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GEOTECHNICAL DESIGN MANUAL

CHAPTER 2- PROJECT GEOTECHNICAL PLANNING

GEO-ENVIRONMENTAL SECTION

OREGON DEPARTMENT OF TRANSPORTATION

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SUMMARY OF CHANGES

Chapter	Summary of changes made	Date revised
2	Updated All Chapter Content	3/27/2018

2 PROJECT GEOTECHNICAL PLANNING

2.1 GENERAL

General Geotechnical planning for projects with significant grading, earthworks, and structure foundations, from the earliest project concept plan through final project design are addressed in this chapter. Detailed geotechnical exploration and testing requirements for individual design are covered in detail in Chapter 3, Chapter 4, and Chapter 5. This chapter also provides direction for geotechnical project definition and creation of the subsurface exploration plan for the project design phases. General guidelines for subsurface investigations are provided in chapter 3 in addition to specific guidelines regarding the number and types of explorations for project design of specific geotechnical features.

The success of a project is directly related to the early involvement of the geotechnical designers in the design process. For larger projects that involve an Environmental Impact Statement (EIS), the geotechnical designer needs to be involved with the assessment of various options or corridor selections. Ideally, for all projects, the geotechnical designer will be involved during the first scoping efforts. At this point, a study of the project concept is begun by gathering all existing site data and determining the critical features of the project. This information can then be presented at the project kick-off meeting and/or scoping trip. The project-scoping trip is a valuable opportunity to introduce the roadway and structural designers, and project leaders to the geologic/geotechnical issues that are expected to affect the project. Continued good communication between the geotechnical designer and the project leader and project team is vital.

2.1.1 GEOTECHNICAL PROJECT ELEMENTS

All proposed project scopes should be reviewed by an engineering geologist and/or geotechnical engineer for a determination of the project elements (if any) that require a geologic investigation and geotechnical design. This allows the geotechnical designers to begin formulating a prospective scope of work and budget estimate. There are common project elements that are always the subject of a geotechnical investigation and design such as bridge foundations and landslide mitigations, and there are project elements that, depending on the site history and underlying geology, may or may not need investigation and design, or may require different levels of effort. The geotechnical designers will be able to determine the level of effort based on their own or other’s knowledge and experience of the site to make these judgments. Because of the underlying site conditions, elements that generally do not warrant geotechnical design for most sites may require it at others. Conversely, investigation and design efforts may be scaled back or eliminated at other sites due to known favorable conditions, and the significance of the project feature. It is the responsibility of the geotechnical designers to make these decisions.

The common project elements on transportation projects that are the subject of engineering geologic investigation and geotechnical design for construction are:

- Structure Foundations (bridges, viaducts, pumping stations, sound walls, buildings, etc.).
- Retaining walls over 4 feet in height as measured from the base of the wall footing to the top of the wall and any wall with a foreslope or backslope.
- Cuts and embankments over 4 feet in height.
- Tunnels and underground structures.
- Poles, masts and towers.
- Culverts, pipes and conduits.

This last group of elements, culverts, pipes and conduits, exemplify the broad range of design and investigation that may occur on any project. A 24-inch culvert replacement at a depth of 3 feet below a proposed roadway alignment would normally require the hand-collection of soil samples from the pipe location, submittal of those samples to the laboratory for chemical properties testing, and forwarding the results to the project designer for selection of the appropriate pipe materials for that location. If however, that same culvert was to be installed under a large, existing embankment while under traffic using trenchless methods, then the required investigation and design effort would be close to what is required for a tunnel or underground structure.

2.1.2 GEOTECHNICAL PROJECT TASKS AND WORKFLOW

The expected milestones for geotechnical input on projects and the review of geotechnical work is outlined in Appendix 2-A Geology / Geotechnical QC MATRIX, and the Project Flowchart.

Certain project checkpoints and tasks may be added or eliminated based on the project scope and/or requirements. Each individual project prospectus should be consulted to determine which tasks and QC checkpoints would apply.

2.2 PRELIMINARY PROJECT PLANNING

2.2.1 GENERAL

The creation of an efficient geologic/geotechnical investigation and identification of fatal flaws or critical issues that could affect design and construction as early in project development as possible is essential. Use the maximum amount of effort to obtain the greatest amount of information as early in each phase of investigation as possible so that each successive phase can capitalize on the information previously gathered. The result is a more thorough and cost-effective geologic and geotechnical investigation program.

Projects with a small number of defined structure locations or limited earthwork typically do not require numerous phases of investigation. Such projects normally proceed through an initial background study, site reconnaissance, and ensuing subsurface exploration at the TS&L phase. Larger projects in contrast, will usually benefit from a phased sequence of field exploration. The geologic/geotechnical investigation will occur as a reconnaissance-level examination and preliminary subsurface exploration during the Field Survey phase of the project. More detailed, site-specific exploration is accomplished later as the project develops through the TS&L and Approved Design phases.

Phased subsurface exploration is beneficial because:

- Phased subsurface exploration allows information to be obtained in the early stage of the project that can be used to focus the exploration plan for the more detailed design stages. This is where previously gained information can be used to maximize the efficiency of the final exploration, and to assure that previously identified geotechnical problems and/or geologic hazards are thoroughly investigated and characterized.
- Additionally, the Exploration Plan can be more clearly defined and easier to manage. In this regard, the number of borings, their depths, and laboratory testing programs can be determined in advance of actual mobilization of equipment to a project area.

For most projects, mobilization costs for exploration equipment are high, so efforts should be made to reduce the number of subsurface investigation phases whenever practical. However, the site location, project objectives, and other factors will necessarily influence the investigation phases and mobilizations. Some of the additional factors to consider are site access, availability of specialized equipment, environmental restrictions, safety issues, and traffic control.

To economize field investigations and provide contingencies for ongoing project changes, consider the following:

- A substantial amount of background study should take place prior to mobilization to a project site. The information derived from this research provides a basis for the design of the Exploration Plan and help focus the on-site investigation.
- In addition, all resources used in the development of the background study should be organized and documented in such a manner that another geotechnical designer would be able to continue the project without going back to the beginning to get the same information. Keep a list of all documents used in the background study, such as field notes and sketches from initial site reconnaissance, reports, or investigations from previous or nearby site investigations, and other published literature.
- Any critical issues such as geologic hazards, problem materials or conditions, or contamination identified during the initial study should be clearly documented and highlighted throughout the project to avoid any surprises later on in the design or construction phases.

2.2.1.1 Project Scale and Assignment of Resources

Geotechnical designers should use their professional judgment with respect to the scope, scale, and amount of resources to utilize during preliminary project studies. Larger projects obviously necessitate a greater effort in the early examination of background materials such as previous reports for an area, maps, published literature, aerial photographs, and other remote sensing.

Even the smallest bridge replacement or grading project, background study is just as important, and although of a smaller scale, should be carried out with the same diligence as a similar study for a major realignment. A thorough and expedient background study is essential for these smaller projects since unforeseen conditions and additional unplanned field investigations are much more difficult to absorb in a smaller project budget. It follows that for a larger project; a more thorough background investigation is warranted since unforeseen conditions can have a compounding effect during design and construction that may affect even the most generously funded projects.

The amount of background research needed for a project is usually unknown until the study begins and the potential site conditions are assessed to some degree. It is up to the geotechnical designer to determine the amount of background study needed and the cost-benefit of such studies with respect to the project design.

Using Remote Sensing and Existing Information

Ordering new remote sensing studies to assess surrounding landforms is probably not necessary for in-kind bridge replacement projects unless some special conditions are observed during the field or office study. However, failure to procure and study a set of aerial photographs along a proposed realignment would be poor practice. Project background studies for major realignment projects and landslide mitigations typically make more use of remote sensing and published literature while replacement and modernization projects will rely more heavily on previous site studies and reports.

2.2.2 OFFICE STUDY

The foremost objectives of initial office study are 1) early identification of critical issues that will affect the project's scope, schedule, or budget, and 2) efficiently plan detailed site studies and formulate a subsurface investigation program.

2.2.3 PROJECT STAGE 1

The first stage of any project should begin with a review of the published and available unpublished literature to gain a thorough understanding of the existing site conditions and composition. Such an understanding includes knowledge of the geologic processes that have been the genesis of, or have in some way affected the project site. The site geomorphology should receive the most scrutiny from the geotechnical designer since characteristic landforms are created by specific geologic processes, and composed of particular materials. The site geomorphology, coupled with the literature and results of previous studies, will aid the geotechnical designer in predicting what materials will be encountered, and how they will be distributed across the site.

2.2.4 PROJECT STAGE 2

The second stage of a project involves the detailed examination of the proposed project components and in particular, the geotechnical elements. This includes an appraisal of the project prospectus as well as any conceptual or preliminary plans available from the roadway designer or project leader. The project geotechnical features such as bridge foundations; earth-retaining structures, cuts, embankments and any other earthworks should be identified and located. Once the project geotechnical features are recognized, they can then be analyzed with respect to the background information previously collected.

2.2.4.1 Existing Information and Previous Site Investigation Data

Current transportation projects take place almost exclusively on or near existing routes, for which a considerable amount of subsurface information already exists, in most cases. Subsurface information is collected for bridge foundations, retaining walls, cut slopes, embankments, and landslides. Additional subsurface data has also been collected for incidental structures such as sound walls, sign bridges, poles, masts, and towers, and facilities such as water tanks and maintenance buildings. Since many transportation projects take place in urban areas, additional information may also be available from other nearby public works projects and private developments involving structures and earthworks. Local agencies may possess subsurface information for their projects as well as data provided by consultants.

Subsurface information collected for ODOT projects primarily resides in the region geology office in which the data was collected. The first inquiry into project geotechnical information should be to the appropriate region Geotechnical office. In addition to the region Geotechnical offices, additional information may be found in the following sources, which are all located in Salem:

Old Roadway and Geo-Hydro Section Files

Statewide geotechnical project files are also archived and stored in the main Oregon State Archives building in Salem. These consist of project files that were developed between about 1930 (or earlier) and about 2004. The bulk of the files are from the old Roadway Section Geotechnical Group and typically involved roadwork projects such as landslide and rockfall repairs, embankment design and other roadway geotechnical work performed statewide during this time period. In 1997, the ODOT Bridge Section's Foundation Unit was combined with the Roadway Geotechnical Group and the ODOT Hydraulics Section to form a new Geo-Hydro Section. The Geo-Hydro Section later added the region geotechnical offices to the section and for a brief period of time up until 2004, geotechnical design was centralized in Salem and geotechnical project files for that period of time are stored in these archives.

The procedure for obtaining these hardcopy files are outlined in Appendix 2B. A database listing of the projects archived can be searched to see if a project of interest is available.

Bridge Section Archives

Past Bridge Foundation Reports, drill logs and other foundation design information, for projects designed prior to about 1997 are also stored separately in the State Archives Record Center in Salem. These files are located through use of the Bridge Section Archive database. Requests should be made through the HQ Bridge Section Office. In requesting these files, it is important to know the information needed to best locate the request material. Appendix 2C summarizes the project information that should be included in the request in order to conduct for best search of the archive database.

HQ Microfiche Files

Construction records of past bridge projects are available on archival microfiche records in the Salem TLC office. These records extend back to at least the 1930's and may include information on pile installation (records), plan changes, survey field notes, material testing information and various written correspondence that took place during the construction of the bridge. The files are located in the *Maps and Plans* storage room of the Salem TLC and indexed by Structure Number. A microfiche viewer is available for viewing and saving selected files.

2.2.4.2 Office Research for Bridge Foundations

In addition to the sources of information listed above, office research for bridge foundation work generally consists of a review of foundations for the existing structure and any other pertinent foundation information on other nearby structures. The structure owner may have subsurface information such as soil boring logs or "as-constructed" foundation information such as spread footing elevations, pile tip elevations, or pile driving records.

The HQ Bridge Section archives contain Foundation Reports and boring logs for many bridges constructed between the early -1960s to about 1997. Subsurface information on some earlier ODOT bridges may also be available in the Bridge Section construction records.

Maintenance and construction records for existing bridge(s) should also be reviewed for information relevant to the design and construction of the proposed structure. As-Constructed bridge drawings are available online, internally to ODOT through the ODOT Bridge Data System (BDS). Piles driving record books are also available on request from the HQ Bridge Section.

Office research work for structure foundations typically includes (but is not limited to) gathering the following information for the existing structure(s):

- Location and structure dimensions, number of spans, year constructed.
- Superstructure type (e.g. RCDG, composite, steel beam).
- Subsurface data (e.g. foundation reports, boring logs, data sheets, groundwater conditions, etc.).
- Type of Foundation (e.g. spread footings, piles, shafts).

Applicable "as-constructed" foundation information such as:

- Spread footing elevation, dimensions, and design or applied load.
- Pile type and size, pile tip elevations or lengths (pile record books), design or actual driven pile capacity and the method used to determine capacity (resistance) (dynamic formula (ENR, Gates), wave equation, PDA/CAPWAP).
- Drilled shaft diameter, tip elevations.
- Construction problems (e.g., groundwater problems, boulders or other obstructions, caving, difficult shoring/cofferdam construction).
- Foundation–related maintenance problems (e.g., approach fill or bridge settlement, scour problems, rip rap placement, corrosion, slope stability or drainage problems).

A review of old roadway design plans, air photos, and soil and geology maps and well logs may also be useful. Particular attention should be given to locating any existing or abandoned foundations or underground utilities in the proposed structure location. Any obstructions or other existing conditions that may influence the bridge design, bent layout or construction should be communicated directly to the structural designer as soon as possible so these conditions can be taken into account in the design of the structure.

This information should be summarized and provided in the Geotechnical Report. All applicable "as-constructed" drawings or boring logs for the existing structure should be included in the Geotechnical Report Appendices.

The Oregon Water Resources Department maintains a database of boring logs on its website. By law, reports must be filed with this agency for all geotechnical holes and water, thermal, and monitoring wells. Thus, the database is fully populated, and may be queried in many ways geographically or by owner, number, constructor, or purpose. These logs are beneficial in rural or remote areas with a dearth of subsurface information.

Note:
A wealth of information can be contained on the logs especially regarding groundwater and depth to bedrock information. There is an entry for soil and rock descriptions on the reporting forms. However, this information should be used with caution since there are no standard reporting formats and well drillers have historically used descriptors unique to their industry (for instance all blue tinted soils being logged as clays). As such, the soil and rock descriptions on the Water Resources forms vary in content and accuracy.

The ORWD database can be located at Oregon Department of Water Resources Database.

In addition to the information provided on the OWRD forms, it is important to simply note the presence of wells in the area that may be affected by the project construction. Projects involving large cut slopes or dewatering efforts can affect the yield of nearby wells. Where this occurs, ODOT typically includes replacement or deepening of the well as part of the Right of Way acquisition.

2.2.4.3 Construction Records

Since most current ODOT, projects are modernization, replacement, or rehabilitations of existing transportation facilities, construction records are commonly available from various sources throughout the agency. Such records may be in the form of as-built plans, construction reports, pile-driving records, and other technical memoranda addressing specific issues and recommendations during project construction. Locate information using:

- **As-built plans**: As-built plans are normally located in the region office where the project was constructed. The Geometronics Unit maintains the engineering documents in Room 29 of the Transportation Building in Salem where Mylar's of project plans reside in addition to some of the as-built plans.
- **Pile records**: Pile record books are maintained by the headquarters office of the Bridge Section.

Region project engineers and construction project managers that have completed previous projects in the area should be consulted with respect to the geologic/geotechnical conditions as well as the construction issues related to those conditions. In addition, section maintenance personnel with a long history in an area will possess a wealth of information regarding the performance of existing facilities; problems encountered, and repair activities that have taken place at a particular site.

2.2.4.4 Site History

Past use of a site can greatly affect the design and construction of a project and can also make a significant impact to its timeline and budget. Typically, much of a site's background and past use will be researched and described for a Phase I or II Environmental Site Assessment produced by the environmental specialists or their consultants in the region geology offices. Information concerning the development of

Environmental Site Assessments and other site use resources can be found in the HazMat Manual. Environmental Impact Statements (EIS) for previous projects in the area are also an important and concise source of previous and current site use information. Some of the remote sensing methods previously discussed may also help determine previous site use in the absence of historic records.

Hazardous Materials

The presence of hazardous materials in the subsurface not only affects the geotechnical design, and the construction approach to a project, but it also greatly affects how the subsurface investigation program is carried out. For this reason itself, it becomes important for the geotechnical designer to determine if previous use of the site, or surrounding locations could have potentially resulted in subsurface contamination. Such uses include any facility or enterprise engaged in the production, distribution, storage, or use of hazardous substances. Hazardous substances are defined by the Environmental Protection Agency (EPA) in 40CFR§261.31 through 261.33. In addition, the EPA further includes as hazardous wastes, such substances with characteristics of Ignitability, Corrosively, Reactivity, and Toxicity according to 40CFR§261.21 through 261.24. For transportation projects, the most commonly contaminated sites are those that are presently, or have previously been occupied by service stations. However, larger manufacturing and processing sites with substantial amounts of contamination are encountered. Within highly urbanized corridors, soil contamination is widespread (particularly within man-made fills) and all soils should be viewed as having the potential to be impacted. When geotechnical investigation must be conducted under such conditions, significant preplanning is required not only to protect the field crew, but also to comply with the numerous environmental regulations that govern everything from required PPE to disposal of contaminated drill cuttings.

Previous Site Use

In addition to contaminated materials, previous site uses have the possibility of leaving behind materials and/or conditions that can be detrimental to the construction or performance of a facility if not properly mitigated. In this regard, deleterious fill materials such as wood waste and ash are commonly associated with timber processing and other operations throughout the state while reclaimed quarries may be filled with deep, unconsolidated debris and spoils. Underground mines and tunnels are present in various locations throughout Oregon. Although uncommon, some instances of such features unexpectedly encountered during construction have occurred. In addition to their obvious geotechnical impacts, such features may be historic locations and thus, be protected by Federal law.

Previous Site Occupation

In addition to previous site use, the geotechnical designer must also consider previous site occupation. A site previously occupied by Native Americans can contain artifacts, or be of significance to contemporaries. Such occupation may require archaeological investigation or preservation activities by qualified personnel. It is also possible that the exploration plan, or even significant project design changes prior to on-site geotechnical investigation will be required. Historic sites, structures, and even trees will also be protected in some instances that will necessitate adjustments to the proposed investigation. Clearly, much of the archaeological and historical issues in connection with a site are outside the purview of engineering geology and geotechnical engineering. However, the geotechnical designer must be aware of the issues to assure that field investigation activities are compliant with the laws and regulations that protect these resources. The Region Environmental Coordinator (REC) should be consulted on the Exploration Plan to evaluate the potential for archaeological/cultural resource impacts.

2.2.4.5 Site Geology

The underlying geology of a project site provides important information concerning the conditions that may be encountered during the investigation and construction phases of a project. Of equal importance is the indication of conditions that either may not be encountered, or will require specific procedures to determine if they do exist. Some particularly deep bedrock horizons, groundwater surfaces, and boulders or other obstructions are examples. Certain conditions can be expected due to the nature of the project site geology.

Oregon has specific geologic terrains, formations, and units with distinct constituents, properties, and characteristics that greatly affect the design and investigation of a transportation project. For example:

- Many of the volcanic rocks that compose the Coast range, Willamette Valley, and Cascades can exhibit deeply weathered soil horizons with isolated zones of less weathered materials, interbeds of weak tuff and other unconsolidated tephra.
- Many of the coastal and inland valleys contain deep, soft sedimentary deposits formed by a rising sea level at the end of the Pleistocene.
- The Klamath Terrain in the southwestern portion of the State is a complex mixture of materials that present difficult conditions for the exploration as well as construction.

Numerous published and unpublished documents are available that provide enough information upon which to base a background study. Naturally, many portions of the State have more information than others depending on population densities and previous site uses. However, some basic information is available throughout the state that can be used for most projects. The geology of a site must be researched and understood before mobilization of drilling equipment. The results of the office study are a key component of the subsurface exploration plan. The following sections provide a discussion of the most common publications and how they contribute to a background project study.

Procedures and techniques for the interpretation of maps, aerial photographs, and other remote sensing products can be found in a wide variety of texts and other publications. Several engineering geology textbooks provide a good background in geologic interpretation for engineering projects. However, landform recognition methods are also very well presented in numerous geography texts and other related books devoted entirely too remote sensing and/or GIS. Geologic interpretation with specific emphasis on landslides is treated in Chapter 8 of the 1996 *TRB Landslides* publication.

Topographic Maps

The U.S. Geological Survey (USGS) prepares and publishes 7.5-minute topographic maps at a scale of 1:24,000 for the entire State, and for most of the rest of the U.S. Topographic maps can be used to extract both physical and cultural information about the landscape and their consultation should be the first step in any site investigation. Contour lines provide information about slopes as well as indications of the underlying geology and geomorphology. The drainage patterns that develop in the contour lines also suggest geologic and human factors that may have influenced site conditions. Transportation and development patterns portrayed on USGS quad sheets are an often-overlooked source of information. Many roads are aligned to avoid existing geologic hazards or areas where construction difficulties are expected such as wetlands, steep slopes, or hard, resistant rock cuts. Quarry and mine site locations are also an important clue with respect to the location and distribution of bedrock materials.

15-minute topographic maps, also produced by the USGS at a scale of 1:62,500 are also commonly available, but since they have been discontinued in favor of the 7.5’ quad sheets, are becoming increasingly rare. The advantage of the 15-minute maps is that they can be very old and may show how land-use has changed in an area since their original survey. Previously existing wetlands that have since been filled or drained, waste areas, quarries, abandoned mines and other problematic areas with respect to transportation projects may be identified. Topographic maps should always be used to identify the arcuate head scarps and hummocky terrain indicative of landslides, wetlands, and general site accessibility with respect to investigation as well as construction.

Sources of Aerial Photos

Aerial photography is the most common, reliable, easy to use, and usually the cheapest source of remote sensing available. Aerial photos are very useful in planning subsurface investigation programs from gaining general knowledge regarding the geology, the extent, and distribution of materials, the location of geologic hazards, potential for encountering contaminants, and determining access for exploration equipment.

Aerial photographs are available through a variety of sources. The ODOT Geometronics Unit would be the first source for aerial photos as their archives date back to the early 1950s and primarily cover the areas around the State's highways and the Oregon coastline. The US Army Corps of Engineers has coverage back to 1929, mostly along bodies of water (coasts and rivers).

Instructions and forms for ordering aerial photographs from the ODOT Geometronics Unit will be found on the Agency's website. Instructions and forms for ordering from the Corps of Engineers is found on their website.

Additional sources of aerial photography are:

- The US Geological Survey
- USGS EROS Data Center
- The USDA Aerial Photo Archives
- Bureau of Land Management
- University of Oregon's Aerial Photography Library
- WAC Corporation
- GeoTerra, Inc.

Many County Surveyor and/or Assessors offices throughout the State are an additional source of aerial photography. There are also a number of internet resources for low-resolution images for site location or other less-detailed applications.

General Use of Aerial Photography

Aerial photographs may be taken on either black and white or color film. Each of them have characteristics that make them superior to one another for different applications although color photographs are generally considered better since many objects are easier to identify when shown in their natural colors. Things to consider include:

- Color photos also allow for the application of color contrasts and tonal variations to interpretations. In some circumstances, black and white photographs allow the geologist or engineer to resolve changes in slope or elevation that may otherwise be lost in the subtle color changes when using natural color aerial photos.
- Another, less commonly available type of aerial photograph are those taken in false color or infrared (IR). Color IR photography responds to a different electromagnetic spectrum than natural

photography. Differences in soil moisture, vegetation type and soil and rock exposure are more readily identified on color IR film.

- Ideally, both black and white as well as color photos of a site should be analyzed for a complete analysis of all features unless color IR photos are available in which case it is generally agreed that for engineering geologic interpretation, natural color and color IR transparencies provide the best information.

With a general understanding of the site geology, the lateral extent of certain geologic features and deposits can be estimated from aerial photography. With a stereo-pair of photographs, the vertical extent can also be estimated in some circumstances. The use of stereo-pairs significantly increases the ease and accuracy of geomorphic interpretation. Subtle landforms may be discerned that may otherwise be hidden from view either on-site or on a two-dimensional image.

Geomorphic Identification from Aerial Photography

Landform identification regularly allows the general subsurface conditions to be determined within the boundaries of that particular feature and thus, an opening impression of the materials to be encountered. Recognized landforms result from particular geologic mechanisms that allow such determinations to be made. These landforms are formed by distinct processes such as fluvial, glacial, or Aeolian and so they are composed of particular materials and compositions. Drainage patterns that develop within or as a result of certain landforms and geologic structures can be used as a diagnostic feature when studying aerial photographs. One of the more important landforms to distinguish during a preliminary study of aerial photography is landslides. Landslides are readily identified by their characteristic arcuate headscarps, patterns of disturbed soil and vegetation, standing water on slopes with no apparent source or discharge (sag ponds), abrupt changes in slope, disrupted or truncated drainage patterns, and upslope terraces.

Other Applications of Aerial Photography

Vegetation is another important feature to evaluate on aerial photographs since it frequently reveals certain subsurface conditions. Vegetative cover is related to numerous factors including soil development on certain bedrock units, depth of the soil profile, drainage and natural moisture content, climate, and slope angle. In addition to the geologic characteristics, the condition or absence of vegetation may be a sign of soil contamination. Zones of dead or discolored vegetation can indicate the presence of a spill or chemical dumpsite that field exploration crews may not be prepared to encounter.

It is also important to review a sequence of aerial photographs from different years to determine the history of site use and the natural or human-caused changes that have occurred. Significant changes in the ground contours and shapes can indicate changes due to geologic processes such as landslides, erosion, and subsidence or changes due to construction on the site such as filling and excavation. Other aspects of the site's history that can be determined are the activities that occurred on site such as chemical processing, fuel storage, waste treatment, or similar activities, which may leave contaminated or other deleterious materials behind.

Geologic Maps

The Oregon Department of Geology and Mineral Industries (DOGAMI), USGS, US Department of Energy, and other agencies publish geologic maps of most of the state at various scales. The USGS has published a map of the entire state at a 1:500,000 scale. These geologic maps generally use the USGS topographic maps as a base layer. Geologic maps portray the distribution of geologic units and provide a general description of each that includes the rock or sediment type, geologic age, origin, and brief summary of its properties and physical characteristics. Additional information concerning geologic hazards, groundwater, and economic geology is typically included.

DOGAMI also publishes special studies on geologic hazards in certain heavily populated or problematic areas of Oregon. Geologic Hazard maps are generally produced to portray specific themes such as slope stability, liquefaction potential, amplification of peak rock accelerations, and potential tsunami inundation zones. Such maps provide a general indication of the extent and magnitude of the hazards they were produced to portray.

Geologic maps for the state are available from DOGAMI and at most of the State Universities libraries. Publications are also available for purchase on line from DOGAMI. In addition, many local agencies and municipalities have contracted for hazard mapping and planning. These publications may be available from the local agency offices. DOGAMI is now in the process of a digital map compilation for the state. This compilation allows for the electronic querying of geologic information published in a selected area. The geologic information contains pertinent engineering characteristics in many areas. Currently, the compilation map for the NE sextant of the state is available on CD.

Soil Surveys

The US Department of Agriculture, Natural Resources Conservation Service (formerly the Soil Conservation Service) has published soil surveys for all of the counties in Oregon. Although these reports are intended for agricultural use, they provide valuable information on the surficial soils in and around a project area. These bound volumes include maps and aerial photographs showing the lateral extent of soil units and a description of the overall physical geography including local relief, drainage, climate, vegetation, and description of each soil unit together with its genesis. Commonly, the soil units are overlain on a topographic and aerial photographic base. The reports contain engineering classifications of the surficial soil units, a discussion of their characteristics such as drainage and susceptibility to erosion suitability for use in some construction applications.

Remote Sensing and Satellite Imagery

Remote sensing, by the largest definition, involves the collection of data about an area without actual contact. By this definition, the previously discussed methods of air photo and map interpretation would be classified as remote sensing. However; for this section, remote sensing is restricted to imagery obtained by systems other than cameras, or images that are enhanced to distinguish different characteristics of the earth’s surface.

Remote sensing as discussed in this section generally utilizes sensors that detect particular electromagnetic energy spectra that is mostly generated from the sun and subsequently reflected or emitted from earth. In addition, active systems that transmit and detect energy from the same platform such as an airplane or satellite are also used to collect imagery. The primary purpose of this distinction is that aerial photographs allow examination of images in the electromagnetic spectrum visible to the human eye. Other imagery allows examination of features with reflectance or energy emission properties that are either outside the spectrum visible to humans or occur with other features with overlapping spectral reflectance that obscures them to the human eye. Examples of these other remote sensing systems are: Multispectral Scanning Imagery, Thermal IR Imagery, Microwave Imagery, and Light Detection and Ranging. Despite their advantages, these remote sensing systems are not a substitute for stereo photographs and their higher detail, interpretive returns, and overall economy. They are merely a tool to allow additional interpretation capability for engineering geologic studies.

Thermal IR Imagery

These systems obtain images from the thermal wavelength range, generally from 8µm to 14µm, and contain the energy emitted from the earth that was previously stored as solar energy. The thermal properties such as conductivity, specific heat, and density of various materials produce different responses to temperature changes. Such responses can be measured to allow differentiation of various surface materials. In a sense, thermal IR imagery can be described as a photograph of the earth's albedo.

Obviously, the longer wavelength of thermal IR images will result in a much lower resolution than a corresponding photographic image. For this reason, thermal data is used to enhance images of areas with certain surface conditions that are not generally detected by aerial photography. In this regard, areas composed of materials with similar or overlapping reflectance properties may not show up on an aerial photograph, but their different thermal properties will make them stand out on a thermal IR image.

The primary uses of thermal IR imagery are for mapping changes in soil and rock compositions and anomalous groundwater flow characteristics on an aerial photograph base. Typical engineering geology applications of thermal IR imagery are:

Fault delineation

Locating seepage at soil and rock contacts

Mapping variations in weathered rock profiles

Mapping near-surface drainage

Multispectral Scanning Imagery (MSS)

MSS systems produce imagery from several distinct ranges, throughout the photographic and thermal spectrum. These distinct spectra are typically referred to as a band. Each spectral is concurrently recorded by the scanning instruments along the aircraft or satellite flight line. Much of the data available came from the Landsat satellite program during the 1970s and 1980s. The early Landsat satellites used only four spectral bands and achieved a resolution of about 80 meters. Later satellites used 7-band sensor array with a 30-meter resolution from 6 of those bands. The seventh was a thermal IR sensor. Special aircraft flights with 24-band sensors can also be obtained.

Images from MSS data can be used to examine the spectral signatures and reflectance of surficial materials and objects. Different soil and rock materials, as well as the extent of rock weathering, can be identified by comparing color variations from the different spectral bands. MSS image analysis for engineering geology is typically used to identify major landforms and tectonic features. In addition, the length of time over which the images were collected allows observation of changes in vegetation, land use, and the locations of catastrophic events such as fault rupture, flooding, and landslides. As with thermal IR imaging, MSS is generally used as an enhancement of aerial photography rather than a substitute for it.

Microwave Imagery (Radar)

Radar utilizes electromagnetic energy from the microwave spectrum, typically with wavelengths from 1mm to 1m. Radar imaging may come from either an active or a passive system. In this regard, passive systems are a form of thermal IR imaging using the wavelengths that increase to the range of microwaves whereas active systems emit pulses of energy that are transmitted to the earth's surface where they are reflected back to a receiver.

The most common technique for this type of imagery is Side-Looking-Airborne-Radar (SLAR). For this technique, the radar scans a portion of the earth's surface laterally from an aircraft in a direction perpendicular to the flight line and at a depression angle measured downward from the horizontal. Overlapping images created from this method allow stereo viewing of surface features and objects. Objects that are more perpendicular to the pulse provide a strong energy return to the receiver while smooth or horizontal surfaces reflect the energy away from the receiver resulting in a dark image. It then follows that reflection angles and surface roughness as well as vegetation and moisture content influence the energy returned to the receiver. Objects and features extending above the surface project radar shadows that are related to the angle of incidence of the energy transmitted and received. These shadows accentuate the surface topography and thus, structural trends.

SLAR images are typically used in an engineering geology application to identify the surficial expression of geologic structures, drainage features, structural patterns, and trends. SLAR imagery is complimentary to aerial photography and should not be a substitute for it. However, SLAR images have many advantages that provide additional information that is difficult to extract from an aerial photograph. Their primary advantage is the enhancement of major features that are obscured by the greater detail of an aerial photograph. Another advantage of SLAR is the ability to obtain clear images at night and in heavy cloud cover.

Light Detection and Ranging (LiDAR)

This technology utilizes an active system that is similar to radar in the manner by which it creates an image. In this regard, energy is emitted from a source and reflected from the earth's surface back to a receiver. However, in this case, a laser is used to measure the distance to specific points and generates a digital elevation model of the earth's surface similar to standard photogrammetric methods. LiDAR equipment is typically mounted in an aircraft although numerous ground-based applications have been developed that are beneficial to highway engineering geology, and in particular, rock slope design.

The primary advantage of LiDAR is during post-processing of the data that allows vegetation to be stripped from the data to provide a bare-earth terrain model. This is a particularly useful technology in much of Oregon where heavy vegetation obscures much of the ground surface. Landforms that would typically be obscured stand out in sharp resolution on a LiDAR image where the vegetation has been removed. In addition to vegetation, structures and dwellings can also be removed. This is also advantageous where development has occurred over large, ancient structures to the extent where they completely obscure its features. Disturbed areas and earthworks are also plainly visible on bare-earth LiDAR images. This allows clear distinctions to be drawn between fills and embankments, and natural ground surfaces. Bare-earth models also provide a clear resolution of existing stream courses and channels. Other imagery and photogrammetry-derived mapping often contain erroneously located stream segments due to forest cover and/or ongoing lateral migration. LiDAR images not only provide an unmistakable location of the stream course, but also a clear rendition of the stream banks and terraces.

ODOT currently stores LiDAR bare-earth and reflective imagery files on the GIS server as hill shade images and Digital Elevation Models (DEM) files. This server is accessible on the ODOT system. DOGAMI provides access to LiDAR imagery in a web-view format on their web page: https://gis.dogami.oregon.gov/lidarviewer/

Raw ASCII and .LAS-format files are available from ODOT's GIS unit as requested. In order to load the raw or binary datasets, an external hard drive of at least 500 GB capacity must be provided as these files are extremely large. LiDAR imagery and DEMs are normally viewed, manipulated, and analyzed with GIS software and specific GIS software extensions. Specialized software is also available for LiDAR data and imagery analysis. ASCII and .LAS files can be used to produce a .dtm file compatible with later versions of Bentley InRoads.

Numerous contractors are available that can provide LiDAR data products; however, ODOT participates in the Oregon LiDAR Consortium (OLC) for new acquisitions. The Oregon Department of Geology and Mineral Industries (DOGAMI) were given a legislative mandate to extend LiDAR coverage throughout the state.

The consortium model was approved for funding, collection, and sharing new LiDAR datasets. DOGAMI, as head of the consortium retains the LiDAR contractor and develops cooperative agreements between consortium members. The consortium benefits all members by provided additional coverage for lower cost. As the aerial extent of each acquisition order increases, the cost per square mile decreases. In addition to lowering the unit cost, more contiguous areas of LiDAR data are acquired providing greater benefit to all members. Members of the OLC include Federal, State, and Local agencies, Tribal governments, private entities, and not-for-profit organizations.

2.2.5 SITE RECONNAISSANCE

2.2.5.1 General

The purpose of site reconnaissance in geotechnical project planning is to verify the results of the office study, and to begin formulation of a site-specific exploration program that will address the issues identified, and determine some of the logistics required to complete the next phase of investigation. At this stage, the geotechnical designer should know what to look for at the site, and, with preliminary or conceptual plans in hand, should observe the anticipated conditions with respect to the proposed project features. Surficial expression of features and landforms should be checked on the project plans as well as delineating additional features noted during the site reconnaissance. It is also important to assure that the project maps are accurate with respect to the actual site conditions, and that significant features were not overlooked or misrepresented on the preliminary or conceptual design phase maps. The scope of the site reconnaissance depends greatly on the site conditions, accessibility, and project complexity. The value of the site reconnaissance is realized later on in the project through a more efficient and thorough site exploration and geotechnical design. Therefore; site reconnaissance should be complete and systematic to achieve the final objectives of the office investigation, and may involve a significant level of effort in the field depending on the project site itself.

2.2.5.2 Verification of Office Study and Site Observations

The topography and geomorphology of a site should be reconciled in the field with what was anticipated in the office study and shown on any maps or aerial photographs. Review and assess the following:

- Outcroppings, road cuts, streambeds, and any other subsurface exposures should be noted to verify the anticipated conditions based on the published geologic maps and literature. The presence of artificial fills should be noted and described with respect to its composition, lateral extent, and estimated volume.
- Surface waters, springs, wetlands and other potentially sensitive areas that may affect the project work should also be noted. In addition, an effort should be made to identify the 2-year flood zone for future reference.
- Boulders, blocks, and oversized materials in streambeds, or projecting from embankments should be noted as they may be indicative of obstructions in the subsurface. Such obstructions are one of the most common sources of changing site conditions claims on projects that involve pile driving, shaft/tieback/soil nail drilling, and excavations. Oversized materials observed on the surface may not be encountered during exploratory drilling and thus, the field reconnaissance may be the only record of their occurrence. In addition to boulders and blocks, existing, abandoned structures such as foundations and utility vaults can also be an obstruction to foundation installation and excavation.
- Any landslide features observed in the office study should be examined in addition to any new features discovered during the site reconnaissance. All indicators of unstable slopes such as springs sag ponds, bent tree trunks, disturbed plant communities, abrupt vegetation changes, and hummocky terrain should also be noted. Measurement and delineation of all features and

indications of slope stability should be completed during the reconnaissance. Complete investigation of slope stability affecting a project area necessarily involves areas that may extend a substantial distance away from the proposed alignment.

- The performance of existing and nearby structures should be evaluated during the site reconnaissance. Evidence of settlement, deformation, tilting, or lateral movement can indicate site conditions that possibly will affect the project design and further exacerbate the performance issues during construction.
- At bridge sites, the existing footings should be evaluated with respect to stream scour. Exposed pile caps or footings as well as riprap protection generally indicate that scour has been a concern at the site previously.

2.2.5.3 Preparation for Site Exploration

Potential boring locations should be identified with respect to the preliminary or conceptual plans available at the time of the site reconnaissance. Once the locations are determined, an assessment can be made in connection with how they will be accessed by exploration equipment and personnel. Many projects can be investigated by routine methods with common equipment. However, for some projects, site access can cost almost as much if not more than the actual subsurface exploration itself. Physical site access, traffic control, environmental protection, and many other issues can arise that increase the complexity, and subsequently, the cost of the exploration program. Every site is different, so each must be assessed individually to determine what methods, procedures, equipment, and subcontractors will be needed. Some of the most common issues that need to be addressed are:

- **Traffic Control** – Flagging, lane restrictions, and pilot cars are required when working in or near the travel lanes. In such instances, traffic will need to be controlled for the entire time the exploration crew is on site. In other areas, traffic control may be needed while loading or unloading equipment and supplies. In many areas, lane restrictions are only allowed for nighttime operations. In every case, all efforts will be made to minimize the impact to the traveling public.

- **Equipment Required** – Determining whether the site can be accessed using a standard truck-mounted drill rig or whether a track-mounted drill will be needed. It may also be necessary to consider difficult-access equipment that must be transported by crane, helicopter, or hand-carried.
- **Physical Access** – Considering additional equipment to access a site and analyzing the cost-benefits of their use vs. other drilling equipment and investigative methods. For some sites, bulldozers and excavators may be needed to construct an access road for drilling equipment, barges may be needed for in-water work, and special low-clearance equipment may be needed for work in and around utilities. Where access roads are problematic due to environmentally sensitive areas that need to be avoided, overall impact, cost, and reclamation requirements; alternative equipment or methods should be looked upon as a potential cost or problem-saving measure where the integrity of the exploration information is not compromised.

  For in-stream work, project scheduling becomes a significant issue since restrictions will be imposed on the times of the year when such activities will be allowed. Furthermore, the logistics of carrying out in-water work bring additional requirements such as determining the draft of the barge needed for the depth of the water, how the barge will be anchored, where the barge will be launched from, how the crew will access the barge during a shift change, and determining the effects of tidal or current changes on the drilling operations. A marine surveyor should be engaged for particularly complex over-water operations, and on some waterways, their review of operations is required.

Where bridges are replaced at their present location, and conditions allow, drilling may be conducted through the existing bridge deck although efforts must be made to assure that only the deck and not the superstructure are penetrated.

- **Drilling Conditions** – Where high groundwater levels, deep water, and loose or heaving sands and gravels, and obstructions are anticipated, the appropriate drilling methods and materials should be specified.

- **Materials and Support** – Remote locations may require special considerations for supporting the field crew and the equipment. In this regard, additional logistics may be needed for delivering drilling supplies, fuel, lubricants, etc., and for the timely delivery of samples back to the laboratory and office. All-terrain vehicles may be needed to support the drill crews in such situations, or else preplanning needs to be carried out to schedule or arrange for extra site provision. Locations for drill water should be identified ahead of time, and where an ODOT facility is not available, permits will need to be obtained ahead of time for fire hydrants, private sources, or extraction from streams and lakes.

- **Right of Way** – The methods by which permits of entry for exploration on private property are obtained vary from region to region, and frequently, within a region. For all cases, the region Right of Way section in which the project is taking place should be consulted prior to exploration, and then notified in advance, when and which private properties will be accessed. The Right of Way section manager or their subordinate will recommend either a standard permit of entry form, or they will obtain the permit of entry internally.

  In many instances, private property owners will refuse to grant entry. For these, the Right of Way section will be required to handle the negotiations for site access, and determine the terms and conditions.

- **Utility Conflicts** – During the site visit, the location and type of utilities should be noted. The names and contact information located on the utility risers, stakes, and poles should be recorded. In all cases, the Utility Notification ("One-Call") Center must be contacted at least two working days prior to commencement of site operations at 1-800-332-2344. The One-Call Center will recount the utility services that they will notify based on their records. The geotechnical designer or drilling supervisor will be responsible for notifying any other utilities operating in the area based on their observations of facilities during the site reconnaissance. Responsibility for maintaining the utility location markings during site operations belongs to the field exploration crew.

2.2.5.4 Reconnaissance Documentation

During the field reconnaissance, photographs should be taken of all the predominant features previously discussed. Each photograph should be appropriately labeled with the object of the photo, the direction it was taken, where it was taken from, the date, and ideally, the latitude and longitude of the photograph's origin obtained with GPS equipment.

The observations taken during the site visit should be documented in a memorandum or short reconnaissance report depending on the scope and complexity of the project. The report should provide a list and a description of all the observations made, and the prominent features encountered during the office study and site reconnaissance. Each feature should be located with reference to the project stationing or reference grid. Once again, there is considerable benefit to locating features with GPS equipment for long-term record keeping since project stationing can change, projects can be postponed for long periods of time, and future projects will occur that will utilize this document. Preplanning for geotechnical design is correlative to any other investment; the earlier in the process the work takes place, the longer the benefits can be reaped.

2.3 REFERENCES

- American Association of State Highway and Transportation Officials, Inc., 1988, *Manual on Subsurface Investigations*.
- C.H. Dowding, Ed., *Site Characterization & Exploration*, ASCE Specialty Workshop Proceedings, Northwestern University, 1978.
- U.S. Department of Transportation, Federal Highway Administration Evaluation of Soil and Rock Properties, Geotechnical Engineering Circular No. 5, FHWA-IF-02-034, April 2002.
- Turner, Keith A., and Schuster, Robert L., Eds., *LANDSLIDES Investigation and Mitigation, Transportation Research Board Special Report 247*, 1996, Pages 140-163.
- Geotechnical Investigations, U.S. Army Corps of Engineers Engineering and Design Manual, EM 1110-1-1804, January 2001.

APPENDIX

LIST OF TABLES

APPENDIX 2-A GEOLOGY / GEOTECHNICAL QC MATRIX

Table 2-1 Geology / Geotechnical Matrix Checklist QC Check #1 – Scoping

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Scope									
Project Name and Key Number									
Existing structures, earthworks and known hazards									
Proposed structures and earthworks									
Design Narrative, defined project area									
Project Geography									
Bodies of water									
Terrain Features									
Climate									
Region									
Project Geology									
Province									
Bedrock and Quaternary Geology									
Structural Geology									
Geologic Hazards									
Geomorphology									
Geologic Impacts/Performance of existing structures									
Performance of existing structures									
Previous design efforts in the project area									
Cost Estimates for Proposed Work (Design and Construction)									
Monitoring period									
Summary of findings and project implications									

Table 2-2 Geology / Geotechnical Matrix Checklist QC Check #2 – Scope of Work

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Project Scope									
Schedule of work									
Geology Scope of Work									
Geotechnical Scope of Work									
Rock Slope Scope of Work									
Exploration Scope of Work									
Geology project budget									
Geotechnical project budget									
Rock slopes project budget									
Monitoring period schedule and budget									

Table 2-3 Geology / Geotechnical Matrix Checklist QC Check # 3 – EIS

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Survey of proposed alignments and alternatives									
Bedrock units to be encountered									
Surficial units to be encountered									
Physical geography – effects on proposed alignments and/or slope geometries									
Location									
Extent									
Climate									
Topography									
Geologic Province									
Character of expected geologic units and their performance history									
Geologic hazard potential									
Summary of known geologic hazards									
Summary of known geologic impacts to existing features									
Performance of structures and earthworks along proposed corridors or alignments									
Known geotechnical-related problems in existing structures and earthworks in the proposed project area									
Mitigation methods and costs for potential geotechnical issues									
Geotechnical characterization/estimated properties of geologic units									
Discussion of the performance of project area materials and geologic units									
Correlation of properties of expected materials with similar studies									
Cost-benefit analysis of proposed alignments and/or locations									

Table 2-4 Geology / Geotechnical Matrix Checklist QC Check # 4 – Concept

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Concept Plan Review									
Reconnaissance Report (File Summary Survey)									
Consultation of published literature									
Consultation of unpublished literature									
Aerial photographs and other remote sensing									
Aerial photographs from different years to review varying conditions through time and site history									
As-built plans									
Maintenance records									
Region file survey									
Consultant reports									
RHRS/Unstable slope inventory									
Review of maintenance activities that have affected the site (e.g. rock fall containment, slope stability, drainage)									
Review of geographic and geologic conditions affecting slope stability with respect to conceptual evaluation of landslide/rock fall remediation schemes									
Determine the potential effect of outside stakeholders on the remediation options (USFS, Gorge Commission, Tribal Governments, etc.)									

Table 2-5 Geology / Geotechnical Matrix Checklist QC Check #5 – Exploration Plan

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Exploration Plan									
Exploration Plan Summary									
Survey Requirements									
Work Products									
Scope, Schedule, Budget									
Project Features requiring subsurface investigation									
AASHTO compliance for project features									
Boring/Exploration spacing									
Boring/Exploration depth									
Sampling frequency									
FHWA recommended standard practices for rock slopes									
Evaluation/inclusion of alternative or supplementary exploration methods									
Consideration of alternative tests and/or techniques that would provide better quality and economy									
Appropriate rock slope mapping and drilling programs for the proposed mitigation measure									
Evaluation of the expected site conditions and compatibility with standard exploration procedures									
Minimum explorations for trenchless pipe installation and associated features									
Exploration Plan Review									
Structures and earthworks for exploration									
Proposed exploration at each structure location									

Table 2-6 Geology / Geotechnical Matrix Checklist QC Check #6 – 2/3 TS&L

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Field Exploration Review									
Site-specific field explorations									
Borings									
Test Pits									
Hand-auger holes									
Geophysics									
In-Situ testing									
Site and vicinity reconnaissance									
Project-level geologic mapping									
ASTM conformance									
Drilling methods									
Sampling and testing									
Deviations from standards noted and described									
Review of alternative tests or techniques									
Quantity of samples for laboratory testing (collection and recovery)									
Adequate samples and laboratory testing to characterize and determine the extent of subsurface materials									
Undisturbed samples in cohesive and/or compressible materials									
Core drilling procedures									
ODOT standard core box placement and labeling									
HQ or larger-sized core diameter									
Triple-tube recovery system									
Recovery appropriate for the materials encountered (never less than 80% unless special conditions exist)									
Core specimens labeled and photographed while wetted									
Legible and appropriate core photography									
Specimens removed for laboratory testing replaced in the core box with the appropriate marker									
Drilling techniques correspond to the materials encountered									
Augers used while investigating for the piezometric surface in soil									
Indication where natural moisture content was altered by introduced fluids									

Table 2.6 Geology / Geotechnical Matrix Checklist QC Check #6 – 2/3 TS&L (continued)

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Methods used to determine piezometric surface in rock									
Fluids used to stabilize boreholes in sandy material or other heaving conditions									
Measures to avoid affecting SPT and other testing values and intervals in heaving conditions									
Drilling activities recorded on standard boring log forms									
Fluid return and color changes									
Drill action and rate									
Shift/personnel changes									
Bit wear									
Drilling techniques									
All information used for interpretation of subsurface conditions									
Locations where groundwater was encountered									
Open hole water levels recorded at the beginning of each drilling shift									
Dry holes specifically noted									
Types, quantities, ad depths of backfill and sealing materials									
Soil and rock materials identified, classified, and described according to the current version of the ODOT Soil and Rock Classification Manual									
Complete soil and rock descriptions									
Additional physical properties, diagnostic, or distinguishing features recorded on the logs									
Boring locations surveyed with respect to State Plane Coordinates and true elevations									
Conversion to SPC/true elevation where assumed values are used									
Borings referenced by project stationing									
Borings referenced by bearing and distance to permanent features or reference points in the absence of an existing base map or survey									
Preliminary subsurface drawings and/or model for adjusting exploration according to current findings									

Table 2.6 Geology / Geotechnical Matrix Checklist QC Check #6 – 2/3 TS&L (continued)

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Boreholes abandoned according to Water Resources standards									
Instruments installed according to their purpose (e.g. inclinometers installed below the slide plane, piezometer-sensing zones in the water-bearing strata, etc.)									
Records of piezometer casing type/size, slotted zones, slot size/frequency									
Records of sealing and filter pack placement, sizes and grades of the materials									
VWP Installations									
Manufacturers calibration sheets									
Field calibration results									
Initial reading consistent with manual observation									
Inclinometers									
Appropriate slurry mixture									
Slurry quantity recorded									
Distinct zones of grout-take noted									
A0 direction noted, proper A0 inclinometer alignment									
Tube stick-up recorded									
Water Resources Hole Reports completed correctly and filed within the 30-day requirement									
Appropriate rock mass classification system used to evaluate rock slope excavation performance									
Rock slope surface mapping									
Overburden thickness and type									
Discontinuity thickness, type, surface roughness, spacing, orientation, and shape									
Zones of differential weathering on the slope									
Location and volume of seeps and springs									

Table 2.6 Geology / Geotechnical Matrix Checklist QC Check #6 – 2/3 TS&L (continued)

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Preliminary Geotechnical Recommendations									
TS&L Foundation Design Memo									
Description of proposed project									
Anticipated subsurface conditions									
Preliminary foundation design recommendations									
Foundation types									
Preliminary capacities									
Rational for selecting the recommended foundation type and capacity									
Discussion of liquefaction potential and associated effects									
Suggested retaining wall types									
Preliminary slope recommendations									
Site Model Review									
All exploration locations located on plan view maps referenced to the project									
Plan view maps developed to the appropriate scale to show the necessary features with respect to the overall project									
Appropriate plan map contour interval and labeling									
Borehole collar elevations consistent with nearest contours									
Standard map elements									
Cross-sections, fence diagrams, profiles and/or block diagrams used to display the 3-dimensional distribution of geologic units, features, structures, and engineering properties									
Geologic model consistent with engineering properties of defined units									
Material properties/laboratory testing results recorded on the drill logs									
Laboratory testing used to develop engineering geologic units									

Table 2.6 Geology / Geotechnical Matrix Checklist QC Check #6 – 2/3 TS&L (continued)

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Laboratory testing results displayed graphically to support the engineering geologic model (e.g. graphs or charts plotting engineering properties with depth or along a graphic lithology column)									
Laboratory testing program included samples from each boring or test pit to confirm the field and visual classification									
Laboratory results incorporated into the final drill logs and subsurface model									
Laboratory testing to verify or confirm interpretations or further characterize a unit									

Table 2.6 Geology / Geotechnical Matrix Checklist QC Check #6 – 2/3 TS&L (continued)

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Final drill logs match the interpretive drawings and preliminary drawings for the Geotechnical or Foundation Datasheets									
Clear distinction between observed and inferred features and relationships in the geologic model									
Review laboratory test results to determine if modifications are required in specific geologic units at different locations in the subsurface model									
Process developed to incorporate laboratory testing to assure correct and consistent material classification and description between borings and to develop engineering geologic stratigraphy from the test results									
Review physical properties testing to determine if initially misidentified materials occur elsewhere in the project subsurface									
Related soil classifications modified as a result of physical properties test results									
Results of instrumentation programs match the engineering geologic model									
Geologic model encompasses the project design details to show the effect of the geology on the facility									
Proposed cut lines, excavations, tunnel/pipe alignment, and foundations all plotted in the subsurface model									
Geologic features affecting the design such as seeps, springs, piezometric surfaces, and daylighted adverse structures clearly shown and identified in the model									
Blocky or rubble-zones that could produce over break in rock cuts or excavations									
Boulders or other obstructions in proposed excavations or pile and shaft foundations									
Groundwater surfaces									
Delineation of collapsible or expansive soils									
Cuts or fills on known or potential slide areas									

Table 2.6 Geology / Geotechnical Matrix Checklist QC Check #6 – 2/3 TS&L (continued)

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Foundations in or near bog/marsh areas									
Excavations below the groundwater surface, determination of the amount of water that will be encountered and the effect of piezometric drawdown on groundwater resources									
Delineation of potentially soft subgrade on the project plan map									
Geologic interpretation of materials and stratigraphy incorporates the engineering properties of the strata encountered (e.g. geologic units are subdivided down to the level of distinct engineering properties)									
Cross-cutting relationships established									
Quaternary-aged features and discontinuities identified									
Determine if weak or weathered rock sources identified for use on the project are likely to be friable or nondurable									
Slake Durability testing of exposed rock face material									
Thorough representation of materials tested for strength and compressibility rather than reliance on empirical correlations, especially those based upon Standard Penetration Tests									
Appropriate strength tests conducted to distinguish between drained and undrained conditions where needed									
Determine if the total stress envelope of the CIU test with pore pressure measurements has been used improperly to define the relationship of undrained shear strength with depth									
Determine if the existing and proposed state of stress has been accounted for during strength testing									
Evaluation of consolidation tests: reconciliation of the test-derived preconsolidation pressure with the actual stress history of the sample									

Table 2-7 Geology / Geotechnical Matrix Checklist QC Check #7 – Preliminary Plans

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Engineering Geology Report									
Geotechnical Report									
Rock Slope Report									
Preliminary Geotechnical Datasheets									
Datasheets completed for all required structures or features									
Profiles drawn along project alignment centerlines or specific offsets									
Cross-sections, additional profiles completed to show structure-specific information, or to provide additional information in areas of complex geology									
Sample and property data									
Subsurface model used to develop the Geotechnical Datasheets									
Subsurface information shown on the datasheets matches the final logs									
Drawings made at appropriate scales to show the needed level of detail									
Interpretation shown on the datasheets									
Geotechnical Datasheets completed according to Subsurface Information Policy									
Detail Drawings and Plans									
Review geotechnical items in the bid schedule									
Assure specification writer’s review of geotechnical items in the special provisions									
Review specification writer’s modifications of geotechnical items in the special provisions									
Correct length and locations for buttresses, surface and subsurface water collection and discharge features shown on the plans									
Correct materials called out on the plans									
Sequence of construction for buttresses									

Table 2.7 Geology / Geotechnical Matrix Checklist QC Check #7 – Preliminary Plans (continued)

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Staged construction sequence for surcharging, wick drains, and ground improvement									
Appropriate drainage discharge locations									
Recontouring of slide areas clearly shown									
Surface water drainage in slide areas addressed in the plans or detail drawings									
Buttress, drainage, or other features shown with the correct elevations and dimensions									
Slope protection mat and rock fall protection fences									
Mesh type									
Anchor spacing									
Quantities									
Special provisions, including those for high-impact fences									
Standard Drawings included in the plans									
Special access issues and requirements									
Standard drawings and special provisions for PVC-coated mesh									
Rock Bolts and Dowels									
Design Loads									
Design Lengths									
Locations									
Quantities									
Corrosion protection									
Performance and proof-testing requirements									
Reference to the Qualified Products List									
Rock fall Retaining Structures									
Type, Size, and Location									
Quantities									
Slopes (Rock fall Protection Berms)									
Backfill type specifications									
Special Provisions									
Rock Slope Drainage									
Location									
Drain lengths									
Drain angles and orientations									
Quantities									
Water collection and disposal									

Table 2.7 Geology / Geotechnical Matrix Checklist QC Check #7 – Preliminary Plans (continued)

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Shotcrete									
Locations									
Areas of coverage									
Quantities									
Anchorage									
Reinforcement									
Standard drawings and details									
Drainage									
Performance requirements									
Installation details									
Temporary Rock fall Protection									
Review type for suitability									
Locations									
Length									
Height									
Required materials and quantity									
Details									
Rock Blasting and Rock Excavation									
Quantity of Controlled Blast Holes									
Overburden slopes and slope breaks shown on the plans									
Special Provisions									
Blast Consultants									
Noise/vibration monitoring									
Preblast survey									
Blasting plan review									

Table 2-8 Geology / Geotechnical Matrix Checklist QC Check #8 – Advanced Plans

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Preliminary Wall Drawings									
Review subsurface information on Geotechnical Datasheets for retaining structures									
Retaining Wall Drawing Review									
Type, Size, Location, Height, Backslope									
Quantities									
Backfill types									
Wall drainage									
Special Provisions									
Design Changes and Addenda									
Design calculations for added structures and features									
Design calculations for structures and features that have moved									
Review design assumptions									
Changed Criteria									
Changed Type, Size, Location									
Changed Quantities									
Additional exploration requirements for added structures or features									
Appropriate exploration carried out for added structures or features									
New data incorporated into the overall geologic interpretation									
Further characterization of geologic units with additional data									
Resolution or confirmation of previous inferences and interpretation									
Additional risk assessment									

Table 2-9 Geology / Geotechnical Matrix Checklist QC Check #9 – Final Plans

	Geology			Geotech			Rock Slopes		
	YES	NO	N/A	YES	NO	N/A	YES	NO	N/A
Final Plan Review									
Geotechnical or Foundation Datasheets completed for all structures, facilities, ad features for which they are required									
Geotechnical Datasheets completed according to Subsurface Information Policy									
Engineer or Geologist has stamped all sheets that they are responsible for									
Information provided on the datasheets exactly matches what is presented on the final logs and in the Engineering Geology report									
Final review of detail and plan sheets									
Final review of bid item quantities									
Final review of Special Provisions									

APPENDIX 2-B OLD ROADWAY AND GEO-HYDRO SECTION FILE RETRIEVAL

These are project files that were developed between about 1930 and 2004. The bulk of the files are from the old Roadway Section Geotechnical Group and typically involve landslide and rockfall repairs, embankment design and other roadway geotechnical work performed statewide during this time period. Bridge and retaining wall foundation design work was done in the Bridge Section Foundation Unit up until about 1997 and those project files can be found in the ODOT Bridge Section archives. In 1997 the old Bridge Foundation Unit and the Geotechnical Group (which was under the Roadway Design Section) were combined (along with the bridge and roadway hydraulics units) to become a new ODOT Geo-Hydro Section. From 1997 to about 2000, Region Geology Sections were gradually incorporated into the Geo-Hydro Section until there was a statewide Geo-Hydro Section. Then in 2004, the ODOT reorganization plan decentralized G-H section personnel back to the individual regions and Salem headquarters.

Therefore, geotechnical project files in the state archive system consist of the following:

> 1930 – 1997: Project files from the original Roadway Geotechnical Group; these are statewide highway projects, typically roadway related only (no bridgework)
>
> 1997 – 2004: Project files for statewide roadway and bridge work (Bridge Foundation Unit and Roadway Geotechnical Groups were combined)

After 2004, all geo-project work was relocated to the regions and all new project files should be found in each regions filing system.

APPENDIX 2-C BRIDGE SECTION FILE ARCHIVE RETRIEVAL

The following information should be supplied to the HQ Bridge Section to find project files in the Bridge Archives:

- Contract Number
- Bridge Name
- Bridge Number
- Section Name

This is the information that is most likely typed on the archive project file labels and recorded in the Bridge Section archives database. The following narrative and instructions are intended for ODOT personnel with access to ODOT computer servers and databases. Outside agencies and consultants should contact the HQ Bridge Section for assistance in retrieving Bridge Section archive files.

Many projects have more than one bridge included in the project files and not all the bridge numbers are listed on the contract file labels and, if so, they are not recorded in the archive database. If you search the archive data based on the bridge number alone and do not find the file(s) this way, they may still be there. If the files are not found using just the bridge number, then find and search by the contract number of the project that constructed the bridge to see if the bridge files can be found that way. In addition, when there was more than one bridge in a project, the contract file label typically listed only the lowest bridge number of all the bridges in the project.

Finding the Contract Number: Searching by contract number is the best way to find the project file. Contract numbers are not in the BDS and one way to find them is using the FileNet database of scanned roadway plans (similar to the BDS). Once you are logged into FileNet, go to "Map Center" and then "Contract Plan Search." Search the database using the bridge number, project title, highway/M.P., or other information to find the plans set that contains your bridge. Once you are sure you have the right project, click on the "Contract Plans Properties" link (little link in the third column, next to Project Title) and the project's contract number is in there. Also, take note if any other bridges were built on the project with LOWER bridge numbers than the one you are looking for.

Search the bridge archives using the Contract Number, Section Name, and Bridge Number and also by the LOWEST bridge number in the project.