial photographs, previous as-built plans, personal communications with individuals with local knowledge and other sources. The Department may have soils data on file from State projects and as-built drawings as well as pile driving records for existing structures. Existing boring information or well drilling logs can contain relevant and useful information. This data can be quite useful in setting preliminary boring locations and depths and in predicting problem areas. Maintenance records for nearby roadways and structures may also provide insight into the subsurface conditions. For example, indications of differential settlement or slope stability problems may provide the geologist or geotechnical engineer with valuable information on the long-term characteristics of the site.

Project drawings and cross sections may be obtained from the design team. Considerable information may be gathered about the project history by review of the design files and materials section files. At this stage the geotechnical staff should gather together all of the available file information into a project file, including Design Study Reports, if available, relevant environmental documents, previous project geotechnical reports, air photos, drawings, test hole logs, etc., as discussed below. Review of this information provides a basis for understanding the geology, topography, and geomorphology of the area. An initial understanding of the engineering properties of subsurface materials and groundwater characteristics can often be obtained from this available data, which can help in developing the exploration plan.

4.4. Topographic Maps

These maps portray physical features, configuration and elevation of the ground surface, and surface water features. Interpretations of these maps can aid the geotechnical staff in determining changes in relief and slope angles, landform and drainage characteristics, identification of potential landslide terrain, accessibility for field equipment, and possible problem areas. (A complete set of digital topographic maps of the entire state is available through the computer program TOPO!) Additional topographic maps are sometimes prepared on a larger scale by the Department during early planning phases of a project. Department plan sets often include detailed topography of the project within the right of way.

4.5. Aerial Photographs

Aerial photographs and ortho photgraphs are available from the Department, other agencies and private aerial photogrammetry firms. These photos are valuable tools in planning the site reconnaissance and, depending on the age of the photographs, show manmade structures, excavations, or fills that affect accessibility and the planned depth of exploration. Historical photographs can also provide a better understanding of how the project site has been modified throughout the years. It may be useful to obtain new air photo coverage of the project alignment.

4.6. Geological Maps and Reports

Considerable information on the geological conditions of an area can be obtained from geological maps and reports. These reports and maps show the location and relative position of the different geological strata and present information on the characteristics of these materials. This data can be used directly to evaluate the rock conditions to be expected and indirectly to estimate possible soil conditions, since the parent material is one of the factors controlling soil types. Geological maps and reports can be obtained from the USGS, DNR's Division of Geological and Geophysical Surveys, university or other resource libraries, the Geotechnical or Materials Sections of DOT&PF, and other sources.

4.7. Soils Conservation Service Surveys

These surveys are compiled by the U.S. Department of Agriculture (Soil Conservation Service) usually in the form of soils maps. These surveys can provide valuable data on surface soils including areal extent, mineralogical composition, grain size distribution, and depth to rock, water table information, drainage characteristics, geologic origin, and presence of organic deposits

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4.8. Hydrogeological Surveys and Well Logs

Hydrogeological surveys generally focus on the presence, depth, amount, and condition of groundwater. These resources can aid the geologist by giving some indication about the presence and depth of groundwater in terms of its effect on construction conditions and its control over shear strength of soil and rock masses. Water well logs produced by private drilling contractors may be recorded by other State agencies such as DNR. In addition to groundwater information, such logs can serve as useful tools in supplying general subsurface information, including depth to bedrock near bridge locations.

5.0 EXPLORATION PLANNING

During the planning for exploration, several steps may be underway at once. The geotechnical staff will usually be working on schedule and budget at the same time they are developing the exploration plan and obtaining access and environmental permits.

5.1. Preparation of Scope, Schedule and Budget

At an early stage of the work, the geotechnical staff assigned to the project prepares a scope, schedule and budget memorandum for the design project manager. This document represents the understanding between the materials section and the design team as to the nature of the work, the estimated cost and timing of the geotechnical work and the deliverable documents that will arise from the work. The geotechnical staff must review enough of the work already done on the project to understand the project requirements, as described above, and the work needed to provide design data. The Regional Geologist and the Regional Materials Engineer should prepare the scope, schedule and budget for the design project manager's approval. For regional work or structure foundation investigations involving Statewide Materials staff, the Chief Geologist should also review and participate in preparation of the scope, schedule and budget.

5.2. The Exploration Plan

The exploration plan is the principal guide for the geotechnical staff in the conduct of the investigation. Thus, preparation of the exploration plan is one of the most important steps in the geotechnical investigation. Keep in mind that the exploration plan is a flexible guideline for the exploration. Unexpected conditions and findings as the field work is underway, scheduling problems due to equipment efficiency, weather, and many other factors can lead to changes to the ongoing program.

The geotechnical engineer and the assigned field geologist and other supporting materials staff cooperatively prepare the exploration plan for conducting the geological investigation. Once the preliminary research and record review has been done, the plan is prepared and submitted to the design project manager for approval.

The preparation of the exploration plan requires a site visit, if possible, by the geotechnical engineer and geologist assigned to the project and representatives of the design staff. For remote sites with difficult access, it may be necessary to rely on file information and interviews with staff members who have visited the site during the pre-design phase. File materials, air photos, topographic maps, and other data, as described above, can be used to prepare a base document of mapping and images. The proposed exploration elements can then be plotted on the base document.

At a minimum, the exploration plan should consist of:

- Proposed scope of the investigation, including reconnaissance and design investigations as required.
- Schedule of work and deadlines for deliverable documents.
- Proposed staff.
- Enumeration of project requirements for borrow materials, quantity of cut and fill materials, etc.
- Maps, drawings or images of the project site, showing existing and proposed alignments, site access, proposed structures, drainage features, etc.
- Outline of sampling and testing program.

- Proposed drilling or other exploration equipment.
- Proposed test hole/test pit locations and depths.
- Spacing and depth of test holes. The Department typically spaces exploratory holes at 500 foot intervals in fill sections and at 200 foot intervals in cut sections. However, this only a rule of thumb and the project requirements and expected soil conditions may dictate smaller or larger intervals between hole locations. In addition, the plan may require modification once the field work begins. Alteration of exploration plans is not unusual, but should be undertaken with concurrence of the regional geologist, regional geotechnical engineer, and regional materials engineer. For reference, see Appendix D – *Guidelines for Minimum Number of Investigation Points and Minimum Depth of Investigation*, from *Geotechnical Engineering Circular No. 5 - Evaluation of Soil and Rock Properties*, FHWA Publication FHWA IF-02-034 (April 2002). Also refer to guidelines in *"Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications,"* FHWA Publication FHWA ED-88-053 (Revised February 2003). The suggested spacing for test hole or test pit locations should be modified as necessary for project specific requirements.
- Discussion of required environmental permits and constraints that may affect the geotechnical work schedule
- Discussion of rights or entry or access permits necessary for the field program
- Utilities that may conflict with exploration sites.
- Proposed material site locations and access routes.
- Known or expected geologic hazards.
- Right of Way and property boundaries.

Any significant changes to the exploration plan once field work is underway should be made in consultation with the geotechnical engineer. The principal reason the plan is a flexible guideline is that as each new piece of data is acquired by the field geologist and synthesized with the information already known, a better picture of the conditions and features of the overall project is developed. As each test hole or test pit is advanced, the geologist assesses the new information and decides where the next piece of information should come from and how it should be obtained. Where uniform conditions occur as expected during planning, few changes are likely to be made to the investigation. However, where conditions are variable and not as expected, major changes to the field exploration may be necessary to accomplish the goals of the investigation.

5.3. Permits and Access for Geotechnical Investigations

Once the exploration plan has been drafted and test hole or test pit locations have been selected, send the plan to the design project manager for forwarding to the appropriate staff with a request for access and environmental permits for field operations. The field geologist or Regional Geologist should make a written request to the project manager well in advance of the expected commencement of the field work to avoid scheduling problems. Once permits and rights of entry have been issued, the field geologist should review the documents for conformance with the exploration plan. Copies of permits and rights of entry should be kept with the field crew during the course of the investigation.

6.0 RECONNAISSANCE INVESTIGATIONS

6.1. Objective and Purpose

The objective of reconnaissance is to identify the key issues that will influence project design and to provide geotechnical and engineering geology data to the reconnaissance or design engineer to assist in selecting the best location for project elements. Conclusions by the geotechnical staff should be drawn from background information and field studies to assist the engineer in avoiding areas that may present design, construction, and/or maintenance problems. Although other considerations may, in some cases, force a choice of alternatives other than the "best" alternative from a geotechnical perspective, the reconnaissance report should alert the design engineer to the additional costs and problems associated with alternate choices.

Some projects may require an extensive geotechnical reconnaissance while others may require only a limited study. For example, rebuilding of existing airfields or roads may require only an examination of the performance of the existing facility and a review of "as-built" plans and construction records. For a new alignment, extensive geotechnical reconnaissance (including test holes and sampling) may be required for cuts in unknown soil types and large fills with questionable foundations, retaining walls, bridges, or possible subsurface drainage problems.

6.2. Site Visit

The geotechnical staff assigned to the project must visit the site to develop an appreciation of the topographic, geologic and geotechnical concerns of the project and become knowledgeable of access and working conditions. Pertinent project information (project development documents) and other conceptual information should be obtained from the project design team before the site visit. If at all possible the staff should have a set of plans (Plans-in-Hand or Pre-PS&E) and cross sections for the reconnaissance. A reconnaissance visit should be performed only after the geotechnical staff has an understanding of the project requirements and has a good understanding of the apparent geological conditions at the project.

The appropriate geotechnical staff should perform the field reconnaissance, preferably on foot. The value of ground reconnaissance cannot be overstated. For new alignments, it may be advisable to conduct aerial reconnaissance before or after the ground reconnaissance. The reconnaissance will almost always include air photos, but with an understanding of the limitations on amount and detail of the information from air photos. As part of the reconnaissance, key site locations and conditions, and exploration equipment access routes should be photographed.

6.3. Checklists

The geology/geotechnical staff is encouraged to make use of checklists in preparing for field investigations. Each field employee should develop and use his or her own checklists using as guides published checklists such as those included in:

Checklists and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications, FHWA ED-88-053 (rev. February 2003),

Subsurface *Investigations*, FHWA-HI-97-021 (1997)

Evaluation of Soil and Rock Properties, Geotechnical Engineering Circular No. 5, FHWA-IF-02-034 (2002)

Manual on Subsurface Investigations, American Association of Highway and Transportation Officials (1988)

6.4. Important Reconnaissance Issues

The following are some of the important issues that should be addressed during the field reconnaissance and should be resolved during the design level investigation:

- Geology and Topography – study and summarize the regional and site geology and topography and how they may affect the geotechnical investigation and project design. For example, if the area geology indicates the bedrock is highly weathered and fractured shale, any required rip rap would likely come from outside the project limits. Similarly, if the area is known to have considerable fine-grained surface soil and shallow groundwater, slope stability and settlement problems may occur and the geotechnical investigation should focus attention on those issues.
- Existing Transportation Facilities – Assess present alignment, existing embankments, soil and rock slopes, drainage features, effectiveness of culverts, conditions of existing bridges and approaches and retaining walls, etc.
- Planned New Alignment or Site – Assess the planned preferred alignment or sites and other possible alternates for feasibility and potential geotechnical problems with the alignment.
- Make “station-to-station” descriptions of the proposed alignment or site identifying the soil and rock strata. It may be advisable to take small numbers of representative samples of soil and rock for testing to generally delineate the soil and rock conditions. Identify problems areas of deep organic soils, suspected frozen ground, unstable slopes, water problems and other conditions.
- Existing Slopes – Assess the stability factors of major slope-forming geologic units. Natural slopes and any existing soil or rock slope failures should be measured and observed. Cut slope angles and orientations should be measured and their relative performance evaluated. Refer to the Erodibility Chart in Appendix C.
- Rock exposures – compare stratigraphy to information obtained from available data. Mapping and subsurface explorations and laboratory testing will ultimately define the rock units. Delineate outcrops or exposures that warrant further investigation in terms of structural mapping for stability analysis or that may be quarry sites.
- Groundwater and Surface Water – Estimate the general nature of surface water and groundwater regimes at the project site. Develop concepts for future investigations.
- Geologic Hazards – Identify geologic conditions that may tend to adversely affect project development plans (landslides, rockfall, frozen ground, soft ground, faults, flooding, erosion, etc.). Devise methods of investigating the degree of potential impact.
- Material Sites - Identify and preliminarily assess known and potential borrow sites and quarry sites in the project area. This includes assessment of large cut areas that may provide significant quantities of material for the project. Take limited numbers of soil and rock samples to confirm that material quality is adequate for the project requirements. Survey for adequate quantity and detailed quality testing should be conducted during the design investigation.
- Preliminary Assessment of Structure Sites – Identify general site characteristics and potential problems with exploration and construction such as adverse bedding in rock formations,

soft or weak rock formations, potential fault locations, possible liquefaction hazard, presence of boulders and cobbles, soft ground, frozen ground, etc.

- Scope of Future Explorations – Determine the scope of design investigation to best accomplish the project needs given the conditions at the site. Identify geotechnical problem areas requiring special attention during the design investigation.
- Design Investigation Logistics – Define the type, approximate locations and depths of geotechnical borings. Determine approximate routes of access to each drilling location and impact of vegetation. Look for any indications of overhead and underground utilities. Evaluate potential water sources for use during drill operations. Evaluate potential concerns that may need to be addressed while planning an exploration program (permits, overhead utilities, heavy or difficult vegetation, water crossings, equipment security, private property, etc.). If possible, exploration locations should be located with a Driller/Operator. It is desirable to review the proposed boring locations following utility locations to determine if any borings need to be relocated to avoid buried utilities. The presence of utilities may need to be rechecked for the adjusted boring locations.
- Environmental – Identify potential impacts the exploration program may have on: vegetation, lakes and streams, swamps or marshes, subsurface materials, landforms, and the surrounding area. Gather information needed to address best management practices for field exploration. See Appendix E.
- Historical or Cultural - Report any unidentified historical or cultural sites if there are conflicts with the investigation plan.

The deliverable result of the reconnaissance study is a reconnaissance report addressing the issues outlined above and any other issues unique to the project. The report may be focused on geological issues or may have a broader coverage of geotechnical or materials issues. Refer to the *Alaska Geotechnical Report Preparation Guide* for details on the preparation of geotechnical reports.

7.0 DESIGN INVESTIGATIONS

7.1. Objectives and Purpose

The objective of design level geological/geotechnical investigations is to provide all the geotechnical information necessary to complete the design of the project or facility. The ultimate product of a design level investigation is the formal geotechnical report with engineering recommendations. The geotechnical report provides the geotechnical data the designers use to make design decisions. The geotechnical report also provides the baseline of geotechnical data against which differing site conditions claims during construction will be compared. It is obviously very important for the materials staff to give as much attention to detail as possible to provide the highest possible quality data to the design team and well written and complete documentation for the project records and contract documents.

Often, the design investigation is performed in two or more phases. The preliminary or reconnaissance work, as discussed above, is usually done early in the design process before the final alignment is set and before structure locations are fixed. The early work typically includes a limited number of test holes, widely spaced and sited to capture general information about stratigraphy, soil and rock characteristics, groundwater, rock slopes, extent of soft ground, etc. For the design phase work, test holes will be located at close intervals to fully characterize and map surface and subsurface conditions along the alignment and at structure locations. This work may be done in several phases as an iterative process as problem areas are assessed and solutions identified and when design changes are made.

As discussed above in the Reconnaissance section, the use of checklists is strongly encouraged. While checklists are not intended to replace a thorough process of thinking through the appropriate steps of the investigation, such lists provide a useful aid in the process.

7.2. Mapping the Alignment - Surface Soils, Rock, Topography, Drainage, Vegetation

The field geologist should make use of geologic maps, topographic maps, aerial photography and make a foot reconnaissance of the project site or alignment. The value of ground reconnaissance cannot be overstressed and should be employed at every feasible opportunity. The geologist should make station by station notes, maps or sketches of the entire project area to identify the following features:

- Landforms
- Soil types and distribution
- Rock types and distribution
- Presence of rock exposures
- Usability of cut materials
- Amount of waste in cuts
- Amount of waste from surface organics and peat deposits
- Drainage issues and recommendations for subcuts, underdrains, etc.
- Erodibility of soil (<u>see</u> Erodibility Chart at Appendix C)
- Vegetation
- Groundwater conditions in cut and fill zones
- Presence of geologic hazards such as:
  - Soft ground and settlement issues
  - Frozen ground
  - Rockfall hazards
  - Rock or soil slope stability problems
- Material sites locations, accessmaterial types, and volumes

The list is not all-inclusive and many other issues may be involved on any particular project. Contact the local Maintenance & Operations staff to obtain details about particular problems noted along the alignment such as seasonal problems like springtime rockfall and seasonal springs and icing problems.

The geologist should conduct probing along the alignment to make a station-by-station determination of depth of organic material and waste soils within the footprint of the work. Seasonal reconnaissance may be necessary to identify areas of icing, seasonal frost depth, presence of springs, snow drifting, rockfall and other conditions that may occur only during particular times of the year. Locations and elevations should be determined using compass, level and tape or GPS. The alignment should be divided into logically separated sections based on the field mapping. Divisions may be based on landforms, soil or rock profiles, presence of cuts and fills, or other factors.

7.3. Rock Slope Mapping and Measurements

A detailed discussion on rock structural mapping is given in the Department's *Alaska Field Rock Classification and Structural Mapping Guide*. Field mapping should begin by observing road cuts, drainage courses, and bank exposures. A site plan and large-scale topographic map of the project area is essential for field mapping. The main objective of these initial observations is to confirm the general types of soil and rock present. Note any features that may assist in the engineering analysis, such as the angle and performance of existing slopes, or the stability of open excavations or trenches. The type and condition of vegetation may give an indication of ground and surface water regimes, as well as an indication of landslide or slope stability concerns.

Make note of any feature that may affect the boring program, such as accessibility, structures, overhead utilities, signs of buried utilities, or property restrictions. In addition, structures should be inspected to ascertain their foundation performance and their susceptibility to damage from construction-related ground vibrations or settlement due to embankment placement.

For rock slopes, performance of slopes and the rockfall history are important indicators of how a new slope in the same material will perform. More detailed rock structural mapping entails observing and measuring lithologic contacts and the engineering characteristics and orientation of rock discontinuities that make up the rock mass. The measurements are typically made with a geological or structural compass and consist of determining the dip and dip direction of rock discontinuities such as faults, joints, foliation, shear and bedding planes, and contacts with other rock units. These measurements can be presented graphically on a spherical projection such as an equal area stereonet. For more detail, see the Participant's Manual for the NHI course "Rock Slopes" (Module 5: No. 13235, 1998).

The AASHTO Manual on Subsurface Investigations (1988) describes the procedures for engineering geological mapping. It also provides suggestions for preparing geologic maps for different applications, such as Project Area Geologic Maps, ROW Geologic Maps, File Geologic Maps, Site Geologic Maps, and other special mapping (see Reference Chapter 4)

7.4. Field-Developed Cross-Sections

Field-developed cross-sections are applicable to nearly all types of site-specific geotechnical investigations. Their use can be applied to excavation and placement of materials; foundations and slopes; specific development of groundwater and aggregate resources; and for the graphic portrayal and analysis of significant features related to slope stability, seismicity, drainage, or other characteristics. Although these cross-sections lack the precision of high order engineering surveys, preparing them provides an excellent opportunity to observe the project area and apply the scientific method in resolving surface and subsurface relationships and other field observations.

Standard cross-sections prepared by survey crews or taken from digital terrain models do not depict the interpreted geotechnical relationships and other features that may prove very important during the design process. Another advantage to field-developed cross sections is that the sections are developed and plotted during the reconnaissance, so discrepancies can be identified and resolved immediately. This provides a high level of confidence when used later in the office.

The cross-section field gear typically includes a field notebook, cloth tape, hand clinometer, calculator, and Brunton compass. Measurements include all slope breaks and other identifiable, geotechnical features such as landslide cracks and groundwater features. The significance of each feature is described in the field notebook. Since slope breaks commonly occur as the strength characteristics of the subsurface material changes, many times the slope breaks represent contacts between different soil and/or rock units. Measurements of the contact orientation (strike, dip and surface trace) are normally denoted where appropriate in the field notebook.

The points comprising the cross-section should be plotted on graph paper as “x” and “y” coordinates while in the field. The coordinates can be readily calculated from the slope distance and angle between each point with the aid of a calculator. Include the interpretations of the surface and subsurface materials and relationships on the section along with relevant estimates of engineering parameters. The section should show the distribution of soil and rock units, estimated location/elevation(s) of surface and subsurface water, and original ground lines prior to any previous excavation, filling or slope movements. As these interpretations are developed, plan any explorations that may be needed to confirm the subsurface model that will be used in the analysis and design phase.

7.5. Logging Test Holes

The original field-prepared test hole or test pit log is the single most important document containing field data associated with geological investigations. A clear and complete record of field exploration activities and findings is essential. The field logs and final drafted drill logs should contain all the relevant information obtained during the field work. Field geologists normally record information from test holes and test pits directly onto the field logs. Additional information is recorded in field books and may be included as part of the final test hole logs.

The information contained within the test hole log, test pit log or penetrometer log (collectively referred to hereafter as “test hole logs”) is transferred to a final drafted form for publication. See Appendix A & B for examples. The original logs are retained and remain in the official record. One of the reasons the test hole logs are important is they are often the only contemporaneous record of what happened during the investigation and the observations made by the field geologist. If there is a claim on a project involving geotechnical issues, the test hole logs will be among the first documents requested. If there is a differing site conditions claim, the test hole log and the geotechnical report set the baseline from which any change in conditions is compared. It follows that preparation of the test hole log in the field must be given a great deal of attention to assure that a proper record is maintained and that the critical data is recorded and preserved.

The other and more obvious importance of the test hole log is to collect geological field data in one place for later transfer to the design team who need the data in their design process. Collecting, listing, preserving and reporting this data accurately and completely is of primary importance in the design process.

Due to the importance of the information, test holes and test pits should be logged at the time they are drilled or excavated by an experienced engineering geologist who has demonstrated knowledge, skills and abilities in performing this work. Logging test holes and performing geological investigations requires a specialized set of skills and abilities. Engineering geology is a part of a continuum of practice between engineering and geology that encompasses the application of geological principles, methods, and techniques to the study, investigations and interpretation of earth materials. Those who are not trained in the principles and techniques may make critical errors in classifying earth materials and understanding the geological relationships that are important to understanding the characteristics of the materials and the geologic setting in which they exist. The failure to correctly identify, interpret, log and report on the types of earth materials encountered on our projects can lead to improper design of Department facilities and expensive construction claims.

7.5.1. Supervision of Subsurface Explorations

The following guidelines for field geologists are summarized from the FHWA Subsurface Investigation Manual and the AASHTO Manual on Subsurface Investigations (Section 7.11):

- Thoroughly comprehend the purpose of the fieldwork in order to properly characterize the site for the intended engineering applications.
- Be thoroughly familiar with the scope of the exploration program. Maintain a copy of the exploration plan.
- Be familiar with site, access conditions, and any restrictions.
- Review existing subsurface and geologic information before leaving the office.
- Constantly review the totality of field data as it is obtained to synthesize the knowledge as it relates to the purpose of the investigation.
- The field staff should maintain frequent contact with the geotechnical engineer or foundation engineer regarding work progress, conditions encountered, problems, etc.
- Fill out forms regularly. Obtain a sufficient supply of boring and test pit logs and any other necessary forms to cover the expected explorations.
- Closely observe the driller's work at all times, paying particular attention to:
    - Current depth (measure length of rods and samplers)
    - Drilling and sampling procedures
    - Any irregularities, loss of water, drop of rods, etc.
    - SPT blow counts
    - Depth to groundwater and degree of sample moisture
    - Do not hesitate to question the driller, or to provide direction to ensure proper procedures are followed.
- Classify soil and rock samples. Put soil samples in jars and label them. Make sure rock cores are properly boxed, photographed, stored, and protected.
- Verify that undisturbed samples are properly taken, handled, sealed, labeled, and transported.
- Bring necessary tools to job.
- Do not hesitate to stop work and call a supervisor or manager if in doubt, or if problems are encountered.
- Always remember that the field data are the bases of all subsequent engineering decisions, and as such are of paramount importance.
- Make certain the site of exploratory test pits and test holes is maintained free from excessive damage by

equipment operations and discharge of cuttings and drilling fluids. Refer to Appendix E – "Best Management Practices for Spill Prevention and Erosion Control During Geological/Geotechnical Field Investigations" for guidance.

7.5.2. Format of Test Hole Logs

The Department has numerous forms for logging test holes, test pits and penetrometer soundings. See Appendices A and B. There are differences in the formats used among the regions and between Statewide Materials and the regions. The Department nearly uniformly uses a graphical/database software package (gINT) to produce test hole logs, but there are some test hole logs produced in AutoCAD. Test hole logs may be published as single pages or as part of plan and profile sheets or in one of many other formats. There is no common statewide agreement as to conventions for soil names combined with graphical representations, so it is important to include a legend that includes an explanation of the test hole logs with each geotechnical report. Soil names are assigned with reference to the *Alaska Field Guide for Soil Classification* and the Unified Soil Classification System (ASTM D2487, D2488).

The content of test hole logs varies to some extent depending on the purpose of the test hole. Shallow test pits to evaluate soils under an embankment require a different set of data than deep test holes to evaluate suitability of a site for deep foundations for a bridge.

However, certain basic information is needed:

- Project identification
- Start and finish date
- Weather conditions
- Test hole number
- Test hole location (station and offset, grid coordinates, latitude and longitude) to appropriate level of accuracy. (Accuracy level will vary between regions and with project and location. For example a bridge foundation may require accuracy of +/- 1 foot, but for a road centerline investigation on the NHS road system +/- 3 feet may be adequate. For a remote airport, +/- 10 feet may be accurate enough)
- Test hole collar elevation to appropriate level of accuracy and notes as to datum used
- Names of geologist and crew
- Description of exploration equipment (drill, excavator, etc.)
- Drilling method (solid flight auger, hollow stem auger, driven or drilled casing, rotary wash, casing advancer, rock coring methods, etc., including diameter of casing, auger, tools, etc.)
- Notes on method of advancing casing, including pre-drilling, blow counts, and use of casing advancer
- Notes on use of penetrometer, including blow count and pullout force from draw works or casing jack
- Sampler types and sizes and hammer type (auto hammer vs. rope and cathead)
- Sample data (depth, recovery, type of sample, SPT blow count)
- Groundwater information (depths, dates, description: artesian, perched, flow rates, etc.)
- Depth, description and results of any in situ field testing such as vane shears
- Description of materials encountered (soil, rock, obstacles, boulders, etc.) and depths to top and bottom of identified layers
- Description of moisture condition, color, odor, texture, temperature (noting frozen soil and description of ice), presence of boulders and cobbles, presence of organics and peat
- Field classification of materials
- Graphic log of materials
- Drilling notes (use of drilling muds, rate of advance, problems such as

heaving sand or loss of circulation, times for core runs, abandoned holes due to boulders or cave-in, etc.)

Any additional notes on terrain, apparent geology, drainage features, vegetation, sketches or cross sections of the area may be made on the drill logs or in field books as appropriate.

Field logs must be neat, legible and complete so that the logs may be easily read by supervisors and by the drafting personnel and translated to gINT logs. Vague, illegible, and incomplete descriptions are unacceptable.

7.6. Soil Profiles

Geological/geotechnical reports are often accompanied by soil profile sheets developed from test hole logs and laboratory test data. The soil profile can be a useful visual display of subsurface conditions. Profiles may be prepared longitudinally along an entire alignment or at specific sites where such information may be useful. More typically, profiles may be prepared for bridges, retaining walls or other structures where a limited area is targeted. When the geologist or engineer can prepare a profile with confidence, there is an indication that an adequate investigation has been conducted. Where there are many questions about the profile, it is likely that additional test holes are needed.

Use of profiles presents some risk. A soil or rock profile is a geologist's or engineer's best interpretation of the subsurface conditions, involving considerable judgment in extending the interpretation away from test hole locations or other data points. Projection of the information even for short distances may result in misleading representations and eventual claims. Keep in mind that the geotechnical report is the baseline for geotechnical conditions on a construction project. In any differing site conditions claim, the question is: "differing from what?" The answer is: differing from the conditions presented in the geological/geotechnical report.

Designers tend to desire a continuous profile of the subsurface conditions along the entire project alignment. Where conditions differ between test hole locations, the value of the profile is questionable and the geotechnical staff must exercise caution in producing, using and publishing profiles that are based on incomplete information or in variable subsurface conditions. In cases where there is a legitimate need for an accurate profile, the test hole spacing should be reduced and the geotechnical staff should consider various methods to increase confidence in the data, including probing, and geophysical methods.

7.7. Subsurface Exploration Methods

The information obtained from the steps discussed above is used to develop a subsurface exploration program. Guidelines concerning the number and depth of explorations and sampling and in situ testing requirements are discussed in:

- *Alaska Geotechnical Procedures Manual Checklist,* Geotechnical Procedures Manual (2005)
- *Checklists and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications,* FHWA ED-88-053 (rev. February 2003),
- *Subsurface Investigations*, FHWA-HI-97-021 (1997)
- *Evaluation of Soil and Rock Properties,* Geotechnical Engineering Circular No. 5, FHWA-IF-02-034 (2002)

Discussions of the various types of in situ tests to be performed during a subsurface exploration program may be found in several standard references below. Frequently used AASHTO and ASTM standards for subsurface explorations are listed in below in Section 19 - Specifications and Standards.

Once environmental permits, rights of entry and utility clearances have been obtained, field explorations can begin. Many methods of field explorations exist. The subsections below contain brief descriptions of the most common methods. Further detail is also available in standard reference works, including those references cited above.

7.7.1. Test Pits and Trenches

Pits and trenches are the simplest methods of observing subsurface soils. They consist of excavations performed by hand, backhoe, or dozer. Hand excavations are often performed with posthole diggers or shovels and offer the advantages of speed and ready access for sampling. In addition, bulk samples obtained from test pits are likely to be more representative of the actual gradation than sample obtained by drilling methods. Hand excavations are severely hampered by limitations of depth; and they cannot be used in very loose soils, boulders, below the water table or during the winter months.

7.7.2. Hand/Auger Probes

These are manually operated, solid stem or hollow bucket augers that can be used to quickly and cheaply observe shallow (less than 15 feet) subsurface conditions. They do minor disturbance to the ground surface, but are difficult to advance in rocky or dense material. Probes with steel rods are also useful in quickly delineating depth of organic soil or peat deposits, and soft soils.

7.7.3. Exploration Drilling Techniques

Borings are the most common method of exploration. They can be advanced using a number of methods. Excellent discussions of drilling methods are described in the following manuals: 1) U.S. Army Corps of Engineers, Soil Sampling Engineering Manual, 2) AASHTO Manual on Subsurface Explorations, and 3) NHI Manual on Subsurface Investigations, No. 13321 (Module 1). The most common methods are discussed below:

7.7.4. Solid Flight Auger Borings

Auger borings are advanced into the ground by rotating the auger while simultaneously applying a downward force using either hydraulic or mechanical pressure. The auger is advanced to the desired depth and then withdrawn. Samples of cuttings can be removed from the auger; however, the depth of the sample can only be approximated. These samples are disturbed and should be used only for material identification. This method is generally used to establish shallow soil strata and water table elevations, or to advance to the desired stratum before Standard Penetration Testing (SPT) or undisturbed sampling is performed. However, it cannot be used effectively in soft or loose soils below the water table. In addition, this method has limited capabilities in dense, rocky material where it may encounter refusal. See Section 19 - Specifications and Standards - ASTM D 1452 (AASHTO T 203).

7.7.5. Hollow-Stem Auger Borings

A hollow-stem auger consists of a continuous flight auger surrounding a hollow drill stem. A central "plug" bit, at the end of a drill rod is used to prevent soil from entering the hollow stem as the hole is advanced between samples. The hollow-stem auger is advanced in a manner similar to other augers; however, removal of the hollow stem auger is not necessary for sampling. The "plug" bit is removed and SPT and undisturbed samples are obtained through the hollow drill stem, which acts as a casing to hold the hole open. This increases usage of hollow-stem augers in soft and loose soil. Usually no drilling mud is required, which could otherwise interfere with accurate groundwater level readings. In addition, this method of drilling is extremely fast, cost effective, and requires little to no water. In some sandy and silty soils below the water table, removal of the center "plug" bit, allows sand to "heave" into the hollow stem, interfering with and affecting the validity of the SPT. One option when these conditions are encountered is to add water or drilling mud to the inside of the hollow stem to create a head of water and prevent heaving. Another disadvantage of hollow stem auger is that refusal may occur in boulders or dense rocky soils. See Section 19 - Specifications and Standards - ASTM D 6151 (AASHTO T 251).

7.7.6. Rotary Drilling

This method consists of using a rotary drill with rotating thick-walled, hollow, drill rods usually attached to a tri-cone bit. Water or drilling mud is circulated from a mud tub, and then through the drilling rods as the drill rod is advanced. The drilling mud lifts the drilling cuttings out of the borehole while maintaining hole stability. The drill cuttings are screened and separated from the drilling mud, which is then re-circulated. To collect a sample, the drill rods and bit are pulled out of the hole and are replaced with drill rods and the required sampling device. This method is fast, and provides excellent sampling and in situ testing data due to minimal disturbance to the soils at the bottom of the borehole prior to sampling. It is effective in all soil types except for very gravelly material with cobbles and boulders. No information can be reliably obtained about groundwater levels during the drilling operation, and the soil material between sampling intervals is difficult to observe from the drilling mud return.

7.7.7. Air Drilling/Downhole Hammer

This type of drilling uses a compressed air actuated downhole hammer drill to breakup and remove cuttings from the borehole as the drill bit is advanced. Both rotary or percussion techniques can be utilized and either open hole (rotary reverse circulation) or under-reamed casing advancement (ODEX) can be used in the drilling process. SPT samples can be obtained; however, the materials between samples are highly disturbed. This type of drilling is generally fast, but expensive, and is most useful when drilling deep holes in dense gravels and boulders where traditional Hollow Stem Auger and Mud Rotary techniques cannot reasonably drill or sample.

7.8. Penetrometer Soundings

A sounding is a method of exploration in which either static or dynamic force is used to cause a rod tipped with a solid tip or a testing device to penetrate soils. This method can be useful to determine the depth to harder strata or rock from the resistance to penetration.

7.8.1. Alaska Penetrometer Test

The Alaska Penetrometer Test (APT) dynamic penetrometer method uses a 2.5" O.D. heavy wall steel drill rod with a blunt tip, driven by a 340 pound drive hammer. Blows per foot are recorded and the blow counts are used to assess relative differences between test locations. The Department typically uses the APT dynamic method alternating with drilled test holes at bridge and other structure sites. While this test method does not correlate directly with soil properties it may be used to find bearing layers and as a quick, inexpensive means of filling gaps between conventional test holes.

7.8.2. Cone Penetrometer Test

Full-sized static and dynamic cone penetrometers (CPT) are a common sounding method, although not used often in Alaska. In this test, a cone tipped rod is driven with hammer blows or pushed into the soil using a reaction weight. Instrumentation in the cone tip and rods provides measures of tip resistance, sidewall friction, pore water pressure and other characteristics that can be correlated to soil properties. The CPT is generally used for fine-grained cohesionless and cohesive soils. One disadvantage of this investigation method is that no samples are obtained.

7.8.3. Dynamic Cone Penetrometer

A small-scale cone penetrometer test (Dynamic Cone Penetrometer or DCP) is in use in Alaska for shallow investigations, primarily in support of pavement design and management programs. The ASTM test method (ASTM D6951) describes the procedures for the test which provides strength values for in situ soils. The DCP is a portable field test that requires a relatively minimal amount of equipment. The DCP provides a direct correlation with the more expensive and time-consuming California Bearing Ratio for use in pavement design methods.

8.0 GEOPHYSICAL METHODS

Geophysical methods can sometimes provide general subsurface profile information, such as the depth to bedrock, depth to groundwater, and the extent of granular/rock borrow areas, peat deposits, or subsurface anomalies. Geophysical methods of exploration can provide a rapid and economical means of supplementing subsurface borings and test pits. These exploration techniques are most useful for extending the interpretation of subsurface conditions beyond what is determined from small diameter borings. A limitation of these techniques is that no samples are recovered. It must be emphasized that geophysical methods might not be capable or successful in all situations and should be carefully evaluated to determine whether any methods are appropriate for the specific project requirements and site conditions. A 2002 study for the Department using seismic refraction, ground penetrating radar and electrical resistivity, performed for materials sites in the Northern Region indicated that success of geophysical methods was very dependent on the operator and on the surface and subsurface conditions at the specific site under investigation.

"*Geophysical Technology for Identification of Geology/Geophysical Characteristics", AKSAS Project No. 74736* (*Task 2 Report – Evaluation of Geophysical Methods – Field Program, Golder Associates, September 23, 2002.)*

The reliability of geophysical results can be limited by several factors, including the presence of groundwater or frozen soil, presence of organic soil layers at the surface, non-homogeneity of soil stratum thickness, gradation or density, and the range of wave velocities within a particular stratum. Subsurface strata that have similar physical properties can be difficult to distinguish with geophysical methods. Because of these limitations, for most design applications, geophysics should be considered a secondary exploration method to drilling, and should generally be accompanied by conventional borings. A professional experienced in the particular method should conduct the investigation and interpret the field data. In many cases, it may be best to provide only the field data along with a discussion of the limitations of the methodology and the data and leave interpretation of the data to the reader. For additional information, see ASTM D 6429, FHWA, "*Application of Geophysical Methods to Highway Related Problems," FHWA-IF-04-021 (2004), "Geophysical Exploration for Engineering and Environmental Investigations,"* U.S. Army Corps of Engineers, Engineering Manual EM-1110-1-1802 (1995).

Geophysical techniques can be grouped into two categories: 1) methods conducted from the ground surface, and 2) methods conducted in or between boreholes. Passive methods include the use of gravimetric, electric, magnetic, thermometric, and nuclear techniques. Active methods include the use of seismic, acoustic, electric, electromagnetic, and nuclear techniques. The geophysical methods most commonly used for transportation engineering purposes in Alaska include:

8.1. Seismic Refraction and Reflection

These methods rely on the fact that seismic waves typically travel at different velocities through different materials. The times required for an induced seismic wave to travel from the energy source to vibration detectors (geophones) after being refracted or reflected by the various subsurface materials are measured. The measured seismic velocities are used to interpret certain material properties and the thickness of the units that comprise the subsurface profile. Seismic refraction is limited to profiles in which velocities increase with depth. Seismic investigations can be performed from the surface or from various depths within borings. For cross-hole seismic techniques, see ASTM D 4428. For the seismic refraction method, refer to ASTM D 5777. See Section 19 - Specifications and Standards

8.2. Electrical Resistivity

This method is based on the differences in electrical conductivity between subsurface strata. An electric current is passed through the ground between electrodes and the resistivity of the subsurface materials is measured and correlated to material types. Several electrode arrangements have been developed, with the Wenner (four equally spaced electrodes) being the most commonly used in the United States. See Section 19 - Specifications and Standards - ASTM D 6431.

8.3. Ground Penetrating Radar (GPR)

The velocity of electromagnetic radiation is dependent upon the material through which it is traveling. GPR uses this principle to analyze the reflections of radar signals transmitted into the ground by a low frequency antenna. Signals are continuously transmitted and received as the antenna is towed across the area of interest. The interpreted results yield a profile of the subsurface material interfaces. The depth of signal penetration is limited in finer grained soils. See Section 19 - Specifications and Standards - ASTM D 6432.

9.0 SOIL SAMPLING

Using existing soil sampling techniques, there is no way to obtain a truly "undisturbed" sample. The selection of the correct sampling tool, drilling technique, and borehole stabilization method should be based on the soil type being sampled and the subsurface conditions. The incorrect preservation and shipment of samples may further disturb the specimens to the point where they are no longer usable.

Laboratory tests on samples recovered during field investigations are the means by which field identification of samples is confirmed. Lab tests also are critical for "proving up" the quality of borrow materials used during construction. "Undisturbed" samples are taken for determination of critical soil characteristics. Great care should be taken to assure that samples are delivered safely to the testing laboratory in as close as possible to their natural condition. Samples should be carefully and completely identified with a waterproof means of identification. Samples used for natural moisture content must be sealed to prevent moisture loss. Samples that may contain organics should also be sealed to allow for wet preparation methods.

Common methods of soil sampling during field explorations include those listed below. All samples should be properly preserved and carefully transported to the laboratory to maintain sample integrity. See Section 19 - Specifications and Standards - ASTM D 4220. Obtain samples that represent each geologic material encountered. In test holes, take samples at five-foot intervals, or where the stratigraphy changes.

Exercise caution in sampling below the groundwater surface. Sampling below water level may result in washing out fines and non-representative samples. In sandy soils below water table the soil may readily "heave" into the casing or hollow auger stem. It may be necessary to keep a head of water inside the casing or auger stem to prevent heave. It may be difficult to distinguish between disturbed material below the auger or casing tip and undisturbed in-situ soil. Note any apparent difficulty in obtaining samples and note any concerns about whether the samples and blow counts from standard penetration tests are representative.

For materials that are significant to project design and construction, take as many samples as needed to fully characterize the material. The size and type of samples required is dependent on the testing needed, the relative sizes of the soil particles (larger particle sizes require larger samples) and the confidence in the understanding and interpretation of the subsurface conditions. The field geologist should err on the side of taking more samples than are necessary. Some samples may be left untested.

9.1. Disturbed Sampling Methods

9.1.1. Bag (Bulk) Samples

Bag samples are obtained from auger cuttings or test pits. The quantity of the sample depends on the type of testing to be performed, but can range up to 50 pounds or more. Testing performed on these samples could include classification, gradation, moisture content, organic content, maximum density, quality tests including LA Abrasion, degradation, Nordic ball abrasion, etc.
R Value, pH and resistivity (corrosivity) may also be tested from bulk samples. A portion of each sample to be tested for moisture content should be placed in a sealed container such as a plastic bag, tin or jar in order to accurately determine the natural moisture content. Refer to AASHTO, ASTM and Alaska Test Methods for sample sizes. See Section 19 - Specifications and Standards.

9.1.2. Cuttings Samples

These are highly disturbed and sometimes altered (in particle size) samples obtained from drilling operations. Samples from solid stem auger test holes are recovered from drill cuttings spun to the surface from the annulus between the auger and the test hole wall. These are highly disturbed samples that may have had particles crushed and broken down, may have increased fines content and may be mixed with several stratigraphic layers. These problems are exacerbated in frozen ground conditions when advancing the augers takes much longer and the augers grind on the soil cuttings for long periods of time. Hollow stem augers are used to allow less disturbed samples to be recovered from below the auger tip. Cuttings samples should only be used to try to identify major changes in lithology. The depths from which cutting samples are obtained can only be roughly estimated, but can be aided by changes in drilling action.

9.1.3. Standard Split Spoon Sampler

Also known as a split barrel sampler or split tube sampler, this method is used in conjunction with the Standard Penetration Test (SPT). See Section 19 - Specifications and Standards – ASTM D1586 or AASHTO T 206. The standard SPT sampler is an 18 inch long 2-inch (O.D.) split tube, threaded on each end to accommodate adapters and a driving shoe. The sampler is driven into the soil with a 140-pound hammer free-falling 30 inches. After the sampler has been driven 18 inches, it is withdrawn and the sample removed. The Department routinely uses longer samplers (24 inch) to obtain larger samples.

The sum of the number of hammer blows required to drive the sampler the second and third six-inch increments is the standard penetration value referred to as the uncorrected "N" value (blows per foot). N values can be correlated to a number of different design parameters including relative density, angle of withdrawal, friction and shear strength. The Department periodically calibrates the hammers and samplers with a pile driving analyzer. Consultants providing services to the Department must also conduct this calibration. A suggested calibration interval is every two years.

The sample should be immediately examined, logged and placed in sample jar for storage. These are disturbed samples, and are not suitable for strength or consolidation testing. They are adequate for moisture content, gradation, and Atterberg limits tests, and valuable for visual identification. See Section 19 - Specifications and Standards - ASTM D 1586 or AASHTO T-206.

9.1.4. Larger Diameter Split Tube Samplers

California Modified Sampler (CMS) or Dames & Moore Sampler are two names for the same sampler - split barrel samplers that are similar to the split spoon samplers used with the SPT test. The CMS is a 3-inch (O.D.) split barrel, which is driven into the soil normally with a 300-pound hammer, free-falling 30 inches. It is threaded at both ends for accepting inner rings that are 2.36-inches I.D. by .98-inches high. These ring samples can be used for various soil property tests; however, they are considered disturbed samples. Generally, this sample is used to facilitate sample recovery in coarser-grained material due to its larger diameter as compared to the standard split spoon (SPT) sampler. Blow counts obtained from the penetration of this sampler are sometimes correlated to SPT values. However, these correlations are not standardized, and engineering judgment should be applied when they are used.

9.2. Partially Disturbed Sampling

The Denison sampler is a large diameter, double tube core barrel, which is effective in obtaining 5-7/8-inch diameter samples of hard cohesive soils, soft rock, cemented soils, and soils containing gravel that cannot be obtained with push-type samplers. This sampler consists of a rotating outer barrel with cutting teeth on the bottom and an inner barrel with a smooth cutting shoe. The sample is captured in a very thin inner liner, which facilitates retrieval and handling. Core catchers should not be used unless absolutely necessary to retain the soil sample. Care should be taken not to overdrive the sample to avoid disturbance.

The Pitcher sampler is also a double tube core barrel and is effective for the same soils as the Denison sampler. The primary advantage the Pitcher sampler has over the Denison sampler is that the Pitcher sampler automatically adjusts the amount by which the inner barrels lead the cutting bit as the hardness of the soil varies. The Pitcher sampler can also accept a standard thin wall sample tube in lieu of the inner barrel/liner.

The Sprague & Henwood sampler is a triple tube sampler designed for sampling overburden materials, and is an improvement over the Denison and Pitcher samplers.

9.3. Undisturbed Samples Using Thin Wall Samplers

9.3.1. Shelby Tube Sampler

This thin wall sampler is suitable for sampling all cohesive soils. Difficulty may be encountered in sampling very soft and wet soils that tend to drop out of the sampler. Damage to the sampling tube (resulting in a poor sample) sometimes occurs when sampling hard, cemented, or gravelly soils. Other tools are available for these difficult conditions. Good samples must have sufficient cohesion to remain in the tube during withdrawal. Cohesionless soils will likely need improved sampling methods, as described below.

A Shelby Tube is a thin walled steel tube, usually 3 inches (O.D.) by 30 inches long. The beveled cutting edge of the Shelby tube is slightly smaller in diameter than the inside of the tube, which allows the sample to slide easily in the tube with little disturbance. The tube is pushed into the soil with a fairly rapid, smooth stroke a distance of 24 inches and then retracted. If sample recovery becomes difficult, i.e., the sample stays in the ground, the tube should be left in place for roughly 10 to 15 minutes. During this waiting period, the sample will swell slightly to fill the sampler, increasing the likelihood of retaining the sample when the tube is retracted. This method produces a relatively undisturbed sample. Care should be taken to not over push the sample to avoid disturbance. The ends of the Shelby Tube should be properly sealed immediately upon withdrawal. See Section 19 - Specifications and Standards - ASTM D 1587 or AASHTO T 207. The sample is suitable for unit weight, strength and consolidation tests.

9.3.2. Piston Samplers

There are several varieties of piston samplers. These are not often used in Alaska practice. In this method, a piston is positioned at the bottom of the thin wall tube while the sampler is lowered to the bottom of the hole, thus preventing disturbed materials from entering the tube. The piston may be locked in place on top of the soil to be sampled. A sample is obtained by pressing the tube into the soil with a continuous, steady thrust. Sampler types include the stationary piston, the floating piston sampler, the retractable sampler, and the hydraulic (Osterberg) piston sampler fixed-sampler. Samples generally have a better recovery ratio than those from the Shelby Tube method.

9.4. Undisturbed Block Samples

Block sampling is a reliable method for minimizing sample disturbance. However, because gaining access to the zone to be sampled can be limited by the depth of overlying material and because the sampling process is fairly rigorous and time consuming, most samples are obtained via drilling. Samples can be carefully carved from test pits for special testing in the laboratory. The advantage of block samples is that the test pit offers a broad area to detect critical materials and ability to obtain the exact amount of the desired material. The size of the sample should be large enough to perform planned laboratory testing.

For block samples, the dimensions of the sample are controlled by the thickness of specimen of interest and by the size of the box used to hold the sample. A column of the soil is carefully exposed so that, when the sample box is centered over the column, a one-inch open space is left on all sides of the sample and a half-inch space is left at the top. The empty areas are then filed with microcrystalline wax. After the wax congeals, the top of the box is attached and the sample is carefully detached from the underlying ground with a spade. The sample is inverted and a half-inch of material is removed. This area is filled with wax. After it congeals, the bottom of the box is attached and the sample is ready for transport to the laboratory. The block samples should be carefully handled and should be protected with a moisture-proof barrier (i.e., plastic wrap and wax) and placed within a sturdy and stable container so the sample is fully supported/constrained.

10.0 ROCK SAMPLING AND CORING

Rock samples can be obtained from outcrops, test pits, or rock cores through drilling operations. Samples obtained from outcrops or test pits are termed "grab samples". Typically, the sample sizes for classification and identification should be small enough to carry, but large enough to be tested in a point load device or utilized as hand specimens. For bulk samples for quality testing, sample sizes may be 200-300 pounds. Refer to AASHTO, ASTM and Alaska Test Methods for sampling methods and test methods for required sample weights. See Section 19 - Specifications and Standards. These samples should be labeled, and the location where they were obtained should be identified on a site map.

For rock coring, a sampling barrel is advanced through rock by the application of downward pressure during rotation. Rock cores are obtained using core barrels equipped with diamond or tungsten carbide tipped bits. There are three basic types of core barrels: single tube, double tube, and triple tube. Because single tube core barrels generally provide poor recovery rates, their use is not recommended. Double and triple tube core barrel systems, which are described below, are preferred. To protect the integrity of the core from damage (minimize extraneous core breaks), split inner tube swivel-type core barrels are preferred.

Circulating water removes ground-up material from the hole, while also cooling the bit. The rate of advance is controlled to obtain the maximum possible core recovery. A continuous rock core sample may be obtained with this drilling method. Core drilling is the most widely used method to explore subsurface rock formations. It is preferable to perform rock coring with as large a core barrel as possible in order to optimize core recovery and minimize core damage due to drilling action. An HQ-Size System is recommended where possible. The Department routinely uses both HQ and NQ sizes. See Section 19 - Specifications and Standards - ASTM D 2113 or AASHTO T 225.

It is essential to make every possible effort to obtain high quality core and to ensure that the maximum amount of data is obtained from the core and the drilling program. Core drilling is expensive and usually constitutes a major expenditure of effort in a geotechnical investigation. The field geologist should work closely with the drilling crew so that everyone understands the goals of the drilling program and the expectations for the work. The purposes for coring may be as simple as confirming that the test hole has intercepted bedrock and as complex as determining the structure and orientation of discontinuities of the rock mass and determining the characteristics of the groundwater regime. The quality of the core is a function of the skill of the driller and the type and condition of the drill rig and tooling used. The equipment must be selected carefully to maximize the return on the investment in recovered high quality core and other geotechnical information. When using a solid inner barrel, a hydraulic ram or pumped drilling fluid should be used to expel the core from the core barrel into an appropriate "V" shaped holding tray. Under no circumstances should the core barrel or inner tubes be subjected to hammer blows or other abuse to remove the core. See Section 19 - Specifications and Standards - ASTM D 2113 or AASHTO T 225.

10.1. Double Tube Core Barrel

The double tube core barrel consists of an inner core barrel tube and an outer tube that serves as the drill rod. The cutting end of the core barrel is equipped with a diamond or tungsten carbide drill bit. As coring progresses, fluid is introduced downward between the inner and outer tubes to cool the bit and to wash ground-up material to the surface in the annulus between the core barrel and the wall of the drilled hole. The inner tube protects the core from the highly erosive action of the drilling fluid. In a rigid type core barrel, both the inner and outer tubes rotate. In a swivel type, the inner tube remains stationary while the outer tube rotates. Several series of swivel type core barrels are available. The size of core that can be recovered is governed by the size of the drill bit. For standard applications, these will vary from 1.062-inch up to 3.270-inch O.D. Larger diameters generally obtain better core recovery in softer, highly erodible or highly fractured materials. The minimum diameter core obtained should be no less than A-size (1.062- to 1.185-inch O.D.). As a rule, it is recommended that a core size of H (2.406- to 3.000-inch O.D) be routinely used.

10.2. Triple Tube Core Barrel

Triple tube core barrel systems are similar to the double tube system described above, but include an additional inner liner. Two types of inner liners are used to retain the core, a clear plastic solid tube or a thin metal split tube. This barrel best preserves recovered fractured and poor quality rock cores in their in situ state.

10.3. Core Logging

A maximum amount of useful data will be collected during the drilling program if the field geologist uses a systematic method for logging, photographing and handling the core. Photographs should include a card describing the details of the core – project, test hole number, depth, date, etc. When logging core, use standard terminology from Department guides and standard references such as those produced by the International Society of Rock Mechanics and referenced in the Department's *Alaska Field Rock Classification and Structural Mapping Guide*. The use of ambiguous, vague and undefined terms is not helpful. Note that this guide does not provide step-by-step detailed instructions for logging core. Use the appropriate references for guidance in describing rock. (e.g., Travis, *Classification of Rocks)* Each geologist must develop and follow a routine that includes standard methods and results in standardized test hole logs and useable data.

Use current Department log forms for recording data in the field. Logging notes must include the basic data for all rock descriptions and such other information as may be required on a project-specific basis. The logs must include information about the test hole number, test hole location, collar elevation, water table, drilling methods, drill rig, tooling, core barrel type and size, weather, field crew, description of the soil and rock encountered including notes on percent recovery, RQD, fractures per foot, weathering, structure, presence of discontinuities and their characteristics, orientation of discontinuities with respect to the axis of the core, strength, color, grain size or crystal size, and rock type.

When the cores are delivered to the office or laboratory, the field geologist and others may make further examination of the cores and take additional photographs. As a result of these further examinations, the field geologist (and no one else) may make additional notes on the test hole logs. Test results for quality tests and petrographic analysis may also be added to the field logs for inclusion in the final drafted logs produced using gINT.

Rock cores, and certain types of drive samples, are usually the only physical sample evidence of the subsurface profile that remain available for a given site. In order to maintain the integrity of this record, it is beneficial to photograph the samples before parts are removed for testing purposes, or drying, or other disturbance occurs. Photographs provide for the preservation of the sampling record in the event that vandalism, negligence, or accident cause loss or destruction of the physical sample. It also may be desirable to photograph specific sampling techniques and equipment for future reference.

Although it is much more preferable to photograph samples under controlled conditions, including supplementary lighting and camera support devices, this may not be available under field conditions. Care should be given to optimize the size of the core within the photograph in order to show as much detail as possible. Digital color photographs are recommended. For more details, refer to the AASHTO Manual on Subsurface Investigations, Section 7.10.

10.4. Core Handling

Rock cores from geotechnical explorations should be handled with great care. Obviously, the cores are expensive to obtain and mishandling can result in loss of important data. The cores should be stored in structurally sound boxes made for the purpose. Wooden or metal boxes with hinged or fitted lids, waxed cardboard and plastic boxes are all acceptable. Once the core has been logged and photographed inside a split liner or immediately after extruding into a tray, the core can be carefully transferred to the core boxes. It may be necessary to break intact core to fit the boxes, but this should be avoided, if possible. Breaks in the core that occur during or after the core is transferred to the boxes should be refitted and marked to so indicate. Lay out core in the box in the same orientation as text in a document – left to right, top to bottom. Use wooden spacer blocks with depth markings to denote top and bottom of core and core loss. Use enough blocks to make up the entire length of the run. Mark the core boxes with permanent marker on the lid and both ends to show project name and number, structure name and number, test hole number, date, depths, and box number. Refer to "Subsurface Investigations" §3.2 and ASTM D 5079 for practices of preserving and transporting rock core samples. See Section 19 - Specifications and Standards.

10.5. Oriented Cores

In some rock slope or rock foundation applications, it is important to understand the precise orientation of rock discontinuities for the design. Orienting recovered rock core so it can be properly mapped and evaluated, as though it were still in place, requires special core barrels. In the past, core barrels were weighted on one side and used in an inclined boring. The heavier side of the barrel generally stayed on the down side of the hole allowing the core to be properly oriented when removed. Other techniques, such as using clay to make an impression of core run ends, have also been used for this purpose. Currently, specialized core barrels that scribe a reference mark (line) on the side of the core as it is drilled are more routinely used. Special recording devices within the core barrel relate known azimuth orientations to the reference mark so that when the core is subsequently removed from the core barrel, it can be oriented to the exact position it occupied in situ. These specialized core barrels are relatively expensive, and require additional training to use them properly and interpret the results.

10.6. Downhole Imaging

Test holes can be accessed with digital or film cameras to visually inspect the condition of the sidewalls and distinguish changes in lithology. Recently, digital down-hole cameras have been used in conjunction with computer programs that analyze digital images to identify fracture zones, shear zones, joint patterns, and other discontinuities and their orientations in rock core holes. Refer to AASHTO Manual on Subsurface Investigations, Section 6.12.

11.0 FIELD TESTING OF SOIL AND ROCK

The Department routinely conducts only a few soils and rock tests in the field. See "*Alaska Field Guide for Soil Classification and Alaska*" and "*Alaska Field Rock Classification and Structural Mapping Guide.*" For cohesive soil, we may conduct pocket penetrometer or Torvane tests on disturbed or undisturbed samples. Field geologists should be familiar with the pocket penetrometer and the Torvane and should routinely carry these instruments on investigations where cohesive soil strength may be an issue. We also test peat, organic soil and soft cohesive soil using full size vane shear test apparatus and methods. Our drill rigs routinely carry torque wrenches suitable for use in full size vane shear testing. The field geologist is responsible for making sure the vane shear apparatus is present when needed.

Occasionally, there may be reason to perform point load tests on rock samples in the field. Statewide Materials has a point load testing device suitable for either field or laboratory testing. Only those geologists who have been trained in the test method and the use of the testing equipment should attempt to run point load tests. Installation of in situ testing devices and equipment is discussed below.

12.0 EXPLORATION DIFFICULTIES

As discussed in the AASHTO Manual on Subsurface Investigations Section 7.8, limitations and difficulties may be encountered during explorations, which are common to all exploratory techniques. They are usually a result of site-specific geologic conditions and/or a function of the wrong equipment or technique being utilized. Several of these limitations and difficulties are described below.

12.1. Improper Drilling Techniques

The Department stresses the importance of the quality of geotechnical data and samples recovered during field investigations. Geotechnical staff must be aware of potential drilling problems and how to avoid them in order to properly obtain field information and samples. See AASHTO Manual on Subsurface Investigations, Section 7.12 and NHI 13321, Section 3.5. The following is a partial listing of common errors:

- **Failure to clean slough and cuttings from the bottom of the borehole.** The driller should not be allowed to sample through slough. Preferably the driller should reenter the boring and remove the slough before proceeding.
- **Jetting to advance a split barrel sampler to the bottom of the boring.** This method should not be used at any time as it produces unnecessary disturbance of soil in the sampling zone.
- **Poor sample recovery.** This may be due to improper use of sampling equipment or procedures and many other factors. When poor recovery is affecting a sampling program the field geologist should cease operations and confer with the drilling crew and supervisor to assess whether the sampling methods should be changed.
- **Forcing recovery of thin-walled tube samples by overdriving the sampling barrel to obtain a sample.** When sampling soft or noncohesive soils with thin wall samplers (i.e., Shelby Tube), it may be very difficult to recover an undisturbed sample because the sample will not stay in the barrel. The driller should be clearly instructed not to force recovery of thin wall tube samples.
- **Improper sample types or insufficient quantity of samples.** The field geologist and driller should be given clear instructions regarding the sample frequency and types of samples required. The field geologist and driller must keep track of the depth of the borings and the materials being recovered at all stages of the boring to confirm the sampling interval and obtain appropriate samples of changing soil and/or rock formations.
- **Improper hole stabilization.** Rotary wash borings and hollow-stem auger borings below the groundwater level require a head of fluid to be maintained within the drill stem at all times to prevent materials from surging up ("heaving") into the casing/augers. When the drill rods are withdrawn, or as the hollow stem auger is advanced, this fluid level will tend to drop, and must be maintained by the addition of more drilling fluid. In some formations and particularly in alluvial soil in active flood plains, the heaving problem can be severe. For this reason the Department's foundation investigations are not drilled with hollow stem auger because it is more often subject to the heave problem. Instead, foundation investigations are normally drilled with casing and rotary methods to minimize heave and improve the quality of samples. Use of drilling mud such as bentonite is recommended in heaving conditions, particularly for foundation investigations where sample quality is critical.
- **Sampler rods lowered into the boring with pipe wrenches, rather than hoisting plug.** The rods may be inclined

and the sampler can hit the boring walls, filling the sampler with debris.

- **Improper procedures for performing Standard Penetration Tests.** The field geologist and driller must assure that the proper weight and hammer drop are being used and that automatic hammers are maintained and adjusted frequently. The Department uses automatic hammer systems on all foundation projects and as the first choice for centerline projects. In remote areas with difficult access where small drills without auto hammers must be used or where portable equipment must be used, safety hammers are acceptable, so long as AASHTO/ASTM methods are followed. See Section 19 - Specifications and Standards – ASTM D 1586 or AASHTO T-206.

12.2. Sample Recovery

Occasionally, sampling is attempted and little or no material is recovered. In cases where a split barrel or some other type of sampler is used to recover a disturbed sample, it is appropriate to make a second attempt to recover the material immediately following the first failed attempt. In such instances, the sampling device may be modified to include a retainer basket, a hinged trap valve, or other measures to help retain the sample.

In cases where an undisturbed sample is desired, the field supervisor should direct the driller to drill to the bottom of the attempted (disturbed) sampling interval and repeat the sampling attempt. The sampling method should be reviewed, and the sampling equipment should be checked to understand why no sample was recovered (such as a plugged ball valve). It may be appropriate to change the sampling method and/or the sampling equipment, such as waiting a longer period of time before extracting the sampler, or extracting the sampler more slowly and with greater care, etc. If recovering a sample at a specific depth is necessary, a second boring may be advanced to obtain a sample at the prescribed depth using the improved technique.

Generally, sample recovery less than 10% is considered inadequate for representative sampling. However, the criteria may be waived for the specific situation (i.e., in thick, uniform deposits, recovery considerably less than 10% may be acceptable).

Various sampling devices equipped with check and pressure release valves, sample retaining springs, baskets and lifters should be used or determined to be operational. Occasionally, drillers will modify equipment to meet their specific drilling technique, which may have major effects on sample recovery.

12.3. Sample Disturbance

As discussed above in §9.0 sampling disturbance is a critical issue. Sample disturbance is dependent principally on sampling methods. Sampling methods may be dictated by drilling methods that are in turn dictated by cost constraints, accessibility to sites and numerous other factors. In addition operator error may result in undue disturbance of the samples. The field crew should be made aware of the importance of the samples and trained in sampling techniques designed to maximize sample recovery and limit disturbance. Although the Department does not often take "undisturbed" samples, the situations that require them warrant the expenditure of considerable time and effort to obtain and keep them as undisturbed as possible.

12.4. Obstructions

The termination of an exploration above the required design depth due to boulders, fill material, excessively dense materials, and other obstructions may occur during any investigation. When this occurs, it usually implies that the correct exploration method might not have been selected for the anticipated subsurface conditions. Specialized tools and equipment are available to increase the capacity of conventional drilling equipment. In some cases, obstacles are anticipated and a solution is to redrill the boring a few feet away.

12.5. Problematic Geologic Conditions

Special consideration and care must be taken when selecting the proper sampling equipment, obtaining the sample, and evaluating the performance of problematic geologic conditions. A list of these problems includes, but is not limited to the following:

- Organic Soils and deep peat deposits
- Frozen soil/permafrost and interpretation of gradation of soils
- Metastable soils (loess, alluvial deposits & mud flows)
- Variably or highly weathered or broken rock
- Faults and joints
- Asbestos-containing rock
- Sensitive or quick clays
- Unstable ground (landslides)
- Unstable rock exposures
- Meander loops & cutoffs
- Very dense glacial soils
- Boulders and cobbles
- Loose, granular soils
- Noxious or explosive formation gases
- Fill Material
- High groundwater and saturated soils
- Sampling below water table
- In coarse gravelly deposits, recovery of representative sample

12.6. Groundwater Conditions

Groundwater can affect the stability of the borehole, especially in cohesionless soils (gravel, sands, and some silts). Water flowing into the hole could cause caving and quick (liquefying) conditions, which would artificially reduce the SPT blow counts being measured, as well as make drilling and sampling progress difficult. Casing or drilling muds such as bentonite or polymers are typically used to stabilize the borehole in such situations. Use of hollow stem auger in these situations is discouraged because formation water often flows freely into the augers both through joints and through the auger tip, causing sampling problems and disturbance of the soil below the auger tip.

Where precise water level data is important, the affects of drilling water additives (bentonite and other materials) on the permeability of certain soils should be evaluated. In soils with lower permeability and flow rates, such as in silt or silty sand, the use of bentonite mud can dramatically limit the movement of water by coating the walls of the boring. A bentonite coating can reduce the likelihood that piezometer readings will represent true ground water levels or that the water levels in the boring will respond accurately to natural groundwater changes. In these situations, alternative drilling techniques, such as using casing, should be considered to help produce a stable borehole without relying on additives that can affect permeability. Following drilling, especially whenever low permeability conditions exist, staff should wait for an adequate period of time for the water level to reach equilibrium within the borehole before initiating groundwater measurements.

It is preferred that a groundwater reading should be made 24 hours after completing the boring to allow the water level to reach equilibrium. In fine-grained soils, depending on the permeability, even this period may not be adequate. The installation of permanent or temporary observation wells, which provide access for measuring the groundwater table over a longer period, can eliminate this difficulty. Observation wells are generally an inexpensive safeguard against erroneous assumptions regarding the presence and behavior of the groundwater conditions. Proper installation procedures for instrumentation are discussed in Section 12.0 below.

12.7. Contaminated Sites

The Department does not conduct hazardous materials explorations, testing, or evaluations. If contaminants are expected in the exploration area, the Department will hire a Consultant with expertise in this field to conduct the exploration. When contamination is observed or encountered during drilling operations, drill crews will suspend operations and without delay contact management and, if required by regulations, the Department of Environmental Conservation or other agencies for instructions on the appropriate response. Initial actions may require sealing the boring and demobilization from the site.

There are many problems and issues inherent in sampling and handling contaminated soils. The U.S. Environmental Protection Agency (EPA) document number 625/12-91/002 titled "Description and Sampling of Contaminated Soils – A field Pocket Guide" contains guidelines, background information, and a list of useful references on the topic.

Some signs of possible contamination are:

- Prior land use (e.g., old fill, landfills, gas stations, military installations, etc.)
- Stained soil or rock
- The apparent unnatural lack of vegetation or presence of dead vegetation and trees must be considered in the local site context. While in some places this could indicate contamination, in others it is just normal frozen ground conditions.
- Odors. It should be noted that highly organic soil may have a rotten egg odor that should not necessarily be construed as evidence of contamination. However, this odor may also be indicative of highly toxic hydrogen sulfide. Drilling crews should be instructed about this concern.
- Presence of liquids other than groundwater or pore water
- Signs of prior ground fires (e.g., at landfill or building sites). Established landfills will emit methane gas, which is colorless and odorless, and in high concentrations in the presence of sparks or fire will explode.
- Presence of visible elemental metals (e.g., mercury)
- pH is Low (<2.5) or High (>12.5).

Field crews who observe these signs should note them and report them as required. If an immediate safety hazard is apparent, the field crew should take whatever steps are appropriate to avoid injury to themselves or the public.

13.0 INSTRUMENTATION INSTALLATION

Geotechnical instrumentation may be required, depending on the scope of the project, the design elements, and the site conditions. Many geotechnical investigations include the installation of in situ testing devices including standpipes for groundwater measurements, piezometers, standpipes for installation of thermistor temperature monitoring, and slope indicator tubing. The geologist or geotechnical engineer in charge of such installations should work closely with the drilling crew to discuss the procedures in advance so that these installations are constructed properly.

Selecting the proper instrumentation and installing it correctly are important to insure that high quality geotechnical data is obtained at a reasonable cost. A discussion of the types of instruments and the proper techniques to use during installation may be found in various standard references. Some of the equipment and methods may be found in manufacturers' literature. A discussion of selected instrumentation installation procedures is given in Appendix A of the AASHTO Manual on Subsurface Investigation. An in-depth discussion on the installation of Inclinometer Casings is given in Section 4.1.5 of Chapter 11 of the TRB Special Report 247, Landslides: Investigation and Mitigation. Such summaries are not intended to be a strict guideline, nor are they all inclusive of the variety of methods and procedures that may be used for instrumentation installation. Since, as specific operational details and subsurface conditions vary, the installation techniques may need to be customized. Experience with standard applications and procedures are important before significant modifications are attempted.

14.0 BOREHOLE BACKFILLING/SEALING

Once boreholes or test holes have been completed they shall be backfilled or sealed, depending on circumstances. Where groundwater is present and there is the possibility of damage to an aquifer, the test hole should be sealed to prevent entry of surface water into the test hole and to prevent mixing of multiple groundwater layers or aquifers. Two references offer guidance regarding completion of test holes: AASHTO R-22-97, "*Decommissioning Geotechnical Exploratory Boreholes*" and National Cooperative Highway Research Program Report No. 378, "*Recommended Guidelines for Sealing Geotechnical Holes"* (1995).

14.1. Backfilling Exploratory Test Holes

All test holes should be properly backfilled at the completion of the field exploration. This is typically required for safety considerations and to meet the requirements of environmental permits. Generally, exploration test holes are re-filled with cuttings brought to the surface in the drilling operation. Backfill may also include bentonite chips, pellets or powder that may be placed directly in the borehole or mixed with soil cuttings and placed in the borehole.

Holes in pavements and slabs should be filled with quick setting concrete, or with asphalt concrete, as appropriate. Backfill for holes in soil surfaces should be mounded accommodate settlement and to drain surface water away from the borehole.

Generally, exploration pits can be backfilled with the spoils generated during the excavation. The backfilled material should be compacted to avoid excessive future settlements. Tampers or rolling equipment may be used to facilitate compaction of the backfill. If possible, vegetation removed from the test pit are should be saved and replaced at the surface of the test pit site. Excavations within existing roadways should be backfilled with granular material and compacted in lifts to restore subgrade support.

14.2. Sealing Exploratory Test Holes

Sealing test holes may be necessary to prevent contamination/commingling of groundwater by infiltration from the surface and mixing of groundwater aquifers penetrated by the boring. Sealing boreholes may be accomplished using grout mixtures, and various combinations of cement and bentonite as chips, pellets or powder. The seal may be limited to near the surface to prevent surface contamination from entering the borehole and may extend the full depth of the hole to create a permanent hydraulic barrier in the hole. In boreholes filled with water or other drilling fluids, tremied grout pumped through drill rods or other pipes inserted into the borehole will displace the water or drilling fluid. Provisions should be made to collect and dispose of all displaced drill fluid and waste grout appropriately. Extensive information on sealing and grouting is provided in the NCHRP report referenced above. The grout mixture may be cement, sand and water and may be bentonite mixed with water or water and cement. As noted above, bentonite may also be placed directly in the borehole or mixed with soil cuttings and placed in the borehole.

14.3. Seal Verification Report

Upon completion of sealed test holes, the field geologist should make a record for the project files of the details of the sealing process. A form similar to that shown in Appendix F should be used to record the methodology.

15.0 SAMPLE PRESERVATION AND SHIPPING

Samples of soil and rock are obtained for classification and subsequent testing to determine their various engineering properties. Rock and soil samples represent essential physical information concerning the subject site. These samples are obtained at a considerable cost to the Department and the project. Samples must be preserved, stored, and shipped under conditions that will minimize chances of disturbance or loss. More details are provided in AASHTO Manual on Subsurface Investigations, Section 7.9.

All soil samples and rock cores must be clearly, accurately, and permanently labeled to show all pertinent information which may be necessary in identifying the sample or core, and in determining the character of the subsurface condition.

The preserving, protecting and transporting of samples may be accomplished using the methods described below; but, in practice, any method that satisfactorily protects the sample from such things as shock, detrimental temperature changes (such as freezing or thawing), and moisture loss may be used.

- All samples should be collected from the borehole sampling sites on a daily basis and transported to the field project office or a suitable alternate location. Samples should not be left on a drill rig or in the back of a truck longer than necessary to get to a secure location.
- Rock core and thin wall tube soil samples should never be transported away from the field site in other than specially constructed wood, metal, plastic, or fiberglass shipping containers specially designed to protect them from shock and vibration.
- Samples intended for laboratory testing should not be held at the site in excess of one week.
- All sample containers should be identified as to borehole, depth interval, box number of total sequence, and project number.

16.0 SAMPLE TESTING PROGRAMS

Sample testing programs are tailored to individual projects, each of which will have unique testing requirements depending on the project. Field classifications of rock and soil samples are accomplished following the Department's *Field Soil Classification Guide* and *Field Rock Classification and Structural Mapping Guide*. Laboratory testing is performed to confirm field classifications. Minimum testing requirements will include index and classification testing of representative samples to confirm field classifications. In addition to classifying the soils and rock encountered, other tests may be conducted to evaluate the quality and usability of the soil and rock. Additional tests routinely run include proctor analysis for maximum density and optimum moisture and L.A. Abrasion, Nordic Ball Abrasion, Sodium Sulfate Soundness and Washington Degradation tests for assessment of durability.

When requested by the geotechnical engineer, "special" tests are run to determine organic and organic fiber content, consolidation characteristics, permeability, and strength. For projects where embankments are planned to overlay soft soil or peat deposits, the field geologist will provide thin-wall tube undisturbed samples for testing as requested. The regional geotechnical engineers will develop plans for sampling and testing of these soils and design of surcharges where needed. Permeability testing may be required to assess feasibility of drainage features such as wick drains. In some situations, soil strength testing may be an issue and the geologist will work with the geotechnical engineer to plan sampling and testing protocols tailored to the situation. Rock strength may be an issue where structure foundations rest on rock. We can conduct point load tests in the field or the laboratory and the laboratory is also equipped to run uniaxial unconfined compressive strength tests on rock samples.

17.0 SAFETY GUIDELINES

All field personnel, including geologists, engineers, technicians, and drill crews, and visitors to drilling sites should be familiar with the general health and safety procedures of the Department, specific procedures for drilling and field work, as well as any additional requirements of the particular project. All field crews and visitors to drilling sites and other field work locations should have the proper training in the use of any Personal Protective Equipment required for the work. This may include hard hats, safety boots, hearing protection, eye protection, reflective clothing, and other PPE.

A safety meeting should be held before commencement of field work to discuss any safety issues. Employees should also be aware of and have appropriate training in agency regulations from OSHA or the Alaska Department of Labor and other regulatory agencies in subjects such as first aid, traffic control and flagging.

Typical general safety guidelines for drilling into soil and rock are presented in the NHI Course Manual #13321 "*Subsurface Investigations*," Appendix A. Minimum protective gear for all personnel should include hardhat, safety boots, eye protection, hearing protection, gloves, and reflective clothing for working in or near traffic. The Department will provide necessary safety clothing or protective devices as required and provided for under union contracts.

18.0 GEOTECHNICAL PERSONNEL BEHAVIOR

When planning and conducting geotechnical investigations, Department staff should keep in mind that the field geotechnical crews are highly visible representatives of the Department. The public perception of the agency may be determined by the appearance and behavior of the field personnel and equipment. Each member of the field crew is responsible for maintaining a positive image of the exploration activities, including personal appearance and the appearance of the equipment. Safety is, of course, a principal concern. Operations must be conducted in a manner to maintain safety of the crew members and the public. Extra care must be taken when working close to traffic.

Field crews are often in contact with members of the public for a variety of reasons. All Department employees should maintain a respectful and polite attitude in dealing with the public. When questioned about the field activities, Department employees should generally not provide detailed explanation of our activities, since the project plans are usually not finalized when the exploration activities are underway and misunderstandings can cause significant problems. A general explanation of the field activities may be given to answer an inquiry - further inquiries should be referred to supervisory personnel.

19.0 SPECIFICATIONS AND STANDARDS

Table 19-1, Specifications and Standards provides a partial listing of some standards and test methods used in the conduct of geotechnical field investigations. The list is not exhaustive:

Table 19-1
Specifications and Standards

SUBJECT	ASTM	AASHTO
Conducting Geotechnical Subsurface Investigations		R13
Decommissioning Geotechnical Exploratory Boreholes	-	R22-97
Descriptive Nomenclature for Constituents of Natural Mineral Aggregates	C 294	M146
Soil Investigation and Sampling by Auger Borings	D 1452	T 203
Penetration Test and Split Barrel Sampling of Soils	D 1586	T 206
Thin Walled Tube Geotechnical Sampling of Soils	D 1587	T 207
Diamond Core Drilling for Site Investigation	D 2113	T 225
Test Method for Classification of Soils for Engineering Purposes	D 2487	M145
Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)	D 2488	-
Standard Test Method for Field Vane Shear in Cohesive Soil	D 2573	-
Practice for Ring-Lined Barred Sampling of Soils	D 3550	-
Standard Practice for Description of Frozen Soils (Visual-Manual Procedure)	D 4083	
Standard Guide to Site Characterization for Engineering, Design, and Construction Purposes	D 420	T 86
Preserving and Transporting Soil Samples	D 4220	-
Cross-hole Seismic Testing	D 4428	-
Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)	D 4750	-
Standard Guide for Core Sampling Submerged, Unconsolidated Sediments	D 4823	-
Preserving and Transporting Rock Core Samples	D 5079	-
Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers	D 5092	
Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock	D 5434	-
Seismic Refraction Method for Subsurface Investigation	D 5777	-
Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing	D 5778	
Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling	D 6151	T 251

SUBJECT	ASTM	AASHTO
Selecting Surface Geophysical Methods	D 6429	-
Direct Current Resistivity Method for Subsurface Investigation	D 6431	-
Surface Ground Penetrating Radar Method for Subsurface Investigation	D 6432	-
Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method	G 57	T 288
Provisional Guide for Selecting Surface Geophysical Methods	PS 78	-

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20.2. Computer Programs

Colorado Rockfall Simulation Program (CRSP v. 4.0)

gINT

RockPack II

RocScience Rockfall

RocScience Slide

RocScience Dips

RocScience Swedge

APPENDIX A

EXAMPLE FORMATS FOR TEST HOLE LOGS AND PENETROMETER LOGS

LOG OF TEST HOLE

HOLE # TH04-04

STATE OF ALASKA DOT&PF

Geology Section

PROJECT NUMBER: *56434*
PROJECT: *King Cove Airport Lighting and Paving*
NORTHING: *249387* ***EASTING***: *348312 (Local)*

Station / Location: *6+73*
Offset: *295 Rt*
Elevation: 136'

Equipment Type: *Mobile B-24*
Drilling Method:
Field Crew: *O. Saena and P. Mitchell*

Total Depth: *20.0 feet*
Date: *2/2/2004 - 2/2/2004*
Geologist: *C. BOECKMAN*

Ground Water Data

Depth in (ft.)	8	
Time		
Date	2/2/04	
Symbol	▼	

Depth (Feet)	Sample Type	Number	Blow Count	N-Value	USCS Classification	Subsurface Material	Depth
0–1	GS	FS-4			GW-GM	**GRAVEL with Silt and Sand** (GW-GM) Contains cobbles., Brown, moist, very dense FS-4 p200=6.8%, Sa=24%, Gr=69%, Moisture=14.2%	0.0
							2.0
3					SM	**SILTY SAND with Gravel** (SM) Contains cobbles., Brown, moist, very dense	3.0
4–6	SPT	FS-5	100, 250, 90, 200	340		FS-5 p200=20.4%, Sa=46%, Gr=34%, Moisture=6.7%	
							5.5
8					ML	**SANDY SILT** (ML) Some organics (root systems)., Brown, wet, soft	8.0
10–12	SPT		16, 20, 22, 16	42	GW-GM	**GRAVEL with Silt and Sand** (GW-GM) Contains cobbles., Brown, wet, dense	10.0
14					SM/OL	**SANDY Organic Soil** (SM/OL) Brown, wet, soft FS-7 Moisture=96.1%	14.0
15–17	SPT	FS-7	1, 3, 2, 2	5			
17					SM	**SILTY SAND** (SM) Sandy silt (ML) layers., Brown, wet, stiff	17.0
18–20	SPT		4, 9, 6, 6	15			
20					BOH 20	Notes: Had to offset hole two times to get beyond cobbles in the fill for the apron pad.	20.0

☐ CME Auto Hammer ☒ Cathead Rope Method ☒ 140 lb. hammer with 30 in. drop ☐ 340 lb. hammer with 30 in. drop

Sheet Number 1 of 1

A USCS LOG OF TEST HOLE 2004 LOGS.GPJ 2004TEMPLATE.GDT 3/7/05

PENETROMETER LOG

HOLE # Pen 1

STATE OF ALASKA DOT&PF
Statewide Materials
Geology Section

***PROJECT NUMBER**: ACSTP-0075(1) / 56932*
***PROJECT**: Sterling Highway, Stariski Creek, Bridge No. 667*
***NORTHING**: 1542084, **EASTING**: 931239*

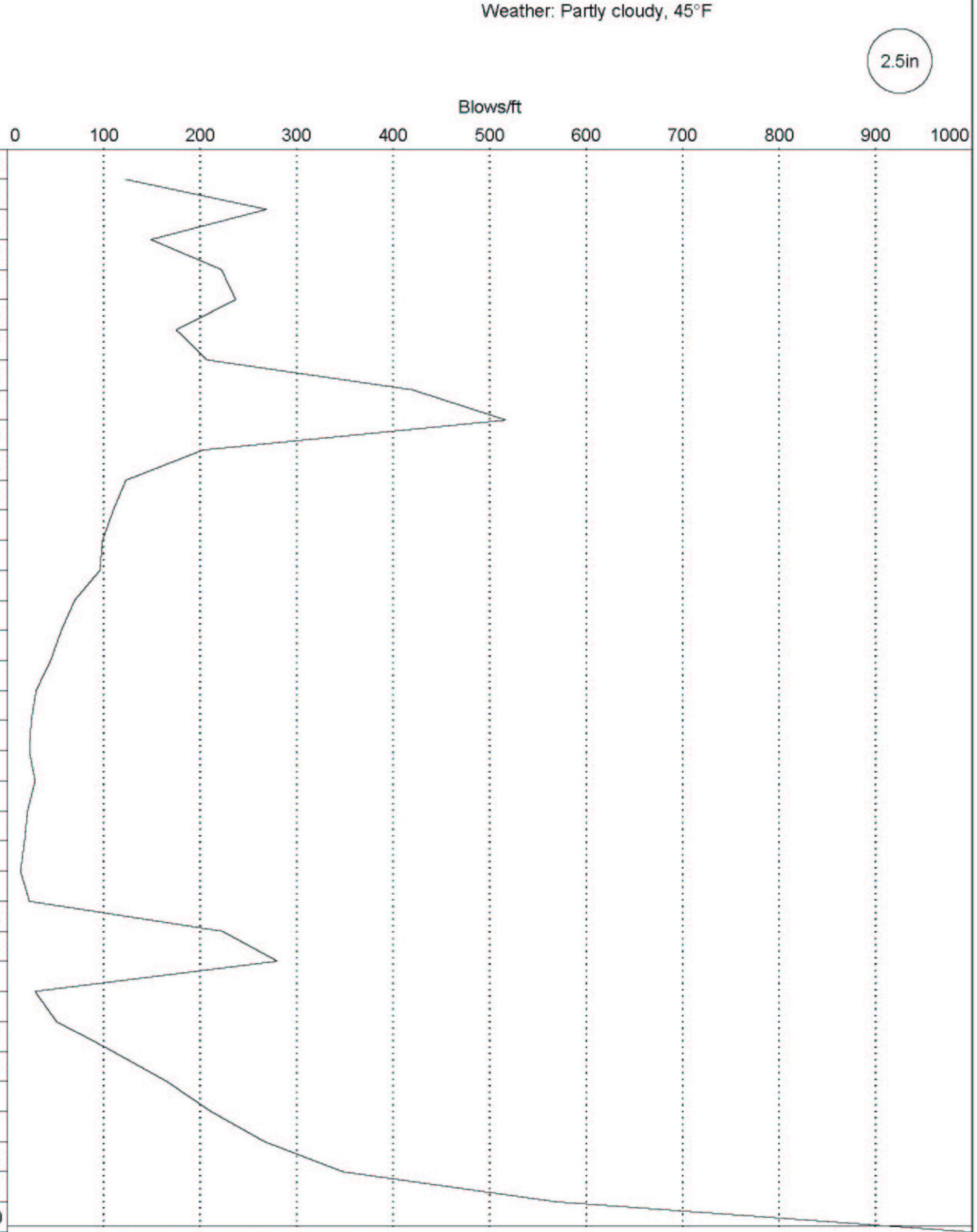
Station / Location: *4985+85.3*
Offset: *Lt. 9.3*
Elevation: *111.4 feet*

Equipment Type: *CME 75 Truck*
Drilling Method: *Penetrometer*
Field Crew: *Hamrick, Ruth*

Total Depth: *35.8 feet*
Date: *10/6/2004 - 10/9/2004*
Geologist: *P. Ondra*

Weather: Partly cloudy, 45°F

Elevation	Depth	Blow Count
111	0	123
110	1	269
109	2	149
108	3	222
107	4	237
106	5	175
105	6	207
104	7	420
103	8	517
102	9	203
101	10	123
100	11	110
99	12	99
98	13	96
97	14	70
96	15	56
95	16	45
94	17	30
93	18	25
92	19	23
91	20	29
90	21	21
89	22	18
88	23	14
87	24	23
86	25	223
85	26	280
84	27	29
83	28	51
82	29	109
81	30	165
80	31	211
79	32	267
78	33	348
77	34	569
76	35	1000



Bottom of Penetrometer Test at: 35.8 feet
Notes: 1. 1000 blows for 10 inches below 35 ft.
2. Penetrometer pullout break force was 66,740 lbs resistance.

C USCS PEN LOG STARISKI CREEK.GPJ 2004 TEMPLATE.GDT 3/7/05

Sheet Number 1 of 1

APPENDIX B

Example Test Hole Log
and Location Presentations

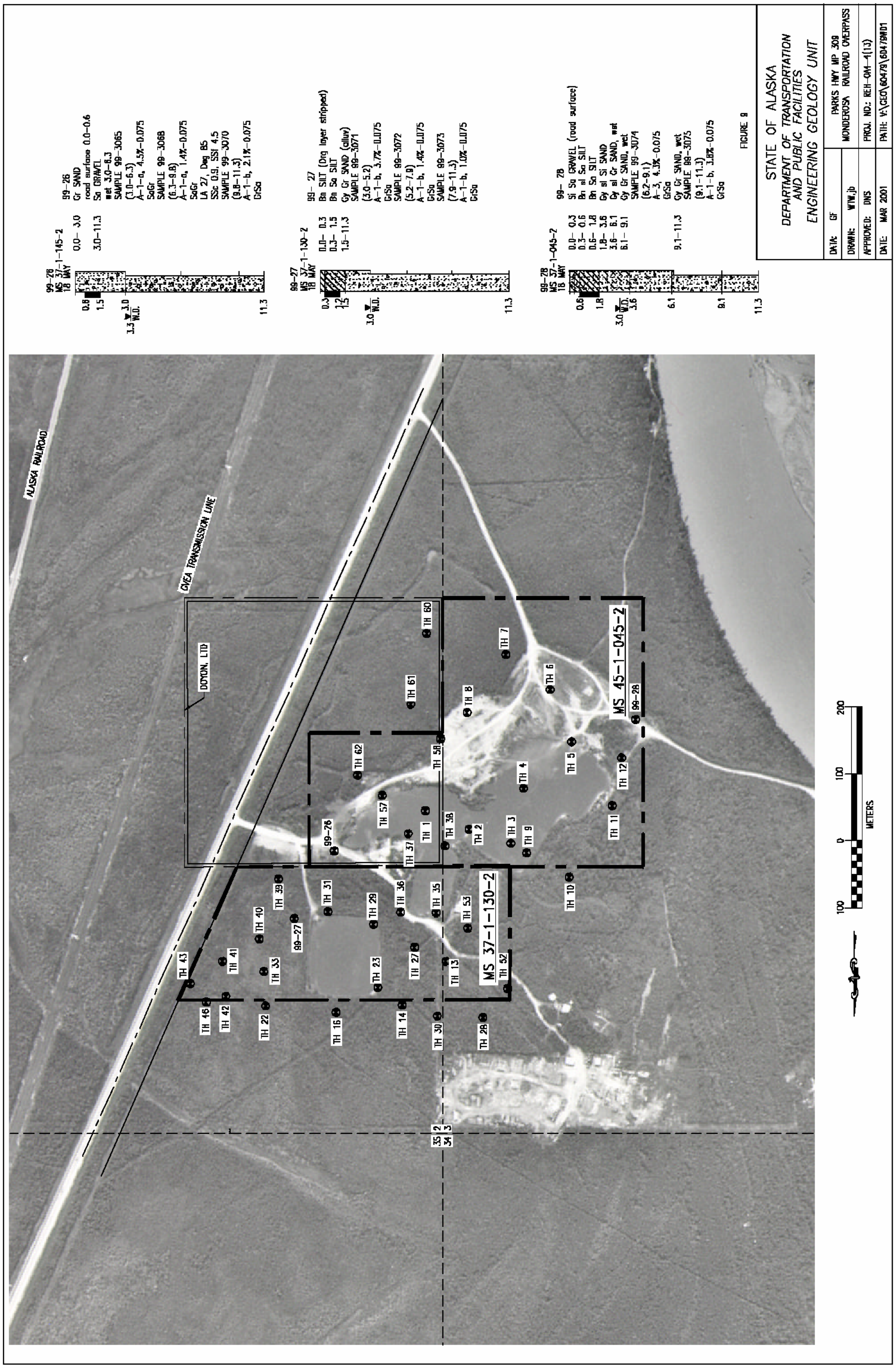
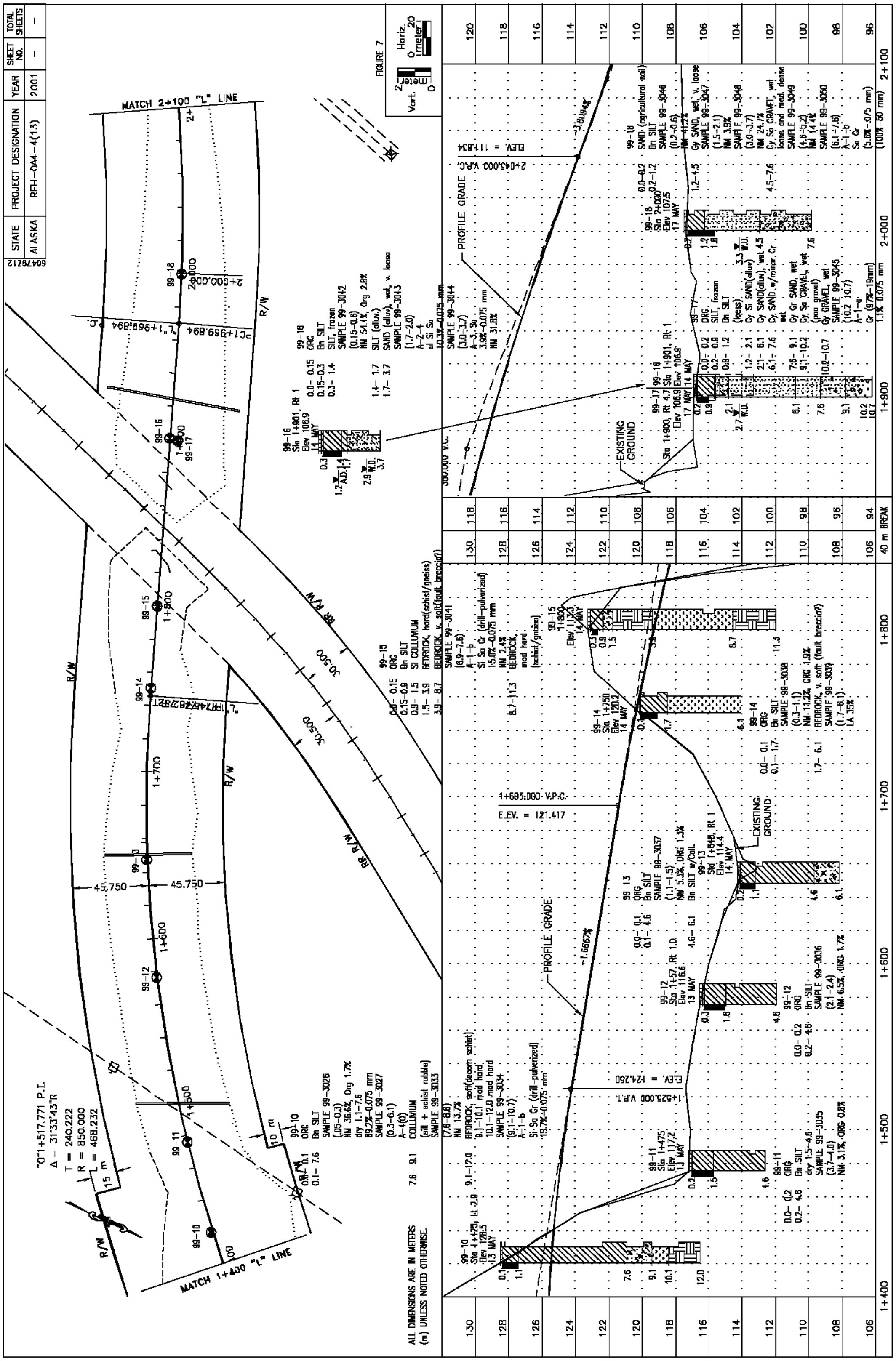
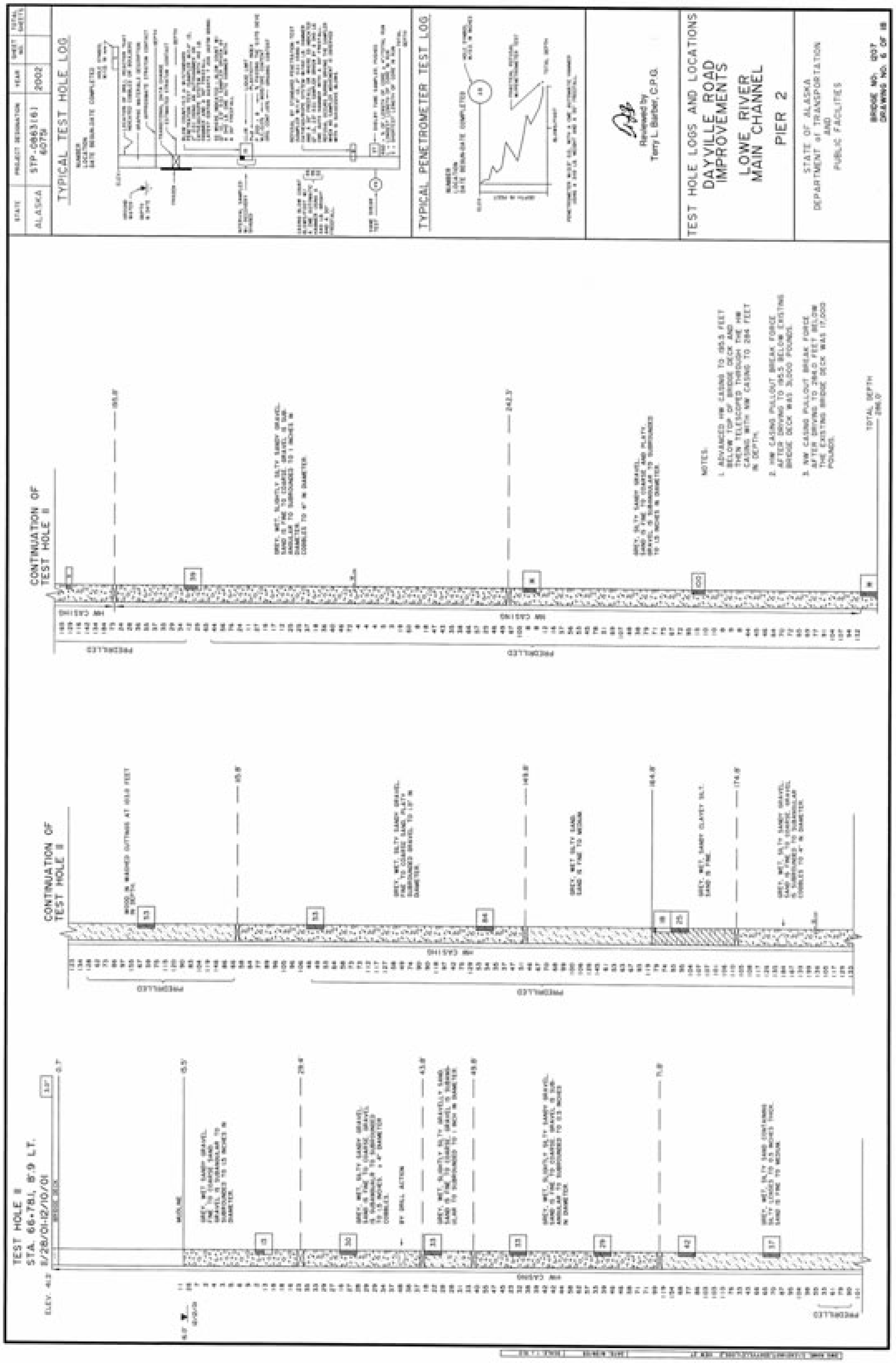
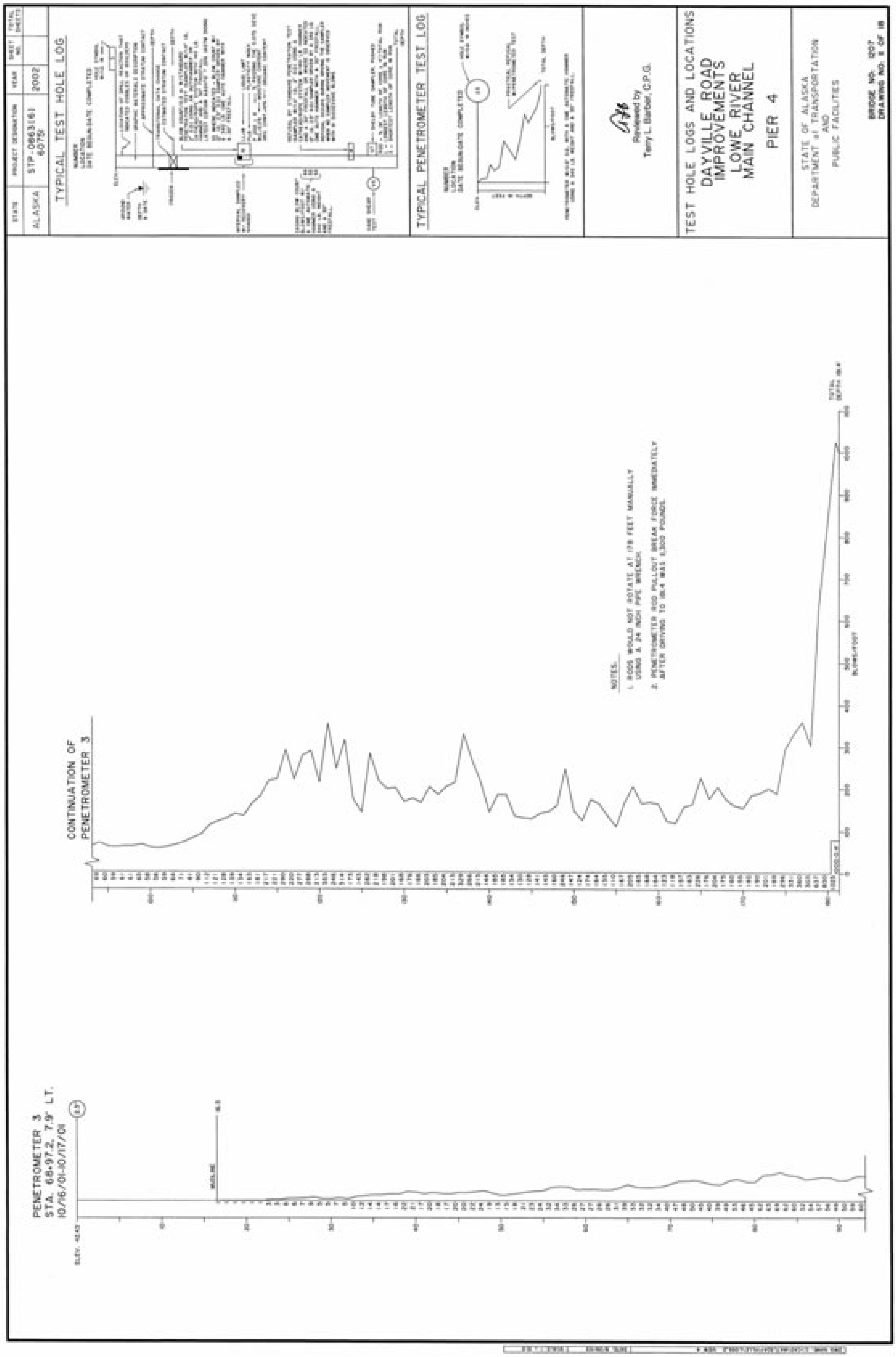


FIGURE 9
STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
ENGINEERING GEOLOGY UNIT
DATA: GF
DRAWN: WTW,jb
APPROVED: DNS
DATE: MAR 2001
PARKS HWY MP 309
MONDEROSA RAILROAD OVERPASS
PROJ. NO.: REH-OA4-4(13)
PATH: V:\GEO\60479\60479MD1
ALASKA RAILROAD
GVEA TRANSMISSION LINE
DOYON, LTD
MS 45-1-045-2
MS 37-1-130-2
METERS


STATE
ALASKA
PROJECT DESIGNATION
REH-0A4-4(13)
YEAR
2001
SHEET NO.
TOTAL SHEETS
FIGURE 7
MATCH 2+100 "L" LINE
MATCH 1+400 "L" LINE
PROFILE GRADE
EXISTING GROUND
ALL DIMENSIONS ARE IN METERS (m) UNLESS NOTED OTHERWISE.
ELEV. = 121.417
1+695.000 V.P.C.
40 m BREAK


TEST HOLE LOGS AND LOCATIONS
DAYVILLE ROAD IMPROVEMENTS
LOWE RIVER MAIN CHANNEL
PIER 2
STATE OF ALASKA
DEPARTMENT of TRANSPORTATION AND PUBLIC FACILITIES
TYPICAL TEST HOLE LOG
TYPICAL PENETROMETER TEST LOG
Reviewed by Terry L. Barber, C.P.G.
CONTINUATION OF TEST HOLE II
TEST HOLE II


PENETROMETER 3
CONTINUATION OF PENETROMETER 3
TYPICAL TEST HOLE LOG
TYPICAL PENETROMETER TEST LOG
TEST HOLE LOGS AND LOCATIONS
DAYVILLE ROAD IMPROVEMENTS
LOWE RIVER MAIN CHANNEL
PIER 4
STATE OF ALASKA
DEPARTMENT of TRANSPORTATION AND PUBLIC FACILITIES

APPENDIX C

SOIL ERODIBILITY CHART

*SOIL ERODIBILITY CHART**

CLASSIFICATION		ERODIBILITY[1,2]				
GEOLOGIC DESCRIPTION	***USCS CLASSIFICATION***[3]	*GENERAL*	*SLOPE ANGLE < 45 degrees*	*SLOPE ANGLE > 45 degrees*	*SLOPE LENGTH < 10 meters*	*SLOPE LENGTH > 10 meters*
ALLUVIAL						
High Energy	GW, GP, GM	Low	Low-Med	Med	Low-Med	Med
Low Energy	SM, SP, SW, ML, CL	Med-High	Med-High	High	Med-High	High
COLLUVIAL[4] **(Slope wash)**	Various	Low - High	Low - High	Low - High	Low - High	Low - High
EOLIAN (wind deposited)						
Dune Sand	SP	High	High	Very High	High	Very High
Loess	ML, SM	High - Very High	High-Very High	Very High	High-Very High	Very High
GLACIAL[5]						
Till	GM, SM, ML	Low-Med	Low-Med	Low-Med	Low-Med	Med
Outwash	GW, GP, GM, SW, SP, SM	Low-Med	Low-Med	Med	Low-Med	Med
Glaciolacustrine	ML, SM, SP	Med-High	Med	High	Med	High
LACUSTRINE (Lake deposits)	ML, SM, MH, OL, CL, CH, OH, PT	High	High	High-Very High	High	High to Very High
MARINE						
High Energy	GW, GP, SW, SF	Med	Med	Med-High	Med	Med-High
Low Energy	SM, ML, MH, CL, CH, OL, OH	High	High	High-Very High	High	High-Very High
RESIDUAL - SEDENTARY[6]	Various	Low - High	Low - High	Low - High	Low - High	Low - High

Notes

1 - Erodibility is the relative, qualitative erosion potential of a particular soil type as related to the indicated slope geometry. "Low" erodibility means little or no significant erosion is likely to occur during construction and the life of the project. "Medium" erodibility means that significant erosion is likely to occur during construction and the life of the project. "High" erodibility means significant erosion will occur during construction and during the life of the project, even with intensive soil conservation methods. Water conditions are assumed to be "worst case", with significant sheet flow and underground water daylighting on the slope. Climate, rainfall, and vegetative cover factors also dictate erodibility but are not addressed here.

2 - Select appropriate BMP after reference to DOT&PF "Standard Specifications for Highway Construction", DOT&PF "Erosion Prevention and Sediment Control Plan – Policy and Procedures; Guide to Preparing Erosion Prevention and Sediment Control Plans", DOT&PF "Best Management Practices for Construction Erosion and Sediment Control," DOT&PF Regional Best Management Practices, AASHTO "Guidelines for Erosion and Sediment Control in Highway Construction, Volume III", and Geotechnical Recommendations and Reports.

3 - Unified Soil Classification System - ASTM D-2487

4 - Mass of loose soil and/or rock fragments that has moved downslope - classification and erosion characteristics vary, depending on parent material, which can include any soil component from clay to boulders and organics.

5 - Till soils are directly deposited by glaciers and may contain any combination of inorganic soil components from clay to boulders.

6 - Weathered in place soil derived from parent rock material; characteristics vary depending on soil type

*Adapted, in part, from Koloski, J.W., Schwarz, S.D., and Tubbs, D.W., "Geotechnical Properties of Geologic Materials," Washington Division of Geology and Earth Resources Bulletin 78, 1989.

APPENDIX D

FHWA GUIDELINES FOR MINIMUM NUMBER OF INVESTIGATION POINTS AND MINIMUM DEPTH OF INVESTIGATION

Source: Evaluation of Soil and Rock Properties – Geotechnical Engineering Circular No. 5, Publication FHWA-IF-02-034, FHWA, April 2002.

Table 3. Guidelines for minimum number of investigation points and depth of investigation.

Application	Minimum Number of Investigation Points and Location of Investigation Points	Minimum Depth of Investigation
Retaining walls	A minimum of one investigation point for each retaining wall. For retaining walls more than 30 m in length, investigation points spaced every 30 to 60 m with locations alternating from in front of the wall to behind the wall. For anchored walls, additional investigation points in the anchorage zone spaced at 30 to 60 m. For soil-nailed walls, additional investigation points at a distance of 1.0 to 1.5 times the height of the wall behind the wall spaced at 30 to 60 m.	Investigate to a depth below bottom of wall between 1 and 2 times the wall height or a minimum of 3 m into bedrock. Investigation depth should be great enough to fully penetrate soft highly compressible soils (e.g. peat, organic silt, soft fine grained soils) into competent material of suitable bearing capacity (e.g., stiff to hard cohesive soil, compact dense cohesionless soil, or bedrock).
Embankment Foundations	A minimum of one investigation point every 60 m (erratic conditions) to 120 m (uniform conditions) of embankment length along the centerline of the embankment. At critical locations, (e.g., maximum embankment heights, maximum depths of soft strata) a minimum of three investigation points in the transverse direction to define the existing subsurface conditions for stability analyses. For bridge approach embankments, at least one investigation point at abutment locations.	Investigation depth should be, at a minimum, equal to twice the embankment height unless a hard stratum is encountered above this depth. If soft strata is encountered extending to a depth greater than twice the embankment height, investigation depth should be great enough to fully penetrate the soft strata into competent material (e.g., stiff to hard cohesive soil, compact to dense cohesionless soil, or bedrock).
Cut Slopes	A minimum of one investigation point every 60 m (erratic conditions) to 120 m (uniform conditions) of slope length. At critical locations (e.g., maximum cut depths, maximum depths of soft strata) a minimum of three investigation points in the transverse direction to define the existing subsurface conditions for stability analyses. For cut slopes in rock, perform geologic mapping along the length of the cut slope.	Investigation depth should be, at a minimum, 5 m below the minimum elevation of the cut unless a hard stratum is encountered below the minimum elevation of the cut. Investigation depth should be great enough to fully penetrate through soft strata into competent material (e.g., stiff to hard cohesive soil, compact to dense cohesionless soil, or bedrock). In locations where the base of cut is below ground-water level, increase depth of investigation as needed to determine the depth of underlying pervious strata.

Table 3. Guidelines for minimum number of investigation points and depth of investigation (continued).

Application	Minimum Number of Investigation Points and Location of Investigation Points	Minimum Depth of Investigation
Shallow Foundations	For substructure (e.g., piers or abutments) widths less than or equal to 30 m, a minimum of one investigation point per substructure. For substructure widths greater than 30 m, a minimum of two investigation points per substructure. Additional investigation points should be provided if erratic subsurface conditions are encountered.	Depth of investigation should be: (1) great enough to fully penetrate unsuitable foundation soils (e.g., peat, organic silt, soft fine grained soils) into competent material of suitable bearing capacity (e.g. stiff to hard cohesive soil, compact to dense cohesionless soil or bedrock) and; (2) at least to a depth where stress increase due to estimated footing load is less than 10% of the existing effective overburden stress and; (3) if bedrock is encountered before the depth required by item (2) above is achieved, investigation depth should be great enough to penetrate a minimum of 3 m into the bedrock, but rock investigation should be sufficient to characterize compressibility of infill material of near-horizontal to horizontal discontinuities.
Deep Foundations	For substructure (e.g., bridge piers or abutments) widths less than or equal to 30 m, a minimum of one investigation point per substructure. For substructure widths greater than 30 m, a minimum of two investigation points per substructure. Additional investigation points should be provided if erratic subsurface conditions are encountered. Due to large expense associated with construction of rock-socketed shafts, conditions should be confirmed at each shaft location.	In soil, depth of investigation should extend below the anticipated pile or shaft tip elevation a minimum of 6 m, or a minimum of two times the maximum pile group dimension, whichever is deeper. All borings should extend through unsuitable strata such as unconsolidated fill, peat, highly organic materials, soft fine-grained soils, and loose coarse-grained soils to reach hard or dense materials. For piles bearing on rock, a minimum of 3 m of rock core shall be obtained at each investigation point location to verify that the boring has not terminated on a boulder. For shafts supported on or extending into rock, a minimum of 3 m of rock core, or a length of rock core equal to at least three times the shaft diameter for isolated shafts or two times the maximum shaft group dimension, whichever is greater, shall be extended below the anticipated shaft tip elevation to determine the physical characteristics of rock within the zone of foundation influence.

APPENDIX E

BEST MANAGEMENT PRACTICES FOR SPILL PREVENTION AND EROSION CONTROL DURING GEOLOGICAL/GEOTECHNICAL FIELD INVESTIGATIONS

**Best Management Practices
for
Spill Prevention and Erosion Control
During
Geological/Geotechnical Field Investigations**

The Alaska Department of Transportation and Public Facilities (DOT&PF) is committed to protecting the environment while conducting field investigation activities for geotechnical and geological investigations in support of our road, airport and structure projects. This appendix outlines our best management practices (BMPs) for such field activities.

During the course of field investigations, DOT&PF crews and consultants often use backhoes, excavators, and drill rigs to advance test borings and test pits. Some of our test holes are drilled through existing embankments through asphalt with little risk of consequences from spills and no risk of erosion. Most of our test holes are drilled on vegetated or bare ground - some ground disturbance is inevitable. In some cases, drilling operations utilize water and/or drilling additives (drilling muds such as bentonite or polymers) to circulate in the test holes. When using water, the circulated water is normally released on the ground surface where it is absorbed into the soil. Some risk of erosion exists during these operations. Some of our exploration operations take place in or near active stream and river channels. In these cases, there is some potential for releases of drilling sediment from circulated drilling water and petroleum products that could enter waters of the state. Following are the BMPs implemented for drilling and exploration operations:

Disturbance minimizing BMPs

- Select the smallest drill rig capable of performing the required drilling.
- Conduct operations in marsh, peat and other soft ground areas during winter months when operating machinery will cause least damage to vegetations.
- Operate drilling and excavating machinery on un-vegetated ground where possible.

Waste Reduction BMPs

- Where possible, re-circulate drilling water and drilling muds in a mud tank or pit
- Minimize the amount of water used for circulation

Sediment Trapping BMPs for Drilling Fluids

- Use mud tanks to prevent fluid loss
- Where appropriate and necessary, use silt fences, straw bales or other barriers to prevent uncontrolled sediment flow
- When drilling through bridge decks, block scuppers and direct flow onto upland locations instead of into stream or river

Site Stabilization BMPs

- For excavated test pits, reshape surface to original contours and re-position vegetative clumps at test pit site.

Risk Minimization BMPs

- Visually inspect drill rigs and excavation equipment for leaks, worn hoses, etc. before commencing operations and on a daily basis
- Fix leaks before continuing with operations
- Use proper equipment to transfer hazardous materials
- Reduce the volume of hazardous materials on site
- Remove sources from the site while not actively working
- Secure any sources left unattended on site
- Use environmentally friendly materials
- Make sure sufficient spill response materials are available before commencing field work.

Maximization of Response BMPs

- Each field operation shall have a spill response kit or materials within easy access at the drilling excavation site
- Every member of the exploration crew shall have had training in spill response techniques
- Maintain phone numbers of supervisor, Department of Environmental Conservation, and spill response hotline numbers.
- Maintain communications in remote sites through use of satellite phones.

Procedure

All necessary and appropriate permits will be in place before the geologist and drill crew commence field activities. All provisions of the permits will be followed until completion of the project.

The approach to protecting the environment is focused on prevention. Prior to commencement of field activities the field geologist shall make a thorough inspection of the exploration areas for sensitive areas – wetlands, streams, drainage channels, porous ground conditions, etc. When sensitive areas are identified activities will be modified as necessary to avoid depositing or releasing drill cuttings or drilling fluids into the areas. If no sensitive areas are identified, drilling circulating water and fluids will be discharged and slowly infiltrated into the ground surface. Cuttings may be removed, if appropriate for the situation and stored in drums for off-site disposal.

APPENDIX F

GEOTECHNICAL EXPLORATORY HOLE SEAL VERIFICATION REPORT

Geotechnical Exploratory Hole Seal Verification Report
State of Alaska – DOT&PF – Geology Section

Project Name	**Project #s (AKSAS, Ledger Code, Collocode)**
Test Hole Number (attach test hole field log)	**Date Finished**
Test Hole Location Sketch	**Hole Location (Latitude/Longitude, Station and Offset, reference to survey monument, etc.)**
	River/Creek/Structure Name
	Bridge Number
Field Geologist	**Driller/Helper(s)**
Drilling Rig	**Drilling Contractor**
Drilling Methods (auger, casing, etc.)	
Hole Diameter	**Hole Total Depth**
Groundwater level(s)	**Artesian Conditions**
Reason for Sealing	
Method of Sealing (seal bottom to top, seal zone depths, seal surface, pour pellets, tremie grout, etc.)	
Quantity/Type of Sealing Materials (Grout, Grout/Bentonite mix, Bentonite chips, pellets, etc.)	
Sealing Difficulties	
Instrumentation Installed (standpipe, piezometer, thermistor, slope indicator, etc.)	
Field Geologist **Date**	**Supervising Geologist** **Date**