County of Los Angeles
Department of Public Works

Manual for Preparation of Geotechnical Reports

July 1, 2013

GEOTECHNICAL AND MATERIALS

ENGINEERING DIVISION

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Guidelines for Preparing Engineering Geology Reports
(James E. Slosson, Revised 1992 - in Association of Engineering Geologists Special Publication #5, *Professional Practice Handbook*, Ch. 2, 3rd Edition, published 1993)

Guidelines for Evaluating the Hazard of Surface Fault Rupture - California Geological Survey (CGS) Note 49 (2002)

Guidelines for Engineering Geology Reports (1998)
(Board for Geologists and Geophysicists)

Geologic Guidelines for Earthquake and/or Fault Hazard Reports (1998)
(Board for Geologists and Geophysicists)

1.0 INTRODUCTION

This manual presents the requirements for geotechnical work for development projects within the County of Los Angeles (County). Many civil engineering projects require geotechnical investigations with input from both an engineering geologist licensed in the State of California (engineering geologist) and a civil engineer, licensed in the State of California, experienced in the field of soil mechanics, or a geotechnical engineer licensed in the State of California (soils engineer) in accordance with the Los Angeles County Subdivisions Code (Code of Ordinances Title 21) (LACSC) Section 21.48.050.8 and the 2011 County of Los Angeles Building Code (Code of Ordinances Title 26) (CLABC) Section 111.

Tentative subdivision maps and grading and building plan submittals that are required to have engineering geology and/or soils engineering reports shall include the relevant report recommendations on the maps and plans. Any map or plan that does not conform to the recommendations of the supporting report(s) will not be recommended for approval until the discrepancies are resolved.

We will be discussing three different types of reports prepared in support of plan submittals. For the purpose of this manual ***only***, the following are clarifications of report types:

- Engineering Geology Report – An engineering geology report submitted for review shall have been prepared by, or under the responsible charge of, an engineering geologist licensed in the State of California. The exception is when an engineering geology report is prepared solely for the purposes of an earthquake fault investigation, which allows for the report to be prepared by, or under the responsible charge of, a professional geologist licensed in the State of California.

- Soils Engineering Report – A soils engineering report submitted for review shall have been prepared by, or under the responsible charge of, a civil engineer, licensed in the State of California, experienced in the field of soil mechanics, or a geotechnical engineer licensed in the State of California.

- Geotechnical Report – A geotechnical report submitted for review shall have been prepared by, or under the responsible charge of, both an engineering geologist licensed in the State of California *and* a civil engineer, licensed in the State of California, experienced in the field of soil mechanics, or a geotechnical engineer licensed in the State of California.

Notes:

- Reports that are submitted for review may have a variety of titles, such as preliminary geotechnical investigation, geotechnical assessment, foundation exploration report, geotechnical design report, rough grading report, final geology report, and so on. For the purpose of this manual, the determination as to which of the three types of reports it is will be based on the licenses and signatures on the report itself. Subsequent sections of this manual may refer to "geotechnical reports" as a generic term for both soils engineering and geotechnical reports.

- References in this manual to "geotechnical consultants" are used to indicate the professional geologist, engineering geologist, civil engineer experienced in the field of soil mechanics, geotechnical engineer, or appropriate combination thereof, who are responsible for the appropriate geotechnical issues addressed or made part of the map and/or plan submittals.

- Mitigation measures and corrective work are terms that may be synonymous in many situations for addressing geologic and geotechnical hazards. However, we feel it is important to note that some measures may be needed to protect a site from offsite hazards, especially when the hazard is not directly able to be removed. For example, a debris flow may originate from an offsite property and a debris wall may be necessary to mitigate the hazard. But if the debris is generated onsite, it may be possible to implement corrective work to remove the debris and eliminate the debris hazard. For the purpose of this manual we may use the terms of mitigation measures and corrective work interchangeably even when the final connotation may actually mean one, the other, or both.

When engineering geology and soils engineering reports are required, the geotechnical consultants shall coordinate their reports for the submission to any or all of the County of Los Angeles Department of Public Works Divisions (Public Works). The results of the investigations may be presented separately or prepared together and submitted as a geotechnical report.

The purpose of this manual is to provide geotechnical consultants with the information necessary to prepare adequate and acceptable reports, and to address questions commonly asked by consultants and the public. It is not the purpose of these guidelines to establish rigid requirements, but rather to act as a guide for the preparation of engineering geology and geotechnical reports to meet the requirements of County Codes and other governmental regulations, policies, and criteria.

Although this manual is updated periodically, written County Codes and policies are subject to revision and the most current versions may not be represented in this document. The County of Los Angeles Department of Public Works Geotechnical and Materials Engineering Division (GMED) may notify geotechnical consultants of substantive changes to this manual and GMED Directives via direct mail or publication in local society newsletters [e.g., Association of Environmental & Engineering Geologists (AEG), American Society of Civil Engineers (ASCE)]. Should a question arise, it is recommended that geotechnical consultants contact the Public Works Geotechnical Development Review Units directly for clarification.

All geotechnical (engineering geology and soils engineering) reports, letters, addenda, and review sheet responses submitted shall be in hardcopy format and also in an electronic version on a compact disc or flash drive in Adobe® Portable Document Format (PDF) with searchable text and that include all maps, tables, figures, cross sections, etc. associated with the report. The electronic version shall include an electronically generated representation of the licensee's seal, signature, and date of signing. Projects cannot be approved until this requirement has been met. At this time we cannot accept reports submitted via e-mail.

All engineering geology and geotechnical reports submitted to this office must be appropriately manually wet signed and wet stamped by the engineering geologist and soils engineer.

Comments and questions about this manual may be directed to Charles Nestle (Engineering Geology) at cnestle@dpw.lacounty.gov or (626) 458-4923, or to Brian Smith (Soils Engineering) at bsmith@dpw.lacounty.gov or (626) 458-4925.

2.0 ENGINEERING GEOLOGY REPORTS

The following guidelines are for engineering geology reports prepared by California State licensed Engineering Geologists for compliance with governmental regulations. These guidelines are intended to supplement those outlined by the California State Board of Professional Engineers, Land Surveyors, and Geologists (BPELSG), California Geological Survey (CGS) [formerly California Division of Mines and Geology (DMG)], the United States Geological Survey (USGS), and other professional organizations. Copies of some pertinent references are found in the Appendix and links to others are provided in the "Additional Resources" section. It cannot be overemphasized that these are ***minimum*** standards and that the geologic conditions on many project sites may warrant that these standards be exceeded.

2.1 GENERAL GUIDELINES

Various guidelines have been prepared by CGS, AEG, BPELSG, and the former California Department of Consumer Affairs Board for Geologists and Geophysicists to assist in the preparation of engineering geology and fault hazard/seismic reports. The *Guidelines for Preparing Engineering Geology Reports* in the 1993 AEG *Professional Practice Handbook*, The CGS Note 49 *Guidelines for Evaluating the Hazard of Surface Fault Rupture*, and the Board for Geologists and Geophysicists *Guidelines for Engineering Geology Reports* and *Geologic Guidelines for Earthquake and/or Fault Hazard Reports* are included in the Appendix of this Manual for your use and reference. In addition, to those references the *Manual of Field Geology* (Compton, 1962) is an excellent resource and contains a chapter entitled *Preparing Geologic Reports* (Chapter 11).

The *Guidelines for Evaluating and Mitigating Seismic Hazards in California* (CGS Special Publication 117A, 2009), the *Probabilistic Seismic Hazard Assessment for the State of California* (DMG Open File Report 96-08), and the *Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Liquefaction in California* [Southern California Earthquake Center (SCEC), 1999] are particularly applicable for preparation of the seismic portion of an engineering geology report. It is important to understand the definition of a "Project" as defined in the above documents to determine if the proposed development must meet the requirements of those documents.

The proposed development, site conditions, and most importantly, the nature and extent of potential geotechnical hazards, ultimately dictate the scope of the investigation and the applicability of these or any other guidelines.

Seismic criteria and requirements for structural design of buildings are the responsibility of the Building Official; therefore, the Geotechnical Development Review Units shall consider only those aspects of seismic criteria that may affect ground failure potential.

Varying geologic conditions, purposes, and project proposals will require reports of different length, scope, and orientation. Nevertheless, for an engineering geology report to be considered adequate for a typical hillside site and plan, it should at a minimum, include the following:

- An evaluation of at least one set of stereo aerial photographs for the potential presence of landslides and/or faults.

- A review of published maps of the CGS, USGS, State Seismic Hazard Mapping Act, and Alquist-Priolo Earthquake Fault Zoning Act.

- A review of GMED's Development Review files of adjoining properties, and published and unpublished maps of the USGS and CGS. Discrepancies between researched data and data obtained by the consultant must be resolved.

- An <u>accurate</u> site location map.

- A regional geologic map and, if necessary to address site stability, regional cross sections.

- A site geologic map and geologic cross sections to illustrate local geologic structure and stratigraphy.

- Exploration data to substantiate geometry and geologic conditions.

- Identification of potential failure surfaces and modes of failure based upon geologic structure and stratigraphy.

- Plot of geology versus depth of data obtained in exploration borings on geologic maps and cross sections for assessment of site stability.

- An explanation of how the geologic data presented substantiates the report's conclusions.

A full and complete presentation of all pertinent geologic data and factors must be included in the report. The conclusions and recommendations presented in the report must be fully supported by the data and must be based on the most logical analysis. Addenda engineering geology reports may be requested for additional information and supporting data to substantiate regulatory compliance and professional opinions.

Preparers of reports must consider existing available data for a site or plan evaluation. The geotechnical consultant is advised that all available geologic data from existing Public Works files and from adjacent developments to the particular site being studied will be used in the review process. Discrepancies between the submitted reports and on-file pertinent data must be resolved before the subdivision maps and/or plans can be recommended for approval. Adjacent property files used or reviewed by the geotechnical consultant should be referenced in submitted reports.

2.2 TYPES OF ENGINEERING GEOLOGY REPORTS

Different types of engineering geology reports are required depending upon the stage of development review or approval requested, such as environmental impact, tentative subdivision, final map recordation, building or grading permit, rough grading, etc. The general scope of reports required for purposes of the various development stages are provided below. Additional details for review and processing of these reports are found in applicable GMED "GS" Directives in the Appendix.

2.2.1 Environmental Impact Documents (Geologic Portion)

The scope of the engineering geology report must be sufficient to identify existing and potential geologic hazards and to present measures to mitigate their effects on the environment relative to the proposed development project. The investigation in preparation of the report should provide sufficient data to determine the extent of work required to mitigate any potential geologic hazards.

2.2.2 Tentative Subdivision Map Reports

All engineering geology reports submitted for the purpose of determining development feasibility of a tentative subdivision map must be based on the latest tentative map submitted to the Los Angeles County Department of Regional Planning (Regional Planning). Sufficient geologic information must be presented to demonstrate that the site is suitable for the proposed development as designed and that existing or potential geologic conditions have been identified, their effect on development established, and adequate mitigative measures and design provided.

A copy of the tentative map must be used as a base for the geologic map. Cross sections must be provided through landslides, high-cut slopes or those requiring stabilization, high fill slopes requiring slope stability analyses, and over-steepened natural slopes or those with potentially unstable conditions. Confirmation of geotechnical mitigative design in peripheral areas of subdivisions in hillside terrain must be provided where offsite properties may be affected or where offsite access for remediation could be inhibited.
Generally, the scale of the tentative map should be sufficient for geologic purposes (minimum 1 inch = 100 feet). In some cases, the consultant or reviewer may deem it necessary for a more detailed map and cross sections to be prepared.

2.2.2.1 *Digital Submittal Ordinance*

LACSC Sections 21.40.040 and 21.40.080 require geology and soils engineering reports prepared for new tentative maps submitted through Regional Planning to be submitted in digital format. Each report must be submitted in hardcopy format and also in an electronic version on a compact disc or flash drive in Adobe® Portable Document Format (PDF) with searchable text and that include all maps, tables, figures, cross sections, etc. associated with the report.

2.2.2.2 *Subdivision of a Landslide*

By policy, landslides may not be subdivided. Proposed lot lines must be located such that the landslide is located entirely within one lot, or the landslide must be stabilized. Hazards from landslides must be evaluated as outlined in this manual and must be remediated for proposed building areas on lots within the subdivision. Each lot of a subdivision must have a safe buildable area.

Where an existing landslide affects an adjacent lot within the same subdivision or adjacent properties, Directive GS086.0 (see Appendix) requires the landslide to be evaluated as outlined in this manual.

2.2.2.3 *Ungraded Site Lots*

The Los Angeles County Subdivisions Code (LACSC) and Planning and Zoning Code state that every lot must have a building site safe for the intended use. In addition, LACSC Section 21.24.010 requires that access free of geotechnical hazards must be provided for each lot. Any geotechnical hazards, which must be removed in order to provide a building site and access, generally must be mitigated before the tract or parcel map may be recorded.

Some developments may be subdivided into lots where the specific types and locations of structures have not been determined and/or the developers do not intend to perform any grading or required corrective measures prior to the recordation of the final subdivision map (Final Map). These types of developments may be designated as "Ungraded Site Lots" and the subdivision recorded in accordance with GMED's Directive GS001.0 (see Appendix) criteria and requirements.

2.2.3 Restricted Use Area Letter/Report

The "Restricted Use Area" (RUA) report/letter is part of the geotechnical subdivision recordation process. GMED's Directives GS051.0 and GS063.0 (see Appendix) provide specific details regarding the requirements for this process.

All geologic hazards, such as landslides, debris flows, and active fault traces that may affect a proposed subdivision must be mitigated. In some cases, if it can be demonstrated that the hazard will not affect buildable areas, the geotechnical consultants may recommend that the area affected by the hazard be designated as a RUA. Only unmitigated geologic hazards and the areas underlain by geotextiles used in the support of slopes or retaining walls may be designated as a RUA and the application of this process is subject to the approval of the geotechnical reviewers. RUAs are easements dedicating to Los Angeles County the right to restrict building within those areas.

Prior to recordation of a subdivision, a letter or report is required to be submitted by the engineering geologist and soils engineer that states whether or not RUAs are recommended. If so, the RUA letter must provide a discussion of the basis for its delineation, and include a geotechnical map that depicts the boundaries of the RUA. Once established by the consultant and approved by the geotechnical reviewers, the RUA must be labeled as "Restricted Use Area" on the recorded Final Map.

2.2.4 Grading Plan Reports

The report shall present all the geological information for the area pertinent to the proposed grading. Cross sections of existing and proposed significant slopes that may be unstable must be included. The geologic map must utilize a copy of the latest grading plan as a base. The scale of the map should be appropriate to permit sufficiently accurate measurements for analysis of remedial design and construction. Generally, for geologic purposes, the scale of the map and cross sections should be prepared at a minimum scale of 1 inch = 40 feet. If the grading plan is revised, the geologic map and cross sections should also be revised using the new plan as a base.

Geotechnical consultants must manually sign and date copies of the grading plan to verify that their recommendations have been incorporated in the grading design and are shown correctly on the plans. At the grading plan review stage, engineering geology reports prepared to address a tentative map are commonly requested to be expanded to provide additional exploration, detailed analysis, and testing.

Reports addressing grading plans must demonstrate that the proposed grading (and by implication the proposed future structures) will be stable and safe from geologic hazards. Grading in areas that have factors of safety for gross static stability less than 1.5 will not be approved except for certain situations as defined in GMED's Directives. Where onsite sewage disposal is necessary, the reports must include data, analysis, and recommendations to assure that effluent will not "daylight" on the surface, create instability or adversely affect adjacent property.

2.2.5 Fault Investigation Reports

2.2.5.1 *General Requirements*

The following is paraphrased from the 2011 County of Los Angeles Building Code:

SECTION 113 - EARTHQUAKE FAULTS

113.1 General. The construction of a building or structure near a known active earthquake fault and regulated by this Code shall be permitted as set forth in this Section.

113.2 Scope. The provisions of this Section shall apply only to permits for buildings or structures on individual lots or parcels and are not intended to be supplementary to geologic investigations required to qualify divisions of land as set forth in Title 21 of the *Los Angeles County Code, the Subdivision Code*.

113.3 Definition. For the purpose of this Section, a geologist shall be a professional geologist, licensed by the California State Board of Professional Engineering, Land Surveyors, and Geologists to practice geology in California.

113.4 Known active earthquake faults. For the purpose of this Section, known active earthquake faults are those faults which have had displacement within Holocene time (approximately the last 11,000 years) as defined in the most current issue of CGS Special Publication 42 (see Additional Resources).

113.5 Construction Limitations. No building or structure shall be constructed over or upon the trace of a known active earthquake fault which is shown on maps maintained by the Building Official. These maps include, but are not limited to, Earthquake Fault Zone Maps prepared under *California Public Resources Code* (CPRC) Chapter 7.5 of Division 2 (also known as Alquist-Priolo Earthquake Fault Zoning Act), Sections 2622 and 2623.

The absence of a known active earthquake fault trace at the proposed building location shall be determined by a professional geologist licensed in the State of California in the following cases:

1. When the proposed building is within 50 feet of that line designated by the Building Official as the assumed location of a known active earthquake fault on the aforementioned maps.

2. When the proposed building is within 50 feet of the most probable ground location of the trace of a known active earthquake fault shown on the aforementioned maps.

In these cases, the Building Official may require the excavation of a trench for the purpose of determining the existence of an active earthquake fault. Such a trench will be required if a lack of distinguishable fault features in the vicinity prevents the building official from determining by a site examination, review of available aerial photographs, or by other means that the fault trace does not underlie the proposed building. The trench shall be approximately perpendicular to the most probable direction of the fault trace, at least 1-1/2 feet wide, and at least 5 feet in depth measured from natural grade or to a depth satisfactory to the building official.

> Note: All fault investigation excavations must extend through the Holocene and into Pleistocene deposits in order to clearly define or eliminate the possibility of Holocene fault activity.

The trench must be accessible for mapping and inspection by the Building Official, when requested, and meet the requirements of *California Code of Regulations*, *Construction Safety Orders* (Title 8, Division 1, Chapter 4, Subchapter 4). The trench need not extend further than the full width of the proposed structure plus 5 feet beyond the traversed exterior walls. A known active earthquake fault shall be presumed nonexistent if an exposure is not found by the Building Official or a geologist in the walls or floor of the trench.

The Building Official may require a more extensive investigation by a professional geologist as evidence to the absence of a known active earthquake fault prior to the issuance of a permit for Groups A, E, I, H, R-1 and R-2 Occupancies; and B, F, M, and S Occupancies over one-story in height.

The results of the investigation, conclusions, and recommendations shall be presented in a geology report prepared by a professional geologist as defined by CLABC Section 113.3. The report shall comply with the guidelines presented in CGS Note 49 (see Appendix).

EXCEPTION: The provisions of this Subsection do not apply to:

1. One-story, detached light-frame buildings not intended or used for human occupancy and not exceeding 1,000 square feet in gross-foot area or 12 feet in building height.

2. Alterations or repairs to an existing building provided that the aggregate value of such work within any 12-month period does not exceed 50 percent of the value of the existing building. For the purposes of this, CLABC Section 113.5 "Alternation" does not include an addition or additions.

113.6 Maps of active faults. Public Works shall maintain maps available to the public showing the location of known active earthquake faults. In the absence of additional information, the location of known active earthquake faults shall be as shown on Earthquake Fault Zone maps as required by CLABC Section 112.

113.7 Earthquake fault zones. Work within the earthquake fault zones established under CPRC Sections 2622 and 2623 shall comply with State laws, policies, criteria, rules, and regulations applicable to such work. Fees established by the Alquist-Priolo Earthquake Fault Zoning Act (APEFZ Act) shall be collected and disbursed as required by State law.

In addition to the State regulations, the provisions of this Section shall apply when geologic investigations, mapping, aerial photographs, other acceptable data or Earthquake Fault Zones Maps show the location of a known active earthquake fault as defined by CLABC Section 113.4.

2.2.5.2 *Active Fault*

The *Policies And Criteria Of The State Mining And Geology Board With Reference To The Alquist-Priolo Earthquake Fault Zoning Act* [*California Code of Regulations*, Title 14, Article 3] (APEFZ Act Policies) Section 3601(a) defines an active fault as "one which has had surface displacement within Holocene time (about the last 11,000 years)." This definition is followed in CGS Special Publication 42 (SP42), interim revision dated 2007, Page No. 5 by: "This definition does not, of course, mean that faults having no evidence for surface displacement within Holocene time are necessarily inactive. A fault may be presumed to be inactive based on satisfactory geologic evidence; however, the evidence necessary to prove inactivity sometimes is difficult to obtain and locally may not exist."

Surface rupture of an active fault in a depositional environment could subsequently be covered by additional material, and would, therefore, not necessarily have ruptured the current ground surface, yet still have had activity in Holocene time. Therefore, Los Angeles County considers a fault active if it has displaced Holocene materials, and requires a fault investigation to penetrate the Holocene-Pleistocene boundary. All fault investigation excavations must extend through the Holocene and into Pleistocene deposits in order to demonstrate the lack of Holocene fault activity. If appropriate data cannot be provided, then the presence of an active fault trace within the area of investigation must be assumed.

2.2.5.3 *Fault Setback Requirements*

Los Angeles County has not established a minimum setback from the trace of an active fault. CLABC Section 113.5 states that, "no building or structure shall be constructed over or upon the trace of a known active earthquake fault…." The same Section states that a geology investigation is required "when the proposed building is within 50 feet of the assumed location of a known active earthquake fault..." or "when the proposed building is within 50 feet of the most probable ground location of a trace of a known active earthquake fault...."

The APEFZ Act also does not establish a minimum fault setback. APEFZ Act Policies Section 3603(a) of the APEFZ Act states that "the area within 50 feet of such active faults shall be presumed to be underlain by active fault branches of that fault unless proven otherwise...." CPRC Section 2621.6 requires fault studies for "Projects" (defined as subdivisions of land, any commercial development, and a development of four or more single-family residences), but does not require a fault study for a single-family wood frame dwelling.

The building setback from an active fault trace is recommended by the consulting geologist investigating the property. Many geologists recommend a 50-foot fault setback; however, smaller setbacks may be recommended by some geotechnical consultants based on the data obtained during the fault investigation.

2.2.5.4 *Single-Family Residential Development*

Fault investigations for single-family residential developments are governed by the CLABC and are required whenever the proposed building location may be underlain by the surface trace of an active fault.

CLABC Section 113.5 states that "no building or structure shall be constructed over or upon the trace of a known active earthquake fault...." The same Section states that a geology investigation is required "when the proposed building is within 50 feet of the assumed location of a known active earthquake fault..." or "when the proposed building is within 50 feet of the most probable ground location of a trace of a known active earthquake fault...."

All available fault maps such as the State Alquist-Priolo Earthquake Fault Zones maps, CGS and USGS Open File Reports, various published and unpublished fault maps, and geotechnical consultant reports for nearby properties are used to make this determination.

2.2.5.5 *Commercial Development*

Fault investigations for commercial developments are governed by the CLABC *and* the APEFZ Act (commercial development is defined as a “Project” by the APEFZ Act). Therefore, a fault investigation for a commercial development is required whenever the proposed building location may be underlain by the surface trace of an active fault, and/or if the property, or a portion of the property lies within the boundaries of an Alquist-Priolo Earthquake Fault Zone.

The APEFZ Act or, more specifically, CPRC Section 2621.6 requires fault studies for “structures for human occupancy...” when they are located within zones of active faulting as mapped by the State. The APEFZ Act also states that "the area within 50 feet of such active faults shall be presumed to be underlain by active fault branches of that fault unless proven otherwise..." APEFZ Act Policies Section 3603(a).

Additionally, CLABC Section 113.5 states that "no building or structure shall be constructed over or upon the trace of a known active earthquake fault...." The same Section states that a geology investigation is required "when the proposed building is within 50 feet of the assumed location of a known active earthquake fault..." or "when the proposed building is within 50 feet of the most probable ground location of a trace of a known active earthquake fault...."

2.2.5.6 *Subdivision Development*

A fault investigation for a tentative subdivision of land is required whenever the property or a portion of the property to be subdivided lies within the boundaries of an Alquist-Priolo Earthquake Fault Zone, or if the property or a portion of the property may be underlain by a fault that, based on available information, is considered active by the County.

The APEFZ Act requires fault studies for subdivisions of land within zones of active faulting as mapped by the State (Section 2621.6). The APEFZ Act also states that "the area within 50 feet of such active faults shall be presumed to be underlain by active fault branches of that fault unless proven otherwise..." APEFZ Act Policies Section 3603(a). Additionally, CGS SP42 states on Page No. 6 that "Zone boundaries on early maps were positioned about 660 feet (200 meters) away from the fault traces to accommodate imprecise locations of the faults and possible existence of active branches. The policy since 1977 is to position the *EFZ* boundary about 500 feet (150 meters) away from major active faults and about 200 to 300 feet (60 to 90 meters) away from well-defined, minor faults." The County interprets these statements to imply that an active fault trace may be present anywhere within the boundary of an Alquist-Priolo Earthquake Fault Zone; therefore, all areas within the project site must be investigated per the requirements of the APEFZ Act. In some cases, the County may allow areas of potential faulting to be designated as "Restricted Use Areas" in lieu of investigation.

2.2.6 Seismic Hazard Evaluation Reports

2.2.6.1 *Residential Development*

CLABC Section 1802.2.7 sets forth the requirement for structures determined to be in Seismic Design Categories D, E, and F. See Directive GS045.0 (see Appendix) for application to Single-Family Residential Development.

2.2.6.2 *Commercial Development*

Proposed commercial structures must comply with the requirements of *California Public Resources Code* Chapter 7.8 of Division 2, Sections 2690 through 2699.6 (also known as the Seismic Hazards Mapping Act). However, CPRC Section 2693(d)(2) states that a "Project" does not include alterations or additions to any structure within a seismic hazard zone that do not exceed either 50 percent of the value of the structure or 50 percent of the existing floor area of the structure.

2.2.6.3 *Subdivision Development*

All areas within proposed tentative subdivision maps and all subdivision grading plans must comply with the requirements of the Seismic Hazards Mapping Act (SHMA) and all other applicable County Codes and policies.

2.2.7 In-Grading Geology Reports

During grading operations sufficient geologic inspections must be made by the geotechnical consultant to assure that all geologic conditions are as anticipated and that any geotechnical remediation is completed per their recommendations. Periodic in-grading inspection reports are generally required during project construction. If unanticipated adverse conditions are encountered, the Building Official may require that the construction cease until the impact of the conditions can be properly assessed.
The primary purposes of in-grading geotechnical reports are to inform the Public Works Geotechnical Development Review Units of the following:

- Grading status;
- Any unanticipated geologic conditions encountered;
- Compliance with the geotechnical consultants' recommendations; and
- Any revised recommendations and/or corrective measures.

Adequate inspections must be performed by the engineering geologist. Canyon clean-outs and buttress and shear keys must be inspected and approved by the engineering geologist prior to the placement of any fill. The geotechnical consultants must work together in determining the need for subdrains and the extent of removals of loose surficial materials and/or landslide debris.

If a design change is made during grading, the geotechnical consultants should immediately notify the geotechnical reviewers to determine if review of the revised design will be required prior to its construction.

2.2.8 Reconstruction Reports (Geologic Hazard Damage)

Unless otherwise exempted by the CLABC and Public Works policies, geotechnical reports and remediation for reconstruction must meet the same current County Codes and policy requirements for new construction. The applicant is encouraged to contact the Building Official's representatives at the Building and Safety District Office (BSD) for guidance regarding proposed repair of damages from ground failure, such as from landsliding or earthquakes. The BSD may, at their discretion, require the proposed work be reviewed by the Geotechnical Development Review Units.

2.2.9 Final Geology Reports

At the completion of rough grading, and prior to geotechnical approval of the completed grading, the engineering geologist is commonly required to submit a final geology report with a geologic map based on the as-graded plan. Additionally, one or more as-graded geologic cross sections may be required. The purpose of final geology report is to:

- Present the results of any additional mapping performed during grading (including buttress/stabilization fill back cuts, removal bottoms, etc.);
- Obtain the geotechnical consultants' specific approval of rough grading;
- Show and discuss any change in geology that may have been encountered and the effect of those changes on the recommendations incorporated in the approved grading plans;
- Location of subdrains and other drainage structures incorporated into the fill; and
- Present recommendations for proposed structures and for any proposed onsite sewage disposal systems.

The engineering geologist must include in the final geology report a finding regarding the safety of the completed grading and any proposed structures against hazard from landslide, settlement, or slippage (see CLABC Section J105.12.3) and a statement that, to the best of their knowledge, the work within their area of responsibility is in accordance with their reports and applicable provisions of the CLABC.

The final geologic map must be based on a map showing original topographic contours and post-site grading (as-built) contours. This data becomes a permanent record and may be used to assess future grading or construction projects. It may also be used to evaluate any problems should they arise.

A final geology report should contain references to all existing reports applicable to the grading. Those not previously submitted should accompany the final geology report, to expedite geologic approval of rough grading.

The final geologic map should, at a minimum, include the following:

- Geology as exposed by the grading in natural slope areas in sufficient detail to justify the engineering geologist's conclusions that the site will be safe for the intended use;

- Areas containing fill;

- Tract, parcel, lot numbers, and their boundaries corresponding to the subdivision map;

- All geologic data collected prior to and during grading;

- Geologic data collected in back cuts, shear keys, buttresses, and excavations; and

- Location of all final geologic cross-sections, subdrains, springs or seeps, shear key (fill) excavations, buttress fills, approved sewage disposal area, special replacement fills, recommended "Restricted Use Areas", geologic hazard setback lines, landslides removed and/or not removed by grading, pertinent geology of the adjoining natural terrain, exploratory excavations and borings not removed by grading, areas of over-excavation and replacement, and sufficient geologic symbols to clearly depict site geology.

If the Geotechnical Development Review Units determine that the final geology report and/or map is not sufficiently detailed to substantiate the safety and stability of the site for the intended use, the recommendation for the rough grading approval will be withheld until the safety and stability of the site can be demonstrated.

When the geologic map and/or final geology report information is in conflict with field observations, the recommendation for the rough grading approval will be withheld until the conflicts are resolved.

2.2.10 Building Plan Reports (Hillside Developments)

The report shall present all the geological information relevant to the stability of the project area, with cross sections of all slopes that may be unstable. The geologic map and cross sections must be prepared utilizing a copy of the latest foundation/building plan with existing topography as a base. Generally, for geologic purposes, the scale of the map and cross sections should be prepared at a minimum scale of 1 inch = 40 feet.

If the plan is revised, a geologic map and cross sections based on the new plan will probably be necessary. Generally, the geotechnical consultants must sign the plans to verify that their recommendations have been incorporated and that the building location is approved.

Where onsite sewage disposal is necessary, the report must include an evaluation and recommendation to assure that effluent will not surface, create instability, or adversely affect adjacent property.

2.2.11 Change of Consultant Letter

GMED requires that a letter/report from the new engineering geologist of record be submitted when a change in consultant occurs during the process of review or during construction. If a change of consultant occurs during project construction, the construction must stop until the change has been approved by the Building Official. Clarification and resolution of pertinent discrepancies in professional opinions and data of in-progress construction or grading will be required before the recommendation for approval can be provided by the Geotechnical Development Review Units.

2.3 REPORT CONTENTS

Some of the information presented in this section is repeated from General Guidelines.

2.3.1 General Information

Except for the above-discussed "In-Grading Reports" and "Restricted Use Area Reports," all geologic reports shall contain the following items and statements:

- Title page that includes all available property identifiers such as site address; tract, parcel map, and lot number; APN; and the plan check number (most or all of this information is indicated on the Geologic Review Sheet after the first review).

- Location and size of the area being investigated and its general setting with respect to major geographic and/or geologic features.

- Topography and discussion of drainage, runoff, rainfall, and vegetation as pertinent to development and site stability.

- A description of earth materials within the subject area and an indication of their competency.

- Information regarding the nature and source of available subsurface data.

- Name of the geologist(s) responsible for the field mapping upon which the report is based and the dates the mapping was performed.

- Manual, original wet signature by an engineering geologist on all reports submitted for review.

- A citation list of all references and aerial photographs cited and/or reviewed. References shall be *applicable to the property in question*.

- County of Los Angeles Building Code Section 111 Statement. Note: a standalone geologic report that addresses only the potential for fault rupture are not required to comply with the Section 111 statement requirements.

- Geologic map based on the development plan and depicting existing and proposed topography (if grading plan) and description of earth materials from field surface mapping and subsurface exploration.

2.3.2 Surficial Materials

Define and map areas of surficial materials present relative to development, including distribution, thickness, and stability (with evaluation by a soils engineer). Directive GS047.0 (see Appendix) provides additional guidelines for building sites proposed near the toes of natural slopes.

2.3.3 Geologic Structure

Map and identify daylighted or unsupported discontinuities such as bedding, schistosity, joints, faults, slide planes, etc. When daylighting is encountered, provide orientation on cross sections and define pertinent engineering geology characteristics for stability consideration by the soils engineer.

2.3.4 Geologic Map, Cross Sections, and Data

The California State licensed Engineering Geologist should map the geologic formations and other mappable earth materials, geologic structures, and surficial features in detail, in accordance with professional practice. The map and cross sections should present all relevant geologic features needed for a complete and accurate evaluation of the feasibility and design of the project, so that site geology can be objectively reviewed.

A detailed geologic map is an essential part of all geologic reports, such that all data pertinent to site analysis and stability is shown. A regional geologic map is commonly necessary for the typical hillside development as geology of adjacent properties must be considered for a thorough evaluation of onsite stability. Existing maps prepared by other qualified Engineering Geologists may be adequate, if acceptable to the Engineering Geologist in responsible charge, and to the reviewing geologist.

All geologic maps must use, as their base, the most recent legible development plan and topography. Information shown on the base map must be at an appropriate scale that clearly shows geologic features. The scale for a grading plan should be no smaller than 1 inch = 40 feet and for a subdivision map no smaller than 1 inch = 100 feet. Terminology, nomenclature, symbols, lithologic descriptions, formation names, etcetera, used on the maps, plans, and cross sections shall conform to the USGS or CGS.

Cross sections are generally necessary to depict geologic conditions, and must be at true scale (horizontal=vertical). The California State licensed Engineering Geologist is responsible for providing the necessary geologic profiles in the report in sufficient detail that the stability of the site can be determined. The plotting of true and apparent dips of bedding and other discontinuities (such as joints, faults, etc.) is required on the geologic cross sections to substantiate interpretations.

Data and features to be shown on the geologic map are to include, but not be limited to, geologic structure and distribution of bedrock and surficial materials. The geologic structure must be supported by data to establish a clear statistical trend or lack thereof.

2.3.5 Adverse Geologic Conditions

If not already included in other sections of the geologic report, the following should be addressed by the geotechnical consultant:

- Potential daylighted or unsupported bedding/discontinuities in cut and natural slopes or underlying fill areas.

- Evidence and cause of subsidence or settlement (such as observed fissures, cracks in structures, drainage offsets, or evidence from historic records and surveys).

- Potential for debris flows on natural slopes (e.g., colluvial filled swales, colluvial aprons, talus, debris flow deposits, etc.).

- Active faults and their effects upon the proposed development relative to the County of Los Angeles Building Code. Project sites in APEFZ Act mapped earthquake fault zones must comply with Act requirements and guidelines (see CGS's Special Publication 42 and Note 49 for specific details).

- Hydrogeologic conditions and characteristics relative to stability, particularly relative to existing landslides and potential liquefaction areas.

- Seismic shaking related to potential ground failure (such as landslides, liquefaction, etc.). Sites located within SHMA zones must comply with SHMA requirements and guidelines (see CGS Special Publication 117A and GS045.0 for specific details).

- Potential presence of earth materials subject to hydroconsolidation or consolidation, or that may be contaminated with hazardous materials or fluid.

2.3.6 Subsurface Exploration

Subsurface exploration with detailed graphic and descriptive logs is one of the most important and necessary aspects of any engineering geology investigation. They are needed to show and substantiate professional opinions, conclusions, and remediation proposed. The nature of an engineering geologist's work is visual; that is also true of the engineering geologist reviewing the report. The preparation and presentation of clear and accurate graphic logs of the observed subsurface data significantly reduces the time required to review the report, and often minimizes or eliminates review comments based on the written description (which depending on the thoroughness of the description, may appear more as opinion than fact).

Detailed logs and graphic depictions shall illustrate and describe conditions in exploratory borings or excavations, including the physical properties, discontinuities, and other relevant geologic information.

> Note: County reviewers will refer to published geologic maps and reports on file for the subject and adjacent properties during review of the project. This information may aid in limiting or guiding subsurface work; therefore, it is strongly suggested that geotechnical consultants review the same information prior to initiating their subsurface investigation. If published information indicates the property is within or may be affected by a mapped landslide, the geotechnical consultants must review, reference, and acknowledge that information, depict the mapped landslide boundaries on their geologic map, and provide subsurface data that confirms or denies the existence of the landslide. If reports submitted for a project indicate conditions that differ from those presented in reports on file, the geotechnical consultants will be required to review, reference, and acknowledge that work and provide subsurface data to substantiate their conclusions.

Subsurface exploration and testing requires coordination with the soils engineer where geotechnical engineering evaluation and analyses are warranted or required.

Subsurface exploration for the investigation of a proposed subdivision should be sufficient to preclude design changes after the tentative map has been approved. If adverse geologic conditions requiring a design modification are discovered during the investigation for the grading plan review, the approved tentative map will have to be modified and resubmitted through Regional Planning and possibly require another public hearing. Additional subsurface data will be required by the geotechnical reviewers in areas where a potential design change may be necessary. For example: will a debris basin be required resulting in the loss of one or more lots where the proposed grading is adjacent to natural terrain such as at the base of natural slopes and swales?

The following are some of the conditions or circumstances that warrant subsurface exploration:

- Landslide areas:
  - To define the depth and areal extent of the landslide deposits and affected area.
  - To identify slide planes or zones of deformation and materials for geotechnical engineering testing and analysis.

- o To define three-dimensional geometry and hydrogeology (piezometers may be required) necessary for analysis and/or design of remediation).

- o To check geology peripheral to and beneath the landslide to determine the potential for enlargement and the consequent need for additional remediation.

- Areas of suspected landsliding and/or anomalous topography: to determine the origin of the land form and, if any, present or future hazard exists.

- Areas that do not contain sufficient natural exposures to establish a clear, reliable, geologic structural picture; or contain unreliable natural exposures (e.g., exposures affected by creep).

- Proposed fill areas for slopes exceeding 20 feet in height, unless data gathered in the immediate vicinity permits an assessment of stability.

- Proposed cut slopes exceeding 50 feet in height (required exploration at least 10 feet below the elevation of the toe of the cut, or equivalent data, to determine geologic conditions affecting slope stability). If fills are proposed above the cut, the total height of the slope includes the fill portion.

- To substantiate remediation design.

- To identify and investigate active and potentially active faults identified onsite and as required in the Alquist-Priolo Earthquake Fault Zones Act, the County of Los Angeles Building Code, and the Los Angeles County Safety Element.

- To substantiate mathematical models used for slope stability and landslide analyses.

- To investigate potential areas of seismically induced settlement, lateral spreading, expansive soils, and geomorphic/depositional areas for the presence of collapsible soils.

2.3.7 Landslides

The investigation of a landslide should:

- Consider proposed development and remediation,
- Determine geometry and mechanics of movement,
- Evaluate groundwater/hydrogeologic conditions past and present, and estimate effects of change in land use,
- Provide slope stability analyses and earth material testing by a soils engineer, and
- Include specifically observed slide plane data, geologic mapping, and study of stereo pairs of aerial photographs.

The interpretation of three-dimensional geometry, groundwater conditions, and material strengths must be based on subsurface exploration data. Although "worse case" scenarios may be useful where information is scarce, data are necessary for landslide parameters for approval of development and/or remediation plans. Generally, a minimum of three points/borings are necessary to define a planar failure, and more are needed for arcuate or other complex landslide geometries and large planar type landslides.

2.3.8 Conclusions and Recommendations

The geotechnical consultants should verify:

- All report conclusions are based on the most logical interpretation of the data presented in the report. Consider that simple interpretations may be more accurate than complex ones.
- Geologic recommendations specify remediation methods that are commensurate with the reliability of the data presented.
- Corrective measures are clearly depicted on the geologic map, incorporated into the development plans, and the plans are approved by the Engineering Geologist by wet signature or stamp.

- In general, the conclusions and recommendations consider the effects of the proposed development upon future geologic processes as well as the effects of geologic features and processes upon the proposed grading, construction, or land use.

- Geotechnical conditions and remediation have been cooperatively determined between the geologist and soils engineer where geotechnical engineering testing and stability analyses are appropriate.

- Governmental regulations and policies have been met.

- Compliance with County Codes including, but not limited to, the following:

    - Los Angeles County Subdivision Code.

    - County of Los Angeles Building Code Sections 110.2 (Geotechnical Hazards), 111 (Engineering Geology and Soils Engineering Reports), 112 (Earthquake Fault Zone Maps), 113 (Earthquake Faults), and Appendix J (Excavation and Grading).

- Compliance with State regulations and policies including, but not limited to, the following:

    - Alquist-Priolo Earthquake Fault Zoning Act and applicable portions of CGS SP42.

    - *California Code of Regulations*, Policies and Criteria of the State Mining and Geology Board with Reference to the Alquist-Priolo Earthquake Fault Zoning Act (Title 14, Sections 3600 through 3614).

    - Seismic Hazards Mapping Act and CGS Special Publication 117A as applicable. Directive GS045.0 (see Appendix) provides details regarding review of reports for site with a liquefaction potential.

- Unequivocal findings are stated in all reports for building or grading plans that the proposed and/or completed grading, site, and structure will be safe from the hazards of "landslide, settlement, or slippage" and will not adversely affect property outside of the developed area in accordance with CLABC Section 111.

- The content of the engineering geology reports leads to conclusions that assure:
    - All grading and building areas will be safe and stable, including any proposed offsite work.
    - The presence of a safe buildable site exists on each lot of a subdivision where ungraded lots are proposed.
    - Remaining natural slopes have been assessed for stability, including the potential for daylighted discontinuities and surficial failure.
    - Geologic conditions in proposed fill areas have been found to be adequate to support surcharges, and the need for benching, keying and removal of surficial materials and subdrains has been addressed.
    - Additional subsurface exploration warranted by a change in development plans has been provided.

3.0 SOILS ENGINEERING & GEOTECHNICAL REPORTS

The following guidelines are the minimum requirements for the preparation of geotechnical reports for regulatory compliance. Geotechnical reports shall be prepared by a civil engineer, licensed in the State of California, experienced in the field of soil mechanics, or a geotechnical engineer licensed in the State of California (soils engineer). These guidelines are intended to supplement County Codes and policies and when possible provide clarifications for report requirements. Pertinent GMED Directives are provided in the Appendix. The Additional Resources section of this manual provides reference to documents and internet links that may be used to support the report preparation and research. The standards discussed in this section may not cover all proposed site developments and additional guidance and more conservative standards may be required.

Geotechnical reports must include recommendations and conclusions based on soil data, records, geologic conditions, and analyses of geotechnical hazards in relation to the proposed site developments or remediation. Geologic hazards must be identified, analyzed, and remedial measures recommended.

The Soils Engineer of record must acknowledge all pertinent previous geotechnical reports and make a statement that he/she agrees with their findings, conclusions, and recommendations or provide appropriate modifications. Modifications should be supported with discussions and may need to be substantiated with additional data as necessary.

When both an engineering geology and soils engineering report are required for the evaluation of the safety of a building site, the two reports shall be coordinated before submission to the building official. Engineering geology reports shall be prepared by an engineering geologist licensed in the State of California.

3.1 GENERAL GUIDELINES

All soils engineering and geotechnical reports submitted for review shall have been prepared by, or under the responsible charge of, a civil engineer, licensed in the State of California, experienced in the field of soil mechanics, or a geotechnical engineer licensed in the State of California. The reports shall bear the signature and seal or stamp of the licensee and the date of signing and sealing or stamping. For additional details on this requirement see the *Business and Professions Code* Sections 6700 through 6799 (also known as the Professional Engineers Act).

It is the responsibility of the soils engineer to review the project and determine what items must be covered (e.g. slope stability, collapsible soils, liquefaction, pile design, construction constraints, mitigation of effects to offsite property, etcetera) in the preparation of a geotechnical report. The report must demonstrate that property and public welfare will be safeguarded in accordance with current County Codes and policies. Provisions of the CLABC Section 110.2 requires that the building site will be free of geotechnical hazards, such as landslide, settlement, or slippage, and that the proposed work will not adversely affect offsite property. CLABC Section 111 requires the report contain a finding to show compliance with CLABC Section 110.2.

The CLABC Section 111 statement must clearly make a finding regarding the safety of the site of the proposed work against hazard from landslide, settlement or slippage and a finding regarding the effect that the proposed work will have on the geotechnical stability of the area outside of the proposed work. The finding must be substantiated by appropriate data and analyses.

The CLABC Section 111 statement is mandatory for all geotechnical reports except for reports prepared for tentative subdivision and environmental impact reports. Although the 111 Statement is optional for these specific types of reports, there must be sufficient supporting information that demonstrates to the satisfaction of the Building Official or Public Works Land Development Division Subdivision Mapping Section (Subdivision Mapping Section) that the sites will be developable and that the required CLABC Section 111 Statement can be provided at a later stage of development.

The following are minimum requirements, and content of all soils engineering and geotechnical reports submitted to GMED:

3.1.1 Report Age

The report must have been prepared within one year prior to submittal to the Geotechnical Development Review Units for verification of compliance with County codes and policies. For geotechnical reports older than one year prior to submittal, an update report/letter will be required, at a minimum, to verify the validity and applicability of the original report.

The update report/letter must address the latest proposed development, the existing site conditions, and utilize the latest plans and/or tentative map as a basis for the geotechnical maps within the report. The update report/letter must address any changes to the proposed scope of work, the existing conditions, or geologic hazards. Additional soils data, updated analyses, and updated geotechnical maps may be required to provide adequate revised recommendations and conclusions.

3.1.2 Description of Site and Proposed Development

The report must contain a description of the existing site conditions and a description of the proposed development. The description of the existing site conditions should include, but not be limited to, the location, size, topography, geologic/geotechnical conditions and hazards. The description should address any proposed grading and all proposed structures that will be constructed for the development of the subject site.

Approximate earthwork volumes must be included within the description for developments with proposed grading. There should be a distinction made between the volumes of cut and fill materials. In addition, offsite grading that may influence the proposed development must be addressed.

Basements, habitable structures, and locations and types of retaining walls should be specified as part of the description. If special foundations and specific geotechnical recommendations are provided within the report, it should be addressed as part of the description of the proposed development.

3.1.3 Subsurface Conditions

Geotechnical reports shall describe the earth materials and subsurface conditions based on subsurface explorations. References shall be made to the boring logs, trenches, pits, cone penetration test soundings (CPTs) and other subsurface explorations utilized to characterize the soil data, soil properties, and subsurface conditions. Descriptions of the subsurface conditions should be clear and consistent with the subsurface exploration and soil data collected. The logs of all subsurface explorations and subsurface data should be included within or appended to the report.

When subsurface explorations or subsurface conditions are referenced from a separate report or source, those reports or sources should be provided, such that the Geotechnical Development Review Units can review the material in its original form. Referenced materials may be required to be submitted for review.

Note: Reference materials and data that is deemed not relevant (e.g. offsite data is from a source too far away to be relevant, adjacent site data is for fill and proposed site is native, etc.) by the Geotechnical Development Review Units will not be permitted to be used in support of the proposed site development.

The current and historical groundwater conditions and the seasonal groundwater fluctuation should be included in the report. The report shall address the effects the groundwater, seasonally high groundwater, seepage effluent, and flows from onsite infiltration systems may have on the proposed site improvements and offsite properties.

Subsurface descriptions must be based on documented subsurface information and/or soil data from subsurface explorations. Engineering experience and engineering judgment alone will not be adequate for GMED regulatory review processes.

3.1.4 Subsurface Exploration and Laboratory Testing Programs

It is the responsibility of the soils engineer to determine the extent of subsurface exploration and laboratory testing programs. The subsurface data and laboratory testing results must be sufficient to provide an accurate characterization of the subsurface conditions. Data shall be used to evaluate potential geologic and geotechnical hazards and conduct engineering analyses. The geotechnical recommendations and conclusions shall be based on appropriate subsurface data, laboratory testing results, and engineering analyses.

All subsurface exploration and laboratory testing programs should first consider the specific geotechnical/geologic information necessary for the proposed development. Previous subsurface exploration and laboratory testing may be referenced if found to be applicable to the proposed development. When appropriate, the soils engineer or engineering geologist should coordinate the subsurface exploration and laboratory testing programs. If geological information is not required, the soils engineer must determine the exploration and testing program needed for the proposed development.

The summary of laboratory test results shall be provided along with the full description of laboratory tests performed (e.g. moisture and drainage conditions during any shear strength tests, shear rates, overburden pressures, etc.). Laboratory testing protocols and results shall be clearly stated. When applicable, the laboratory results should be appended to the appropriate subsurface exploration logs.

Sufficient subsurface exploration information and laboratory test results must be provided to substantiate all findings, analyses, conclusions, and recommendations. Soil data collected for geotechnical analyses must be clear, relevant, quantitative, and objective.

3.1.5 Engineering Analyses

The report shall describe and address all engineering analyses conducted for the proposed development. Supporting analyses, calculations, input and output data for computer based analyses, force diagrams, etc., shall be contained in the report, as necessary. Relevant items necessary to conduct a full review of the proposed development should be included in the soils engineering and/or geotechnical report. Exclusion of supporting documents and analyses in the report may impede a full review and cause review comments to be generated requesting those documents and analyses be provided.

Analyses such as slope stability analyses, liquefaction analyses, settlement analyses, lateral spread, etc. must address the results of any proposed mitigation measures. GMED Directives (see Appendix) criteria and requirements shall be followed unless superseded by more conservative Codes or policies.

3.1.6 Conclusions and Recommendations

The report shall clearly state all conclusions and recommendations by the soils engineer. All mitigation measures must be supported with data, engineering analyses, and, as necessary, figures and diagrams.

3.1.7 Geotechnical Map and Cross Sections

The Geotechnical Map must show the location of subsurface exploration, geology of the site, lot lines, existing and proposed grades, locations of sewage disposal systems, existing and recommended remedial measures, geotechnical setbacks, and recommended “Restricted Use Area(s).” The Geotechnical Map must utilize the most current plans or subdivision map as a base for geotechnical mapping.

All geotechnical maps included within the report shall be considered a part of the report and shall not be considered a part of the plans or subdivision maps.

All geotechnical maps should be numbered or identified by sheet and by the report date. When the geotechnical map requires more than one map sheet, the individual map sheets should include easily discernible match lines. An index map of all sheets may be required if there are many sheets associated with the project plans, which may be the case with large subdivisions and long storm drains.

The geotechnical maps must include all boundaries of the subject site. The topography for areas immediately outside of the subject boundaries should also be included to verify whether geologic hazards will affect the subject site or whether the proposed development will affect adjacent properties.

The geotechnical maps shall have a legend that describes all symbols, geologic formations, geotechnical cross-sections, contours, lines, shading, hashing, colors, etc. All sheets must have a north arrow or north symbol.

The scale of the geotechnical map should be sufficient for geologic and geotechnical purposes. The scale of the map will be dictated by the current policies of the Subdivision Mapping Section and the Building Official. However, tentative maps are typically required to be at a scale of 1 inch = 100 feet and grading plans to be at a scale of 1 inch = 40 feet. In some cases, the consultant or reviewer may deem it necessary for a more detailed map scale to be prepared.

Cross sections are generally necessary to depict geologic conditions for use in slope stability analyses or for clarification of subsurface stratigraphy. Cross sections must be at true scale (horizontal=vertical).

3.2 GEOTECHNICAL REPORT ORGANIZATION

The geotechnical report shall be completed in such a manner to ensure that all geotechnical factors affecting the subject site and the proposed development have been considered. The geotechnical report must consider the site stability including temporary conditions during construction. The report must also consider the effect of the proposed development on geologic and geotechnical stability of adjacent property. The geotechnical report must contain recommendations with supporting data, analyses, and calculations, and include all references used. The geotechnical report shall be wet-signed by a licensed civil engineer competent in the field of soils engineering and wet-stamped with the civil engineer’s seal or stamp. The date of signing and sealing or stamping must be included.

The report pages, along with all field and laboratory information, shall be 8-1/2 inches wide by 11 inches high sheets bound and presented in such a manner that future reproduction can be made. Plans and maps greater than 8-1/2 inches wide by 11 inches high (oversized) shall be folded to this size or smaller and presented in such a manner that future reproduction can be made. All oversized sheets should be made part of the bound report as inserts into pouches or sleeves.

All subsurface exploration and laboratory data utilized within the report should be presented and organized such that they can be specifically referenced. All locations of subsurface exploration should be shown on a geotechnical map with a legend that explains the various subsurface explorations that were conducted. All applicable laboratory data should be indicated on the subsurface exploration logs and should be provided in the report for reference.

Engineering analyses, such as slope stability, L-pile, liquefaction, etc., shall include the input data, output data, and any relevant figures or diagrams. If such analyses are conducted with a proprietary program or one which may not be easily accessible, a written calculation of the analyses may be required. If large input and output files are generated from analyses they may be presented on a CD in PDF format.

All geotechnical maps should be identified by sheet and by the report date. Individual map sheets should include match-lines if the site is not easily discernible by referring to the project plans. An index map of all sheets may be required if there are many sheets associated with the project plans, this may be true of large tract sub-divisions, tentative maps, storm drains or other projects.

All geotechnical reports, letters, addendums, and review sheet responses must be submitted in hardcopy format and also in an electronic version on a compact disc or flash drive in Adobe® Portable Document Format (PDF) with searchable text and that include all maps, tables, figures, cross sections, etc. associated with the report. The electronic version shall include an electronically generated representation of the licensee's seal, signature, and date of signing. Projects cannot be approved until this requirement has been met.

3.3 TYPES OF GEOTECHNICAL REPORTS

3.3.1 Environmental Impact Documents

From a geotechnical standpoint, the purpose of an Environmental Impact Document is to identify the possible adverse geotechnical impacts on the environment and in analyzing the proposed mitigation measures. The report shall contain, at a minimum, the following items:

- Soil descriptions and behavior.
- Identification and assessment of all geotechnical hazards that may impact the proposed development.
- Potential geotechnical issues that the proposed development may have on its surroundings.
- Subsurface water conditions and water infiltration potential.
- Mitigation measures that may be required to address geotechnical hazards, including, but not limited to, expansive soils, slope instability, debris flows, liquefaction and associated seismically induced settlement, lateral spreading, and collapsible soils.

3.3.1.1 *Initial Study*

Initial studies for proposed developments within the County's jurisdiction are typically completed by staff at the Department of Regional Planning and can be completed with or without geotechnical reports. This is a screening procedure to assess the level of impact a proposed project may have on the environment. Projects that have a potentially significant impact may trigger the requirement for an Environment Impact Report (EIR).

An engineering geology, soils engineering, and/or geotechnical report may be prepared for the Initial Study to justify the determinations shown in the soils and geology section of the initial study. The report in support of the Initial Study should address potential impacts that geotechnical hazards will have on the proposed development and its surroundings and recommend any mitigation measures that may be necessary.

3.3.1.2 *Environmental Impact Report*

If a proposed development is identified to have potentially significant impacts and an EIR is required, impacts due to soils or geology issues must be addressed in an appropriate report (engineering geology, soils engineering, or geotechnical report). The report must be prepared to address all geotechnical issues that may affect the proposed development and its surroundings, including those identified in the Initial Study. The soils report must have sufficient data and analyses to support the recommendations provided by the soils engineer.

The engineering geology, soils engineering, and/or geotechnical reports are typically included in the EIR appendix. The text portion of the EIR shall summarize the findings of the geotechnical report and recommendations that mitigate potential geotechnical hazards. The recommendations summarized in the text portion of the EIR must match the ones shown in the geotechnical report.

3.3.2 Geotechnical Report for Conditional Use Permits

A soils engineering or geotechnical report prepared in support of a conditional use permit must identify and address all geotechnical hazards potentially affecting the feasibility of the proposed project. The report must discuss and evaluate the geotechnical hazards to determine whether mitigation measures are necessary to comply with County Codes and policies. Recommended mitigation measures shall be shown on the geotechnical map and, as necessary, appropriate cross sections.

3.3.3 Tentative Subdivision Report

The purpose of a tentative subdivision map and the accompanying report(s) is to demonstrate that the site is suitable for the proposed future development. Therefore, the geotechnical consultants must present sufficient information to establish that the site will be safe for the intended use and that all existing and potential geotechnical hazards will be mitigated. The recommended mitigation measures must be demonstrated to be feasible for the proposed future development, including all building pads, utility corridors, and access routes. It also must be demonstrated that the proposed future development will not cause geologic or geotechnical instability on the subject site or to offsite properties.

3.3.3.1 *Geotechnical Map*

Grading shown on the geotechnical map must conform to the grading shown on the latest tentative map or Exhibit "A".

For example, if a proposed tentative subdivision was previously a part of an established parent tract or is part of a phased subdivision, the geotechnical maps of the tentative map report must clearly identify the lot boundaries and lot numbers from the latest tentative map. The lot boundaries and lot numbers from the parent tract or other phases shall not be used in the report.

The lateral extents of geotechnical hazards must be delineated and labeled on the geotechnical map. If corrective work is proposed to mitigate the geotechnical hazards, a note should be added to specify the corrective work. If corrective work is not being proposed and a geotechnical setback will be established, a note on the delineated areas must indicate, “Soils Susceptible to ___________, Not Suitable for Support of Structure”.

All geologic hazards and areas underlain by geotextiles used in the support of slopes or retaining walls plus 10 horizontal feet from the edges of the geotextile should be delineated as, “Restricted Use Areas” on the geotechnical maps.

The geotechnical map should also depict the following:

- Locations of all subsurface explorations.
- Locations of all cross sections presented in the report.
- Locations and dimensions of all recommended remedial measures.
- Geologic information (i.e., material type, strike and dip of bedding, etc.).

3.3.3.2 *Geologic and Geotechnical Hazards*

Geologic hazards include, but are not limited to, areas subject to landsliding, debris flows, active fault traces, and slopes with factors of safety for gross static stability less that 1.5 or pseudostatic stability less than 1.1. Geotechnical hazards include, but are not limited to, soils susceptible to hydroconsolidation, high expansion, excessive settlement, lateral spread, liquefaction, or seismically induced settlement.

Landslides exhibiting factors of safety below the minimum County standard along with their possible affected areas are considered a geologic hazard and may not be subdivided. Lot lines must be located such that each landslide hazard, its containment area, and the surrounding area that will be affected by any future failures are contained entirely on one lot. The hazard must not pose a threat to any proposed and/or existing building areas on the lot, adjacent lots, and/or offsite property. Each lot must have a site suitable for development as determined by Public Works. Additional details regarding subdivisions impacted by existing landslides are provided in Directive GS086.0 (see Appendix).

Areal extents of geologic and geotechnical hazards affecting the subdivision from both within the site and offsite properties must be clearly defined, shown on the geotechnical map, and mitigation measures and/or corrective work must be recommended. Mitigation measures and/or corrective work to address geologic and geotechnical hazards must be based on site data and engineering analyses and shall be addressed at the tentative map stage.

Where an existing landslide or other geotechnical hazard affects an adjacent lot in the same proposed subdivision, it must be removed, stabilized, or otherwise mitigated. Where an existing landslide or geotechnical hazard affects offsite property outside of the subdivision, but the existing conditions will not be changed, worsened, or otherwise affected by any proposed site developments (e.g. roads, buildings, drainage, effluent, etc.), and the hazard does not affect onsite or offsite building areas, the hazard may not always be required to be mitigated.

Due to the potential large areal impact of some hazards, such as large landslides, the corrective work to address the hazards may be extensive. Therefore, the geotechnical consultants must be aware of the effects of their corrective work on the tentative map and the tentative map review process.

Any unmitigated geologic hazard and any affected surrounding area within the proposed subdivision that will remain on the Final Map must be designated as a "Restricted Use Area." Also, any unmitigated geotechnical hazard that will remain on the Final Map must be designated with a "Geotechnical Note" on the final subdivision map. Additional details regarding these requirements are provided in the following section and Directive GS063.0 (see Appendix).

3.3.3.3 *Restricted Use Areas and Geotechnical Notes on the Map*

Any unmitigated geologic hazard, as discussed in the previous section, and the affected surrounding area within the proposed subdivision, must be designated as Restricted Use Area (RUA) by the geotechnical consultants. Areas underlain by geotextiles used in the support of slopes or retaining walls plus 10 horizontal feet from the edges of the geotextile must also be designated as RUA. RUAs must be shown on the tentative map, geotechnical maps, and Final Map.

Slopes with factors of safety for gross static stability less that 1.5 or pseudostatic stability less than 1.1 and the areas that may be affected by these potential slope instabilities must be designated as RUAs on the Final Map. Refer to GMED's Directives for additional details.

A letter must be submitted by the engineering geologist and/or soils engineer identifying any areas to be designated as RUAs.

Any proposed development within an RUA will require an engineering geology and/or geotechnical report that can demonstrate to the satisfaction of the County that the development will be safe for the intended use and will not adversely affect adjacent property. RUAs can be modified on the recorded subdivision map when it can be demonstrated to the satisfaction of the County that the area removed from an RUA meets the requirements described above. Refer to Directive GS063.0 (see Appendix) for additional details.

Soils susceptible to hydroconsolidation, high expansion, excessive settlement, lateral spread, liquefaction, or seismically induced settlement are <u>not</u> considered geologic hazards for the purpose of Code enforcement, and therefore, are <u>not</u> designated as "Restricted Use Areas."

On a very limited basis, at the request of the geotechnical consultants and the property owner, an area suspected of having a geologic hazard that has not been geotechnically explored and is not likely to affect the proposed development, may be allowed to be designated as a "Restricted Use Area" in lieu of exploration. The Geotechnical Development Review Units will review the request, site information, relevant documents and maps, and make a determination on whether or not this designation will be allowed.

3.3.3.4 *Ungraded Site Lots*

Some properties may be subdivided into lots where the specific types and location of structures have not been determined and/or the developer does not intend to perform any grading or mitigation measures prior to Final Map recordation. The property developer must show that these lots can be constructed with safe access and buildable site(s) free from geologic and geotechnical hazards. These "Ungraded Site Lots" can be recommended for approval with the following criteria.

- The geotechnical consultants must identify in their reports, through appropriate data and analyses, all grading and corrective work necessary to provide safe access and buildable site(s) that are free from geologic and geotechnical hazards.
- Grading for slopes steeper than 5:1 gradient will require a concept-grading plan or an "Exhibit A" originated through the County of Los Angeles, Department of Regional Planning.
- All recommended grading and/or corrective work must be self-contained within each lot. Recommended grading and/or corrective work that crosses lot lines disqualifies the affected lots from the being designated as "Ungraded Site Lots."
- All unmitigated geotechnical and geologic hazards shall be shown on the Final Map as "Restricted Use Areas" and "Geotechnical Notes" as defined in the section above and Directive GS063.0 (see Appendix).

A note must be placed on the final map stating that geotechnical report(s) detailing development requirements are available for review at Public Works Geotechnical and Materials Engineering Division. Directive GS001.0 (see Appendix) presents further details regarding the geotechnical requirements applied to "Ungraded Site Lots."

3.3.3.5 *Digital Submittal Ordinance*

Sections 21.40.040 and 21.40.080 of the Los Angeles County Subdivision Code have been amended to require geology and geotechnical reports prepared for new tentative maps submitted through the Department Regional Planning on or after September 10, 2005, to be submitted in digital format. Each report shall be submitted in hardcopy format and also in an electronic version on a compact disc in Adobe® Portable Document Format (PDF) with searchable text and include all maps, tables, figures, cross sections, etc. associated with the report.

3.3.4 Grading Plan Report

The geotechnical report in support of a grading plan must address the existing onsite conditions, identify potential geologic and geotechnical hazards, and provide conclusions and recommendations for the proposed development. All supporting data, analyses, and calculation for the basis of the conclusions and recommendations must be provided within the report. The data, analyses, and calculations must be in sufficient detail to demonstrate that the proposed grading will not cause, or be affected by, onsite and offsite geologic and geotechnical hazards.

The geotechnical report prepared for a grading plan must also include, when applicable, the following:

3.3.4.1 *Geotechnical Map*

- Scale (horizontal=vertical) of 1 inch = 40 feet with a bar scale for verification and scaling.
- Utilize the latest version of the grading plan as a base for geotechnical mapping.
- Locations of all subsurface explorations.
- Locations of all cut and fill slopes and corresponding gradients and elevations.
- Locations of all cross sections presented in the report.
- Locations and dimensions of all recommended remedial measures (i.e., buttress fill, stability fill, keyways, soldier piles, etc.).
- Geologic information (i.e., material type, strike and dip of bedding, etc.).

- Layout of proposed subdrainage system.
- Limits and depths of removal and recompaction.
- Locations of RUAs, limits of landslides, fault setbacks, and geotextiles locations plus 10 feet beyond the length of geotextiles.
- Special foundations and grading requirements for corrective work for, but not limited to, soils subject to hydroconsolidation, high expansion, lateral spread, liquefaction, or seismically induced settlement.
- Approximate limits of all unsuitable soils to be left in-place and prominently labeled with the note: "Unsuitable Soils - Not suitable for the Support of Structures".
- Location of all proposed settlement monuments.
- All geotechnical and geologic setbacks, as necessary.
- Private sewage disposal system(s).

3.3.4.2 *Geologic and Geotechnical Hazards*

Geologic hazards include, but are not limited to, areas subject to landsliding, debris flows, active fault traces, and slopes with factors of safety for gross static stability less that 1.5 or pseudostatic stability less than 1.1. Geotechnical hazards include, but are not limited to, soils susceptible to hydroconsolidation, high expansion, excessive settlement, lateral spread, liquefaction, or seismically induced settlement.

Areal extents of geologic and geotechnical hazards affecting the plans must be clearly defined, shown on the geotechnical map, and mitigation measures and/or corrective work must be recommended. Mitigation measures and/or corrective work to address geologic and geotechnical hazards must be based on site data and engineering analyses. Mitigation measures and/or corrective work necessary to address geologic and geotechnical hazards must be addressed at the tentative map stage.

The depth and extent of geotechnical hazards must be clearly determined by the soils engineer with substantiating laboratory data and analyses. For example: soils being evaluated for hydroconsolidation shall include consolidation testing of in-situ undisturbed samples at sufficient depths and lateral extents to quantify the site's collapse potential.

When an unmitigated geologic hazard is part of a plan submittal and not associated with a subdivision map, it shall be delineated as a geologic/geotechnical setback area and shown as such on the geotechnical map and grading/building plans.

3.3.4.3 *Geotechnical Descriptions*

Provide a geotechnical description of soil and rock encountered and observed at the subject site. Soil descriptions shall include, at a minimum, engineering classification with dry density and moisture content, descriptions of soil stiffness/density, moisture condition, and optional components that quantify and describe gravel, cobble, organics, and other relevant information throughout the depth of the subsurface explorations. Standard Penetration Test values shall be also included when appropriate. Rock shall include material descriptions appropriate to the formation. Depending on the existing and proposed conditions the following may be required: geologic assessment of hardness, degree of weathering, strata thickness, clay surfaces, and oriented planar discontinuities such as strike and dip of bedding, joint spacing, joint thicknesses, fractures, and fault surfaces.

An excellent resource for describing and presenting subsurface materials is the California Department of Transportation's *Soil and Rock Logging, Classification, and Presentation Manual* (see Additional Resources).

3.3.4.4 *Groundwater Conditions*

Provide information on the historic high ground water table, seasonally high groundwater table, depths to groundwater encountered in all subsurface explorations, and, water surface from all seepage systems or infiltration systems that will be part of the proposed site improvement.

The report shall address the effects of static and/or perched groundwater on the proposed grading construction and proposed development. This includes, but not limited to, backcut slopes, shoring, buttress fill, temporary excavations, and other considerations during grading and construction of site improvements.

The historic high water table shall be used in all geotechnical analyses (i.e. slope stability, etc.), unless information is provided which justifies the use of a higher or lower water table.

The CGS Guidelines for Evaluating and Mitigating Seismic Hazards in California (SP117A) (see Additional Resources) requires that liquefaction analyses consider hydrologic conditions of the current, historical, and potential future depth of subsurface water. The historic high groundwater level shall be used in the liquefaction analysis unless a shallower level (higher elevation than historic high) is determined to be appropriate.

3.3.4.5 *Geotechnical Cross Sections*

Geotechnical cross sections used in the slope stability analyses must:

- Be drawn to an undistorted (horizontal=vertical) minimum scale equal to 1 inch = 40 feet.
- Show the location of all the geologic features, including bedding planes, fractures, and material types.
- Show the critical potential failure planes.
- Indicate the various shear strength parameters in the appropriate failure plane segments.
- Show all recommended buttress, stability fill, or shear key dimensions.

3.3.4.6 *Slope Stability Analyses*

Slope stability analyses must be accompanied by a summary of the input parameters, types of analyses conducted, results of analyses, and prints of the input and output conducted by either hand calculation or computer software. In some cases, the Geotechnical Development Review Units may require certain procedures or conditions (e.g. Limit Equilibrium, Simplified Janbu, Bishop, Spencer, Translational, Rapid Drawdown, etc.) be evaluated to determine the effect on proposed site conditions and offsite properties. Also, a sample of the analyses conducted using computer software may be required to be verified with hand calculations. Discrepancies between report data and independent analyses conducted by the Geotechnical Development Review Units will need to be resolved before the plans can be recommended for approval.

3.3.4.7 *Engineered Fill*

Engineered fill and proposed structures shall not be placed into, or founded on unsuitable soils. There must be a clear examination of the conditions of the existing earth materials prior to placement of new fill or development of structures. The geotechnical consultants must demonstrate that engineered fill and proposed structures will be placed on competent natural materials or certified engineering fill. Certification for engineered fill will only be accepted if it is placed, keyed, or benched into competent material.

3.3.4.8 *Subdrains*

Provide recommendations regarding provisions for reducing water infiltration into fill slopes, and a subdrainage system to convey excess water away from fill slopes or behind retaining walls. When a subdrainage system is recommended, address the minimum requirements for the filter and drain material gradations and any associated geofabric. Provide details showing the size of the subdrain pipe, minimum pipe slope, perforation alignment, filter and drain material locations, and all necessary dimensions. Include subdrain design requirements, descriptions, and details on the plans.

3.3.4.9 *Chemical Testing*

The most common factor in determining soil corrosivity is electrical resistivity. There are various ground conditions and moisture contents that lend to soil being potentially detrimental to foundation elements. The geotechnical report shall evaluate the soil at the project site for potential conditions that are corrosive to ferrous metals and deleterious to concrete and provide recommendations for the following conditions:

- Soils are considered to have a propensity for corrosive or deleterious conditions when the minimum resistivity is less than 1,000 ohm-centimeters.

- Soils are considered corrosive to ferrous materials (i.e. iron and steel) when chloride concentration is greater than or equal to 500 ppm.

- Soils are considered deleterious to foundation elements (e.g. lime in concrete) when the pH is 5.5 or less.

- Soils are considered deleterious to concrete when soluble sulfate concentrations are equal to or greater than 2,000 ppm in soil and 1,000 ppm in saturated soil.

See Section 3.4.2 of this manual for more discussions regarding chemicals, their effects on foundation elements, testing, and requirements for recommendations.

3.3.5 In-Grading Geotechnical Report

An in-grading geotechnical report must be prepared and submitted monthly or at the intervals requested by the Geotechnical Development Review Units review sheet(s). If applicable, this report must be coordinated with the in-grading geology report. The in-grading geotechnical report must contain, at a minimum, the following information:

- Actual limits and depths of removal and recompaction of unsuitable soils.
- Any changed conditions requiring design revisions.
- Analyses demonstrating that, based on any changed design, the site will be safe for the intended use and will be in conformance with State and County Code and Policies.
- Location of settlement monitoring monuments.
- Verification that all conditions of approval of the approved plans are being complied with.

If soil parameters and/or as-graded topography does not conform to the design requirements, provide the revised calculations, analyses, recommendations, and necessary mitigation measures needed for the changed conditions. An updated finding may be necessary to substantiate that the development complies with CLABC Section 111.

3.3.6 Rough Grading Geotechnical Report

At the completion of rough grading and prior to geotechnical approval of the completed grading the rough grading geotechnical report must be prepared and submitted. If applicable, this report must be coordinated with the rough grading geology report. The rough grading geotechnical report must contain, at a minimum, the following:

- An as-graded map showing original and final topographic contour lines. As-graded map should utilize the approved grading plans as a base.

- Show and discuss any change in site conditions that may have been encountered and the effect of those changes on the approved grading plans.

- Locations of all compaction tests plotted on an as-graded map.

- A table of all compaction test data that includes types of compaction tests conducted, dates, test numbers, locations (extra details as necessary), maximum dry densities, required relative compactions, and field compaction results.

- Verification by the soils engineer that the fill shear strength parameters met or exceeded design values utilized in the approved geotechnical report.

- Verification by the soils engineer of the number of relative density tests conducted by the Sand Cone Method.

- Location of subdrains and other drainage structures incorporated into the fill.

- Chemical test results. See Section 3.5.8 of this Manual for additional details.

- A statement regarding the amount of anticipated total and differential settlement. Also, settlement calculations and settlement monitoring data may be required.

- All pertinent geotechnical recommendations/mitigation measures.

- All data and final graphs of settlement monuments.

- All items required for the in-grading report.

- The soils engineer must include a finding regarding the safety of the completed grading and any proposed structures against hazard from landslide, settlement, or slippage (see CLABC Section J105.12.2) and a statement that, to the best of their knowledge, the work within their area of responsibility is in accordance with their approved reports and applicable provisions of the CLABC Appendix J.

- If an engineering geologist was retained to provide services in accordance with CLABC Section J105.5, the rough grading geotechnical report must include a final description of the site geology and any new information disclosed during the grading. The report shall also disclose the effect of any new information, if any, on the recommendations that were incorporated in the approved grading plans. The report shall contain a final as-built geologic map and cross-sections depicting all the information collected prior to and during the grading. The rough grading geotechnical report shall contain a finding regarding the safety of the completed grading and any proposed structures against hazard from landslide, settlement, or slippage and a statement that, to the best of their knowledge, the work within their area of responsibility is in accordance with their approved reports and applicable provisions of the CLABC Appendix J.

If the Geotechnical Development Review Units determine that the rough grading geotechnical report and/or map is not sufficiently detailed to substantiate the safety and stability of the site for the intended use, the recommendation for the rough grading approval will be withheld until the safety and stability of the site can be demonstrated.

When the information in the rough grading geotechnical report is in conflict with field observations, the recommendation for the rough grading approval will be withheld until the conflicts are resolved.

3.3.7 Building Plan Report

The geotechnical report for a building plan must include all items required for grading plan reports. Appropriate data and analyses must be provided to substantiate that the development complies with CLABC Section 111.

The geotechnical report prepared for a building plan shall also provide, at a minimum, the following:

- Foundation design recommendations for, but not limited, mat foundations, pile/caissons, micro-piles, ground modifications, special foundations, etcetera.
- Foundation embedment depths and embedment materials must be provided.
- Retaining wall design recommendations. This includes but not limited to seismic loading, at-rest conditions, braced conditions etc. All connections associated with the retaining walls must be addressed (e.g. tie-backs, lagging, etc.)
- A determination as to the anticipated total and differential settlement, and mitigating measures required to protect the structures.
- Analyses of the corrosive properties of the soil.
- Justification for foundation setbacks from top and bottom of slopes if less than minimum County Code requirements.
- Private sewage disposal systems.
- Geotechnical map utilizing building plot plan as a base.
- All geotechnical/geologic setbacks, as necessary.

If the building plan is part of a subdivision development, the conditions set forth in the approved geotechnical report(s) for the subdivision must also be met. If the building plan is for a single-lot development, the geotechnical report(s) must demonstrate that the proposed development (including all structures, utility rights-of-way, and driveways) will be located on stable material and that the development will be safe for the intended use and will not adversely affect offsite property.

3.3.8 Infrastructure Report

The Soils Engineer must provide a specific "stand alone" report for the proposed infrastructure. The report should address the current site conditions, the proposed development and latest infrastructure plans.

Infrastructure that will become property of the County must meet the requirements as presented in the Public Works Design Manuals, current edition of Standard Specifications for Public Works Construction (Green Book), and project plans and specifications. Geotechnical reports prepared in support of the infrastructure projects must conform to the provisions of CLABC Sections 110 and 111.

The following are several types of facilities that may be addressed in a typical infrastructure project geotechnical report:

- Water Tanks
- Debris Dam Seismic Upgrades
- Basins (e.g. Retention, Detention, Desilting, and Debris Basins)
- Closed Conduits (e.g. storm drains, sewer lines, water lines, etc.)
- Open Channels (e.g. trapezoidal flood protection channels, etc.)

3.3.8.1 *Subsurface Exploration*

For conduit projects that will be in excess of 300 feet in length (storm drains, water lines, etc.), subsurface explorations (trenches, borings, CPTs, etc.) shall be spaced at intervals not to exceed 300 feet. The intent of this spacing is that no part of the project shall be more than 150 feet from a boring. Spacing of subsurface explorations may be increased when the geotechnical consultant has extensive data from nearby projects and can provide data to support the claim for a uniform subsurface condition. Reduction of the spacing may be required when additional data will be needed. All other infrastructure projects, including tunneling/jacking, will have an exploration program that is based on the individual project requirements.

The interval between subsurface explorations shall be reduced as necessary to determine changing conditions (i.e. soil and bedrock contact varies, etc.). The following are suggested exploration spacing reductions for conduit projects:

- Locate subsurface explorations in areas in which topography or other evidence indicates a probability of soil conditions differing from those of surrounding areas.

- Locate borings adjacent to existing structures where special construction measures may be necessary.

- Locate subsurface explorations in areas where future fill will be placed or bedrock is encountered.

- Locate subsurface explorations in areas where potential differential settlement or lateral deformation may affect the project.

- Include subsurface explorations at each sump or depression along the alignment of the project.

- Subsurface explorations shall be located near the downstream and upstream ends of the conduit projects that do connect into existing site improvements.

Additional borings may be required if strata continuity between the borings cannot be determined. In addition, the maximum and minimum profiles of any submerged area must be considered in the design.

In order for conduit foundations to be determined, subsurface explorations shall extend to the following depths:

- Where no groundwater is encountered, data collection shall be carried to a depth of at least 5 feet below the proposed storm drain invert.

- Where groundwater is encountered in the vicinity of the subgrade or above, subsurface explorations shall be carried to a depth of 10 feet or twice the structure width below the proposed storm drain invert, whichever is deeper.

- If unsuitable material is encountered near the proposed conduit subgrade, subsurface explorations shall be carried through the unsuitable material until competent material is located.

- Where the construction will involve structural foundations (such as footings or piles), the borings shall be carried sufficiently below the footing subgrade or pile tip elevation to furnish bearing capacity and settlement information for proper design of the foundation.

- In areas where fill is to be placed, the borings shall be continued a sufficient depth below invert to allow determination of probable settlement.

- In the event that a project is redesigned subsequent to the geotechnical report and the final grade is lowered or the alignment is changed, additional borings shall be drilled as necessary to conform to the above requirements for those portions of the alignments that have been redesigned.

- In areas where the slope stability may be a hazard affecting the proposed storm drain, additional borings shall be provided to assess the potential stability of the slope.

The geotechnical consultants, at their discretion, may conduct as little as one boring for conduit projects that are less than 300 feet in length and they feel the subsurface data will furnish sufficient design information for the entire project length.

3.3.8.2 *Required Information*

The geotechnical report, as appropriate to the infrastructure project, must address the following:

- The soil types, consistency, apparent density, moisture content, and extent of materials that may be encountered. Also, modifiers, such as, percent and size of oversized material is very important to project construction planning.

- Subsurface soil conditions that may affect excavation and trenching, such as caving conditions, groundwater, and boulders.

- Recommendations, with descriptions, for special equipment and procedures.

- Location and extent of overexcavation of unsuitable support materials.

- Location, nature, extent, and hardness of rock.

- Slope stability analyses (gross, seismic, surficial, surface erosion and geologic conditions) of all cut, fill, and natural slopes whose stability may affect the conduit or temporary construction necessary for the conduit placement.

- The suitability of excavated materials (including bedrock) for use as fill, backfill, or bedding.

- The engineering properties of the soils and loads required to design excavation shoring systems.

- The suitability of imported and onsite soils for use as fill, backfill, and bedding.

- The groundwater conditions and potential adverse effects, such as settlement on adjacent structures due to dewatering operations. This should be accompanied by anticipated areas of influence based on supporting data.

- The presence of substances in groundwater or in the native soils deleterious to concrete, steel, or other construction materials.

- Location of and mitigation recommendations for all cut/fill transition areas.

- Design recommendations for all applicable downdrag loads. Down drag calculations shall be provided for manholes or other similar structures with a depth of 20 feet or greater from the future ground surface to the storm drain.

- Pavement Structure Requirements.

- Effect on the structure of existing or anticipated loads due to future fill placement or foundation loads placed on existing grade. This includes structural loads, overall settlement, and differential settlement.

- Section 111 statement specifically addressing the proposed infrastructure.

Specific and detailed recommendations with supporting data shall be presented as described elsewhere in this section of the manual. Additional specific problems involving the construction of the drain shall be noted such as the handling of organic materials, peat, diatomaceous soils, water control during construction, jacking or tunneling, trash dumps, special foundations (such as piles, etc.)

3.3.9 Basins

Slope stability analyses are required for all basins. Analyses shall evaluate both interior and exterior slopes. Analyses shall include impoundment of water within the basin and provide recommendations for any case where the factors of safety are below County minimum standards. Basins designed with interior slopes steeper than 3H:1V gradient and have outlet structures shall also be evaluated for slope stability with a rapid drawdown condition. The minimum factor of safety is 1.50 for the rapid drawdown condition.

The geotechnical report shall include recommended mitigation measures regarding the effect of erosion on the side of the basin. The report shall also evaluate all geologic and geotechnical hazards, including but not limited to, the potential for hydroconsolidation or expansion of soils adjacent to the basins caused by the infiltration of impounded water within the basin.

When debris basins are utilized as mitigation and collection of geologic hazards (i.e. debris flows, landslides, etc.), the debris basins must be sized to accommodate 100 percent of the anticipated debris volume. Volume calculations for 100 percent of the anticipated debris and the 100 percent of available containment area must be provided.

Estimated debris volumes from geologic hazards are considered independent of erosional volumes calculated by hydraulic analyses. Debris basins must be sized for the cumulative geologic hazard and erosional debris volumes.

When a basin will also be used for infiltration or percolation purposes, the geotechnical report determine the infiltration rate in conformance with current County standards and policies. Substantiating data for the infiltration rate must be provided. See Section 3.3.12 of this manual for additional commentary and direction.

3.3.10 Bridge Foundations

The California Department of Transportation, Division of Engineering Services has prepared the following guidance documents: "*Foundation Report Preparation for Bridges*" and "*Seismic Design Criteria*" (see Additional Resources). Bridge projects that will be conducted for or reviewed by Caltrans should be prepared in general conformance with the aforementioned guidance documents.

Bridge foundation reports require, at a minimum, the following geotechnical considerations:

- Description of site topography, geologic conditions (including soil and rock depths, thicknesses, and extents), depth to competent materials/rock, and groundwater conditions (existing elevations, dates measured, historic high groundwater, etc.).
- Discussion and recommendations for geologic and geotechnical hazards, such as scour, landslides, seismically induced settlements, embankment failures, fault rupture potential, ground subsidence, soil's corrosion potential, and so forth.
- Design criteria for pier and abutment foundations (i.e., ultimate lateral passive resistance, depth of foundations in relation to scour, etc.) with specific details such as anticipated pile lengths and bearing capacities.
- Foundation types that are not applicable or constructible at the site should be identified and briefly discussed.
- Fill specifications for abutments, approach ramps, wingwalls, and various other structural components.
- Foundation design and wall pressures for the wing walls.
- Seismic design parameters (e.g. design response spectrum, peak ground acceleration, Vs30 values, etc.).
- Discussion on geotechnical issues that may have an effect on construction considerations (e.g. caving conditions, shallow groundwater, cobble layers, etc.).

When possible the report shall also include and/or address:

- Existing foundation systems at the site and the lateral, compressive, and tensile capacities used in their design.

- A list of all site factors used (e.g. near-fault factor, basin amplification factor, etc.).

- Depth to rock with a shear wave velocity greater than 760 m/s and 1,000 m/s when the site is located within a deep sedimentary basin [as shown in the 2013 Caltrans Seismic Design Criteria, Appendix B (see Additional Resources)].

- Whether or not a site-specific ground motion analysis is needed or has been conducted.

- Reference to other seismic recommendations prepared under separate cover (e.g., fault rupture reports).

The soils engineer must coordinate his work with the engineering geologist (regarding geologic conditions), hydraulic engineer (regarding scour), and structural engineer (regarding bridge and foundation design requirements and loading conditions).

3.3.11 Levees and Dam Structures

Geotechnical reports shall be prepared for the evaluation of levees systems or debris dam structures [i.e. dams and debris dams not overseen by the California Department of Water Resources Division of Safety of Dams (DSOD)].

> Note: Dams and debris dams overseen by the DSOD shall be operated per their Statutes and Regulations. Evaluations of those structures and systems are to be in compliance with DSOD technical specifications (see Additional Resources) and our current County Codes, policies, and guidelines. Geotechnical reports shall comply with DSOD documents. Any geotechnical aspect of the project that has not been provided guidance by a DSOD document shall comply with our current County Codes, policies, and guidelines. At no point shall an understanding of differences between State and County guidance documents be assumed by the geotechnical consultants. Public Works shall be contacted to provide clarification on a case by case basis.

3.3.11.1 *Reviewed Information*

The geotechnical consultants must collect and review all available pertinent information. The reviewed information and/or resources should include, but is not limited to, the following:

- Regional geology reports, site-specific geology reports, aerial imagery, boring logs, soil testing data, foundation material characteristics, and inferred stratigraphy.

- Reports prepared for design of the levee or dam structure, relief well and piezometer installation reports, and all design computations.

- As-built drawings showing geometry, materials, and construction methods.

- Annual and periodic inspection reports, including groundwater studies, and testing performed on the relief wells and piezometers.

- Reports on repairs or alterations made to the levee system or embankments. Alterations include construction or abandonment of utilities (e.g. conduits, force mains, water lines, oil or natural gas pipelines, electrical or telecommunication cables) that cross over, under, or through the levee embankments.

- Levee or dam system's operation and maintenance (O&M) manual.

3.3.11.2 *Site Visit Assessment*

After reviewing all available information, the geotechnical consultants shall conduct a field inspection of the levee or dam system to verify seepage control measures (e.g. relief wells, seepage berms, cutoffs, riverside blankets, active collection and discharge systems) and erosion control measures are functioning properly. The geotechnical report shall include the summary of the site observations, an assessment of the current conditions, and note any evidence of seepage and piping from previous flood events. Also note conditions at all active utility crossings, especially conduits through or under the levee or dam system. Great effort should be made to locate abandoned utility crossings and document the current conditions.

3.3.11.3 *Geotechnical Report for Levees and Dam Structures*

If a conclusive determination supported by substantiating data cannot be made concerning the levee or dam system, the geotechnical consultants shall include the following in the geotechnical report:

- Address and provide corrective recommendations for any observed slope erosion, scour (due to uncontrolled runoff of channelized flow velocities), inadequate slope protection systems, burrowing rodent activity, and any other observed or perceived deficiencies.

- Identify deteriorated conduits or inadequate utility crossings and provide corrective recommendations for those conditions.

- Note locations where the existent embankment cross-section is substandard or does not match as-built drawings and provide corrective recommendations.

- Note locations of settlement, cracks, or signs of slope instability and provide corrective recommendations.

- Note any encroachments or alterations in the levee system not documented and evaluated for their impact to the levee or dam system.

- Explanation of the subsurface exploration location selection process that includes a discussion of reviewing geologic information for locating zones of weakness in foundation materials.

- All subsurface exploration and laboratory data collected.

- Evaluate all geologic and geotechnical hazards that may have an effect on the levee or dam and provide recommendations based on data and analyses. Analyses shall include, at a minimum, the following:

    - Slope stability analyses that include static, seismic, rapid drawdown, and full retained water conditions for both slope faces of the levee or dam structures.

- Seepage through the embankments, foundation materials, or both.

- Performance of relief wells and effectiveness of gravity drain closure structures.

- Bearing capacity, static and seismically induced settlements, and overtopping performance.

Engineering analyses, such as slope stability, liquefaction, etc., shall include the input data, output data, and any relevant figures or diagrams. If such analyses are conducted with a proprietary program or one which may not be easily accessible, an example written calculation of the analyses may be required. If large input and output files are generated from analyses they may be presented on a CD in PDF format.

3.3.11.4 *Seismic Analyses*

Critical sections representative of the levee or dam system and its foundation materials should be evaluated for liquefaction and the related seismically induced settlements. Where liquefaction is indicated, the soils engineer shall perform a post-earthquake limit equilibrium stability analysis using the undrained residual strength for the liquefied soils. If the undrained residual shear strength is based on published empirical correlations, the references for those correlations shall be discussed and included in the report referencing. The Geotechnical Development Review Units will evaluate whether the empirical correlation is suitable for use in the analyses or additional supporting data is necessary. Appropriate drained or undrained shear strength parameters shall be used to represent the remaining soils in the analyses. If the slope stability analyses do not meet the minimum County factors of safety, more detailed seismic deformation analyses may be required to determine how the system will perform in the seismic event.

Projects with an indication of widespread potential for liquefaction and an inadequate post-earthquake factor of safety shall also be evaluated using a rigorous seismic deformation study. Portions of the levee or dam structure that do not have an adequate level of protection remaining shall be addressed. Where liquefaction and/or seismically induced deformation to the levee embankment is calculated, the capability to repair these damaged sections, prior to the next flood event, shall be taken into account in the geotechnical report and corrective work recommendations provided as necessary.

Seismic evaluations shall also assess the impacts of seismic shaking and ground deformation on seepage control measures (loss or reduced effectiveness of these features can reduce levee stability in subsequent flood events).

Additional guidance documents by the United States Army Corps of Engineers (USACE) should be consulted when doing any work on evaluating or designing levees. At a minimum the USACE Engineering Manual EM 1110-0-1913 and Engineering Technical Letter (ETL) 1110-2-569 should be used as guides when certification of levees will be conducted.

3.3.12 Percolation Basins and Low Impact Development Facilities

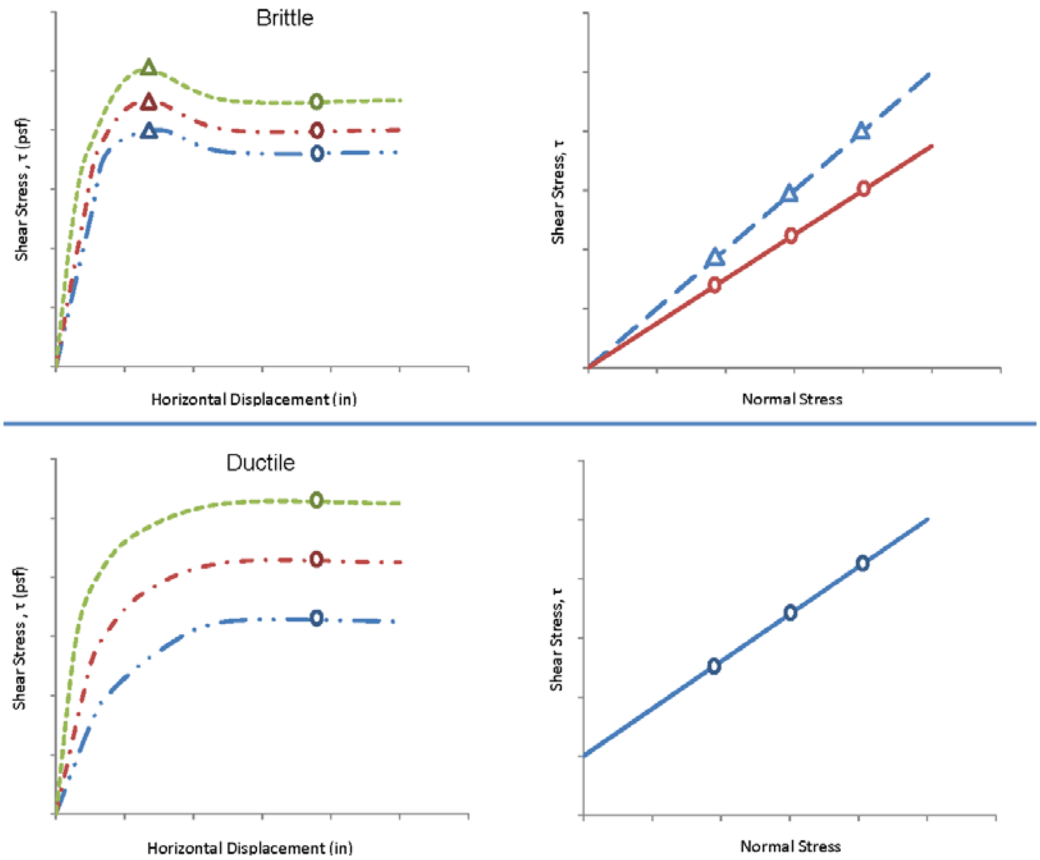
Reports for percolation basins and Low Impact Development (LID) facilities must address the impact of the proposed facilities will have on the development. Sufficient subsurface information must be obtained from the location(s) of the proposed basins or facilities and tests must be performed at depths that are relevant to the proposed basins or facilities. The report must specify and describe in detail the method that is used for the testing and determination of the percolation rate (see current version of Directive GS200.1 for specific requirements). The percolation rate must be expressed in inches per hour.

3.4 LABORATORY AND FIELD TEST REQUIREMENTS

The following represents the geotechnical data that generally is required to be included in geotechnical reports:

3.4.1 Shear Strength Parameters

Shear strength parameters for soils can be obtained through various laboratory tests. For the purpose of this manual, shear strength parameters are discussed based on the stress-strain behavior of the soil. In *general*, soils exhibit a brittle or ductile stress-strain behavior, as shown in the Figure below. Brittle soils typically have distinctly different peak and residual shear stresses, where the peak shear stress is marked at an apex of the curve and the residual shear stress is defined at the larger sample deformation or shear strain. Ductile soils have stress-strain behaviors that generally show a peak shear stress plateau that is approximately equal to the residual shear stress at large strains.



Displacement rates, degrees of saturation, inclusions (gravel, etc.), and appropriate normal stresses are just a few of the parameters that may have significant impacts on the shear strength results. The geotechnical consultants shall consider these parameters in their evaluation of the shear strengths.

One method of determining shear strength is the Direct Shear Test [American Society of Testing and Materials (ASTM) Standard Designation D3080 for soil and ASTM D5607 for rock]. This test is suitable for determining consolidated drained strength properties of undisturbed or remolded samples.

Repeated shear test shall consist of multiple back and forth shearing passes on the same sample until a consistent displacement curve can be documented. Typically a repeated shear test consists of 4 to 5 passes, however the number shall be as many as needed to show at least 2 passes with the same displacement curve results. Repeated shear testing can serve as an indicator of a materials strength loss, but may not necessarily be indicative of the actual shear strength parameters.

Tests shall be conducted on and/or appropriately representative of in-situ soils and rock. Shear strength parameters shall be provided graphically in the report as strength or failure envelopes. The stress-strain curves, in support of the strength envelopes, must be submitted when residual shear strength parameters are to be used in geotechnical analyses.

Results of the laboratory data shall be included in the geotechnical report and include, at a minimum, the following: depths and locations of samples, moisture contents and densities of samples before and after testing, stress-strain curves, displacement/strain rates, total displacement of samples, range of normal stresses applied, drained/undrained condition, and supporting standards (ASTM, etc.) used to conduct testing.

The proper shear strength to be used in the geotechnical analyses depends on the problem being evaluated as well as the type of analysis being considered (see Section 3.5 of this manual).

Additional information regarding sampling and evaluation of shear strength parameters can be found in Sections 6 and 7 of the *Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Landslide Hazards in California*, by Southern California Earthquake Center, dated June 2002 (see Additional Resources).

3.4.2 Moisture Content and Dry Unit Weight

Provide the dry unit weight and corresponding moisture content of each type of material encountered during the subsurface exploration. In-situ dry densities and moisture contents must be provided to represent the full depth of the subsurface explorations. There are various ASTM standards for moisture analysis or determining water content, therefore the geotechnical consultant shall determine which testing standards are appropriate to their project and provide references to those tests and results in the geotechnical report.

3.4.3 Consolidation Tests

Consolidation tests on undisturbed samples performed in accordance with ASTM D2435 should be provided for determining the magnitude and rate of consolidation of soils. To evaluate the collapse potential of soils potentially subject to hydroconsolidation, tests should be performed in accordance with ASTM D5333-03.

Note: As of 2012, the American Society for Testing and Materials has withdrawn ASTM D5333 from their listings of standards due to a lack of updating requirements; however we feel the last approved version of this test is still valid and appropriate for determining collapse potential.

3.4.4 Expansion Index and Swell Potential Tests

Expansion Index (EI) Test results should be performed in accordance with ASTM D4829 and conform to the requirements of the current edition of the County of Los Angeles Building Code. Swell potential of cohesive soils should be performed in accordance with ASTM D4546.

3.4.5 Compaction Test

To determine maximum dry density and optimum moisture content, tests should be performed in accordance with ASTM D1557 (also known as the Modified Proctor). Correction factors for oversized particles (ASTM D4718) and water content (ASTM D2216) may be necessary. When conditions dictate the use of significantly less compactive effort and the soils to be compacted are fine-grained, the maximum dry density and optimum moisture content, tests should be performed in accordance with ASTM D698 (also known as the Standard Proctor). Graphs for maximum dry density must be provided.

Field density tests should be performed in accordance with ASTM D1556 (Sand-Cone Method) and ASTM D6938 (Nuclear Gauge Method). Per County policy, at least 10 percent of all field density tests should be performed using the sand cone method. Depending on the proposed site improvements and percentage of oversized particles to be evaluated additional test methods, such as ASTM D5030, may be necessary.

3.4.6 Sand Equivalent Test

Sand equivalent tests should be performed in accordance with Caltrans California Test Method (CTM) 217 to determine the relative proportions of fine-grained materials in soil and fine aggregates. This test can provide an indication of whether material is suitable for jetting as an alternative to mechanical compaction.

3.4.7 Permeability Test

To determine the permeability of soil in the laboratory, a constant head or falling head test should be performed based on the soil type and subsurface conditions. For in-situ infiltration field tests, shallow soil profiles may use the Double-Ring Infiltrometer ASTM D3385 standard or Well Permeameter Test. Additional test methods are discussed in ASTM D5126 for determining hydraulic conductivity in vadose zone soils. The Well Permeameter Test (United States Bureau of Reclamation Test 7300-89) is also considered a valid testing method. Regardless of what test is conducted, when the results will be used in support of an infiltration feasibility study or a LID facility the tests shall conform with the requirements and guidelines in the current version of Directive GS200.1 and Section 3.3.12 of this manual.

3.4.8 Sieve and Hydrometer Analysis

Sieve and hydrometer analysis performed in accordance with ASTM D422 should be performed to determine the grain-size distribution of soils.

3.4.9 Atterberg Limits

To determine the liquid limit, plastic limit and plasticity index of soils, tests should be performed in accordance with ASTM D4318.

3.4.10 Unconfined Compression Tests

The unconfined compressive strength of cohesive soils and rock should be determined by ASTM D2166 and ASTM D2938, respectively. Preparation of rock core specimens should be performed in accordance with ASTM D 4543.

3.4.11 Point Load Strength Index Test

Estimating uniaxial compressive strength and determining a point load strength index of rock should be performed in accordance with ASTM D 5731.

3.4.12 Uniaxial Compressive Test

Test performed to determine the stress-deformation characteristics of rock, calculate the Young's modulus, and to evaluate the suitability of rock to support foundations. Tests shall be performed in accordance with ASTM D3148.

3.4.13 Organic Content

The determination of the organic content in soils shall be performed in accordance with ASTM D2974.

3.4.14 Corrosion Testing

Chemical testing (sulfate, chloride, resistivity, pH, etc.) of onsite soils shall address the presence of chemicals deleterious to concrete and ferrous materials. The tests must be conducted in accordance with California Test Methods, Department of Transportation, or equivalent.

An evaluation of the site soils should include sampling and corrosion testing of the in-situ soils to remain in place and potential fill sources. The most important constituent of corrosion testing and mitigation is the understanding and control of the soil moisture. Completely dry soil will have negligible effects on foundation systems. Soils with a flowing groundwater table may present a condition where ionization of soil electrolytes and the oxidation process may create an extremely corrosive site condition. Evaluations of corrosivity should consider the sites current, past, and future groundwater table and into what soils the foundation systems will be placed.

The geotechnical report must consider and test for sulfide-sulfate minerals in the soil, rock mass, and/or groundwater. Recommendations in the geotechnical report must include mitigation measures such as either the removal of the sulfide and sulfate materials down to a depth so as not to influence the proposed structure, or treatment to remove the sulfides and/or design of foundations to resist the effect of the sulfides.

The geotechnical report shall evaluate the soil at the project site for potential conditions that are corrosive to ferrous metals and deleterious to concrete. Testing shall be conducted in accordance with Department of Transportation California Test Methods (CTM) (see Additional Resources) or other appropriate test methods acceptable to the Geotechnical Development Review Units.

Depending on the project, additional testing and requirements may be necessary. Caltrans projects should utilize and reference the current edition *California Department of Transportation* Corrosion Guidelines (see Additional Resources) or structural concrete in contact with soils should utilize and reference the requirements in the current edition *American Concrete Institute* (ACI 318) Building Code Requirements for Structural Concrete and Commentary (see Additional Resources).

3.4.14.1 *Sulfide-Sulfate*

Sulfide minerals may be encountered in unweathered bedrock. When exposed to air and moisture, sulfides will undergo a chemical reaction to become sulfates, which can create other problems as described below. During this process the sulfide minerals may expand as much as eight times. Often this reaction is described as soil expansion (see Section 3.4.1.4 of this manual). However, the standard expansive soil test will not detect this potential chemical reaction. At the present time, there is little known about the rate of the chemical reaction. In some areas, the chemical reaction occurs within a few days after exposure. In other areas, this reaction is very slow, affecting structures years after construction. Sulfide minerals have been encountered in the Castaic Formation of the Basin Range in the Castaic area and in the Santa Monica Mountains from Topanga to Encino.

Certain sulfate minerals present in the soil, rock mass, or groundwater have a detrimental effect on concrete. Most prominent of these are sulfates of sodium, magnesium, and calcium. These sulfates react chemically with hydrated lime and calcium aluminate of the hardened cement paste to form calcium sulfate and calcium sulfoaluminate.

When soluble sulfate concentrations are equal to or greater than 2,000 ppm in soil and 1,000 ppm in groundwater, mitigation measures must be taken to protect any concrete structures in contact with the soils. If the soil is not to be removed, appropriate cement type must be used. Soils and water shall be tested in accordance with CTM 417.

3.4.14.2 *Chlorides*

Large concentrations of chlorides will adversely affect any ferrous materials such as iron and steel. Soils are considered corrosive and deleterious to ferrous materials when chloride concentration is greater than or equal to 500 ppm. Soils and water shall be tested in accordance with CTM 422.

3.4.14.3 *pH*

Soils are considered deleterious to foundation elements (e.g. lime in concrete) when the pH is 5.5 or less. Soils and water shall be tested in accordance with CTM 643 or other appropriate test methods acceptable to the Geotechnical Development Review Units.

3.4.14.4 *Resistivity*

The most common factor in determining soil corrosivity is electrical resistivity. As a soil's resistivity decreases, its corrosivity increases. Soils are considered corrosive to foundation elements when the minimum resistivity is less than 1,000 ohm-centimeters. Resistivity tests must be performed on soil samples in a saturated condition.

There are various ground conditions and moisture contents that lend to soil being potentially detrimental to foundation elements. Soils and water shall be tested in accordance with CTM 643. Aqueous solution tests such as EPA Tests or similar methods are not acceptable for determination of resistivity.

3.5 STANDARDS FOR GEOTECHNICAL ANALYSES

3.5.1 Slope Stability

Evaluating the stability of slopes may be one of the most important tasks required of soils engineers. An improper analysis can result in impacts to life safety, ingress/egress to adjacent areas, and numerous other problems. Due to the complexities that might occur at various geologic locations within the County of Los Angeles, slope stability analyses shall be conducted for site specific topography and geologic conditions. Conditions at one slope on a property may be completely different that other slopes within the same property. It is typically a combined effort of an engineering geologist and a soils engineer to determine what slopes need to be evaluated, which slopes are critical or representative of a site, and what corrective work may be necessary to address conditions that do not meet the County's minimum factors of safety standards. An excellent resource when preparing for or conducting slope stability analyses is the *Soil Strength and Slope Stability* book by J. M. Duncan and S. G. Wright (see Additional Resources).

3.5.1.1 *Slope Stability Analyses*

Slope stability analyses (including establishing design criteria and performing calculations) will generally be required for all cut, fill, and natural slopes when the slope gradient is steeper that 2H:1V (Horizontal:Vertical) and/or any gradient when the slope height exceeds 30 feet. Slope stability analyses may be required for any slope height or gradient when there are indications that the slope may not meet County minimum standards.

The data to be utilized in the slope stability analyses shall be based on detailed site plans, geologic/geotechnical cross sections, detailed field descriptions, onsite exploration data, and laboratory test data. It is the responsibility of the geotechnical consultants to determine the weakest potential failure surface based on the aforementioned factors. In performing any analysis, the critical scenario must be evaluated, such that planned use of the site will address all potential adverse scenarios. Without the proper selection of the critical phreatic surfaces, topography, stratigraphy, and geologic and soil data the slope stability analyses might not be adequate to support the CLABC Section 111 statement and additional analyses will be required.

Reasonable effort shall be made to obtain in-situ samples for shear strengths of landslide shear/bedding plane material. However, there may be conditions where "relatively undisturbed" samples might not be accepted by the Geotechnical Development Review Units to represent landslide gouge or bedding plane material due to sampling orientation and/or sample disturbance.

Shear strength parameters assigned to landslide shear/bedding plane materials may have to be based on past or current back analyses (see Section 3.5.1.4 of this manual) or obtained through repeated shear testing. The assignment of shear strength parameters in slope stability analyses must be justified with laboratory test data, geologic descriptions, and past performance of similar materials. The sample description, depth, and location must be included for each set of shear strength parameters.

Long-term static loading must be based on residual shear strength values. Peak values may be used for seismic loading or pseudostatic slope stability analyses when appropriate for the rock or soil type being represented.

When multiple sets of shear strength parameters represent the same soils (or very similar materials under similar geologic conditions), the shear strength parameters may be reported on the same graph. However, only the lower 10 percent boundary of data may be used in the slope stability analyses, without explicit explanations as to why certain strengths are appropriate for specific slope stability analyses. The intent of this requirement is not to mandate the most conservative values be applied to an entire subdivision development. Appropriate values shall always be used to represent in-situ and engineered fill soils. This requirement is to assist geotechnical consultants in justifying the need to gather site specific data in support of geotechnical analyses.

3.5.1.2 *Static and Seismic Slope Stability (Global)*

All slope stability analyses submitted for review may be checked by various methods (Modified Bishop, Janbu, Spencer, etc.), to verify compliance with the minimum acceptable safety factor. The following shall be considered when preparing stability analyses:

- Separate calculations shall be performed for static and seismic conditions.

- The minimum factor of safety for gross static stability is 1.50 for static loads. The minimum factor of safety for pseudostatic stability is 1.10 for loading due to seismic shaking. The factor of safety is defined as the ratio of the shearing resistance force to the actual driving force acting along the potential failure surface.

- The pseudostatic slope stability analyses shall be the minimum seismic analysis accepted for design, provided the soils are not potentially liquefiable or expected to undergo significant strength loss during deformation.

- Conventional static methods of slope stability analysis based upon principles of mechanics may be used to analyze the stability of slopes under both static and pseudostatic conditions.

- The analyses shall include the effect of expected maximum moisture conditions, soil weight, and seepage or pore water pressure where applicable. Saturated conditions shall be utilized unless it can be shown that other moisture contents will represent the worst possible conditions for the project.

- Pseudostatic slope stability analyses shall include the effect of static loads combined with the horizontal inertial force acting out of the slope and through the center of gravity of the potential sliding mass. The minimum seismic coefficient for the horizontal inertial force (K_h) shall be equal to 0.15 times the total weight of the potential sliding mass. This minimum value should be increased where, in the opinion of the geotechnical consultants, subsurface conditions or the proximity of active faults warrant the use of higher values. SP117A provides additional guidance and details regarding pseudostatic analyses and alternative methods that might be used to evaluate seismic shaking on site conditions.

Note: At this time, Public Works does not require the more rigorous pseudostatic analyses, as discussed in SP117A, to be conducted. However, on a case by case basis, the Building Official or the Subdivision Mapping Section may require projects that have a high importance factor and significant potential for loss of life (i.e. water tanks on steep slopes above a school, etc.) to provide more rigorous pseudostatic analyses and evaluate anticipated slope displacements and related effects.

- Potential failure modes must be based upon the stratigraphy and structure of the slope analyzed and input from the California State licensed Engineering Geologist.

- The cross section determined to be the critical section shall be used in the stability analyses of the slope or for the buttress design. The use of a weighted average for the Factor of Safety using multiple cross sections of the slope is not acceptable.

- The critical potential failure surface used in the analysis may be composed of circles, planes, or other shapes considered that yields the minimum factor of safety against sliding and most appropriate to the geologic site conditions. In cohesive soils, a vertical tension crack extending down from the top of the slope to the potential failure surface may be used to limit the lateral extent of the potential sliding mass.

- The critical potential failure surface having the lowest factor of safety on strength shall be sought for the static case. This same static surface and sliding mass may be assumed to be critical for pseudostatic case.

- The critical failure surface shall be depicted on geotechnical cross sections used in slope stability analysis. Shear strength parameters used in the analyses shall be depicted on the appropriate segments of the failure plane.

- Soil properties, including unit weight and shear strength parameters (cohesion and friction angle), shall be based on conventional field and laboratory tests and/or field performance. Where appropriate, laboratory tests for long-term residual strengths shall be performed.

- Soil strength parameters used in static stability analyses shall not exceed residual values (as defined in Section 3.4.1.1 of this manual). Soil strength parameters used in a pseudostatic analysis should not exceed peak values unless supported by test results or other convincing physical evidence. Strength parameters above peak values shall be supported by data and accepted by the Geotechnical Development Review Units before the values may be used in any analysis.

- Intact rock with a low fracture density that is unlikely to experience significant weathering over the life of the project may be permitted to use peak shear strength values in both the static and pseudostatic stability analyses when the quality of the rock is supported by field and laboratory data *and* accepted by the Geotechnical Development Review Units.

- Strength parameters representative of along-bedding materials must be used in slope stability analyses for slopes with adverse or daylighted bedding. Where along bedding materials cannot be sampled or tested, shear strength parameters from repeated shear tests may be used. However, if these shear strength parameters do not appear reasonable to the Geotechnical Development Review Units, additional data and testing may be requested to support the strength parameters use in any slope stability analyses.

- Data on the possible adverse impacts of the private sewage disposal system relative to site stability and adjacent properties must be provided. The path of migration of the effluent and the potential for ponding or daylighting of the effluent should be addressed. Slope stability analysis must consider the effect of ponded/perched groundwater.

3.5.1.3 *Surficial Stability and Debris Flows*

A coordinated investigation by an engineering geologist and a soils engineer is commonly necessary for a thorough assessment of the stability of surficial materials.

An analysis is required for:

- Fill or natural slopes steeper than a 2H:1V (Horizontal:Vertical) gradient,

- Any gradient when the slope height exceeds 30 feet, or

- When the height or geologic conditions warrants.

Typically cut slopes that expose natural soils and rock will not need to be analyzed for surficial stability; however exposures of highly weathered rock or soils with an apparent cohesion less than 250 pounds per square foot (psf) may need to need to be analyzed. The evaluation and analysis should consider the following:

- Variability of thickness and irregularity of contacts with underlying firm material or bedrock.
- In-situ surficial materials of high porosity and low density, relative to underlying material or bedrock. The physical properties of the rock and soil materials present onsite.
- Change in slope gradients.
- Variable, concentrated, or uninterrupted surface runoff (no drainage devices).
- Hydrogeologic and geologic conditions relative to stability. When present, bedding plane orientations, joints, and fractures may contribute to the failure mode and therefor shall be included in the analyses.
- The presence of animal burrows, cracks in soils, and fractures that can greatly increase the rate at which runoff can infiltrate into the surficial materials.
- Evaluation of existing adjacent offsite slope performance under similar site and geologic conditions.

The analysis must meet the following requirements:

- If there is insufficient data to establish the depth of the surficial slope materials, the minimum acceptable vertical depth of material saturation shall be 4 feet.
- Calculations shall be performed for surficial stability of slopes under saturated conditions. Calculations shall be based on an analysis using the infinite-slope failure model with seepage parallel to the slope surface or another failure mode that yields the lowest factor of safety.
- The minimum factor of safety for surficial stability shall be 1.50.

- Residual shear strength parameters (cohesion and friction angle) shall be used in surficial slope stability analysis and must be representative of the surficial material.

All slopes with factors of safety of less than 1.50 for surficial slope stability shall be considered to be subject to debris flow hazard. Appropriate mitigation measures must be recommended and shown on the plans. If containment of the debris flow is proposed, then volume calculations for both the anticipated debris and the available containment area will be required. Any debris impact or diversion walls proposed must be designed for a minimum 125 pcf equivalent fluid pressure. Also, mitigation measures that divert debris flow onto adjacent properties (public or private) and/or require periodic maintenance are not acceptable. Mitigation measures that involve the use of materials that may be destroyed in a fire (i.e. plants, geogrid, etc.) will not be accepted. The hazard must be clearly defined and 100 percent of the anticipated volume must be mitigated onsite.

On a case by case basis, the Building Official may allow for the diversion of debris onto a public right-of-way.

3.5.1.4 *Back-Analysis*

A back-analysis may be the only viable method to determine the shear strength parameters of an active landslide or global slope failure. The back-analysis theory assumes that the factor of safety is 1.0 at the instant the rock/soil mass begins to activate. The slope stability calculations may be based on the landslide mass in its original or current position. The back-analysis should not include pore water pressure or other input parameters that may increase the calculated shear strength parameters. The shear strength parameters that satisfy the factor of safety of 1.0 shall be evaluated and the geotechnical consultants assign appropriate shear strength parameters to the material being analyzed. The back-analysis calculated shear strength parameters may be used to design mitigation measures (i.e. buttress fills, shear key, soldier piles, etc.).

3.5.1.5 *Temporary Excavations*

Slope stability analyses shall be performed for temporary excavations. Shear strength parameters to be used in the analysis shall be those defined for the static case. The minimum factor of safety is 1.25. When justified with a very short duration (i.e. days not weeks) and there is no potential impact to adjacent foundations or life safety services, the peak shear strength parameters may be used in stability analyses.

3.5.1.6 *Surface Erosion Resistance*

The soils engineer shall evaluate the erosive properties of the soil and make appropriate recommendations to eliminate slope failure due to erosion caused by rainfall and irrigation of the slope. Soils with an effective saturated cohesion of less than 250 psf are considered susceptible to surface erosion.

3.5.2 Landslide Stabilization

For the purpose of this manual, landslide stabilization includes the stabilization of existing and potential landslides. It is required that a determination be made regarding the stability of ancient, inactive, active, and potential landslides.

If landslides that do not meet the County minimum standards are to remain, it must be demonstrated that they will not adversely affect the proposed development and that the proposed development, including landscape watering and septic systems, will not affect the landslide. When unmitigated geologic hazards are part of a subdivision development, the entire areas affected by the hazard must be designated as RUAs.

There are different types of landslides that often require stabilization:

3.5.2.1 *Massive Landslides*

Massive landslides consist of a landslide that either occurs along a slide plane, bedding plane, fracture plane, etc., or is a rotation type of failure that covers a very large area. Stabilization methods may consist of, but not limited to, the following:

- Buttress Fills - A buttress fill (see Figure 1 in Appendix) designed to enhance slope stability is placed at the toe of the landslide and must be analyzed for the following potential failure planes:
  - Horizontally through the buttress fill,
  - Below the buttress fill in a passive failure mode, and
  - Through the buttress fill in a passive failure mode.
- Shear Keys - A shear key designed to enhance slope stability is analyzed like a buttress fill except that the shear key is placed within the slide mass. Slope stability analysis should consider potential failure planes as required for a

buttress fill above.

- Soldier Piles - Soldier piles consist of various types of piles driven or drilled through the potential failure plane to provide additional shear resistance. These piles must be deep enough and of sufficient diameter to transfer the shear loads exerted by the landslide on the piles to underlying competent material. The spacing and location of the soldier piles will depend upon the amount of shear resistance required by the slope stability analysis, so that the slope will meet County minimum safety factor standards.

For unusual configurations additional potential failure planes may require analyses.

3.5.2.2 *Localized Landslides*

Localized landslides consist of the peeling off of small portions of a steep slope. Usually these types of slopes consist of many bedding planes and fracture planes that are discontinuous, making it very difficult to calculate a safety factor. Methods of stabilization will vary depending on the geologic conditions, failure mode, soil data, and analyses. All stabilization methods must be substantiated with geologic information, soil data and analyses to meet County minimum standards.

3.5.2.3 *Rock Falls*

Rock falls consist of large rocks that periodically break off the face of a cliff and roll down the slope landing on the level areas below or boulders that could dislodge and roll down the slope. Rock fall analysis is generally required where the proposed development is in the path of the potential rock fall or boulder roll. The data to be utilized in the rock fall analysis shall be based on detailed site plans, detailed field investigation, and onsite exploration data, such as:

- The number of and various sizes and shapes of boulders that are currently present at the site, as well as the anticipated sizes of potential large rock that may be break off from the face of the cliff.

- Slope profile that represents the steepest profile at the site.

- Slope surface roughness and irregularity must be based on the anticipated site conditions after the removal of brush and vegetation after a fire.

- Slope material properties expressed as slope coefficients and rock coefficients.

The results of the rock fall analysis must include the trajectory path of the falling rocks or rolling boulders relative to the height of the proposed mitigation measures, the final destination relative to the proposed structures and offsite properties, and the anticipated maximum kinetic energy of the falling rocks at the point where the proposed mitigation measures will be implemented. The various methods for stabilization of rock falls are as follows:

3.5.2.4 *Entrapment and Removal*

A large pit or a containment berm may be constructed at the bottom of the slope in which the rock falls into the pit. The pit or the rock containment area must be designed for 100 percent of the anticipated rock fall volume and that no rock or boulder shall go beyond the outer limit of pit or a containment berm.

3.5.2.5 *Rock Bolts*

Rock bolts may be used to connect large pieces of rock to the stable part of the slope to prevent further slope deterioration. The soils engineer must show and support with figures and analyses that there will be sufficient rock bolting to stabilize the slope. A rock slope analysis may be required for review by the Geotechnical Development Review Units when there is a possibility the stability is controlled by the rock characteristics and mass discontinuities (bedding orientation, joints, faults, foliation, etc.). Safety factors that do not meet minimum County standards for slope stability analyses will require additional corrective work recommendations.

3.5.2.6 *Wire Mesh Slope Control*

The use of wire mesh nets, anchored to the face of the slope, allows rocks to fall off of a slope in a controlled manner and into a confined area without posing a hazard to adjacent areas. The rock debris remains confined at the bottom of the slope. The wire mesh nets must be designed to contain 100 percent of the anticipated rock fall volume. These systems will not be allowed to be used for debris flow prevention or containment. An excellent guideline, *Design Guidelines for Wire Mesh/Cable Net Slope Protection*, has been prepared by Washington State Department of Transportation (see Additional Resources) and should be reviewed when preparing a wire mesh system for the containment of rockfall.

It should be noted that these types of systems are passive restraints and might not be permitted by the Building Official when maintenance of containment area, potential impact to offsite property, and/or the site is not deemed conducive to this mitigation method.

Prior to a full design at a particular site, it is recommended that the geotechnical consultants discuss this mitigation method and its applicability with the Building Official and the Geotechnical Development Review Units.

3.5.2.7 *Rock Barrier Fence*

Rock barrier fences are used to stop or restrain large rocks or boulders from rolling into the areas of proposed development. The rock barrier fences must be designed to contain 100 percent of the anticipated rock fall volume and resist the dynamic impact force of falling rocks.

Rockfall that occurs on or onto a slope shall be evaluated with rockfall analysis calculations. The factors, such as size and shape of rock, coefficient of friction of slope surface, slope angles, and coefficient of restitution must be discussed in the report and included in the analysis. The input and output associated with the rockfall analysis must be provided in the report. It will be reviewed by the Geotechnical Development Review Units for appropriate parameter usage as well as source height, frequency, and the various probabilistic options associated with this type of analysis.

Rock barrier fence plans shall be made part of the plan submittal. It should be noted that these types of systems are passive restraints and might not be permitted by the Building Official when maintenance of containment area, potential impact to offsite property, and/or the site is not deemed conducive to this mitigation method. Prior to a full design at a particular site, it is recommended that the geotechnical consultants discuss this mitigation method and its applicability with the Building Official and the Geotechnical Development Review Units.

3.5.2.8 *Removal of Rockfall Hazard*

Any loose rocks or boulders may be removed from the cliffs or slopes by scaling, other methods of mechanical removal, and/or blasting. The geotechnical consultants must identify all rocks and boulders that need to be removed. Additional evaluation may be necessary to determine whether the removals will create or increase other geologic or geotechnical hazards.

The use of blasting may not be permitted in some areas and should be discussed with the Building Official reviewing the plan submittal.

3.5.2.9 *Structural Setbacks*

Geotechnical structural setbacks must be greater than or equal to CLABC setback requirements. Depending on the proposed site improvements, the structural setbacks may be required from either the top or the toe of the slope. Setbacks shall provide a distance from the slope that allows the slope to fail until it reaches a County accepted stable condition.

3.5.3 Soils Subject to Consolidation and Hydroconsolidation

Soils subject to consolidation include soft clays with very high moisture contents, which when exposed to additional loads such as structures or fills, will experience vertical settlement as the water is expelled from the soil structure. Peat and other highly organic soils fall into this soil category as well because of the potential for large settlements as the organic materials decompose and the remaining voids collapse. This settlement may be long term and shall be considered in the geotechnical report.

Soils subject to hydroconsolidation (a.k.a. hydrocollapse, hydrocompression, soil collapse, etc.) are typically soils deposited in a loose condition. These soils may be able to resist overburden pressures and additional loading at or near their in-place moisture content, but quickly consolidate when saturated or near full saturation. When subjected to increased loading and/or saturation these soils may experience consolidation or collapse greater than 2 percent.

Hydroconsolidation may also occur in soils that contain water soluble cementing agents (e.g. calcium carbonate, etc.). Soil saturation may cause the replacement or removal of these cementing agents. The loss of cementing agents may be the reason that hydroconsolidation has been documented in soils with dry densities above 120 pcf and in soils with large percentages of gravel.

As a *general* rule, sandy soils with an in-situ dry density of approximately 108 pounds per cubic feet (pcf) or less and an in-situ moisture content of 8 percent or less are considered susceptible to hydroconsolidation.

The geotechnical consultant shall evaluate the possibility that consolidation and/or hydroconsolidation may occur within onsite soils and conduct appropriate field sampling and testing and laboratory tests to quantify the full collapse potential of all applicable soil layers. The collapse potential of soils under saturated conditions should be evaluated at project sites and the settlement potential evaluated.

In areas where settlement is anticipated to exceed County minimum standards, the soils engineer shall obtain sufficient data to determine the depth and extent of the hazard and make findings and recommendations to mitigate the geotechnical hazard.

3.5.4 Groundwater Withdrawal

Localized groundwater withdrawal may cause an increase in the effective stress of the soil and cause consolidation of soft clays and loose soils. When a project may cause localized groundwater withdrawal (e.g. during construction) the geotechnical consultants shall evaluate the impact and extent of that settlement and address it in the geotechnical report.

In areas where settlement is anticipated to exceed County minimum standards or affect offsite property, the geotechnical consultants shall obtain sufficient data to determine the depth and extent of the hazard and make findings and recommendations to mitigate the geotechnical hazard.

3.5.5 Liquefaction

Soil liquefaction or cyclic softening describes the substantial loss of soil shear strength due to pore water pressure increase induced by a rapid, dynamic loading, such as a seismic event, high vibration loading, or pile driving operations. When pore water pressures increase, the effective shear strength of the soil may be reduced to zero. As a result, the soil undergoes a temporary transformation from a solid to a softened, liquid-like state.

The following conditions are necessary for soil liquefaction to occur:

- Soil is saturated or near full saturation.
- Sand-like soils exhibit contractive behavior during dynamic loading.
- Clay-like soils exhibit cyclic softening behavior during dynamic loading.

- Soil subjected to rapid loading and does not have an adequate rate of pore water pressure dissipation.

- Pore water pressure exceeds the intergranular pressure within the soil mass.

  Note: Soil liquefaction has been noted to occur in gravels when fine-grained materials within the gravel matrix or an overlying layer impede the dissipation of pore water pressure.

The geotechnical report must consider liquefaction potential of the foundation soils and make recommendations to protect the public during such an event.

SP117A and the *Recommended Procedures for Implementation of DMG Special Publication 117 Guidelines for Analyzing and Mitigating Liquefaction in California* (SCEC, 1999) provide guidelines for evaluating and mitigating seismic hazards in California. Provisions of those publications must be followed in preparation of geotechnical reports that address liquefaction, lateral spreading, seismic settlement, and related seismically induced hazards.

Liquefaction analysis is required for developments classified as a “Project” as defined in the Seismic Hazards Mapping Act and is located within a mapped potentially liquefiable area per the State of California Seismic Hazard Zone Maps. Liquefaction analysis may also be required for a development that is not classified as a “Project”, but it is located in areas designated as “potentially liquefiable” and “liquefiable” on the County’s Seismic Element Map.

Liquefaction exploration and analyses shall conform to the provisions of SP117A and the Public Works Directive GS045.0 (see Appendix).

The following screening criteria guidelines may be used for the exclusion of the liquefaction analyses for the subject site, or for exclusions of specific soil layers in the liquefaction analyses. Screening criteria will require soil data, geology, and onsite information to justify exclusions from the liquefaction analyses. Screening criteria for exclusions may include:

- When the historical high groundwater is deeper than 50 feet and the proposed development does not use deep foundations for support.

- Bedrock is encountered at a shallow depth below the proposed foundations.

- When the SPT $(N_1)_{60}$ blow counts greater than or equal to 30, and/or CPT tip resistance (q_{ciN}), greater than or equal to 160 psf for a specific soil layer.

- Soils with:

  - Plasticity Index (PI) <12 and moisture content greater than 85 percent of the liquid limit, **or**

  - Sensitive soils with a PI >18 are considered to be susceptible to seismically-induced deformation during liquefaction. For soils with PI >18, additional data must be provided to show that the soil is not a sensitive soil.

All reported data and analyses must be clearly supported by the information collected on the subject site. Liquefaction analyses provided in geotechnical reports shall use the following guidelines:

- Provide specific commentary and supporting data for every layer excluded from liquefaction assessment and/or settlement analyses.

- Depth of exploration to a minimum of 50 feet below ground surface, finished grade, or 20 feet below the lowest expected foundations level (bottom of caisson or pile), whichever is deepest, is required for liquefaction analyses.

- When using Cone Penetration Testing (CPT), a confirmation boring that meets the minimum depth of exploration (see Item 2 above) will be required. The CPT and confirmation boring shall be conducted in close proximity to each other, but not be spaced so closely that stress relief would significantly affect the results. More than one confirmation boring may be required considering the size of the subject site, onsite soil data, and locations of liquefiable soil.

- Soil Behavior Type Index (I_c) values may not be used to exclude layers from the quantitative liquefaction hazard evaluation.

- A factor of safety (FS) of 1.30 shall be used in the quantitative liquefaction hazard evaluation to determine the exclusion of layers from settlement calculations. The FS is the ratio of the magnitude corrected cyclic resistance ratio (CRR) to the cyclic stress ratio (CSR) or simply FS = CRR/CSR. Layers that do not have a FS greater than (>) or equal to 1.30 shall be included in the seismically induced settlement calculations.

- For the purpose of performing liquefaction analysis, either a probabilistic or deterministic seismic hazard analysis can be used. A probabilistic seismic hazard analysis must utilize a hazard level of 10 percent probability of exceedance in 50 years. Refer to Directive GS045.0 (see Appendix) for additional details.

- All correction factors applied to raw SPT blow counts shall be discussed and justified.

- Fines correction methods (i.e. modified Stark & Olsen) that have not been supported by the geotechnical profession via published papers shall not be used in the liquefaction analysis.

- Consistent values must be used throughout the analyses, or provide adequate explanation of inconsistent values and have them supported by substantiating data.

- Bridging of nonliquefiable soil layers above liquefiable layers is not considered an adequate explanation or justification of exclusion of those layers in the seismically induced settlement calculations.

- Total seismically induced settlement must be the sum of seismically induced settlements of both the saturated <u>and</u> unsaturated soils.

- Differential settlement shall be taken as half of the total seismically induced settlements over a horizontal distance of 30 feet. In order to use less than half of the total settlement, there must be additional boring(s) and analyses that confirm the difference in the amount of seismically induced settlement.

- Structural mitigation is acceptable for:

    - Up to 1 inch of seismically-induced differential vertical displacement over a horizontal distance of 30 feet,

    - Up to 4 inches of total seismically-induced settlement, and

    - Up to 12 horizontal inches of lateral ground displacement. Anything in excess of these values will require ground modification.

  A combination of mitigation measures that include ground modification, piles, and structural mitigation may be acceptable on a case by case basis.

- Liquefaction hazard assessment must indicate the area/zones subject to liquefaction hazards and provide the associated liquefaction analyses for those area/zones. These areas/zones must be indicated on the geotechnical map of the reports. If the limits of the liquefaction are not supported with substantiating data, the entire project site must be evaluated as having the same liquefaction hazard.

- The liquefaction potential of a proposed development must be evaluated in a geotechnical report and appropriate mitigation measures must be proposed and incorporated into the plans of the subject site.

3.5.6 Lateral Spreading

Lateral spreading most often occurs in areas where an underlying soil layer is susceptible to liquefaction adjacent to gentle sloping ground or a “free face” (e.g. marina seawalls, drainage channels, lake shores, rivers, channels, etc.). Evaluation of lateral spreading shall be conducted for all sites that a potential for liquefaction and are in close proximity to a “free face.” This is due to the fact that relatively thin seams of liquefiable material, over large lateral areas, may serve as significant planes of weakness for lateral displacement over great distances.

Assessment of lateral spread must be conducted based on onsite conditions, regional conditions surrounding the subject site, gravitational forces, and the horizontal dynamic loading.

Soil layers having equivalent $(N_1)_{60}$ blow counts less than or equal to 15 should be evaluated to assess the lateral spreading hazard. The residual undrained shear strength of potentially liquefiable soils may be required by the Geotechnical Development Review Units. Undrained residual shear strengths shall be based on in-situ data, such as CPTs or Field Vane Shear Tests, or laboratory testing of undisturbed (e.g. Shelby tube) samples in clayey soils.

The guideline detailed in this manual may not be used as the only criteria to assess the potential for lateral spreading. A thorough investigation of the subject site and the regional area and an evaluation of all soil data and analyses must be conducted to address the potential for lateral spreading.

Recommended mitigation measures for lateral spreading typically include one or a combination of the following techniques:

- Edge containment structures (e.g. sea wall, dikes, etc.) to provide lateral support.
- Densification of liquefiable soils to reduce liquefaction potential.
- Modification of site geometry to reduce risk of movement.
- Drainage to lower groundwater below the level of the liquefiable soils.

Geotechnical consultants shall assess edge containment structures ability to resist lateral loading and provide substantiating data and calculations. Containment structures that may potentially fail in “brittle” modes (e.g., rigid walls, tiebacks failing due to tension or corrosion losses, etc.) shall be discussed in detail. The Geotechnical Development Review Units may require input and evaluations from a structural engineer prior to mitigation measure being recommended for approval.

Mitigation measures for proposed structures located in areas susceptible to lateral spread must demonstrate the soils beneath the building footprint and the soils providing lateral support to foundations will be free from the effects of lateral spreading.

Ground modification (or combination of ground modification and structural mitigation) may be used in all cases to mitigate liquefaction and/or lateral spreading. Structural mitigation including, but not limited to, the use of mat foundations, may be considered for mitigating up to 4 inches of total seismically induced settlement and up to 12 horizontal inches of lateral ground displacement.

If total seismically induced settlement exceeds 4 inches or lateral ground displacement exceeds 12 inches, ground modification is generally required. However, deep foundations may be used in lieu of ground modification in certain cases if the permitted structures and all associated building code required appurtenances including, but not limited to, primary ingress/egress (including ramps, walks, and fire lanes from the proposed structures to the public right-of-way) are supported by deep foundations and protected against the geotechnical hazards.

3.5.7 Expansive Soil and Rock

Various clays and bedrock formations, such as shale and claystones, expand upon wetting and shrink when dried. The wetted soil expansion can result in a volume increase many times larger than in the dry soil. If not properly evaluated and considered in the design, the high pressure exerted by the soil volume changes can cause significant damage to foundation systems.

Geotechnical reports shall provide the EI test results when expansive soil and/or rock are determined to be onsite. Test results that indicate an EI greater than (>) 50 shall be addressed with data and analyses to support pressures acting on proposed structures.

In areas containing expansive soil and/or rock, the report shall recommend specific design criteria or provide appropriate mitigation measures. Typical recommendations to address expansive soil and/or rock may include, but are not limited to, minimum embedment depth of footings, soil moisture conditioning, additional active pressure on retaining walls, and/or removal and replacement with low expansion soils.

3.5.8 Engineered Compacted Fills and Backfills

All certified fills and backfills must meet the provisions of the current edition of the County of Los Angeles Building Code. Whenever the organic content percentage, as performed in accordance with ASTM D2974, exceeds 2 percent or the percentage allowed by the current building code (whichever is a smaller quantity), the material shall be considered detrimental in accordance with the County Code and will not be accepted as certified fills or backfills. The above standard shall also apply to projects being constructed under the requirements of the Standard Specifications for Public Works Construction. When the Organic Content exceeds 2 percent, it shall be considered "topsoil" as defined in the Standard Specifications and may be used only for the purpose of backfilling areas to be planted.

3.5.9 Foundation Design Criteria

Foundation design criteria and/or recommendations must be included in the geotechnical report and supported by substantiating data. Possible adverse movement of the foundation by either vertical or lateral load must be addressed. Recommendations to mitigate any settlement or lateral movement that exceeds County standards must be provided. The recommended foundation type, installation conditions, and allowable loads must be provided.

3.5.9.1 *Shallow Foundations*

The soil design bearing pressure and lateral resistance capacities based on test data must be specified and conditions described which would require deviating from the maximum design Building Code values. In marginal sites with variable soils or where standard foundations cannot be utilized, the geotechnical consultant must make specific design recommendations. During construction the geotechnical consultant must inspect and approve the foundation excavations before reinforcing steel and concrete is placed.

3.5.9.2 *Deep Foundations*

Deep foundations, such as piles or caissons, must be designed considering the capabilities of the supporting materials based on laboratory test results and geotechnical data. The soils engineer must obtain onsite data a minimum of 10 feet below the bottom of the proposed foundations. For developments within areas that required liquefaction analyses, the soils engineer must obtain onsite data a minimum of 20 feet below the bottom of the proposed foundations. The foundations must be designed for all applicable lateral and downdrag loads. Soil creep must also be considered when determining the foundation design loads.

For piles greater than 24 inches in diameter, capacity may be governed by limiting the settlement to a maximum of 1 inch.

Pile tip elevations must be clearly established by the soils engineer. The design criteria must meet or exceed the minimum standards and/or criteria described in this manual.

Underpinning, such as helical piles (see Section 3.5.20 of this manual), are not permitted for the support of new foundations.

3.5.9.3 *Alternate Setbacks from Slopes*

Foundations on or adjacent to slopes must be placed so that setback dimensions meet the provisions of the current edition of the County of Los Angeles Building Code. Reductions in these minimum setback requirements shall be substantiated, to the satisfaction of the Building Official, by the geotechnical data and slope stability analyses.

An additional geotechnical report specifically requesting such reduction may be required and will be subject to review and approval by the Building Official. Refer to GMED's Directive S001.0 (see Appendix) for additional details.

3.5.10 Geotechnical Setbacks

Geotechnical setbacks may be recommended as a mitigation measure to avoid geotechnical hazards, establish areas that may be affected by geotechnical hazards, or prevent future development from encroaching into areas subject to geotechnical hazards. The soils engineer must provide a specific discussion addressing the limits and the future extent of the geotechnical hazard in relation to any future development and clearly show the location of the geotechnical setbacks on all cross sections and all geotechnical maps where applicable. All recommendations and locations for geotechnical setbacks must be based on existing geology, onsite soil data, and analyses of the subject site. Slope stability analyses are required for geotechnical setbacks associated with slopes.

Slope setbacks required by the CLABC are based on an assumption that the slope in question is stable. Therefore, if factors of safety demonstrate that the adjacent descending slope is potentially unstable the setback must be increased and measured from a hypothetical surface that can demonstrate factors of safety that exceed all County minimum standards for slope stability. This hypothetical slope surface is called a "geotechnical setback line or plane." The onsite geotechnical data and slope stability analyses must be provided to substantiate the location of the plane. Final approval will be subject to the Building Official's review. Refer to GMED's Directive S002.0 (see Appendix) for additional details.

For ascending slopes with the potential for debris flows, landslides, rockfall, etc., the use of geotechnical setbacks must consider the existing conditions, all future proposed developments and the future extent of the geotechnical hazard. The geotechnical setbacks must be substantiated with existing geology, onsite soil data, and slope stability/rockfall analyses of the slopes in questions.

Once the location of the geotechnical setback is reviewed and recommended for approval, the geotechnical setback must be shown on the associated plan for review with the Building Official or the Subdivision Mapping Section. The geotechnical setback must meet County of Los Angeles Building Code setback requirements and County policies.

3.5.11 Shoring System Design Criteria

Shoring systems are usually temporary supporting structures used to retain earth until the facility or excavation is completed. Shoring design parameters are used to determine the soil pressure imposed on the shoring units and must be provided by the geotechnical consultants.

All shoring shall be designed, at a minimum, in accordance with the California Occupational Health and Safety Administration (Cal/OSHA) requirements.

If an excavation affects the stability of existing structures and/or offsite property, shoring must be designed and installed to eliminate the hazardous condition. The design must be in accordance with all standards in this manual and must consider all factors such as slope stability, settlement, creep, etc. The soil strength parameters must not exceed the test values noted in the geotechnical report.

The following information, at a minimum, regarding the soil parameters and loads required to design excavation shoring systems shall be based on the materials reported in the soils engineering/geotechnical report:

- Coefficients of active and passive earth pressure.
- Lateral earth pressure distribution above the subgrade elevation as determined by the Rankine Theory.
- Location and magnitude of any external load(s) that may affect the design and/or performance of the shoring systems.

All trench shoring must conform to the provisions of the *California Code of Regulations*, *Construction Safety Orders* (see Additional Resources). These regulations can be obtained from Cal/OSHA.

All shoring for structures must meet the requirements of the current edition of the County of Los Angeles Building Code.

When justified with a very short duration (i.e. days not weeks) and no potential impact to adjacent foundations or life safety services, the peak shear strength parameters may be utilized to compute the shoring loads.

3.5.12 Retaining Walls

All proposed retaining walls must be addressed in the geotechnical report and must meet the requirements of the current edition of the County of Los Angeles Building Code.

These data shall include, at a minimum, the following recommendations:

- Design soil pressures (bearing, passive, active, at-rest, impact, expansion, etc.).

- Design spectral response acceleration parameter (S_{DS}) at the short period (0.2s), when applicable. Guidance on seismic design parameters is provided in Directive GS103.0 (see Appendix).

- Unless the CLABC or a County policy stipulates a specific method to determine the seismic lateral earth pressure and application of resultant force, then they shall be determined using either the Mononobe-Okabe (M-O) theory or the Generalized Limit Equilibrium (GLE) method.

  NOTE: The Transportation Research Board of the National Academies, National Cooperative Highway Research Program, NCHRP Report 611, *Seismic Analysis and Design of Retaining Walls, Buried Structures, Slopes, and Embankments* (see Additional Resources), in Chapters 3 and 7, provides an excellent discussion and guidance for determining the seismic earth pressures using the M-O and/or GLE methods.

- Coefficient of sliding friction.

- Subdrainage design.

- Surface drainage requirements.

- Necessity for preventing seepage through the wall (structures).

- Amount of freeboard to prevent sloughing over the wall.

In arriving at the above design recommendations, the report must note the following site conditions:

- Wall restraining conditions (deformation conditions).

- Surcharge loads due to sloping backfill, foundation loads, traffic loads, etc.

- Backfill placement requirements including temporary equipment impact loads.
- Foundation Slope Setbacks.
- Shear strength parameters of the materials to be supported.
- Shear strength parameters of the material that will support the retaining structure.
- Effect of adverse slopes on the foundations.
- Effect of geologic conditions that may add surcharge (i.e., adverse bedding, expansive soils, etc.).

3.5.13 Reinforced (or Segmented) Earth Retaining Walls

Reinforced earth retaining walls must be addressed in the geotechnical report and must meet the requirements of the County of Los Angeles Building Code.

Geogrid (or similar reinforcement) details must include the embedment length, spacing, and number of geogrid layers. All geogrid reinforced areas behind the proposed reinforced earth retaining wall plus 10 feet beyond this limit shall be designated as an RUA on subdivision maps or "geologic/geotechnical setback area" on the grading/building plans.

Both internal (overturning, pullout, sliding) and external stability analyses must be provided in the geotechnical report and the accompanied reinforced earth retaining wall report.

The following parameters must be included in the reinforced earth retaining wall's internal and external stability analyses:

- Shear strength of the reinforced fill. In the internal stability analysis, a cohesion of c = 0 psf must be used for the reinforced fill.
- Shear strength of the foundation materials.
- Shear strength of the retained materials behind the reinforced fill.

The geotechnical report (and the accompanied reinforced earth retaining wall report) shall include the following recommendations:

- Design soil pressures (bearing, passive, active, etc.).
- Backfill placement and compaction requirements.
- Foundation slope setback.
- Subdrainage design.
- Surface drainage requirements.
- Seismic lateral pressure as discussed in the Section 3.5.11 *Retaining Walls*.

3.5.14 Building Pads in Transition Areas

All building pads located in cut/fill or bedrock/soil transition areas should be overexcavated a minimum of 3 feet below the proposed bottom of footings. Structural mitigation may be permitted in lieu of overexcavation.

Reaches of conduits (i.e. storm drains, sewer lines, etc.) located in transition areas shall be supported by a minimum of 3 feet of compacted fill or constructed with rubber gasket joints for a minimum of 24 feet on each side of transition. Alternatives to these requirements may be permitted on a case by case basis and will be evaluated on infiltration/exfiltration impacts on to the conduit stability when pipe separations exceed County standards.

3.5.15 Buttress Fill Design for Slope Stabilization

Buttress fills for slope stabilization must be designed for worst case scenario (see Appendix Figure 1) for possible failure planes used in analysis.

3.5.16 Subdivision Impacted by Existing Landslides

The following guidelines and requirements are for the geotechnical review of subdivisions impacted by landslides, with regards to property boundaries and safe building areas. Generally, existing landslides are considered a hazard unless it is demonstrated by subsurface exploration, rock and soil testing, and stability analysis that the landslide has appropriate safety factors.

An existing landslide which if activated could adversely impact offsite property (outside of the subdivision) does not have to be mitigated if the existing conditions will not be changed, worsened, or otherwise affected by the proposed development; and when the hazard does not pose a threat to onsite building areas in the subdivision. It must be clearly demonstrated that the proposed development will not increase the potential for failure of the hazardous conditions otherwise mitigation measures will be required.

An unmitigated landslide hazard, and the surrounding affected areas inside the proposed subdivision, will have to be designated as an RUA.

3.5.17 Differential Settlement

The geotechnical consultants must justify the construction of any structure that will have differential settlement in excess of 1 inch vertical movement over a horizontal distance of 30 feet. In such cases, the geotechnical consultants must provide for protection of the structure against excessive cracking, provide for adequate drainage of the utilities to withstand distortion and deflection due to differential settlement through flexible joints and must be located so the underground utilities can be exposed, if necessary, for periodic repairs.

In areas in which it is suspected that the settlement may exceed County minimum standards described above, it will be the responsibility of the soils engineer to obtain sufficient data and make findings and recommendations to mitigate the problem.

3.5.18 Settlement Monitoring

The soils engineer must clearly show the locations, details, and notes of all recommended settlement monuments on the grading plans. The geotechnical report must clearly identify the lots/pads that are to be associated with each settlement monument and recommend the reading intervals. Rough grading will not be approved until data from the settlement monuments are presented which establish that future settlement will be within Los Angeles County minimum standards.

3.5.19 Vinyl and Fiberglass Pools

Slope stability analysis will be required assuming a rapid drawdown condition (for vinyl and fiberglass pools) in which the depth of the pool from the ground surface to the bottom of the pool is greater than 5 feet. The minimum factor of safety for a rapid drawdown condition shall be 1.50.

The pool must have adequate slope setback meeting the County Code and be setback at least 5 feet from adjacent structure foundations.

3.5.20 Soil Cement

Soil cement and controlled low strength material (CLSM) may be used in engineered compacted fill to increase the shear strength parameters, bearing capacities, or as trench slurry backfill to meet design requirements. Complete recommendations for the proposed use of soil cement must be addressed in the geotechnical report and shall include, but not be limited to, the following:

- Slope stability analysis indicating minimum required strength parameters for the soil cement.
- Mix design including percentage of cement and soil gradation requirements.
- Design cross sections showing the soil cement with the keying and benching into the slope.
- Procedures for mixing and placement of the soil cement.
- Laboratory testing requirements and intervals.
- Required inspections and field testing by soils engineer.
- All required notes and details to be shown on the grading plans.

For all flood control improvements, the requirements stated in the most current version of the "*Soil Cement Standards and Specifications*" (see Additional Resources) document must be complied with. This document may be obtained from the Grading Section of Public Works Land Development Division. This document can also be used as guidance for non-flood control improvements that require soil cement standards.

3.5.21 Existing Foundation Repairs

The geotechnical consultants must clearly determine, describe, and characterize the cause of distress with substantiating soil data and analyses prior to recommending mitigation measures for foundation repairs. The geotechnical consultants shall determine and document the depths and limits of unsuitable soils/conditions. The depths and limits of unsuitable soils/conditions shall be shown on the geotechnical map. It must be clearly shown that the recommended foundation repairs or mitigation measures shall provide adequate support for the existing structure and will not be negatively affect offsite property.

Repair of existing foundations typically involve modifying subsurface conditions or use of a foundation system that gains strength from deeper soils or rock. Such foundation repair methods may include, but are not limited to, mudjacking, helical pile foundations, micro-piles, and deep soil mixing. The geotechnical consultant should evaluate the change in the foundation support and the potential seismic shaking effects on the structure as a whole.

Plans and reports for mudjacking operations shall evaluate and address potential impacts to utility conduits/lines and adjacent property.

The use of mudjacking, helical piles, or similar foundation repair techniques will not be permitted to be used for the purpose of geologic hazard (see Section 2.2.3 of this manual) mitigation, supporting new foundations, or resisting lateral loading.

All calculations and design parameters used to determine the mudjacking placement, helical piles, or similar foundation repair techniques shall be provided to the Geotechnical Development Review Units for their review and must be in conformance with appropriate manufacturer specifications. Final design requirements for foundation repairs, including manufacturer specifications, must be made part of the plans.

3.5.22 Policy Regarding Geotechnical Repairs

For the purpose of this manual, repairs are defined as corrective work performed to protect existing structures such as buildings, roads, utilities, etc. Whenever a repair is recommended or required, it shall be the goal of the designer to meet all the minimum standards in this manual for new construction as required in the Codes.

However, some Code requirements may be waived at the discretion of Building and Safety Division if it can be demonstrated to the satisfaction of the Building Official that:

- Minimum standards cannot be met.
- The overall hazard will be reduced or lessened and that the endangered structures can continue to perform as intended.
- Offsite property will not be adversely affected.
- Section 111 Statement will be provided for the repaired portion of the project. When applicable, Code requirements that were waived must be noted by the geotechnical consultants in their reports, in which case recordation of hazard waiver by the owner will be required.

4.0 ADDITIONAL RESOURCES

American Concrete Institute, Building Code Requirements for Structural Concrete (ACI 318) and Commentary.
www.concrete.org/general/home.asp

American Society of Testing and Materials International (ASTM) Standards
www.astm.org/Standard/

Association of Environmental & Engineering Geologists, Professional Practice Handbook, 3rd Edition (particularly Chapters 2 and 6).
www.aegweb.org/publications-resources/online-publications

Business and Professions Code, Division 3, Chapter 7 (also known as the Professional Engineers Act).
www.leginfo.ca.gov/.html/bpc_table_of_contents.html

California Board for Professional Engineers, Land Surveyors, and Geologists.
www.bpelsg.ca.gov/

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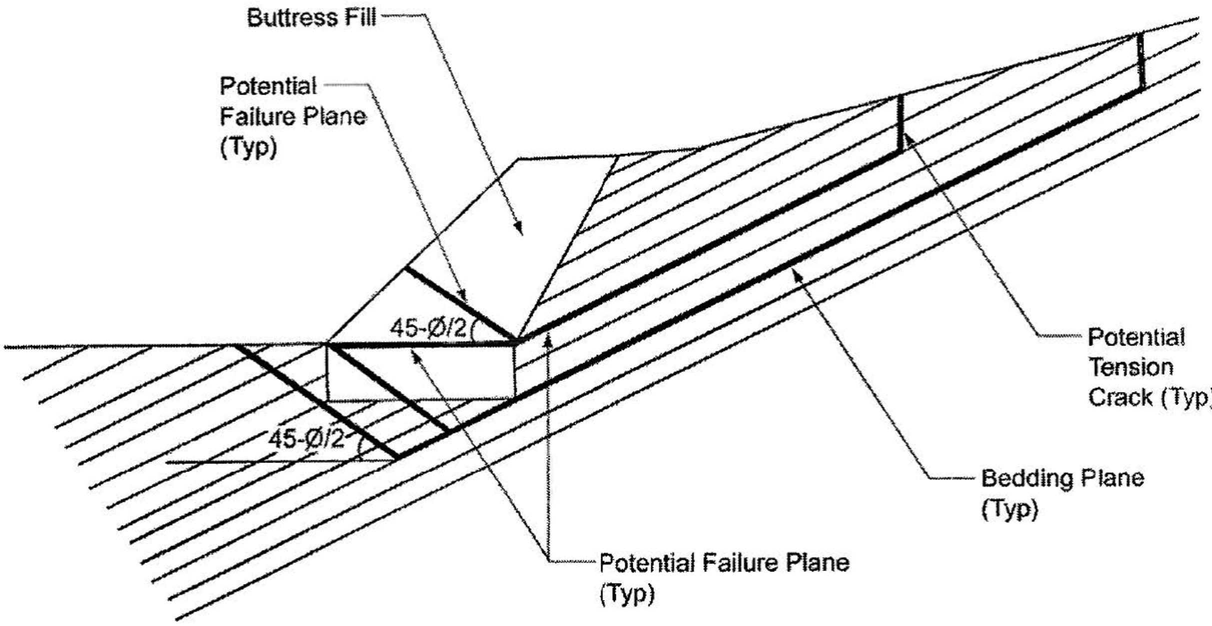
APPENDIX

BUTTRESS FILL DESIGN

Potential failure planes through and below the buttress



Note:
Ø = Angle of internal friction for the buttress fill or the natural materials cross bedding, whichever is applicable

FIGURE 1

UNGRADED SITE LOTS

The Los Angeles County Subdivision Code (LACSC), Section 21.44.320(A), indicates that, "If any portion of the land within the boundaries shown on a tentative map of a division of land is subject to ...geological hazard, and the probable use of the property will require structures thereon, the advisory agency may disapprove the map or that portion of the map so affected and require protective improvements to be constructed as a condition precedent to approval of the map." Also, according to the LACSC Section 21.44.320(C), "If any portion of a lot or parcel of a division of land is subject to...geological hazard, such fact shall be clearly shown on the final map or parcel map by a prominent note on each sheet of such map whereon any such portion is shown. A dedication of building restriction rights over the...geological hazard may be required." In addition, LACSC Section 21.24.010(B) indicates access free of geotechnical hazards must be provided for each lot. Generally, geotechnical hazards must be mitigated before the tract or parcel map is recorded.

However, some properties may be subdivided into lots where the specific types and locations of structures have not been determined and/or the developers do not intend to perform any grading or mitigation measures prior to recordation. These developments may be designated as "Ungraded Site Lots" with the subdivision recorded in accordance with the following criteria:

1. The geotechnical consultants must show in their report(s) through appropriate data and analyses, all grading and corrective work required to provide safe access and building sites free of geologic and geotechnical hazards for each of the proposed lots. A geotechnical map is required which clearly defines the limits of all geotechnical hazards. If a lot or access to a lot is identified as having a geologic or geotechnical hazard, the consultants must clearly identify the hazard in the geotechnical reports and recommend corrective work.

2. For slopes steeper than 5:1 (horizontal: vertical) gradient, a concept-grading plan or a Regional Planning Department "Exhibit A" is required. All recommended grading and corrective work must be self-contained within each lot and depicted on the concept-grading plan or Exhibit A. Grading and/or corrective work that crosses lot lines disqualifies the development from the "Ungraded Site Lots" criteria.

3. All unmitigated geologic hazards include, but are not limited to, areas subject to landsliding, debris flows, and active fault traces must be designated on the Final Map as "Restricted Use Areas." Soils susceptible to hydroconsolidation, high expansion, excessive settlement, lateral spread, liquefaction, or seismically induced settlement are not considered geologic hazards for the purpose of Code enforcement, and therefore, are not designated as Restricted Use Areas.

4. Prior to approval of the development for recordation of the Final Map, the following is required:

   - Access free of geologic and geotechnical hazards must be provided to each lot.

   - The location of "Restricted Use Areas," as recommended in the geotechnical reports (see item 3 above), must be depicted on the Final Map.

   - If any portion of the development is subject to hydroconsolidation, highly expansive soils, excessive settlement, lateral spread, liquefaction, or seismically induced settlement, the following note is required on the Final Map: "According to the Geotechnical Consultants of Record parts or all of Lot(s) (*lot numbers*) are subject to an hydroconsolidation, highly expansive soils, excessive settlement, lateral spread, liquefaction, or seismically induced settlement. For location of geotechnical hazards and corrective work requirements for access and building areas of Lot(s) (*lot numbers*), refer to geotechnical reports by (*consultants*) dated (*date*)."

Approved By:

Michael A. Montgomery
Assistant Division Head

SUBDIVISION - "REMAINDER PARCEL" FOR TENTATIVE AND FINAL MAPS

When the designation “REMAINDER PARCEL” is shown on tentative and final maps, the following geotechnical review criteria shall apply:

1. Geotechnical consultants must demonstrate that each Remainder Parcel contains at least one buildable site and legal access to that site and to the parcel that are free of existing or potential geologic/geotechnical hazards. The designated buildable site on each Remainder Parcel shall be shown to be developable in accordance with the Los Angeles County Building Code and in compliance with requirements of the Department of Regional Planning.

2. Each designated safe buildable site and access to that buildable site must be depicted on the geotechnical map. Corrective measures, such as grading, necessary to create the safe buildable site are not required to be completed prior to recordation of the final map. Geotechnical consultant report(s) shall be referenced, by use of a note, on the final map.

3. Access to the Remainder Parcel must be free of geologic/geotechnical hazards at the time of final map recordation or provide geologic corrective bonds to assure completion of all corrective measures necessary to provide that access.

4. If after providing for lot access and indicating the location of the safe buildable site and access to the buildable site, unmitigated geotechnical hazards still exist on the Remainder Parcel, these areas are not to be designated as “Restricted Use Areas” on the final map. The Restricted Use Area designation and delineation shall be evaluated if the Remainder Parcel is subdivided.

Reference: Subdivision Map Act § 66424.6

Approved By:

Michael A. Montgomery
Assistant Division Head

LIQUEFACTION/LATERAL SPREAD

These guidelines address the geotechnical review of “Projects” (see SP117A, Table 1) in areas that have been designated by the California Geological Survey (CGS) to have a potential for liquefaction in accordance with the provisions of the Seismic Hazard Mapping Act of 1990. These guidelines may be used to address the geotechnical review of non-Projects when directed to do so by the Building Official. Supporting documents for these guidelines are as follows:

- CGS Special Publication SP117A; 2008.
- State of California Seismic Hazard Mapping Act of 1990 (Public Resources Code, Chapter 7.8, Division 2).
- Recommended Procedure for Implementation of DMG Special Publication 117, Southern California Earthquake Center (SCEC); 1999.

Per SP117A, “The State Mining and Geology Board recommends that engineering geologists and civil engineers conduct the assessment of the surface and subsurface geological/geotechnical conditions at the site, including off-site conditions, to identify potential hazards to the project. It is appropriate for the civil engineer to design and recommend mitigation measures. It is also appropriate for both the engineering geologist and civil engineers to be involved in the implementation of the mitigation measures – engineering geologist to confirm the geological conditions and civil engineers to oversee the implementation of the approved mitigation measures.”

Prior to performing a quantitative assessment, a screening investigation should be conducted in accordance with SP117A. If the screening investigation clearly demonstrates the absence of a liquefaction hazard and the Geotechnical Development Review Units concur, the screening investigation will satisfy the site investigation report requirement. Otherwise, a quantitative evaluation is required to assess the liquefaction hazard.

The following screening criteria may be used to determine if specific layers or the maximum investigative depth explored may be excluded from further quantitative evaluation of liquefaction hazard:

1. Estimated maximum past, current, and future groundwater levels are determined to be deeper than 50 feet below the existing ground surface, finished grade, or 20 feet below the proposed bottom of foundations, whichever is deepest.

2. Bedrock or other similarly dense, lithified formational material underlying the site need not be considered liquefiable. Analysis of their liquefaction potential is not required. The presence of bedrock or other similar lithified formational material must be substantiated by either encountering refusal or by providing boring log(s) showing that at least 5 feet of such materials exist. It should be noted that hand augered refusals will not be accepted as adequate exploratory effort.

3. Corrected Standard Penetration Test (SPT) blow counts $(N_1)_{60}$, greater than or equal to 30. A sufficient number of tests shall be conducted to provide at least one SPT blow count record for every 5 feet of depth explored. If nonstandard samplers or penetration tests are used, conversion to SPT blow counts shall incorporate conservative conversion factors (e.g., conversion from California modified split spoon to field SPT blow counts is typically 0.67 to 0.7). Conversion of blow counts from a nonstandard samplers or penetration tests, such as the Becker Penetration Test, to SPT blow counts will require supporting calculations and discussions.

4. Cone Penetration Test (CPT) results of discrete coarse-grained soil layers with corrected CPT tip resistances (q_{c1N}) greater than or equal to 160 tsf (156 kg/cm^2 or 16 MPa).

5. Soils that behave like clays and do not undergo severe strength loss during ground shaking may be generally considered not susceptible to liquefaction. To determine if soils are susceptible to liquefaction, the Plasticity Index (PI) and in-situ moisture content must be determined. Soils considered to be potentially susceptible to undergoing seismically induced deformation during liquefaction are classified in the following manner; **(1)** P1<12 and moisture content greater than 85 percent of the liquid limit, <u>or</u> **(2)** soils with a P1>18 and a degree of sensitivity (S_t) greater than 6.

Typically the S_t is determined as the ratio of undisturbed to remolded compressive strength. Similar tests may also be conducted to determine the S_t such as, ratio undisturbed to remolded shear strength and a consolidated undrained triaxial stress relaxation tests (for additional S_t references, see *Soil Mechanics in Engineering Practice* 3rd Edition by <u>Terzaghi, Peck, and Mesri</u> or *An Introduction to Geotechnical Engineering* by <u>Holtz and Kovacs</u>).

Note: Use of Soil Behavior Type Index (I_c) values may not be used as screening criteria and may not be used to exclude layers from the seismically induced settlement calculations.

If the screening investigation cannot clearly demonstrate the absence of a liquefaction hazard at the site, an engineering geology and/or soils engineering report that addresses the potential for liquefaction and associated settlement and lateral spreading will be required. The report(s) must, at a minimum, include and consider the following:

1. A description of the proposed project's location, proposed grading, drainage, topographic relief, and subsurface geologic conditions.

2. A site plan of the subject site showing the location of all exploratory work, including test pits, borings, penetration tests, and soil/rock samples obtained. The site plan shall also include the direction of north, plan scale, and location of proposed site improvements and property lines.

3. Logs of borings, CPT soundings, test pits, and other subsurface data obtained. Boring logs shall provide raw (unmodified) N-values if SPT's are performed; CPT probe logs shall provide raw qc-values and plots of raw sleeve friction values. It is required that subsurface data be collected and analyzed to a minimum depth of 50 feet below ground surface or finished grade, whichever is deeper. When a structure may have subterranean construction or deep foundations, the minimum depth of exploration must be extended to a minimum of 20 feet below the lowest expected foundation level (bottom of caisson or pile), or 50 feet below ground surface, whichever is deeper. Also, when proposed developments are within several hundred feet of a free face of slope, the depth of exploration shall be adequate to evaluate the site's lateral spreading capacity.

4. Groundwater level to be used in the liquefaction analysis. SP117A requires that the analysis of hydrologic conditions consider the current, historical, and potential future depth of subsurface water. The historic high groundwater level shall be used in the liquefaction analysis unless a shallower level (higher elevation than historic high) is determined to be appropriate.

5. Description of seismic setting, historical seismicity, and methods and/or sources used to determine earthquake ground-motion parameters used in the liquefaction analysis. SP117A indicates that either a Probabilistic or Deterministic Seismic hazard Analysis must be performed in order to obtain a peak horizontal ground acceleration and earthquake magnitude for use in a quantitative analysis. To determine which evaluation is most appropriate to the proposed site improvements, please refer to the following.

   Probabilistic

   Probabilistic Seismic Hazard Analysis must utilize at least a hazard level of 10 percent probability of exceedance in 50 years.

   County reviewers will review the seismic parameters submitted in the site-specific hazard analysis by utilizing the national earthquake source database at http://earthquake.usgs.gov/hazards/. The peak horizontal ground acceleration and mean magnitude will be compared against the acceleration and magnitude values utilized in the submitted quantitative evaluation of liquefaction resistance.

Seismic parameters utilized in the consultant's quantitative evaluation will be accepted if they are equal to or more conservative than the parameters obtained by the County reviewer. Seismic parameters that do not meet the values obtained by County reviewer must be justified by the consultant and approved by the reviewer.

-OR-

Deterministic

Earthquake magnitudes based upon the current United States Geological Survey/CGS database of earthquake sources are readily available and should be utilized in determining a peak ground acceleration and magnitude. The deterministic earthquake event for any fault should be a maximum value that is specific to that seismic source.

Attenuation equations and values must use current literature and site conditions.

Geotechnical consultants should utilize the average ground motion obtained from the three attenuation relations in the quantitative liquefaction evaluation. For high occupancy structures, it is common practice to use a deterministic seismic hazard analysis with a median-plus-one-standard-deviation (84th percentile) in developing ground motion estimates.

Seismic parameters that do not meet values obtained by County reviewers must be justified by the consultant. County reviewers must concur with the justification and/or findings in order for lower seismic parameters to be used in the quantitative evaluation.

6. Consideration of the geologic factors that may control or affect the severity of potential hazards (e.g., site-specific response characteristics due to amplification of soft soils, deep sedimentary basins, topography, near-source affects, etc.).

7. The geotechnical report must comply with and contain a finding in accordance with Section 111 of the County of Los Angeles Building Code.

8. Discussion of proposed mitigation measures, if any, necessary to reduce potential damage caused by liquefaction.

9. Specific commentary and supporting data provided for every layer excluded from liquefaction assessment and settlement analyses.

10. Depth of exploration to a minimum of 50 feet below ground surface, finished grade, or 20 feet below the lowest expected foundation level (bottom of caisson or pile), whichever is deepest.

11. When using the CPT, provide a confirmation boring to meet the minimum required depth of exploration (see Item No. 2 above). The CPT and confirmation boring shall be conducted in close proximity to each other, but not be spaced so closely that stress relief may affect the results.

12. A factor of safety (FS) of 1.30 shall be used in the quantitative liquefaction hazard evaluation to determine the exclusion of layers from settlement calculations. The FS is the ratio of the magnitude corrected cyclic resistance ratio (CRR) to the cyclic stress ratio (CSR) or simply FS = CRR/CSR. Layers that do not have a FS greater than (>) or equal to 1.30 shall be included in the seismically induced settlement calculations.

13. Quantitative analysis shall not combine layers of raw data regardless of data similarity (for example: converting 50 CPT layers of 0.1-foot thickness into a 5-foot thick average layer).

14. All acceleration values must be magnitude weighted in accordance with magnitude scaling factors after Youd and Idriss, 1997.

15. All correction factors applied to raw SPT blow counts and CPT soundings shall be discussed and sufficiently justified.

16. Consistent values must be used throughout the analyses, or they must be adequately explained and supported with substantiating data.

17. Bridging of non-liquefiable soil layers above liquefiable layers is not considered an adequate explanation or justification for exclusion of those layers in the seismically induced settlement calculations.

18. Total seismically induced settlement must be the sum of seismically induced settlements of both the saturated and unsaturated soils.

19. Differential settlement shall be taken at least half of the total seismically induced settlement over a horizontal distance of 30 feet. In order to use less than half of the total settlement, there must be additional borings onsite that confirm the uniformity of the soil stratigraphy and relative density.

20. Assessment of lateral spreading must be conducted when gently sloping ground or free faces (e.g., marina seawalls, drainage channels) are within or in close proximity to the site. Soil layers having equivalent $(N_1)_{60}$ blow counts less than 15 should be evaluated to assess the lateral spreading hazard.

21. Structural mitigation is acceptable for: (1) up to 1 inch of seismically induced differential vertical displacement over a horizontal distance of 30 feet, (2) up to 4 inches of total seismically induced settlement, and (3) up to 12 horizontal inches of lateral ground displacement. Anything in excess of the aforementioned values requires ground modification. A combination of ground modification, piles, and structural mitigation may be acceptable on a case by case basis.

22. A "Project" and applicable non-Projects will be approved only when the nature and severity of liquefaction potential at the site has been evaluated in a geotechnical report and appropriate mitigation measures have been proposed and incorporated into the plans.

23. If CPT data is used in quantitative liquefaction analysis, submittal of the electronic version of CPT data in a spreadsheet format, on a compact disc, will aid in the review process.

24. A copy of all submitted geotechnical reports and review sheets approving the "Project" must be sent to the State Geologist within 30 days of recommending the plan for approval.

Approved By:

Michael A. Montgomery
Assistant Division Head

SURFICIAL SLOPE STABILITY FOR NATURAL SLOPES

This directive provides guidelines applicable for the review of structures proposed adjacent to natural slopes, swales, etc., that have a potential for shallow or surficial failures (excludes gross stability).

Guidelines contained herein exclude additional criteria and requirements that may be imposed by the Building Official or Land Development Division Subdivision Mapping Section relative to runoff, drainage, grading, etc. The requirement for an engineering geology report may be waived by the District Geologist based upon the geologic conditions and/or the scope of the project under review.

1. A coordinated investigation by a Certified Engineering Geologist and a Civil Engineer competent in soils engineering is commonly necessary for a thorough assessment of the stability of natural slopes. Surficial materials include soils, colluvium, talus, slopewash, highly weathered (soil like) bedrock, etc.

2. The geotechnical consultant(s) must demonstrate that proposed structures will be free from landsliding, settlement and slippage as defined in the 2011 County of Los Angeles Building Code (CLABC) Sections 110 and 111.

3. Site specific data must be provided and considered in the assessment of potential mobilization of surficial materials (e.g. debris flows, mudflows).

4. Assessment and/or contents of consultant geotechnical reports should include:

    - Evaluation of significant slopes. Generally, significant slopes are steeper than 2:1 (horizontal:vertical) ratio (>26 degrees), and/or when the height of the slope and geologic conditions warrant.

    - Evaluation of material thickness, density, variability, and potential irregularity of contact with underlying firm material or bedrock.

    - Impact of underlying bedrock or other materials of low permeability that may indicate conditions conducive to potential instability.

    - Variability and concentration of surface runoff (no drainage devices). If drainage devices are necessary and considered in the evaluation, devices must be shown on the plans.

- Change in slope gradients.

- Hydrogeologic and geologic conditions relative to stability.

- Location and description of past surficial failures in the area.

- Presence of animal burrows, cracks in the soils, and fractures that may increase the infiltrate rate into the surficial materials.

- Geotechnical map that includes native drainage courses (e.g. swales, hollows) and proposed drainage devices, and topographic anomalies.

- Coordinated assessment by the consulting engineering geologist and soils engineer.

- Evaluation of existing off-site instabilities and slope performance under similar site and geologic conditions.

- Illustration of geologic and hydrogeologic conditions and data inclusive of cross-sections.

5. A slope stability analysis that evaluates stability of natural surficial materials. The consulting engineering geologist shall supplement the stability analysis with a qualitative assessment that takes into account geologic conditions, slope history, published documents, etc. Mitigative measures should be based upon input from the consulting engineering geologist and soils engineer. Surficial slope stability requirements shall conform to the following:

   - Analysis shall use the infinite slope method with seepage parallel to the slope surface, or other critical surface if identified during the geotechnical investigation.

   - Depth of full saturation shall be 4 feet, unless geologic conditions indicate an alternate thickness is appropriate for the analysis.

   - Minimum factor of safety shall be 1.50.

   - Shear strength parameters used in the analysis shall be representative of surficial materials.

6. The volume of debris calculated for mitigation design/measures should be based upon the slope stability analysis and qualitative input from the geotechnical consultants.

7. If surficial slope stability analyses and/or qualitative data indicate a debris flow potential exists on the subject natural slope, slope setback reductions cannot be granted (see 2011 CLABC Section 1808.7).

8. Walls detaining or diverting debris shall be designed as impact walls. These walls shall be designed for a minimum force of 125 pounds per cubic foot (equivalent fluid pressure). Force acting on the wall shall be applied to the entire height of wall potentially in contact with debris.

9. Mitigative or preventative measures which divert debris onto adjacent properties and/or require maintenance are unacceptable. Debris hazards should be completely mitigated on-site. Mitigative measures, resulting in modification of natural drainage or removal (grading) of natural slope surficial material, are subject to review and approval by the Building Official or Subdivision Mapping Section. Incorporation of paved swales or other devices may be required by the Building Official or Subdivision Mapping Section. Please note that debris fences are not an accepted form of mitigation unless a debris fence maintenance covenant is permitted by the Building Official.

10. Diverting debris onto a public right-of-way may be an acceptable mitigative measure provided the Building Official or Land Development Division Subdivision Mapping Section has assessed and accepted the potential impact of the concentration and deposition of debris onto a public street. The following note <u>must</u> be included on the plans and review sheets to the Building Official or Subdivision Mapping Section:

    Attention Drainage Plan Checker:

    > *Proposed debris flow hazard mitigation plan will potentially divert material onto a public right-of-way. The estimated volume of debris is _________ cubic yards.*

    The Geotechnical Development Review Units shall work with the Building Official to ensure that the volume, area, and depth of debris diverted onto public right-of-ways and the resulting impact to "access free of geotechnical hazards" and life safety services (e.g. fire department, ambulance service) is fully understood by the Building Official and documented.

NOTE: Before preparing comments regarding surficial slope stability, Geotechnical Development Reviewers should have read and be familiar with, at a minimum, the following documents: California Geological Survey Note 33, United States Geological Survey Professional Paper 851 (by Russell H. Campbell, 1975), and the Bulletin of the Association of Engineering Geologist, Vol. XVIII, No. 1, 1981, pp. 17-28.

Approved By:

Michael A. Montgomery
Assistant Division Head

GUIDELINES FOR FINAL MAP CLEARANCE

The subdivider should ensure that any and all geotechnical conditions for approval of the Final Map have been fulfilled prior to the submittal of the Final Map. A copy of the Final Map and payment of verification fees are required to initiate the review process, and these are submitted through Land Development Division. The following items must be submitted to the Geotechnical Development Review Units by the subdivider or his/her agent via the Land Development Division Processing Center:

1. (a) One (1) copy of the Final Map. It must be dated and logged in (stamped) by the Processing Center.

   or

   (b) Three (3) sets of the Final Map must be provided when geotechnical Restricted Use Areas (RUA) or Geotechnical Notes (GN) are on the Final Map. Final Maps must be dated and logged in (stamped) by the Processing Center. For Final Maps with RUAs, each sheet of all three sets of the Final Map must be signed by the geotechnical consultant(s), by manual, original (wet) signatures and indicate their approval of RUAs boundaries.

2. A Restricted Use Area Letter is required. If no RUAs or GNs are required [Situation 1(a) above], a letter from the geotechnical consultant(s) must be submitted that states that there are no RUAs or GNs required for the subdivision. If RUAs or GNs are required [Situation 1(b) above], two copies of the report and geotechnical map that describe and depict the hazard(s) must be submitted.

3. One copy of the receipt showing that the geotechnical verification fees (for technical clearance) have been paid.

4. One copy of the Geologic and Soils Review Sheets, which approve the grading plan for the subdivision, is required.

5. All conditions of the geotechnical approval of the tentative subdivision must be met prior to approval of the Final Map.

6. One copy of the Bond Agreement form showing the amount of Geologic Corrective Bonds required for this project.

Note: Not all projects require Geologic Corrective Bonds. These bonds are required (when grading has not been completed) for corrective geologic grading, such as buttresses fills, stabilization fills, deep removals, etcetera.

Bond Amounts: $4.00 per cubic yard for faithful performance + $2.00 per cubic yard for Labor and Materials. The consulting civil engineer in coordination with the geotechnical consultant(s) determines the cubic yardage. In turn, cubic yardage will be used to calculate the bond amount.

CHECK LIST FOR ABOVE REQUIREMENTS

___ 1. a. 1 copy of Final Map (No Restricted Use Areas or Geotechnical Notes).
b. 3 signed copies of Final Map (with Restricted Use Areas).
c. 3 copies of the Final Map (with Geotechnical Notes).

___ 2. Restricted Use Area Letter or report with geotechnical map.

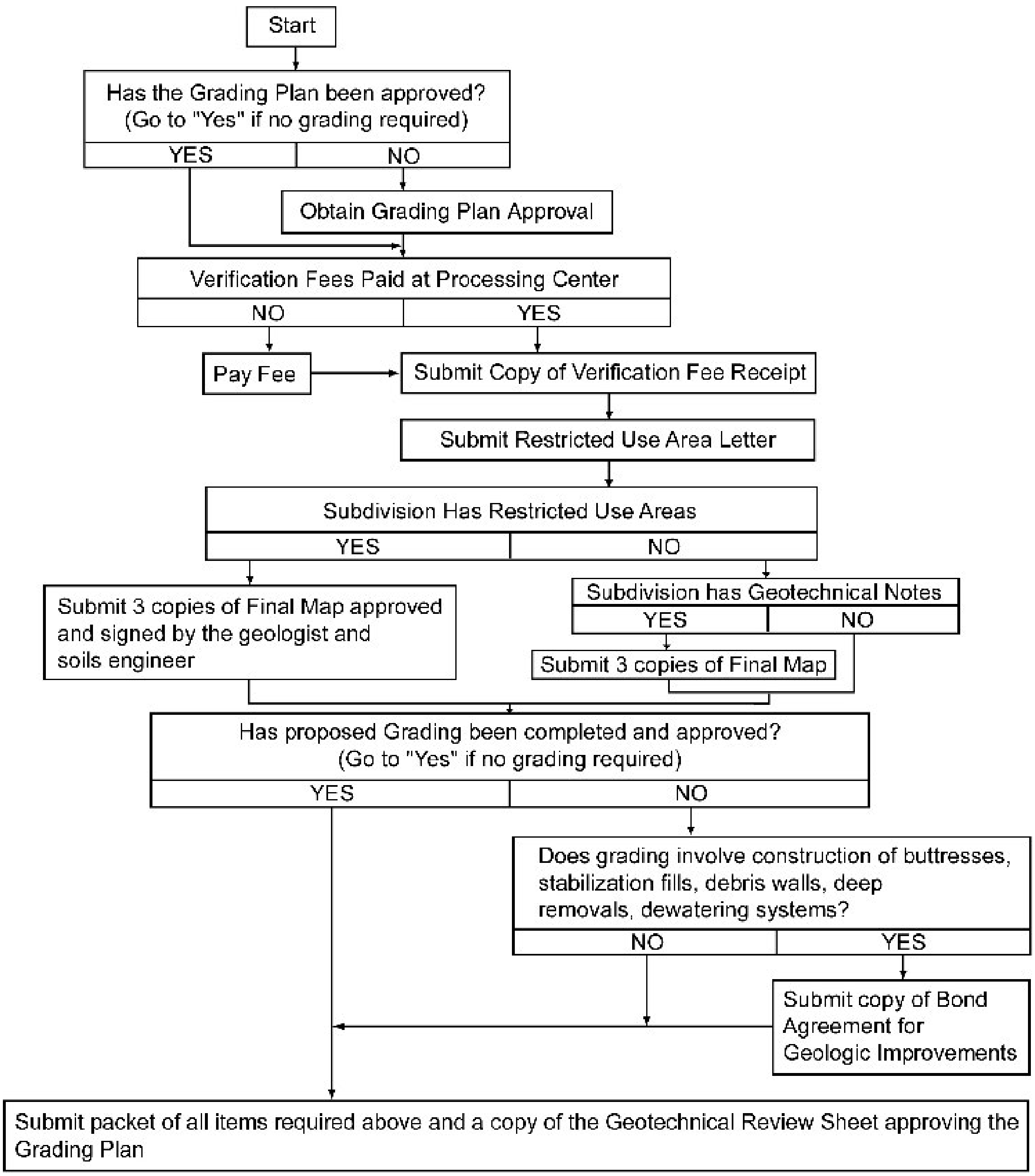
___ 3. Receipt for geotechnical verification fees payment.

___ 4. Bond agreement, as necessary.

Approved By:

Michael A. Montgomery
Assistant Division Head

Flow Chart for Submittal of Final Maps to the Geology Development Review Section



RESTRICTED USE AREAS

Each lot of a subdivision must have, or bonds must be provided to establish, a geotechnically safe buildable area and access free of geotechnical hazards at the time of recordation of the Final Map. Exemptions include, but may not be limited to, "Open Space Lots," "Ungraded Site Lots," and "Remainder Parcels." If any portion of a division of land is subject to geologic hazard, dedication of building-restriction rights (i.e. Restricted Use Area) over the geological hazard area is required. A "Restricted Use Area" (RUA) is recorded on the final map giving the County of Los Angeles the right to restrict building within this area. The dedication is made during the Final Map process (see County of Los Angeles Subdivision Code Section 21.44.320 and Government Code Section 25367). Divisions of land in which each resultant parcel has a gross area of 40 acres or more do not require the recordation of "Restricted Use Areas." If a "Restricted Use Area" or any other dedication is to be made for a minor land division, then that minor land division is ineligible for a parcel map waiver (County of Los Angeles Subdivision Code §21.48.140).

Onsite soils susceptible to hydroconsolidation, highly expansive soils, excessive settlement, lateral spread, liquefaction, or seismically induced settlement are not considered geologic hazards for the purpose of Code enforcement, and therefore, are not designated as Restricted Use Areas.

However, if a portion of a subdivision is identified as having soils subject to hydroconsolidation, highly expansive soils, excessive settlement, lateral spread, liquefaction, or seismically induced settlement, the consultants must recommend corrective work. If the subdivider is not proposing to complete or bond for corrective work, the following "Geotechnical Note" (GN) is required on the Final Map:

> "According to the Geotechnical Consultants of Record parts or all of Lot(s) (*lot numbers*) are subject to hydroconsolidation, highly expansive soils, excessive settlement, lateral spread, liquefaction, or seismically induced settlement. For location of geotechnical hazards and corrective work requirements for access and building areas of Lot(s) (*lot numbers*), refer to geotechnical reports by (*consultants*) dated (*date*)."

Geologic hazards include, but are not limited to, areas subject to landsliding, debris flows, and active fault traces. Unmitigated geologic hazards shall be the basis for determining "Restricted Use Areas" and their delineation on the Final Map.

On a very limited basis, at the request of the geotechnical consultant(s) and the property owner, an area suspected of having a geologic hazard that has not been geotechnically explored and is not likely to affect the proposed development, may be designated as a “Restricted Use Area” in lieu of exploration.
Geotextiles used in the support of slopes or retaining walls are also required to be designated as “Restricted Use Areas.” An additional 10 feet beyond the area of the geotextiles must be included within the RUA to allow for potential future maintenance or replacement of the geotextiles. Excavations in the geotextile areas for swimming pools and footings, planting of trees, etcetera, can damage the geotextiles and negatively impact the stability of slopes, retaining walls, and potentially off-site properties.

“Restricted Use Areas” may be shown on the tentative map and grading plan, but must be designated and shown on the Final Map prior to approval. The geotechnical consultant(s) shall show the extent of “Restricted Use Areas” and geotechnical hazards that warrant the use of “Geotechnical Notes” on the geotechnical map. Extent of RUAs and GNs shall be based on substantiating geotechnical data. Prior to Final Map recordation, the geotechnical consultants must indicate and delineate in their report/letter whether or not “Restricted Use Areas” or “Geotechnical Notes” are required.

For evaluation of “Restricted Use Areas” and “Geotechnical Notes,” the Geotechnical Development Review Section reviewers shall consider the following:

1. Geotechnical hazards must be properly identified, defined, and mapped.

2. Geotechnical hazards that pose a threat to adjoining parcels must be corrected in accordance with established criteria in order to eliminate the threat and may not be placed in “Restricted Use Areas” (see GS086.0).

3. Unmitigated geotechnical hazards must be designated as “Restricted Use Areas.”

4. Future development in a recorded “Restricted Use Area” may be permitted upon submittal and approval of corrective work plans for the geological hazard and additional geotechnical information. Removal of the “Restricted Use Area” designation from the recorded Final Map is not required.

5. Modification and abandonment of “Restricted Use Areas” can be made after the Final Map is recorded by filing a request through Survey/Mapping & Property Management Division. A report and geotechnical map is required to describe the proposed corrective work and delineate the change. Corrective work plans shall be supported with geotechnical data and analyses when RUA modifications or abandonments are proposed.

6. Final Maps with “Restricted Use Areas” shall be processed and reviewed as follows:

- Show boundaries of the “Restricted Use Area” on the map, as required by the Subdivision Mapping Section.
- Three copies of the map are required that have been approved by the geotechnical consultants, by manual original signatures, date, and an approval statement on all sheets.
- Approved maps shall be distributed by the Geotechnical Development Review Unit to the appropriate Building Official’s District Office and/or the Subdivision Mapping Section of Land Development Division.
- Transmittal of the map to the Building Official’s District Office shall include a letter with an explanatory statement that “Restricted Use Areas” are included on the map. Utilize Form 12 to transmit the map.

7. Final Maps with “Geotechnical Notes” shall be processed and reviewed as follows:

- Three copies of the map are required that have been approved by the geotechnical consultants, by manual original signatures, date, and an approval statement on all sheets.
- Approved maps shall be distributed, by the Geotechnical Development Review Unit, to the appropriate Building Official’s District Office and/or the Subdivision Mapping Section of Land Development Division.
- Transmittal of the map to the Building Official’s District Office shall include a letter with an explanatory statement that “Geotechnical Notes” are included on the map. Utilize Form 12 to transmit the map.

Approved By:

Michael A. Montgomery
Assistant Division Head

SUBDIVISIONS IMPACTED BY EXISTING LANDSLIDES

The following guidelines and requirements are for the geotechnical review of subdivisions impacted by landslides, with regards to proposed subdivisions of land and safe building areas. Landslides are considered a geologic hazard unless it is demonstrated to have factors of safety for gross static stability at least 1.5 and pseudostatic stability at least 1.1. Stability analyses shall be supported with onsite subsurface exploration and appropriate laboratory testing.

Unmitigated landslide hazards that, if activated, could adversely impact offsite property (outside of the subdivision) do not have to be mitigated when the following conditions are met:

- Existing landslide hazard already crosses an existing property boundary.
- Existing conditions will not be changed, worsened, or otherwise be affected by the proposed development.
- Hazard does not pose a threat to on-site building areas in the subdivision.
- Proposed development will not increase the potential for failure of the hazard.
- Each landslide hazard is contained entirely on one lot.

An unmitigated landslide hazard and the surrounding affected area inside the proposed subdivision will have to be designated as a Restricted Use Area. The surrounding affected area (e.g. areas upslope of the landslide that may lose lateral earth resistance) determination shall be addressed by the geotechnical consultant(s) and supported with data and analyses.

Cases designated below refer to the Plate (see attached):

Case A

Problem: Proposed lot line crosses landslide.

Solution: Adjust lot line to constrain the landslide on one lot or provide remediation of the landslide. The landslide hazard cannot be subdivided. Designate unmitigated landslide hazard and surrounding affected area as a Restricted Use Area.

Case B

Problem: Designated building area is at the toe of a landslide, which is contained within a single lot of the subdivision.

Solution: Relative to the building area, the landslide must be mitigated (e.g., buttressed or removed) or be demonstrated to be stable and not a threat to the safety of the proposed structure. Alternatively, a safe building area may be found on the lot not affected by geotechnical or geologic hazards. Designate unmitigated landslide hazards and the surrounding affected area as a Restricted Use Area.

Cases C and G

Problem: Landslides are outside of the subdivision boundary where remediation is not possible.

Solution: Unless the building pad can be shown to have an adequate setback from landslide hazard-affected areas or the landslide will be stabilized, an alternate building area is required.

Cases D and E

Problem: A landslide transects the subdivision boundary.

Solution: No mitigation is required because the landslide transects an existing property boundary. However, it must be clearly demonstrated that the proposed development will not adversely affect or contribute to the instability of the landslide in the future. Otherwise, the landslide must be mitigated. If it is determined that the landslide hazard will not be required to be mitigated, designate that portion of the unmitigated landslide hazards and surrounding affected area within the subdivision as a Restricted Use Area.

Cases F and G

Problem: The landslides are either entirely inside or outside of the subdivision perimeter boundary and do not affect the safety of the building area.

Solution: It must be clearly established that the proposed development will not adversely affect or contribute to the instability of the landslide, resulting in adverse effects on adjacent property and relative stability.

Otherwise, the landslide must be mitigated. If it is determined that the landslide hazard will not be required to be mitigated, designate unmitigated landslide hazards and surrounding affected area within the subdivision as a Restricted Use Area.

Case H

Problem: An existing landslide has been determined to be hazard and affected area could cross to an adjacent lot in the same subdivision.

Solution: Landslide must be removed or mitigated.

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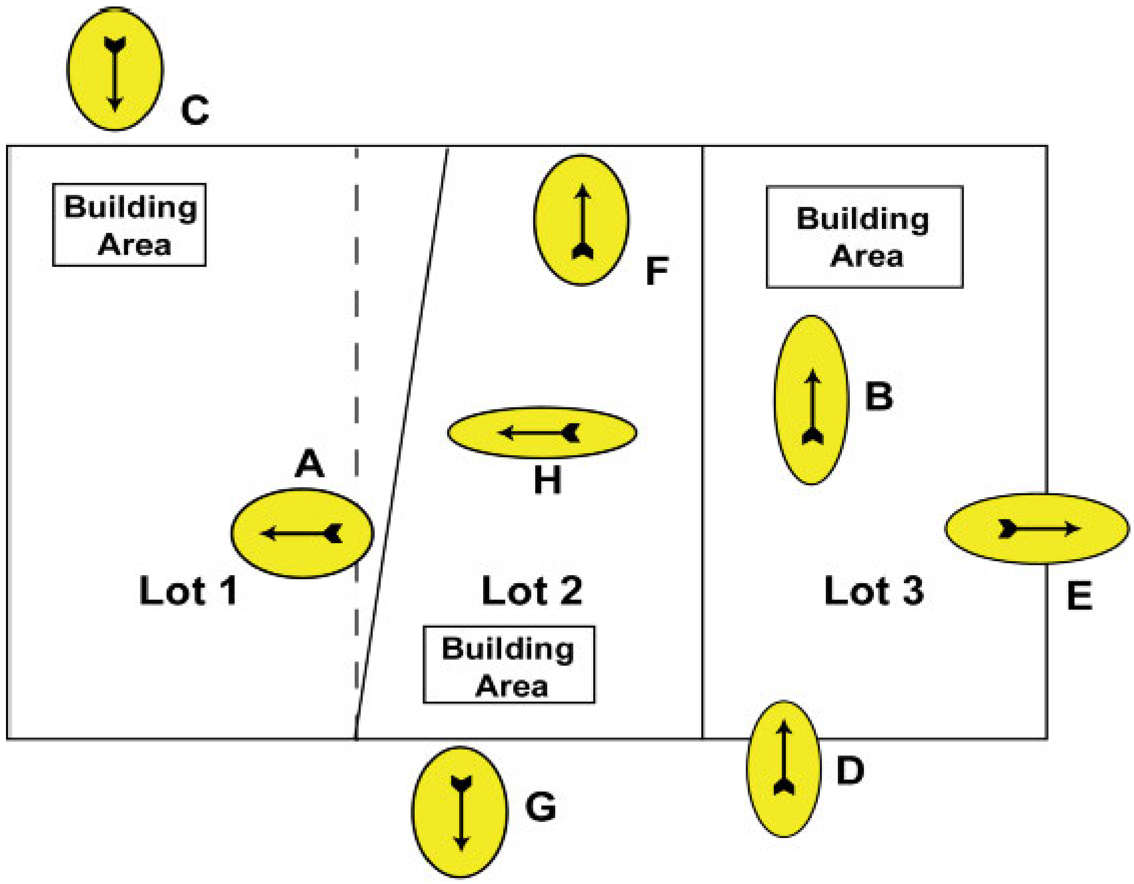

EXPLANATION

(landslide symbol)	Landslide. Arrow indicates direction of movement.
_ _ _	Lot boundary. Short dashes indicate movement of boundary required for Case "A".
———	Boundary of tentative subdivision.
A - H	Case designation.

SEISMIC DESIGN PARAMETERS FOR RETAINING AND MECHANICALLY STABILIZED EARTH WALLS

The County of Los Angeles, Public Works, Building and Safety Division has published Building Code Manual 1807.2 Article 1 (dated 10-25-2012) and Residential Code Manual R404.4 Article 1 (dated 10-25-2012) to provide additional guidance on application of Code requirements.

It is the responsibility of the Geotechnical Development Review Units to verify the geotechnical consultants' short period (0.2s) design spectral response acceleration parameter (S_{DS}) for traditional retaining walls, mechanically stabilized earth (MSE) walls, basement walls, etc.

The Building Official has requested that the Geotechnical Development Review Units verify the data used in the analysis. Authority for this requirement and the analysis procedures to determine the seismic design parameters are provided in Chapters 16 and 18 of the County of Los Angeles Building Code.

It is the responsibility of the geotechnical reviewers to:

- Verify that seismic parameters have been provided for walls greater than 12 feet in height for construction associated with Groups R-3, R-3.1, and R-4 occupancies (per County of Los Angeles Residential Code Section R404.4).
- Verify that seismic parameters have been provided for walls greater than 8 feet in height for construction associated with all other occupancies.
- Determine that the parameters are reasonable and appropriate.
- Report the parameters as a note on the geotechnical review sheets [e.g., NOTE(S) TO THE PLAN CHECKER/BUILDING AND SAFETY DISTRICT ENGINEER: Per the geotechnical consultants, a S_{DS} value of 1.89g shall be utilized for the determination of seismic loading for the proposed unrestrained retaining walls that are greater than 12 feet high].

The Geotechnical Development Review Units will use the United State Geological Survey (USGS) website to verify the SDS value and any supporting data (e.g., Site Class, appropriate ASCE 7 standard, location, etc.) needed to determine that value. The USGS United States Seismic Design Maps website can be found at: http://geohazards.usgs.gov/designmaps/us/application.php.

In addition to seismic design criteria, it is the responsibility of the geotechnical consultants to provide information regarding the geologic conditions (stratigraphy and structure) in the area of proposed walls. This information is to be utilized by the geotechnical consultants to provide information in performing backcut analyses and in determining surcharges from adverse bedding and sloping terrain.

These references also provide the calculations to determine the seismic lateral pressures required for retaining walls with less than 6 feet of retained height, but do not yet require a geotechnical report.

Note: Retained height of all stepped retaining walls shall be combined when the lower retaining walls are surcharged by the upslope retaining walls. Seismic lateral pressure will be required for these stepped retaining walls when the combined retained height is greater than 8 feet, per the Building Code, or 12 feet, per the Residential Code.

Approved By:

Michael A. Montgomery
Assistant Division Head

**GUIDELINES FOR PREPARING
ENGINEERING GEOLOGY REPORTS
REVISED 1992**

by
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assisted by
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These guidelines are intended to be a general aid to professional geologists evaluating site-specific conditions and geologic hazards and to regulatory agencies for review of reports. The guidelines do not include systematic descriptions of all available techniques or topics, nor is it suggested that all techniques or topics be utilized on every project. Variations in site conditions and purposes of investigations may require more or permit less effort than is outlined here. All elements of these guidelines should be considered during field analysis as well as the preparation and review of engineering geology reports.

These guidelines have been revised by the Association of Engineering Geologists in 1992 utilizing the original guidelines prepared by the Building Codes Committee of the Southern California Section in 1965 (Slosson & Phipps, 1992) and later modified by the Utah Section of the Association of Engineering Geologists for the Utah Geological and Mineral Survey in 1986. The California Division of Mines and Geology in 1975 formally adopted the original 1965 version of the guidelines for the purpose of addressing the provisions of Chapter 70 of the Uniform Building Code and for establishing good engineering geology practices, and protecting the health, safety, and welfare of the public. In 1984, the California guidelines (CDMG) were published in the Bulletin of the Association of Engineering Geologists (Slosson, 1984) making them readily available to geologists and reviewers throughout the United States and the world.

I. GEOLOGIC MAPPING AND INVESTIGATION

A. Geologic mapping of the subject area should be completed at a scale which shows sufficient detail to adequately define the geologic conditions present. For many purposes, available geologic maps are unsuitable to provide a basis for understanding the site conditions and independent geologic mapping is needed. If available geologic maps are used to portray site conditions, they must be field checked and updated to reflect geologic, topographic, and/or cultural changes which have occurred since map publication. It is often necessary for the geologist to extend mapping into adjacent areas to adequately define geologic conditions relevant to processes active at the subject area.

B. Mapping should be done on a suitable topographic base map at an appropriate scale with satisfactory horizontal and vertical control. The nature, date, and source of the base should be included on each map. In certain cases where topographic base maps at scales larger than 1:24,000 (U.S. Geological Survey 7½ minute quadrangle) are not available, geologic mapping may be done and presented on an aerial photograph base of suitable scale to permit documentation of pertinent features. On small-scale maps, 1 inch commonly equals 200 feet or more, whereas on large-scale maps 1 inch equals 100 feet or less.

C. The geologist performing the investigation and preparing the map should pay particular attention to the type and geometry of bedrock and surficial materials, characteristics of these materials that may affect their engineering properties, structural features and relationships, and the three-dimensional distribution of earth materials exposed and inferred within the area. A clear distinction should be made on the map and within the report between observed and inferred geologic features and relationships. All seeps, springs, and marshes should be indicated with estimates of discharge rates, if any, at the time of observation.

D. The report should include one or more appropriately positioned and scaled cross sections to show three-dimensional relationships that cannot be adequately described in words alone. Fence or block diagrams may also be appropriate for describing three-dimensional relationships. Cross sections should display the available data and the interpretation of conditions between exposures.

E. The locations of all exploratory excavations (drill holes, test pits, and trenches) should be accurately shown on maps and sections and described in the text of the report. The actual data or processed data upon which interpretations are based should be included in the report to permit technical reviewers to make their own assessments regarding reliability and interpretation.

F. A field meeting among the geologist, the regulatory reviewer, and the owner or developer may be appropriate or desirable during the geologic investigation. Such a meeting will allow pertinent issues to be discussed and fundamental geologic information to be examined by the reviewer. The data from such a meeting and the names of those attending should be included in the report.

II. GENERAL INFORMATION

Each report should include sufficient background information to inform the reader of the general site setting, the proposed land use, and the purpose and scope of the geologic investigation. The following items should be addressed:

A. Location and size of subject area and its general setting with respect to major or regional geographic and geologic features.

B. Name(s) of geologist(s) who did the mapping and logging on which the report is based, dates when the mapping was done and who did the graphic arts and when the graphic arts were completed. The report and map should be signed by the project engineering geologist and/or the supervising engineering geologist. In states in which licensing is required, such as California, those signing the engineering geology reports and maps shall be certified engineering geologists and their certification numbers and/or stamps or seals shall accompany their signature(s).

C. Purpose and scope of the report and geologic investigation.

D. Geomorphology and drainage within or affecting the subject area.

E. General nature, distribution, and abundance of exposures of earth materials within the subject area.

F. Basis of interpretations and conclusions regarding the geology of the subject area. Nature and source of available subsurface information and engineering geology reports or maps. Suitable explanations of the available data should provide a technical reviewer with the means of evaluating the reliability and accuracy of the data. Reference to cited works or field observations shall be made to substantiate opinions and conclusions. New or unique methods of analysis and interpretation should be indicated as such and appropriately documented. Summaries of technical discussions with reviewers in field meetings also should be provided.

G. Disclosure of known or suspected potentially hazardous geologic processes affecting the project area. This should include a statement regarding past performance of existing engineered slopes, as well as engineered facilities (such as buildings or utilities) in the immediate vicinity.

H. Discussion of the limitations of the investigation and analytical techniques used, effect on project of reasonable alternate assumptions and hypotheses, and disclosure of the chosen design-life of the project.

III. GEOLOGIC DESCRIPTIONS

The report should contain an adequate description of all natural materials and structural features recognized or inferred within the subject area. Where interpretations are added to the record of direct observations, the basis for such interpretations should be clearly stated.

The following checklist may be useful as a general, though not necessarily complete, guide for descriptions:

A. **Bedrock**.

1. Identification of rock type (such as granite, sandstone, claystone, shale, slate).

2. Relative age and, where possible, correlation with named formations (e.g., Orinda, Modelo, Rincon, Wasatch).

3. Surface expression (geomorphology), areal distribution, and origin.

4. Pertinent physical characteristics (e.g., color, grain size, nature of stratification, strength of rock materials, variability of characteristics, presence or lack of cementation, spacing, type and continuity of fracturing).

5. Special physical or chemical features (e.g., pervasiveness of fractures, voids, gypsum veins, weathering, hydrothermal alteration).

6. Distribution and extent of zones of weathering; significant differences between fresh and weathered rock.

7. Engineering properties of bedrock material and special characteristics or concerns (e.g., factors affecting grading, construction, and maintenance potential for weathering upon exposure to air in cut slopes).

8. Description of geomorphology including origin of unique features.

9. Weaknesses and/or defects observed in earth materials that may affect stability, strength of material, erosion characteristics, and other factors.

B. **Structural features**-stratification, faults, fractures, foliation, schistosity, and folds.

1. Occurrence, distribution, dimensions, orientation and variability; projections into subject area.

2. Relative ages where pertinent.

3. Special features of faults (e.g., topographic expression, zones of gouge and breccia, groundwater association, nature of offsets, timing of movements, youngest faulted unit and oldest unfaulted unit).

4. Effects on rock materials that may alter strength and stability (i.e., spacing, continuity, and type of fractures and their origin, etc.).

5. Special engineering characteristics or concerns.

C. **Surficial or unconsolidated deposits**-alluvial, colluvial, eolian, alluvial fan, lacustrine, marine, glacial residual, mass movement, volcanic (such as cinders and ash), and historical fill (both engineered and non-engineered).

1. Identification of material, grain size, relative age, degree of activity of originating process.

2. Distribution, dimensional characteristics, variations in thickness, degree of soil development, surface expression.

3. Pertinent physical characteristics (e.g., color, grain size, lithology, compactness, cementation, strength, thickness, odor, pore size, permeability, shrink and swell potential).

4. Special physical or chemical features (e.g., indications of volume change or instability, such as desiccation cracks, slickensides, gypsum, secondary cementation related to weathering processes).

5. Special engineering characteristics or concerns.

6. Potential for consolidation, hydroconsolidation (hydrocompaction) seismic settlement, collapse, erosion, and other forms of ground failure.

D. **Surface hydrologic and subsurface hydrogeologic conditions**.

1. Distribution, occurrence, and variations (e.g., drainage courses, ponds, swamps, springs, and seeps).

2. Identification and characterization of saturated zones and/or aquifers, depth to ground water and seasonal fluctuations.

3. Relationships to geomorphology and geologic features, recharge areas and discharge areas.

4. Groundwater flow patterns and hydraulic gradients.

5. Evidence for earlier occurrence of water at localities now dry (e.g., vegetation, mineral deposits, historic records, photographic).

6. Special engineering characteristics or concerns (such as fluctuating water table, cause and location of perched water, and chemical content of water).

7. Discuss possible changes in groundwater condition that may be caused by the proposed project or effects of other land use changes that may cause changes to this project (i.e., increases in groundwater elevation due to irrigation, ponding of surface waters, sewage efficiency, etc.).

8. Locate and discuss groundwater recharge.

E. **Seismic considerations**.

1. Description of the seismotectonic setting of the subject area (including size, frequency, duration and location of historic earthquakes).

2. Potential for subject area to be affected by surface rupture (including sense and amount of displacernent and width of zone of surface deformation).

3. Probable site response to likely earthquakes (estimated ground motion, duration and response variability).

4. Potential for subject area to be affected by primary and secondary seismic hazards such as earthquake-induced landslides, liquefaction or other types of ground failure, including rock fall.

5. Potential for subject area to be affected by regional tectonic deformation (subsidence or uplift).

6. As an example, refer to CDMG Note 42 (formerly CDMG Note 37) and CDMG Note 43, as used in California as a support document.

IV. ASSESSMENT OF GEOLOGIC FACTORS

Assessment of geologic factors with respect to intended use constitutes the principal contribution of the report. It involves both 1) the effects of the geologic features upon the proposed grading, construction, and land use, and 2) the effects of these proposed modifications upon future geologic processes in the area.

The following checklist includes the topics that ordinarily should be considered in preparing discussions, conclusions, and recommendations in geologic reports:

A. **General suitability** of proposed land use to geologic conditions.

1. Areas to be avoided, if any
2. Effects of topography and slope on proposed land use and vice versa.
3. Stability of earth materials.
4. Flood inundation, erosion, and deposition.
5. Problems caused by geologic features or conditions in adjacent properties.
6. Effects of groundwater on project and vice versa.
7. Other general problems.

B. **Identification and extent of known or suspected geologic hazards** (such as flood inundation, shallow groundwater, storm surge, surface and groundwater pollution, rock or snow avalanche, various types of landslides, debris flow, rock fall, expansive soil, collapsible soil, subsidence, erosion, deposition, earthquake shaking, fault rupture, liquefaction, seiche, volcanic eruption, tsunamis).

C. **Recommendations for site grading**.

1. Prediction of what materials and structural features that will be encountered in proposed cuts and their potential for slope failure
2. Prediction of stability based on geologic factors; recommended avoidance or engineering mitigation to cope with existing or potential landslide masses.
3. Excavation considerations (hard or massive rock, slope failure, groundwater, seepage).

4. General considerations for placement of proposed fill masses in canyons or on sidehills (i.e., benching, subdrains, backdrains).

5. Suitability of excavated material for use as compacted fill

6. Recommendations for positioning fill masses, provisions for underdrainage, buttressing and the need for erosion protection on fill slopes.

7. Other recommendations required by the proposed land use, such as for reorientation of cut slopes, positions of drainage terraces, the need for rock-fall protection on cut slopes, the need for erosion protection on cut slopes.

D. **Drainage considerations**.

1. Relationship of property to FEMA flood zones.

2. Protection from inundation or wave erosion along shorelines, streams, etc.

3. Soil and rock permeability and the effect of infiltration and through flow on site stability

4. Protection from sheet flood or gully erosion and debris flows, mud flows, and avalanches.

E. **Recommendations for additional investigations**.

1. Geophysical surveys, aerial photographic surveys, borings, test pits, and/or trenches needed for additional geologic information.

2. Percolation tests needed for septic system design.

3. Program of subsurface exploration and testing that is most likely to provide data needed by the geotechnical engineer or civil engineer

V. RECOMMENDED TECHNIQUES/SYSTEMS TO CONSIDER

A. Engineering geology mapping can be done using the Genesis-Lithology-Qualifier (GLQ) system rather than the conventional Time-Rock system. The GLQ system (Keaton, 1984, Compton, 1985) promotes communication of geologic information to non-geologists. The Unified Soil Classification System (U.S. Army Corps of Engineers, 1953, and American Society for Testing and Materials, 1990) has been used in engineering for many years and can be adapted for mapping. It has been incorporated into the GLQ system.

B. The Unified Rock Classification System (Williamson, 1984) provides a systematic and reproducible method of describing rock weathering, strength, discontinuities, and density in a manner directly usable by engineers.

C. Systems for mapping landslide deposits are described by Wieczorek (1984) and by Mccalpin (1984).

D. Commonly accepted grading requirements are described in Chapter 70 of the Uniform Building Code.

E. A number of the local governmental agencies have adopted specific ordinances regarding hillside development, citing issues with respect to proximity to fault traces, requirements for septic system designs, waste material disposal requirements, and others. The geologist should check with local agencies regarding such ordinances that might affect specific aspects of the project requirements.

SELECTED REFERENCES for PREPARING ENGINEERING GEOLOGY REPORTS

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Uniform Building Code, 1991, Chapter 23, Part 111--Earthquake Design: International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, CA 90601, p. 156 to 196.

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CALIFORNIA GEOLOGICAL SURVEY

NOTE 49

GUIDELINES FOR EVALUATING THE HAZARD OF SURFACE FAULT RUPTURE

GUIDELINES FOR EVALUATING THE HAZARD OF SURFACE FAULT RUPTURE
(Similar guidelines were adopted by the State Mining and Geology Board for advisory purposes in 1996.)

These guidelines are to assist geologists who investigate faults relative to the hazard of surface fault rupture. Subsequent to the passage of the Alquist-Priolo Earthquake Fault Zoning Act (1972), it became apparent that many fault investigations conducted in California were incomplete or otherwise inadequate for the purpose of evaluating the potential of surface fault rupture. It was further apparent that statewide standards for investigating faults would be beneficial. These guidelines were initially prepared in 1975 and have been revised several times since then.

The investigation of sites for the possible hazard of surface fault rupture is a deceptively difficult geologic task. Many active faults are complex, consisting of multiple breaks. Yet the evidence for identifying active fault traces is generally subtle or obscure and the distinction between recently active and long-inactive faults may be difficult to make. It is impractical from an economic, engineering, and architectural point of view to design a structure to withstand serious damage under the stress of surface fault rupture. Once a structure is sited astride an active fault, the resulting fault-rupture hazard cannot be mitigated unless the structure is relocated, whereas when a structure is placed on a landslide, the potential hazard from landsliding often can be mitigated. Most surface faulting is confined to a relatively narrow zone a few feet to few tens of feet wide, making avoidance (i.e., building setbacks) the most appropriate mitigation method. However, in some cases primary fault rupture along branch faults can be distributed across zones hundreds of feet wide or manifested as broad warps, suggesting that engineering strengthening or design may be of additional mitigative value (e.g., Lazarte and others, 1994).

No single investigative method will be the best, or even useful, at all sites, because of the complexity of evaluating surface and near surface faults and because of the infinite variety of site conditions. Nonetheless, certain investigative methods are more helpful than others in locating faults and evaluating the recency of activity.

The evaluation of a given site with regard to the potential hazard of surface fault rupture is based extensively on the concepts of recency and recurrence of faulting along existing faults. In a general way, the more recent the faulting the greater the probability for future faulting (Allen, 1975). Stated another way, faults of known historic activity during the last 200 years, as a class, have a greater probability for future activity than faults classified as Holocene age (last 11,000 years), and a much greater probability of future activity than faults classified as Quaternary age (last 1.6 million years). However, it should be kept in mind that certain faults have recurrent activity measured in tens or hundreds of years whereas other faults may be inactive for thousands of years before being reactivated. Other faults may be characterized by creep-type rupture that is more or less ongoing. The magnitude, sense, and nature of fault rupture also vary for different faults or even along different strands of the same fault. Even so, future faulting generally is expected to recur along pre-existing faults (Bonilla, 1970). The development of a new fault or reactivation of a long-inactive fault is relatively uncommon and generally need not be a concern in site development.

As a practical matter, fault investigation should be directed at the problem of locating existing faults and then attempting to evaluate the recency of their activity. Data should be obtained both from the site and outside the site area. The most useful and direct method of evaluating recency is to observe (in a trench or road cut) the youngest geologic unit faulted and the oldest unit that is not faulted. Even so, active faults may be subtle or discontinuous and consequently overlooked in trench exposures (Bonilla and Lienkaemper, 1991). Therefore, careful logging is essential and trenching needs to be conducted in conjunction with other methods. For example, recently active faults may also be identified by direct observation of young, fault-related geomorphic (i.e., topographic) features in the field or on aerial photographs. Other indirect and more interpretive methods are identified in the outline below. Some of these methods are discussed in Bonilla (1982), Carver and McCalpin (1996), Hatheway and Leighton (1979), McCalpin (1996a, b, c), National Research Council (1986), Sherard and others (1974), Slemmons (1977), Slemmons and dePolo (1986), Taylor and Cluff (1973), the Utah Section of the Association of Engineering Geologists (1987), Wallace (1977), Weldon and others (1996), and Yeats and others (1997). McCalpin (1996b) contains a particularly useful discussion of various field techniques. Many other useful references are listed in the bibliographies of the references cited here.

The purpose, scope, and methods of investigation for fault investigations will vary depending on conditions at specific sites and the nature of the projects. Contents and scope of the investigation may also vary based on guidelines and review criteria of agencies or political organizations having regulatory responsibility. However, there are topics that should be considered in all comprehensive

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fault investigations and geologic reports on faults. For a given site some topics may be addressed in more detail than at other sites because of the difference in the geologic and/or tectonic setting and/or site conditions. These investigative considerations should apply to any comprehensive fault investigation and may be applied to any project site, large or small. Suggested topics, considerations, and guidelines for fault investigations and reports on faults are provided in the following annotated outline. Fault investigations may be conducted in conjunction with other geologic and geotechnical investigations (DMG Notes 42 and 44). Although not all investigative techniques need to be or can be employed in evaluating a given site, the outline provides a checklist for preparing complete and well-documented reports. Most reports on fault investigations are reviewed by local or state government agencies. Therefore it is necessary that the reports be documented adequately and written carefully to facilitate that review. The importance of the review process is emphasized here, because it is the reviewer who must evaluate the adequacy of reports, interpret or set standards where they are unclear, and advise the governing agency as to their acceptability (Hart and Williams, 1978; DMG Note 41).

The scope of the investigation is dependent not only on the complexity and economics of a project, but also on the level of risk acceptable for the proposed structure or development. A more detailed investigation should be made for hospitals, high-rise buildings, and other critical or sensitive structures than for low-occupancy structures such as wood-frame dwellings that are comparatively safe. The conclusion drawn from any given set of data, however, must be consistent and unbiased. Recommendations must be clearly separated from conclusions, because recommendations are not totally dependent on geologic factors. The final decision as to whether, or how, a given project should be developed lies in the hands of the owner and the governing body that must review and approve the project.

CONTENTS OF GEOLOGIC REPORTS ON FAULTS

Suggested topics, considerations, and guidelines for investigations and reports

The following topics should be considered and addressed in detail where essential to support opinions, conclusions, and recommendations, in any geologic report on faults. It is not expected that all the topics or investigative methods would be necessary in a single investigation. In specific cases it may be necessary to extend some of the investigative methods well beyond the site or property being investigated. Particularly helpful references are cited parenthetically below.

I. Text

A. Purpose and scope of investigation; description of proposed development.

B. Geologic and tectonic setting. Include seismicity and earthquake history.

C. Site description and conditions, including dates of site visits and observations. Include information on geo logic units, graded and filled areas, vegetation, existing structures, and other factors that may affect the choice of investigative methods and interpretation of data.

D. Methods of investigation.

1. Review of published and unpublished literature, maps, and records concerning geologic units, faults, ground-water barriers, and other factors.

2. Stereoscopic interpretation of aerial photographs and other remotely sensed images to detect fault-related topography (geomorphic features), vegetation and soil contrasts, and other lineaments of possible fault origin. The area interpreted usually should extend beyond the site boundaries.

3. Surface observations, including mapping of geologic and soil units, geologic structures, geomorphic features and surfaces, springs, deformation of engineered structures due to fault creep, both on and beyond the site.

4. Subsurface investigations.

   a. Trenching and other excavations to permit detailed and direct observation of continuously exposed geologic units, soils, and structures; must be of adequate depth and be carefully logged (Taylor and Cluff, 1973; Hatheway and Leighton, 1979; McCalpin, 1996b).

   b. Borings and test pits to permit collection of data on geologic units and ground water at specific locations. Data points must be sufficient in number and spaced adequately to permit valid correlations and interpretations.

   c. Cone penetrometer testing (CPT) (Grant and others, 1997; Edelman and others, 1996). CPT must be done in conjunction with continuously logged borings to correlate CPT results with on-site materials. The number of borings and spacing of CPT soundings should be sufficient to adequately image site stratigraphy. The existence and location of a fault based on CPT data are interpretative.

5. Geophysical investigations. These are indirect methods that require a knowledge of specific geo logic conditions for reliable interpretations. They should seldom, if ever, be employed alone without knowledge of the geology (Chase and Chapman, 1976). Geophysical methods alone never prove the absence of a fault nor do they identify the recency of activity. The types of equipment and techniques used should be described and supporting data presented (California Board of Registration for Geologists and Geophysicists, 1993).

   a. High resolution seismic reflection (Stephenson and others, 1995; McCalpin, 1996b).

   b. Ground penetrating radar (Cai and others, 1996).

   c. Other methods include: seismic refraction, magnetic profiling, electrical resistivity, and gravity (McCalpin, 1996b).

6. Age-dating techniques are essential for determining the ages of geologic units, soils, and surfaces that bracket the time(s) of faulting (Pierce, 1986; Birkeland and other, 1991; Rutter and Catto, 1995; McCalpin, 1996a).

   a. Radiometric dating (especially 14C).

   b. Soil-profile development.

c. Rock and mineral weathering.

d. Landform development.

e. Stratigraphic correlation of rocks/minerals/fossils.

f. Other methods — artifacts, historical records, tephrochronology, fault scarp modeling, thermoluminescence, lichenometery, paleomagnetism, dendrochronology, etc.

7. Other methods should be included when special conditions permit or requirements for critical structures demand a more intensive investigation.

a. Aerial reconnaissance overflights.

b. Geodetic and strain measurements.

c. Microseismicity monitoring.

E. Conclusions.

1. Location and existence (or absence) of hazardous faults on or adjacent to the site; ages of past rupture events.

2. Type of faults and nature of anticipated offset, including sense and magnitude of displacement, if possible.

3. Distribution of primary and secondary faulting (fault zone width) and fault-related deformation.

4. Probability of or relative potential for future surface displacement. The likelihood of future ground rupture seldom can be stated mathematically, but may be stated in semi-quantitative terms such as low, moderate, or high, or in terms of slip rates determined for specific fault segments.

5. Degree of confidence in and limitations of data and conclusions.

F. Recommendations.

1. Setback distances of proposed structures from hazardous faults. The setback distance generally will depend on the quality of data and type and complexity of fault(s) encountered at the site. In order to establish an appropriate setback distance from a fault located by indirect or interpretative methods (e.g., borings or cone penetrometer testing), the area between data points also should be considered underlain by a fault unless additional data are used to more precisely locate the fault. State and local regulations may dictate minimum distances (e.g., Section 3603 of California Code of Regulations in Appendix B in Hart and Bryant, 1997).

2. Additional measures (e.g., strengthened foundations, engineering design, flexible utility connections) to accommodate warping and distributive deformation associated with faulting (Lazarte and others, 1994).

3. Risk evaluation relative to the proposed development.

4. Limitations of the investigation; need for additional studies.

II. References.

A. Literature and records cited or reviewed; citations should be complete.

B. Aerial photographs or images interpreted — list type, data, scale, source, and index numbers.

C. Other sources of information, including well records, personal communications, and other data sources.

III. Illustrations — these are essential to the understanding of the report and to reduce the length of text.

A. Location map — identify site locality, significant faults, geographic features, regional geology, seismic epicenters, and other pertinent data; 1:24,000 scale is recommended. If the site investigation is done in compliance with the Alquist-Priolo Act, show site location on the appropriate Official Map of Earthquake Fault Zones.

B. Site development map — show site boundaries, existing and proposed structures, graded areas, streets, exploratory trenches, borings geophysical traverses, locations of faults, and other data; recommended scale is 1:2,400 (1 inch equals 200 feet), or larger.

C. Geologic map — show distribution of geologic units (if more than one), faults and other structures, geomorphic features, aerial photo graphic lineaments, and springs; on topographic map 1:24,000 scale or larger; can be combined with III(A) or III(B).

D. Geologic cross sections, if needed, to provide three-dimensional picture.

E. Logs of exploratory trenches and borings — show details of observed features and conditions; should not be generalized or diagrammatic. Trench logs should show topographic profile and geologic structure at a 1:1 horizontal to vertical scale; scale should be 1:60 (1 inch = 5 feet) or larger.

F. Geophysical data and geologic interpretations.

IV. Appendix: Supporting data not included above (e.g., water well data, photographs, aerial photographs).

V. Authentication: Investigating geologist's signature and registration number with expiration data.

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* DMG Note 41 — General guidelines for reviewing geologic reports, 1998.

* DMG Note 42 — Guidelines for geologic/seismic reports, 1986.

* DMG Note 44 — Recommended guidelines for preparing engineering geologic reports, 1986.

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GUIDELINES FOR ENGINEERING GEOLOGIC REPORTS

GENERAL INFORMATION

These guidelines suggest a format for reports. They do not include complete listings of techniques or topics, nor should all techniques described be used or all topics listed be dealt with in every project.

These guidelines are informational and are not regulations. Language used has been carefully gleaned of mandatory requirements. The guidelines have no force of law and do not set standards of practice. To be enforceable, the guidelines would have to be adopted as regulations in accordance with the Administrative Procedures Act.

On January 23, 1986, the Board of Registration for Geologists and Geophysicists (Board) passed the following resolution:

"The Guidelines have been adopted as useful information documents. Not having been adopted as regulations in accordance with the Administrative Procedures Act, the Guidelines are not legally enforceable."

These guidelines have their roots in eight California Division of Mines and Geology notes, that were published in California Geology during 1973-75. The four guidelines that evolved through the Technical Advisory Committee for the Board of Registration from 1983 to 1989 are:

Guidelines for Engineering Geologic Reports.
Geologic Guidelines for Earthquake and/or Fault Hazard Reports.
Guidelines for Geophysical Reports.
Guidelines for Groundwater Investigation Reports.

I. INTRODUCTION

These guidelines have been prepared by the Technical Advisory Committee of the Board and adopted by the Board on April 18, 1998 to assist those involved in preparing or reviewing engineering geologic reports. The guidelines present general procedures suggested for use by geologists carrying out engineering geologic studies and, while they do not constitute a complete listing of all techniques for such studies, they do include most major topics. In the broad sense, nearly all engineering projects requiring geologic input are also engineering geology projects. Most of these involve identifying and evaluating geologic hazards, using the various exploration tools available today, as applicable, and developing appropriate mitigation measures, if necessary. Projects may include on-land and offshore structures, large excavations, buried tanks and disposal sites for hazardous, designated and nonhazardous wastes. Groundwater and its relationship to other site characteristics is an integral part of engineering geology. Additionally, past uses of a site are becoming increasingly important in evaluating its applicability for a new use.

Engineering geology reports would be expected to be prepared by or under the direct supervision of a certified engineering geologist. Clear descriptions of work and unambiguous presentations of results are encouraged. If the report falls within the scope of the Geologist and Geophysicist Act (Business and Professions Code, Chapter 12.5), it must be signed by the responsible professional(s). If such reports include significant geophysical information, they should be cosigned by a registered geophysicist, or the signed geophysical report may be appended to the geological report. It is important that reports that present conclusions or recommendations based in part on field sampling or field or laboratory testing include the test results with adequate descriptions of the methods employed, and with specific reference to standard sampling, preservation, and testing methods, where appropriate. Where necessary, technical terms will need to be defined.

The following is a suggested guide or format for engineering geologic reports. These reports may be prepared for projects ranging in size from a single lot to the master plan for large acreage, in scope from a single family residence to large engineering structures and for sites in all manner of geologic terrain. Because of this diversity, the order, format and scope of the reports is flexible to allow tailoring to the geologic conditions and intended use of the site. The format is intended to be relatively complete; not all items will be applicable to small projects or low-risk sites. In addition, some items may be covered in separate reports by geotechnical engineers, geophysicists, or structural engineers.

II. REPORT CONTENT

A. Purpose and Scope of the Investigation

Includes a brief description of proposed or existing site use; may also include a description of limitations of the work and authorization to perform the work. The design lifespan of the proposed project should be implicitly stated.

B. Regional Geologic Setting

May include reference to geologic province and location with respect to major structural features.

C. Site Description and Conditions

Includes information on geologic units, landforms, graded and filled areas, vegetation, existing structures, etc., that may affect the choice of investigative methods and the interpretation of data.

D. Description of the Investigation

1. Review of the regional and site geology, and land-use history, based primarily on existing maps and technical literature.

a. Geologic hazards that could affect the planned use of the site.

(1) Significant historic earthquakes in the region.

(2) Fault traces that may affect the site. Is the site within an earthquake fault zone?

(3) Secondary earthquake effects, such as ground breakage in the vicinity of the site, seismically-induced landslides, differential tilting and liquefaction.

(4) Regional effects, such as subsidence, uplift, etc.

(5) Landslides or other earth movements at the site and vicinity.

(6) Soil and rock properties such as high moisture content, low density, swelling, cementation, weathering, fracturing, etc.

b. Other geologic conditions that could affect the planned use of the site.

(1) Soil thickness, types, and relationship to bedrock.

(2) Excavatability of rock materials.

(3) Depth to and characteristics of subsurface water.

c. Conditions imposed on the site by past uses, such as buried objects, contaminated soils, groundwater, or adjacent structures, etc.

2. Interpretation of aerial photographs and other remotely sensed images relative to topography, vegetation, or any other features related to geologic hazards and past site use.

3. Surface investigation.

a. Mapping of the site geology and vicinity; identification and description of geologic units, soil and rock types, and features that could be related to geologic hazards and the proposed use and constructability of the site. A clear distinction should be made on the map and within the report between observed and inferred geologic features and relationships.

b. Evaluation of surface-water conditions, including quality, flood potential in relation to site conditions, geomorphology and drainage within or affecting the subject area.

4. Subsurface investigation.

a. Trenching and any other excavation (with appropriate logging and documentation) to permit detailed and direct observation of continuously exposed geologic units and features.

b. Borings drilled, test pits excavated, and groundwater monitoring wells installed to permit the collection of data needed to evaluate the depth and types of materials and subsurface water. Data points sufficient in number and adequately spaced will permit valid correlations and interpretations.

c. Geophysical surveys conducted to facilitate the evaluation of the types of site materials and their physical properties, groundwater conditions and any other pertinent site conditions. The types of equipment and techniques used, such as seismic refraction, magnetic, electric resistivity, seismic reflection and gravity, and the name of the geophysicist responsible for the work.

5. Special methods (used when special conditions permit or critical structures demand a more intensive investigation).

a. Aerial reconnaissance overflights, including special photography.

b. Geodetic measurements, radiometric analysis, age dating, etc.

E. <u>Results of Investigation</u>

Describes the results of the investigation outlined in Section IV above. The actual data or processed data upon which interpretations are based should be included in the report to permit technical reviewers to make their own assessments regarding reliability and interpretation.

F. <u>Conclusion</u>

Relative to the intended land use or development (made in conjunction with the geotechnical engineering study). Includes a statement concerning the degree of confidence in and limitations of the data and conclusions, as well as disclosure of known or suspected potentially hazardous geologic processes affecting the project area.

1. Presence or absence of active or potentially active faulting at the site or in the vicinity, and the potential for renewed fault activity.

2. Effects on the site from ground shaking.

3. Potential for secondary effects from earthquakes, such as ground cracking, landsliding, and liquefaction.

4. Potential for subsidence or other regional effects.

5. The presence of creep or landsliding; and possible future mass movements.

6. Soil and rock conditions, such as swelling soils that could affect site use.

7. The presence of and possible effects from any other soil and rock defects.

8. Excavation methods.

9. Presence of contamination or any other man-imposed condition.

10. Potential for earthquake-induced flooding, including tsunamis and seiches.

11. Potential for volcanic hazards.

12. Conformance with local, state and federal statutory and regulatory requirements.

G. <u>Recommendations</u>

1. Effect of fault locations on proposed structures at the site. Federal, state, or local law may dictate minimum standards.

2. Placement of structures to best take advantage of geologic conditions.

3. Methodology for excavating and moving materials.

4. Means of correcting site defects, such as buttressing landslides, installing special drainage devices, etc.

5. Correcting contamination or other man-induced site defects.

6. Other recommendations as appropriate for the proposed project.

H. <u>References</u>

1. Literature and records cited and reviewed.

2. Aerial photographs or images interpreted, listing the type, scale, source, and index numbers, etc.

3. Compiled data, maps, or plates included or referenced.

4. Other sources of information, including well records, personal communications, or other data sources.

I. <u>Illustrations</u>

1. Location map to identify the site locality, geographic features, or major regional geologic features.

2. Site development map, at an appropriate scale, to show the site boundaries, existing and proposed structures, graded areas, streets, and locations of exploratory trenches, borings, wells, geophysical traverses, and other data.

3. Geologic map to show the areal distribution of geologic units, faults and other structures, geomorphic features, aerial photo features noted, along with surface water bodies and springs. The geologic map may be combined with the location and site development maps.

4. Geologic cross sections illustrating significant or appropriate geologic features.

5. Logs of exploratory trenches and borings to show the details of observed features and conditions.

6. Geophysical data and the geologic interpretations of those data.

7. Other, as appropriate.

J. Supporting Data Not Already Provided

1. Non-confidential water well data (including bore-hole logs).

K. Signature and Registration Number of the Responsible Professional(s)

1. Registered Geologist, Certified Engineering Geologist.

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GEOLOGIC GUIDELINES FOR EARTHQUAKE AND/OR FAULT HAZARD REPORTS

GENERAL INFORMATION

These guidelines describe the scope of work normally done and suggest a format for reports. They do not include complete listings of techniques or topics, nor should all techniques described be used or all topics listed be dealt with in every project.

These guidelines are informational and are not regulations. Language used has been carefully gleaned of mandatory requirements. The guidelines have no force of law and do not set standards of practice. To be enforceable, the guidelines would have to be adopted as regulations in accordance with the Administrative Procedures Act.

On January 23, 1986, the Board of Registration for Geologists and Geophysicists (Board) passed the following resolution:

"The Guidelines have been adopted as useful information documents. Not having been adopted as regulations in accordance with the Administrative Procedures Act, the Guidelines are not legally enforceable."

These guidelines have their roots in eight California Division of Mines and Geology notes, that were published in *California Geology* during 1973-75. The four guidelines that evolved through the Technical Advisory Committee for the Board from 1983 to 1989 are:

Guidelines for Engineering Geologic Reports.
Geologic Guidelines for Earthquake and/or Fault Hazard Reports.
Guidelines for Geophysical Reports.
Guidelines for Groundwater Investigation Reports.

I. INTRODUCTION

These guidelines are prepared by the Technical Advisory Committee of the Board and adopted by the Board on April 18, 1998 to assist those involved in preparing and reviewing earthquake and fault hazard reports. The guidelines describe the general procedures used by geologists carrying out earthquake and fault hazard studies and, while they do not constitute a complete listing of all techniques in such studies, they do attempt to include all major topics.

The investigation of sites for potential earthquake hazards, including possible surface fault rupture, is a difficult geologic task. The professional performing or supervising each investigation has a responsibility to determine what is appropriate and necessary in each case, and so does the professional who reviews each report.

Many active faults are complex, consisting of multiple breaks. Yet the evidence for identifying active fault traces is generally subtle or obscure and the distinction between recently active and long-inactive faults may be difficult to make. Because of the complexity of evaluating surface and near-surface faults and because of the infinite variety of site conditions, no single investigative method will be the best at every site; indeed, the most useful technique at one site may be inappropriate for another site.

Geologic reports prepared using these guidelines would be expected to be done by or under the direct supervision of registered geologists. Clear descriptions of work and unambiguous presentations of results are encouraged. If the report falls within the scope of the Geologist and Geophysicist Act (Business and Professions Code, Chapter 12.5), the report must be signed by the responsible professional(s). It is important that reports that present conclusions or recommendations based in part on field sampling or field or laboratory testing of samples include the test results with adequate descriptions of the methods employed, and with specific reference to standard sampling and testing methods, where appropriate. Where necessary, technical terms (such as active fault, maximum earthquake, etc.) will need to be defined.

The following is a suggested guide or format for earthquake and fault hazard reports. These reports may be prepared for projects ranging in size from a single lot to a master plan for large acreage, in scope from a single family residence to large engineered structures, and from sites located on an active fault to sites a substantial distance from the nearest known active fault. Because of this wide variation, flexibility in the order, format, and scope of the reports will allow tailoring to the seismic and geologic conditions and intended use of the site. The format is intended to be relatively complete, and not all items will be applicable to small projects or low risk sites. In addition, some items may be covered in separate reports by geotechnical engineers, geophysicists, or structural engineers.

II. REPORT CONTENTS

A. Purpose and Scope of the Investigation

Includes a brief description of proposed or existing site use; may also include a description of limitations of the work and authorization to perform the work. The design lifespan of the proposed project should be implicitly stated.

B. Regional Geologic Setting

May include reference to geologic province and location with respect to major structural features.

C. Site Description and Conditions

Includes information on geologic units, landforms, graded and filled areas, vegetation, existing structures, etc., that may affect the choice of investigative methods and the interpretation of data.

D. Description of the Investigation

1. Review of the region's seismic or earthquake history, based primarily on existing maps and technical literature.

   a. Significant earthquakes during historic time and epicenter locations and magnitudes in the vicinity of the site.

   b. Location of fault traces that may affect the site, including maps of fault breaks and a discussion of the tectonics and other relationships of significance to the proposed construction.

   c. Location and chronology of other earthquake-induced features such as landsliding, lurching, settlement and liquefaction, accompanied by:

      (1) Map showing the location of these features relative to the proposed project.

      (2) Description of the disturbed zone for each feature.

      (3) Estimate of the amount of disturbance relative to bedrock and surficial materials.

2. Interpretation of aerial photographs and other remotely sensed images relative to fault-related topography, vegetation, and soil contrasts, and other lineaments of possible fault origin.

3. Surface investigation.

   a. Mapping of geologic units and structures, topographic features, deformation of man made structures, etc., both on and beyond the site (sag ponds, spring alignments, offset bedding and man made features, disrupted drainage systems, offset ridges, faceted spurs, dissected alluvial fans, scarps, landslide alignments, vegetation patterns).

   b. Review of local groundwater data (water-level fluctuations, groundwater impediments, water quality variations, or anomalies indicating possible faults).

   c. Description of the distribution, depth, thickness, and nature of the various earth materials, including subsurface water, which may affect the seismic response and damage potential at the site.

4. Subsurface investigation.

a. Trenching and any other excavation (with appropriate logging and documentation, including method of cleaning wall) to permit the detailed and direct observation of continuously exposed geologic units and features. This would include trenching done across any known active faults and suspicious zones to determine the location and recency of movement, the width of disturbance, the physical condition of fault zone materials, the type of displacement, the geometry of fault features, and recurrence interval, if known.

b. Borings drilled and test pits excavated to permit the collection of data needed to evaluate the depth and types of materials and groundwater and to verify fault-plane geometry. Data points sufficient in number and adequately spaced will permit valid correlations and interpretations.

c. Geophysical surveys conducted to facilitate the evaluation of the types of site materials and their physical properties, groundwater conditions, and fault displacements, including a description of the types of equipment and techniques used, such a seismic refraction, magnetic, electrical resistivity, seismic refraction, magnetic, electrical resistivity, seismic reflection, and gravity.

5. Other special methods (used when special conditions permit or critical structures demand a more intensive investigation).

a. Aerial reconnaissance overflights, including special photography.

b. Geodetic and strain measurements, microseismicity monitoring, or other monitoring techniques.

c. Radiometric analysis (e.g., C14, K-Ar), stratigraphic correlation (fossils, mineralogy), soil profile development, paleomagnetism, or other age-dating techniques to identify the age of faulted or unfaulted units or surfaces.

E. <u>Conclusions</u>

1. Regarding areas of high risk and potential hazards relative to the intended land use or development (made in conjunction with the geotechncial engineering study) and a statement of the degree of confidence in, and limitations of, the data and conclusions.

a. Presence or absence (including location and age) of active or potentially active faults on or adjacent to the site or in the region of the site if they could affect it (through ground shaking).

b. Types and probability of, or relative potential for, future surface displacement within or immediately adjacent to the site, including the direction of relative displacement and the maximum possible displacement.

c. Secondary effects, such as: liquefaction of sediments and soils, shallow ground rupture, settlement of soils, earthquake-induced landslides, and lurching.

d. Estimates of maximum earthquake, upper bound earthquake, or other definitions of earthquakes if required by statute or regulation for the specific type of project.

F. Recommendations

1. Mitigative measures that provide appropriate protection of the health, safety and welfare of the public.

2. Effect of fault locations on proposed structures at the site. Federal, state and local law may dictate minimum standards.

3. Risk evaluations, if appropriate, relative to the proposed development.

4. Other recommendations as appropriate for the proposed project.

G. References

1. Literature and records cited and reviewed.

2. Aerial photographs or images interpreted, listing the type, scale, source, index numbers, etc.

3. Compiled data, maps, or plates included or referenced.

4. Other sources of information, including well records, personal communications, or other data sources.

H. Illustrations

1. Location map to identify the site locality, significant faults, fault strain and/or creep, geographic features, seismic epicenters, and other pertinent data.

2. Site development map, at an appropriate scale, to show the site boundaries, existing and proposed structures, graded areas, streets, exploratory trenches, borings, geophysical traverses, and other data.

3. Geologic map to show the distribution of geologic units (if more than one), faults and other structures, geomorphic features, aerial photo lineaments, and springs. The geologic map may be combined with the location and site development maps. A clear distinction should be made on the map and within the report between observed and inferred geologic features and relationships.

4. Geologic cross-sections illustrating displacement and/or rupture, if needed to

provide a three-dimensional picture.

5. Logs of exploratory trenches and borings to show the details of observed features and conditions.

6. Geophysical data and the geologic interpretations of those data.

I. Supporting data not already provided

1. Water well data.

J. Signature and registration number of the responsible professional(s)

1. Registered Geologist, Certified Engineering Geologist.

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